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Web-based internet searches for digital health products in the United Kingdom before and during the COVID-19 pandemic: a time-series analysis using app libraries from the Organisation for the Review of Care and Health Applications (ORCHA)

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ABSTRACT

Objectives To explore if consumer interest in digital health products (DHPs), changed following the COVID-19 pandemic and the lockdown measures that ensued.

Design Retrospective time-series analysis of web-based internet searches for DHPs in the UK, split over two periods, pre-COVID-19 lockdown (January 2019–23 March 2020) and post-COVID-19 lockdown (24 March 2020–31 December 2020).

Setting The UK.

Participants Members of the UK general population using health-app libraries provided by the Organisation for the Review of Care and Health Applications.

Primary and secondary outcome measures The primary outcome was volume of searches for DHPs. Secondary outcomes considered search volumes for 25 different therapeutic areas. Outcomes were assessed for significance using a two-stage Poisson test.

Results There were 126 640 searches for DHPs over the study period. Searches for DHPs increased by 343% from 2446 per month prior to COVID-19 lockdown measures being introduced to 8996 per month in the period following the first COVID-19 lockdown in the UK. In total, 23/25 (92%) of condition areas experienced a significant increase in searches for DHPs, with the greatest increases occurring in the first 2 months following lockdown. Musculoskeletal conditions (2,036%), allergy (1,253%) and healthy living DHPs (1,051%) experienced the greatest increases in searches compared with pre-lockdown. Increased search volumes for DHPs were sustained in the 9 months following the introduction of lockdown measures, with 21/25 (84%) of condition areas experiencing monthly search volumes at least 50% greater than pre-lockdown levels.

Conclusions The COVID-19 pandemic has profoundly disrupted the routine delivery of healthcare, making face-to-face interaction difficult, and contributing to unmet clinical needs. This study has demonstrated significant increases in internet searches for DHPs by members of

Strengths and limitations of this study

► This study is a first of its kind in using real-world internet search data for digital health products (DHPs), providing novel insights into consumer interest in this novel therapeutic medium.

► Segmentation of data into 25 different condition areas has enabled exploration of the interest in digital health (at the condition level) in previously unexplored ways.

► The collection of data from members of the UK general public, in significant numbers, allows generalisation beyond this study, suggesting that DHPs may be a valuable tool in the event of further COVID-19 lockdown measures.

► A limitation of the study is that searches for DHPs do not always result in downloads and subsequent usage, limiting interpretation in terms of what we believe the observed increase in internet searches for DHPs means in terms of improvements in tangible health outcomes.

the UK population since COVID-19, signifying an increased interest in this potential therapeutic medium. Future research should clarify whether this increased interest has resulted in increased acceptance and utilisation of these technologies also.

INTRODUCTION

The traditional model of healthcare delivery is based on providing medical services through systems of hospitals, primary care facilities and outpatient clinics.[1] However, the COVID-19 pandemic has profoundly disrupted the routine delivery of physical healthcare, resulting in the widespread

deferral of elective, preventive and outpatient appointments by health authorities.[2–4] Estimates suggest that as many as 40% of appointments have been cancelled or postponed by patients, as part of efforts to avoid public spaces as much as possible.[5] In the USA, ambulatory care visits fell by 60% in the early phase of the pandemic,[6] while in the UK alone, an estimated 1.5 million elective admissions and 2.6 million outpatient attendances were forgone as a result of COVID-19.[7] While the details of the longer-term impact of this significant change in access to services are unclear, short-term cracks are beginning to emerge. Reduced access to services,[8] restrictions on social contact and concerns regarding future employment insecurity have contributed to a significant increase in mental-health sequelae.[9] Additionally, we are yet to observe the full impact that disruptions to cancer services may have. Cancer Research UK estimated that 2400 fewer people started treatment for lung cancer in April–December 2020, compared with the same time in 2019.[10] Similarly, an estimated 344, 1563 and 342 avoidable deaths are expected to occur in the UK as a result of breast cancer, colorectal cancer and oesophageal cancer, respectively, with an estimated 63 229 years of life lost as a result.[11]

Given the increasing barriers to both accessing and using a variety of face-to-face health services, the potential for digital health to address at least some of the mounting unmet clinical needs has gained traction during the pandemic. Digital health products (DHPs) have been available for many years now, slowly increasing in popularity across a wide range of health-related applications in almost all sectors of healthcare.[12] National bodies, including the National Institute for Health and Care Excellence (NICE), are now providing recommendations and guidelines on both the utilisation and evaluation of DHPs.[13 14] These technologies, which are widely accessible and fundamentally flexible, continue to provide an additional means to achieve a continuity of care among those with unmet medical needs.[15] With many clinicians now realising the full potential of these digital tools, and becoming more accepting of DHPs as a potential therapeutic option during the COVID-19 pandemic, including not just notifiable medical devices, but also simpler diet and fitness applications, it is uncertain how consumer attitudes, interest and demand for DHPs have changed during this period. Using data from the world's largest digital health evaluation formulary, provided by the Organisation for the Review of Care and Health Applications (ORCHA),[16] with over 10 000 DHPs reviewed to date, the aim of this study is to determine how internet searches for DHPs for various health conditions has changed since COVID-19 lockdown measures were introduced in March 2020 and throughout the pandemic. Furthermore, this study will also explore whether changes in search volumes for DHPs differed by therapeutic area.

