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The changing App-etite for digital health: A time-series analysis pre & post COVID-19

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Abstract

Objectives

To explore if consumer demand for 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 United Kingdom (UK), split over two periods, pre-COVID-19 lockdown (January 2019 to March 23rd 2020) and post-COVID-19 lockdown (March 24th 2020 to 31st December 2020).

Setting

United Kingdom

Participants

Members of the UK general population using 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 of DHPs during the study period. 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 2,446 per month prior to COVID-19 lockdown measures being introduced, to 8,996 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 two-months following lockdown. Musculoskeletal conditions (2,036%), allergy (1,253%), and healthy living DHPs (1,051%) experienced the greatest increases in searches compared to 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

COVID-19, and the restrictions on social and interpersonal interaction that followed, have undoubtedly changed the way people seek medical care. This study has demonstrated a significantly increased demand for DHPs during COVID-19, signifying improved acceptance of this therapeutic medium, and an increased opportunity to provide support, in the event that a third-wave of COVID-19 restrictions are introduced.

Keywords

Digital health, COVID-19, health-apps

Strengths & limitations of this study

- This study is a first-of-its-kind in utilising real-world internet search data for DHPs, providing novel insights into the demand for this novel therapeutic medium.
- Segmentation of data into 25 different condition areas has enabled exploration of the appetite for 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 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 improvements in tangible health outcomes.

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 United States, ambulatory care visits fell by 60% in the early phase of the pandemic [6], while in the United Kingdom (UK) alone, an estimated 1.5million elective admissions and 2.6million 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 2,400 fewer people started treatment for lung cancer in April to December 2020, compared with the same time in 2019 [10]. Similarly, an estimated 344, 1,563 and 342 avoidable deaths are expected to occur in the UK as a result of breast, colorectal and oesophageal cancers respectively, with an estimated 63,229 years of life lost as a result [11].

Given the increasing barriers to both accessing and utilising face-to-face care, 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]. As many clinicians are 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, it is uncertain how consumer attitudes and demand for DHPs have changed during this period.

Utilising 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 9,000 DHPs reviewed to date; the aim of this study is to determine how consumer demand for DHPs for various health conditions has changed since COVID-19 lockdown measures were introduced in March 2020. We wish to explore whether digital-health is a more 'acceptable' treatment option among members of the public, and ultimately, whether an appetite for digital-health exists?

Materials and Methods

The methodology for this study is a retrospective time-series analysis of real-world consumer demand for DHPs within ORCHA's Digital Health Libraries, split over two time periods; before and after the initiation of COVID-19 lockdown procedures in the UK, which commenced on March 23rd 2020. Our aim was to determine if either the volume (absolute utilisation), or type of DHPs searched for (relative utilisation), changed following the introduction of COVID-19 lockdown measures, and how demand continued throughout the pandemic.

Health-app search data & categorisation

ORCHA are the world's largest independent reviewer of digital health products (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. For the purpose of this study, user's digital-health search term data, used across all ORCHA Digital Health Libraries from 1st January 2019 to 31st December 2020, was collected using Google Analytics. We removed 2,486 searches which were exclusively alpha-numeric, 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 5,276 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 a multi-disciplinary discussion between 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. 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 Supplementary Figure 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. Firstly, we utilised 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 apps tended to include the name of the condition within the app name, and therefore would have been automatically attributed to a condition, this method was particularly useful for apps 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 two-year period of investigation. This figure was the cut off for classification as it was at this point that clear typos and alpha-numeric 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 United Kingdom on March 23rd 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 apps 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) pre and post-March 23rd 2020 (COVID-19 lockdown). A two-sample Poisson test was used to identify if changes in app search frequency, both overall, and by condition area, were statistically significant at the conventional 95% level. All statistical analyses were conducted in Microsoft Office Excel 2013 (Microsoft ®, Redmond, Washington, USA), and Stata 14.

Patient & public involvement

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

Ethical approval

Following consultation, ethical approval was not sought as the study falls under market research using secondary data, which was completely anonymous data and with no personal or sensitive information.

Results

Searches for DHPs

In the period prior to COVID-lockdown measures being introduced (January 1st 2019 to March 23rd 2020), 36,685 searches for DHPs were undertaken using ORCHA Digital Health Libraries, equivalent to 2,446 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 (March 24th 2020 onwards), a total of 89,955 searches for DHPs took place, equivalent to 8,996 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 vs post COVID-19 lockdown), as demonstrated in Table 1. COVID-19, MSK & physiotherapy, allergy, and fitness/diet and weight loss DHPs experienced ~4622%, ~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.