MATERIALS AND METHODS

The methodology for this study is a retrospective time-series analysis of real-world internet searches for DHPs within ORCHA's digital health library, split over two time periods, before and after the initiation of COVID-19 lockdown procedures in the UK, which commenced on 23 March 2020. For the purpose of this analysis, DHPs were defined as health apps, including all health apps with the potential to improve health outcomes, not limited to medical devices, but also including diet and fitness health apps. Our aim was to determine if searches for DHPs changed following the first phase of lockdown, and throughout the pandemic. Additionally, the study aims to explore whether changes in search volumes for DHPs differed by therapeutic area.

ORCHA are the world's largest independent reviewer of DHPs, providing a repository of DHPs, evaluated using a ~350 point objective 'yes' or 'no' scale. These questions take into account a variety of factors, including user experience and usability, clinical assurance and evidence of effectiveness, clinical safety, and data privacy.[16] To date more than 10 000 DHPs have been reviewed and included on ORCHA's 'app-finder' website. During the period of analysis, ORCHA health-app libraries were procured by councils, NHS trusts, clinical commissioning groups and integrated care systems in approximately 70% of NHS regions, providing the ORCHA health-app library free to use, to healthcare providers and members of the public alike. Additionally, during this time period, anyone in the UK could access the ORCHA health-app library free of charge by simply typing ORCHA into their chosen search engine. For the purpose of this study, user's digital health search term data, used across all ORCHA digital health libraries from 1 January 2019 to 31 December 2020, were collected using Google Analytics. We removed 2486 searches which were exclusively alphanumeric, clear typos, or which consisted of just two letters or less. Following this process, there were 126 640 web searches for DHPs within the study period, equal to approximately 5276 searches per month. From this group of 126 640 searches, we identified every unique search term, determining the frequency of use for each over the study period. In order to explore the different types of DHPs searched for, search terms were subsequently attributed to one of 25 condition areas. These condition areas were identified following multidisciplinary input from three healthcare professionals (a midwife, a pharmacy specialist lead and an ophthalmologist) and a health economist, with the aim of covering a broad representation of functions and conditions throughout the human body. An iterative process was used where each contributor added to (or recommended removing conditions) from the contribution of the last. Once all contributors had the opportunity to recommend therapeutic areas for inclusion, a final discussion between all four contributors took place, at which point the condition areas were finalised. We developed an expansive list of search terms attributable to each of the 25 condition areas, using both

MESH headings and condition-specific terms (such as insulin in the case of diabetes, or inhalers for asthma) following methodological guidance for the purpose of literature reviewing. Each of the four contributors then provided independent iterative curation of the search terms, creating a quality control chain. In the event that search terms were missed, they were added and synonyms provided. The search strings used to tag and classify the unique search terms into each of the 25 condition areas are provided in online supplemental file 1.

Remaining terms which had not been initially attributed to one of the 25 condition areas were then attributed using an iterative two-phase tagging approach. First, we used data from the digital health libraries to identify the names of DHPs associated with each of the 25 condition areas. We used a list of the names of the most commonly searched DHPs for each condition, which were then also added to the relevant search strings. This was supplemented by asking a team of several digital health assessors to provide the names of any DHPs they could recall for each of the 25 condition areas. While most DHPs tended to include the name of the condition within the name of the DHP, and, therefore, would have been automatically attributed to a condition, this method was particularly useful for DHPs with names that did not obviously link to a condition area, such as Wysa in the case of mental health, or Xploro for oncology. Following this process, search terms which had not already been attributed to a condition area (untagged) were ordered from the most to least searched (frequency of searches) and reviewed by two independent researchers. Researchers manually descended the list of terms, and in the event, terms were related to one of the 25 condition areas; they were added to the pre-existing search strings. Due to the gamma distribution of search term frequency (non-negative with a significant positive skew), reviewers stopped classifying search terms for any term with less than 10 searches over the 2-year period of investigation. This figure was the cut-off for classification as it was at this point that clear typos and alphanumeric searches which could not clearly be linked to either condition areas with any certainty were most common.

Statistical analysis

Given the differential time periods for data collection and analysis (~15 months before lockdown measures were introduced in the UK on 23 March 2020, and ~9 months after), search frequencies were standardised by determining the mean number of searches per calendar month. The overall change in search frequency (and for DHPs associated with each of the 25 condition areas), between the two time periods under consideration, was determined by comparing the mean frequency of searches (per month) before and after 23 March 2020 (COVID-19 lockdown). A two-sample Poisson test was used to identify if any changes in the volume of web searches for DHPs, both overall, and by condition area, were statistically significant at the conventional 95% level. Data cleaning

was performed using Microsoft Office Excel 2013 (Microsoft, Redmond, Washington, DC, USA), with all statistical analyses conducted using Stata V.14.

Patient and public involvement

For this retrospective study of real-world DHP search patterns, formal patient and public involvement was not sought.

RESULTS
Searches for DHPs

In the period prior to COVID-lockdown measures being introduced (1 January 2019–23 March 2020), 36 685 searches for DHPs were undertaken using ORCHA digital health libraries, equivalent to 2446 per month. As detailed in table 1, DHPs dedicated to mental health, diabetes and healthy living were the most frequently searched for during this period. In the period following the introduction of lockdown measures (24 March 2020 onwards), a total of 89 955 searches for DHPs took place, equivalent to 8996 per month, a 343.4% increase on the previous period (p<0.0001).

Searches for DHPs by condition area

There was substantial variation in changes in DHP search frequency by condition area (pre-COVID-19 vs post COVID-19 lockdown), as demonstrated in table 1. COVID-19, musculoskeletal (MSK) and physiotherapy, allergy and fitness/diet and weight loss DHPs experienced ~4,622%, ~2,036%, ~1,253% and ~1,051% increases in monthly searches for DHPs following COVID-19 lockdown measures, the largest increases observed. Every condition area, other than carer support and guidance/ info, experienced a statistically significant increase in searches for DHPs in the period following COVID-19 lockdown measures.

Searches for DHPs by condition area, over time

While the increased frequency of searches for DHPs occurred immediately following the introduction of lockdown proceedings, as demonstrated within figure 1, the interest in DHPs in different condition areas was sustained over the 9-month period following COVID-19 lockdown measures. In total, 23/25 (92%) of the condition areas analysed experienced monthly search volumes at least 25% greater than pre-lockdown levels, 21/25 (84%) had monthly search volumes at least 50% greater than pre-lockdown levels and 14/25 (56%) experienced search volumes more than 100% greater than pre-lockdown levels.

DISCUSSION
Principal findings

The study provides a first-of-its-kind exploration of the impact of COVID-19, and the ensuing difficulties in accessing face-to-face care, on consumer interest for DHPs under real-world conditions. Using 2 years of

Table 1 Comparison of search frequency pre-COVID-19 and post-Covid-19 lockdown measures, by condition area

Category	Searches per month pre-lockdown* (mean)	Searches per month post-lockdown† (mean)	Increase (%)	Significance‡
COVID	4	197	4622.4	p<0.01
Musculoskeletal and physiotherapy	34	683	2035.5	p<0.01
Allergy	4	45	1253.1	p<0.01
Fitness, diet and weight loss	320	1663	1050.8	p<0.01
Gastroenterology	12	92	767.6	p<0.01
Ears and hearing	22	152	700.0	p<0.01
Kidney	4	27	632.3	p<0.01
Children's health	34	211	613.6	p<0.01
Neurological and neurodevelopmental	119	698	588.3	p<0.01
Cancer	22	131	581.1	p<0.01
Women's health	27	158	576.5	p<0.01
Respiratory	78	398	510.4	p<0.01
Men's health	4	18	487.9	p<0.01
Heart	31	131	422.9	p<0.01
Dental	3	13	399.3	p<0.01
Pain and chronic fatigue	49	191	389.6	p<0.01
Nose and throat	1	5	363.6	p<0.01
Mental health	723	2536	350.7	p<0.01
Pregnancy	48	161	338.2	p<0.01
Eyes and vision	11	29	255.8	p<0.01
Diabetes	244	589	241.8	p<0.01
Addiction	136	274	201.4	p<0.01
Sleep	259	474	183.0	p<0.01
Guidance and info	21	16	74.3	p=0.64
Carer	45	28	63.2	p=0.14
Combined	2256	8920	395	N/A

*Starts from January 2019 to 23 March 2020 (~15 months).
†Starts from 24 March 2020 to the end of December 2020 (~9 months).
‡Significance determined using two-staged Poisson test.

retrospective data (January 2019–December 2020) from the world's largest formulary of DHPs, available to healthcare providers and members of the public in the UK, we observed a significant increase in searches for DHPs. Searches for DHPs increased by 343% from an average 2446 per month prior to COVID-19 lockdown measures being introduced to an average 8996 per month in the 9-month period following the first COVID-19 lockdown. Despite observing a statistically significant increase in searches for DHPs for all but two of the 25 condition areas listed, increases in searches varied substantially by condition area, with MSK and physiotherapy (2,036%), allergy (1,253%) and fitness, diet and weight loss (1,051%) DHPs experiencing the greatest increases in searches. While searches for DHPs should not be considered a perfect proxy for DHP acceptance, downloads and usage,

the data presented here suggest that openness to considering DHPs, and at least researching these tools for the purpose of independent condition and health management, increased following COVID-19 lockdowns.

The strengths of this analysis include the fact that the dataset used includes over 125 000 searches for DHPs by members of the public from the UK, over a 2-year period. As such, when increases in searches for DHPs were observed post-COVID-19 lockdown, the likelihood of this being down to random chance is minimised through the extensive periods of analysis and the high frequency of search data, both pre-lockdown and post-lockdown, under consideration. Additionally, segmentation of search data into different condition areas allowed exploration of internet search volumes for digital health technologies in previously unexplored ways. There are, however, several
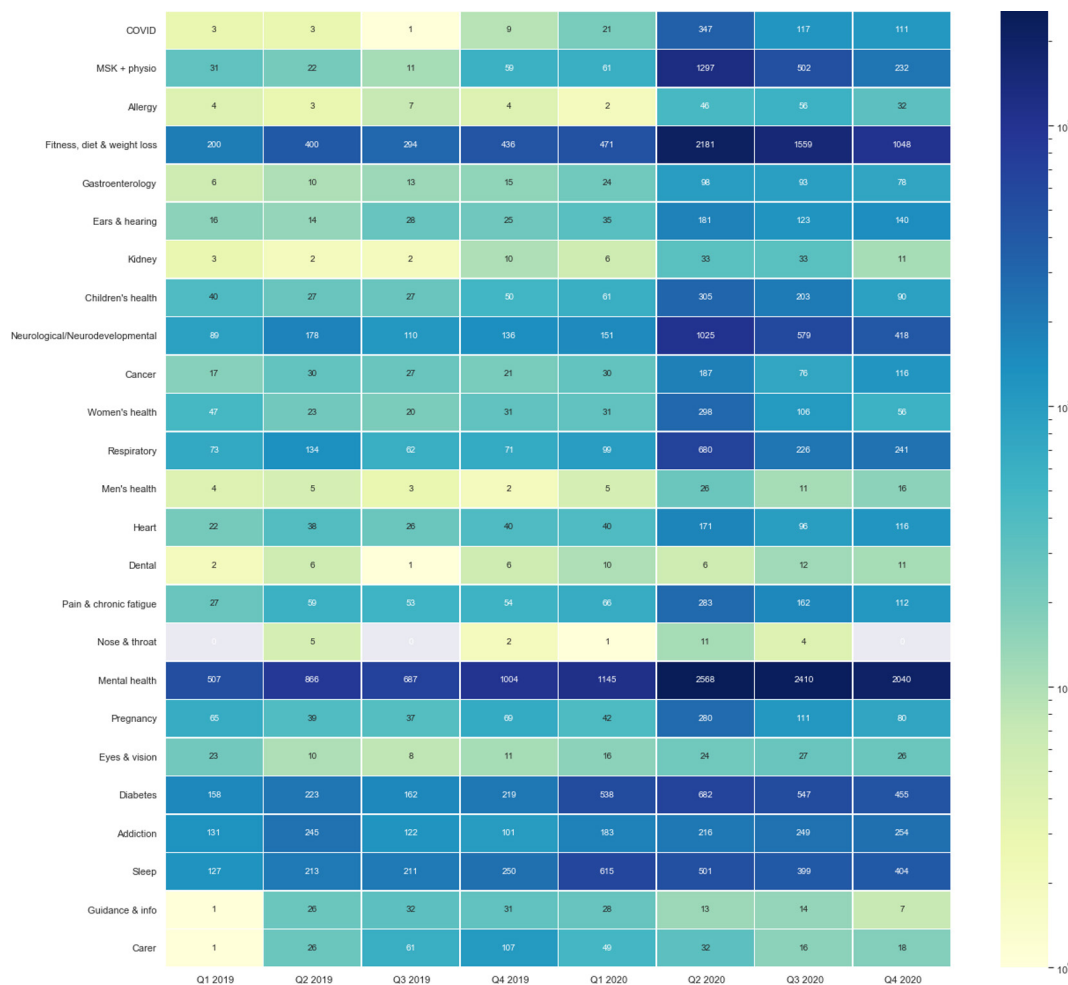
	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Q1 2020	Q2 2020	Q3 2020	Q4 2020
COVID	3	3	1	9	21	347	117	111
MSK + physio	31	22	11	59	61	1297	502	232
Allergy	4	3	7	4	2	46	56	32
Fitness, diet & weight loss	200	400	294	436	471	2181	1559	1048
Gastroenterology	6	10	13	15	24	98	93	78
Ears & hearing	16	14	28	25	35	181	123	140
Kidney	3	2	2	10	6	33	33	11
Children's health	40	27	27	50	61	305	203	90
Neurological/Neurodevelopmental	89	178	110	136	151	1025	579	418
Cancer	17	30	27	21	30	187	76	116
Women's health	47	23	20	31	31	298	106	56
Respiratory	73	134	62	71	99	680	226	241
Men's health	4	5	3	2	5	26	11	16
Heart	22	38	26	40	40	171	96	116
Dental	2	6	1	6	10	6	12	11
Pain & chronic fatigue	27	59	53	54	66	283	162	112
Nose & throat		5		2	1	11	4	
Mental health	507	866	687	1004	1145	2568	2410	2040
Pregnancy	65	39	37	69	42	280	111	80
Eyes & vision	23	10	8	11	16	24	27	26
Diabetes	158	223	162	219	538	682	547	455
Addiction	131	245	122	101	183	216	249	254
Sleep	127	213	211	250	615	501	399	404
Guidance & info	1	26	32	31	28	13	14	7
Carer	1	26	61	107	49	32	16	18

Figure 1 How interest in digital health changed throughout the COVID-19 pandemic?

limitations of this analysis, which must also be considered when interpreting the findings. First, this analysis focused exclusively on searches for DHPs. While this in itself is not a limitation, and was the subject of the research question, searches do not always result in downloads and subsequent usage, nor do they signify acceptance of such technologies, or a changing of beliefs towards digital health Therefore, while we can say with relative certainty that interest in DHPs as proxied by internet search volumes, and consideration of their potential usage as therapeutic options increased as a result of COVID-19 lockdown measures, we cannot definitively confirm whether this increased interest generated tangible improvements in health as a result. Second, while every attempt was made to ensure that the conditions under consideration were varied and representative, using an iterative process of healthcare provider and researcher review, it is possible and also likely that both important and prevalent conditions may not have been addressed by the analysis. This may affect the findings by underestimating (if web searches for the DHPs increased significantly) or overestimating (if web searches hardly changed) the impact that COVID-19 had on web searches for DHPs. Similarly, although the process used to identify terms to classify DHPs was thorough and multidisciplinary, it is possible

that DHPs could have been misclassified or missed altogether. While it is unlikely that key terms were omitted, such as diabetes, cancer, mental health or smoking, it is possible that less obvious names of DHPs were missed, where the name of the DHP has no obvious medical link to the condition under consideration. This may have led to an underestimation of searches for condition-specific DHPs in the periods both pre-COVID-19 and post-COVID-19 lockdown. Finally, as ORCHA libraries are not the only place on the internet to search for health apps, we, therefore, cannot be sure that the findings observed here would be reflected in the wider population, nor can we be certain that the increased interest in searching for DHPs. Additionally, based on the existing study structure, there is no guarantee that the findings observed here will continue to be observed once the COVID-19 pandemic has concluded, something which future research will need to address.

Interpretation in light of other evidence

We found that searches for DHPs increased by 343%, a statistically significant increase from 2446 per month prior to COVID-19 lockdown measures to 8996 per month in the 9 months following the first COVID-19 lockdown. Although this rise may plausibly be attributed to a shift

in treatment seeking behaviour for those experiencing denied or delayed access to routine face-to-face appointments with healthcare professionals,[17–19] there could be alternative justifications for this observed increase in searches for DHPs. These include, but are not limited to, the widespread increase in acceptance of DHPs over time,[20–22] and promotion of this relatively new therapeutic medium by health authorities. Previous studies, including two conducted by the authors of this study,[23 24] have shown that recommendations from health authorities to use DHPs, including the NHS and NICE, can significantly enhance acceptance and utilisation. Recently, the UK has experienced a substantial increase in regulative clarity, and with this, recommendations considering potential uses of digital health have increased significantly; these include the recent release of the NHSX digital technology assessment criteria,[25] and revisions to NICE evidence standards framework.[14] As such, at least some of the increases seen here may have been attributable to latent shifts in attitudes towards digital health, although accelerating them as a result of COVID-19.

Another key finding of this study concerned the impact that lockdown measures may have had, and across different condition areas, as the pandemic progressed. Initially, in the UK, leisure facilities, organised sports and the requirement to stay home, where possible, with the exception of one period of exercise a day, led to individuals going out and taking part in physical activity, whether direct, including organised sports, or indirect, including walking to work, far less than previous. This indirectly may have made physical exercise more 'attractive' as an activity, as one of the only permissible reasons to leave home once a day. Therefore, it is to be expected that the need for fitness DHPs increased, as observed within this study. In the first 3 months following the first period of lockdown, internet searches for fitness-related DHPs increased by 2000%. As the pandemic progressed, and people either worked from home more or were furloughed, which for many was a significant adjustment, the UK also observed a significant surge in alcohol consumption,[4] with a corresponding increase in internet searches for DHPs centred around addiction, as observed in this study.

What does this mean for clinical practice?
While it is unlikely that a face-to-face health service will ever be completely replaced by a virtual experience of any kind, there are clear signs that the healthcare system as we know it is on the verge of change. As evidenced by the findings of this study, it is clear that people are increasingly willing to consider digital health when contemplating seeking treatment for a variety of health conditions. DHPs offer the ability to gather more accurate timely information for healthcare appointments, allow advice to be reinforced and provide new convenient ways to connect with healthcare advice or professionals. Given the potential for a third wave of COVID-19 restrictions in light of new variants, and increased transmissibility, it is, therefore, critical that consumers are directed to safe,

trusted and evidence-based solutions, if the demand for such technologies should arise. This is critical such that any benefits which may be realised either in the absence of, or in addition to face-to-face services, are not overshadowed or negated by the potential dangers of using potentially unsafe and unproven technologies. A large part of this process is informing, and enabling healthcare professionals to also recognise this opportunity, to become more actively involved in the provision of high-quality, trusted and safe DHPs for a variety of conditions. This is not limited solely to high functioning medical devices, but also to DHPs with the aim of improving lifestyle decisions and promoting healthy living, with interest in DHPs from both ends of the spectrum increasingly significantly, as observed in this analysis.

Future research
Future research, which empirically explores attitudes towards digital health and the barriers and facilitators to use among members of the public, is likely to be of a significant value for the NHS in realising its long-term goals. This study has provided a basis for a hypothesis that the interest in digital health increased immediately following the introduction of COVID-19 restrictions. These restrictions undoubtedly impacted access to incumbent services and, therefore, the argument may be made that DHPs were sought as an interim or 'placeholder' measure in order to fulfil unmet clinical needs. While this is a plausible hypothesis, it does require confirming, while the future role of DHPs beyond the pandemic, as things slowly begin to normalise, also requires exploration. Attention should be paid to the specifics of DHPs and how willingness to use such technologies differs by functionality. It is plausible that members of the public were happy to use DHPs, which had limited functionality in the absence of being able to visit a qualified healthcare professional, but would have concerns about using DHPs classed as medical devices. This 'classification' of DHPs, and the different 'types' of DHP consumers are willing to use, is a largely unexplored area of research. Unfortunately, this could not be discerned in this analysis and should be addressed, in addition to the other points raised above, before we can determine whether the observed increase in searches for DHPs was a one-time occurrence, or indeed, the start of a new era of digital medicine.

CONCLUSION
The COVID-19 pandemic has profoundly disrupted the routine delivery of healthcare, contributing to unmet clinical needs and significant increases in related sequelae. Digital health has been posed as one solution to address unmet needs resulting from COVID-19.

This study, which explored real-world interest in DHPs over a 2-year period, has demonstrated significant increases in internet searches for DHPs by members of the UK population since COVID-19, signifying an

increased interest in this potential therapeutic medium. Searches for DHPs increased by 343%, with technologies dedicated to mental health and fitness among those experiencing the greatest increases. Future research should clarify whether this increased interest has also resulted in increased acceptance and utilisation of these technologies also.

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Correction notice This article has been corrected since it first published. Commas have been swapped with decimal in numerical values.

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REFERENCES

1 Senbekov M, Saliev T, Bukeyeva Z, *et al*. The recent progress and applications of digital technologies in healthcare: a review. *Int J Telemed Appl* 2020;2020:8830200.
2 Schmid-Küpke NK, Matysiak-Klose D, Siedler A, *et al*. Cancelled routine vaccination appointments due to COVID-19 pandemic in Germany. *Vaccine X* 2021;8:100094.
3 Spalletta G, Porcari DE, Banaj N, *et al*. Effects of COVID-19 infection control measures on appointment Cancelation in an Italian outpatient memory clinic. *Front Psychiatry* 2020;11:599844.
4 Mansfield KE, Mathur R, Tazare J, *et al*. Indirect acute effects of the COVID-19 pandemic on physical and mental health in the UK: a population-based study. *Lancet Digit Health* 2021;3:e217–30.
5 Shayganfard M, Mahdavi F, Haghighi M, *et al*. Health anxiety predicts postponing or Cancelling routine medical health care appointments among women in perinatal stage during the Covid-19 Lockdown. *Int J Environ Res Public Health* 2020;17. doi:10.3390/ijerph17218272. [Epub ahead of print: 09 11 2020].
6 Mehrotra A, Chernew M, Linetsky D, *et al*. The impact of the COVID-19 pandemic on outpatient care: visits return to Prepandemic levels, but not for all providers and patients. *The commonwealth fund* 2020.
7 The British Medical Association. The hidden impact of COVID-19 on patient care in the NHS in England, 2020. Available: https://www.bma.org.uk/media/2841/the-hidden-impact-of-covid_web-pdf.pdf
8 The Lancet Infectious Diseases . The intersection of COVID-19 and mental health. *Lancet Infect Dis* 2020;20:1217.
9 Holmes EA, O'Connor RC, Perry VH, *et al*. Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. *Lancet Psychiatry* 2020;7:547–60.
10 Cancer Research UK. Lung cancer risks becoming 'forgotten disease' of the coronavirus pandemic, 2020. Available: https://www.cancerresearchuk.org/about-us/cancer-news/news-report/2020-09-17-lung-cancer-risks-becoming-forgotten-disease-of-the-coronavirus-pandemic
11 Maringe C, Spicer J, Morris M, *et al*. The impact of the COVID-19 pandemic on cancer deaths due to delays in diagnosis in England, UK: a national, population-based, modelling study. *Lancet Oncol* 2020;21:1023–34.
12 Gordon WJ, Landman A, Zhang H, *et al*. Beyond validation: getting health apps into clinical practice. *NPJ Digit Med* 2020;3:14.
13 The National Institute for Health and Care Excellence (NICE). Evidence standards framework for digital health products. Available: https://www.nice.org.uk/about/what-we-do/our-programmes/evidence-standards-framework-for-digital-health-technologies
14 The National Institute for Health and Care Excellence (NICE). NG183. behaviour change: digital and mobile health interventions, 2020. Available: https://www.nice.org.uk/guidance/ng183/documents/draft-guideline
15 Banskota S, Healy M, Goldberg EM. 15 smartphone Apps for older adults to use while in isolation during the COVID-19 pandemic. *West J Emerg Med* 2020;21:514–25.
16 ORCHA. Available: www.orchahealth.com
17 Iyengar K, Upadhyaya GK, Vaishya R, *et al*. COVID-19 and applications of smartphone technology in the current pandemic. *Diabetes Metab Syndr* 2020;14:733–7.
18 Vidal-Alaball J, Acosta-Roja R, Pastor Hernández N, *et al*. Telemedicine in the face of the COVID-19 pandemic. *Aten Primaria* 2020;52:418–22.
19 Monaghesh E, Hajizadeh A. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health* 2020;20:1193.
20 Simpson AJ, Honkoop PJ, Kennington E, *et al*. Perspectives of patients and healthcare professionals on mHealth for asthma self-management. *Eur Respir J* 2017;49. doi:10.1183/13993003.01966-2016. [Epub ahead of print: 01 05 2017].
21 Kong T, Scott MM, Li Y, *et al*. Physician attitudes towards-and adoption of-mobile health. *Digit Health* 2020;6:205520762090718.
22 Rowland SP, Fitzgerald JE, Holme T, *et al*. What is the clinical value of mHealth for patients? *NPJ Digit Med* 2020;3:4.
23 Leigh S, Ashall-Payne L, Andrews T. Barriers and facilitators to the adoption of mobile health among health care professionals from the United Kingdom: discrete choice experiment. *JMIR Mhealth Uhealth* 2020;8:e17704.
24 Leigh S, Ashall-Payne L. The role of health-care providers in mHealth adoption. *Lancet Digit Health* 2019;1:e58–9.
25 NHSX. Digital technology assessment criteria (DTAC). Available: https://www.nhsx.nhs.uk/key-tools-and-info/digital-technology-assessment-criteria-dtac/

Supplemental material

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Technical Appendix – Search terms used to identify condition-specific searches for DHTs

Addiction

abstinen*, addict*, alcohol*, booze, cessation, cig*, cigarette, drink*, kwit, my quit route, nicotin*, quit, quit genius, smok*, tobacc*, units

Allergy

allerg*, hay fever, hayfever, intoleran*, itch*, rash, sneez, wheez

Carer

Carer

Cancer

blastoma, cancer*, carcinoma, chemo*, leukaem*, leukem*, lymphom*, malig*, melanom*, mole, my dignio, mydignio, myeloma, oncology, owise, radiotherapy, skinvision, tumor, tumour, untire, vinehealth

Children's health

apart of me, baby, brush DJ, catch app, child*, glue ear, handi, huckleberry, infant*, kids, kooth, little journey, moshi, mycognition ED, neonat*, paed*, pediatric, teen*, thinkninja, toddl*, worrinots, xploro

COVID

covid, corona, n-Cov*

Dental

braces, brush*, calculus, cavities, cavity, decay, dental, dentist, denture, enamel, gingivitis, incisor, jaw, mandib*, maxilla, molar,,al health,,al hygiene,,thodont*, palate, periodontal, periodontitis, plaque, root canal, teeth, tooth, veneer

Diabetes search terms

blood sugar, blood glucose, diab*, freestyle, glycaemi*, glycemi*, hba1c, hedia, hypergly*, hypogly*, insulin, intellin, libre, my desmond, onetouch, oviva, retina risk, SMBG, sugar, sugr, t1d, t1dm, t2d, t2dm, type1, type-1, type2, type-2

Diet & weight loss search terms

activ*, bmi, body mass index, calorie*, celiac, coeliac, couch, Diet*, eat*, fasting, fit bit, fitbit, food*, gluten, gojauntly, healthy living, lincus, liva, meal*, mutu, myfitnesspal, nike, noom, nutrition*, obes*, one you, oneyou, overweight, protein, recipe*, second nature, span health, vegan, weigh*

Ears & hearing

Deaf*, ear, hear*, meniere, tinnitus, vertigo,

Eyes & vision

amblyopia, cataract, eye*, glaucoma, macular, myopia, ophthal*, optom*, presbyopia, retina*, retino*, vision, visual

Fitness search terms

Activ*, cardio, exer*, fit*, garmin, gym, komoot, madbarz, moves4me, peloton, pilates, push up, run, strava, stretch*, walking, work out, yoga

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Gastroenterology

bloat*, bowel, colitis, constip*, crohn*, diarrh*, digest*, FODMAP, gall stone, gallstone, gastroenterol*, gastrointestinal, gut, hemorrhoid*, haemorrhoid*, heart burn, heartburn, IBD, IBS, indigest*, intestin*, reflux, stomach, zemedy

Heart

angina, arrthymia, atrial, beats per, blood pressure, BP, bpm, cardiac, cardiology, cardiovascular, chest pain, cholesterol, coronary, ECG, fibricheck, fibril*, heart, hyperlipid*, hypertens*, pacemaker, pulse

Info & guidance

guidance, info*

Kidney disease

Acr, kidney ,renal, urinalysis,

Men's health

Erect*, man*, men*, penis, penil*, prostate, testic*, testis,

Mental health search terms

7 cups, anger, anx*, big white wall, bipolar, blues, calm, catch, CBT, chill panda, clear fear, cognitive, cognitive behavioral, cognitive behavioural, combined minds, counselling, cove, daylight, depress*, distract, drjulian, equoo, esteem, fear, feeling good, grief, happi*, happy*, head space, ieso, kooth, loneliness, lonely, mania, meditat*, mee two, Ment*, mind, mindful, mindset, mind shift, mood, moshi, my therapy, obsessive, obsessive-compulsive, obsessive compulsive , OCD, pacifica, panic, personality disorder, phobia, psychiat*, psycho*, PTSD, relax, schizophrenia, sidekick, silver cloud, stay alive, stress*, suicid*, think ninja, thrive, trauma, woebot, worry, wysa, youper

Musculoskeletal search terms

ankle, arthrit*, back, bone, chiroprac, elbow, gout, hip, joint*, knee, MSK, Musculo*, osteo*, physiapp, physio*, physitrack, rehab*, rheu*, shoulder*, viatherapy, wrist

Neurological

ADHD, alzheimer*, aphasia, attention deficit, autis*, brain*, cerebral, cerebro, cognition, CVA, CVE, demen*, dyslexia, dysphagia, elevate, epilep*, grey matter, head ache, headache, learning difficulty, learning disability, lumosity, m.s, memor, migraine, MS, multiple sclerosis, neuro*, paraesthesia, parkinson*, speech, stammer, stroke, swallow

Nose & throat

Dysphonia, laryn*, nasal, nose, pharyn*, strep*, throat, tonsil*, vocal,

Pain

ache, CRPS, Fatigue, Fibromyalgia, hurt*, myalgia, ouchie, pain*, sciatica, sore*

Pregnancy

abortion, antenatal, baby, breast start, breastfeed*, conceiv*, concep*, conciev*, eclamp*, fertil*, intrapartum, IVF, lactapp, matern*, miscarr*, mum, mush, natural cycles, neonatal, perinatal, postnatal, postpartum, pre eclamp*, pre-eclamp, preeclamp*, preg*, reprod*

Respiratory search terms

air way, airway, asth*, breath*, bronch*, COPD, cough*, cystic fibrosis, dyspnoea, elfy, hailie, inhaler, lung*, nuvoair, peak flow, pneum*, pulmonary, rafi tone, respiratory, triumf, zephyr guide

Self-harm

Distract, harm, self harm, self-harm, stay alive, suicide*

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Sleep search terms

feeling good, headspace, insom*, moshi, nightmare, night terror, pzizz, Sleep*, snor*

Women's health

breast*, cervical, cervix, continence, contracept*, ferly, flo, flow, gynae*, gyne*, hot flashes, incontinen*, libido, menopaus*, menstrua*, mutu, natural cycles, night sweats, obstetri*, ovarian, ovary, ovul*, painful intercourse, painful sex, PCOS, pelvic, period, sexual health, squeezy, woman, women

Technical Appendix – Search terms used to identify condition-specific searches for DHTs

Addiction

abstinen*, addict*, alcohol*, booze, cessation, cig*, cigarette, drink*, kwit, my quit route, nicotin*, quit, quit genius, smok*, tobacc*, units

Allergy

allerg*, hay fever, hayfever, intoleran*, itch*, rash, sneez, wheez

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blastoma, cancer*, carcinoma, chemo*, leukaem*, leukem*, lymphom*, malig*, melanom*, mole, my dignio, mydignio, myeloma, oncology, owise, radiotherapy, skinvision, tumor, tumour, untire, vinehealth

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