Table 1: Comparison of search frequency pre & post Covid-19 lockdown measures, by condition area.

Category	Searches per month Pre-Lockdown[1] (mean=)	Searches per month Post-Lockdown[2] (mean=)	Increase (%)	Significance*
COVID	4	197	4622.4%	p<0.01
MSK + physio	34	683	2035.5%	p<0.01
Allergy	4	45	1253.1%	p<0.01
Fitness, diet & weight loss	320	1663	1050.8%	p<0.01
Gastroenterology	12	92	767.6%	p<0.01
Ears & 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 & 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 & chronic fatigue	49	191	389.6%	p<0.01
Nose & 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 & 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 & info	21	16	74.3%	p=0.64

Carer	45	28	63.2%	p=0.14
Combined	2256	8920	395%	N/A

[1]Start January 2019 > March 23rd 2020 (~15 months)

[2]Start March 24th 2020 > End December 2020 (~9 months)

**Significance determined using two-staged Poisson test*

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 appetite for 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, and 14/25 (56%) experienced search volumes more than 100% greater than pre-lockdown levels.

Figure 1: How demand for digital health changed throughout the Covid-19 pandemic

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 demand for digital-health products (DHPs) under real-world conditions. Utilising two-years of retrospective data (January 2019 to December 2020) from the world's largest formulary of DHPs, available to members of

the public in the United Kingdom, we observed a significant increase in the appetite for digital health. Searches for DHPs increased by 343% from an average 2,446 per month prior to COVID-19 lockdown measures being introduced, to an average 8,996 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 & physiotherapy (2,036%), allergy (1,253%), and fitness, diet and weight loss DHPs (1,051%) experiencing the greatest increases in searches.

Strengths and limitations

The strengths of this analysis include the fact that the dataset utilised includes over 125,000 searches for DHPs by members of the public, in the United Kingdom, over a two-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 and post-lockdown, under consideration. Additionally, segmentation of search data into different condition areas allowed exploration of the appetite for digital health in previously unexplored ways. There are several limitations of this analysis which must also be considered when interpreting the findings. Firstly, 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. Therefore, while we can say with relative certainty that the demand for, or interest in DHPs increased as a result of COVID-19 lockdown measures, we cannot definitively determine

whether this increased interest generated tangible improvements in health as a result. Secondly, while every attempt was made to ensure that the conditions under consideration were varied and representative, utilizing 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 searches for the DHPs increased significantly) or overestimating (if searches hardly changed), the impact that COVID-19 had on searches for DHPs. Similarly, although the process used to identify terms to classify DHPs was thorough and multi-disciplinary, it is possible that DHPs could have been mis-classified. While it is unlikely that key terms were omitted, such as diabetes, cancer, mental health or smoking, it is possible that less obvious app names were missed, where the name of the app 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 and post COVID-19 lockdown.

Interpretation in light of other evidence

We found that searches for DHPs increased by 343%, a statistically significant increase from 2,446 per month prior to COVID-19 lockdown measures, to 8,996 per month in the nine-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 HCPs [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 digital health products, including the NHS and the National Institute for Health and Care Excellence (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 (DTAC) [25], and revisions to the NICE evidence standards framework (ESF) [14]. As such, at least some of the increases seen here may have been attributable to latent shifts in attitudes towards digital health, albeit 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 United Kingdom, leisure facilities, organized 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 organized 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 apps increased, as observed within this study. In the first three-months following the first period of lockdown, demand for fitness apps 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 the demand for DHPs centered around addiction, as observed in this study.

What does this mean for clinical practice?

Whilst 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 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 realized 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, therefore recommending these products to their patients.

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 significant value for the NHS in realising its long term goals. This study has provided a basis for a hypothesis that the appetite for 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 measure in order to fulfill 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 normalize, also requires exploration, in order to determine if this was a one-time occurrence, or 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, with this time-series analysis exploring real-world demand over the past two-years. Following COVID-19 lockdown measures being introduced, the demand for DHPs increased by 343%, with technologies dedicated to mental health and fitness among those experiencing the greatest increases. This suggests a dramatic shift in treatment seeking behaviour as a result of COVID-19 lockdown measures, signifying increased acceptance of this therapeutic medium, and the increased opportunity to provide support, when access to incumbent services was limited.

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Ethical approval

Following consultation, ethical approval was not sought as the study falls under market research using secondary data, which was completely anonymous data and with no personal or sensitive information.

Availability of data and materials

The data that support the findings of this study can be made available upon request

Conflicts of interest

The authors declare that they have no conflicts of interest.

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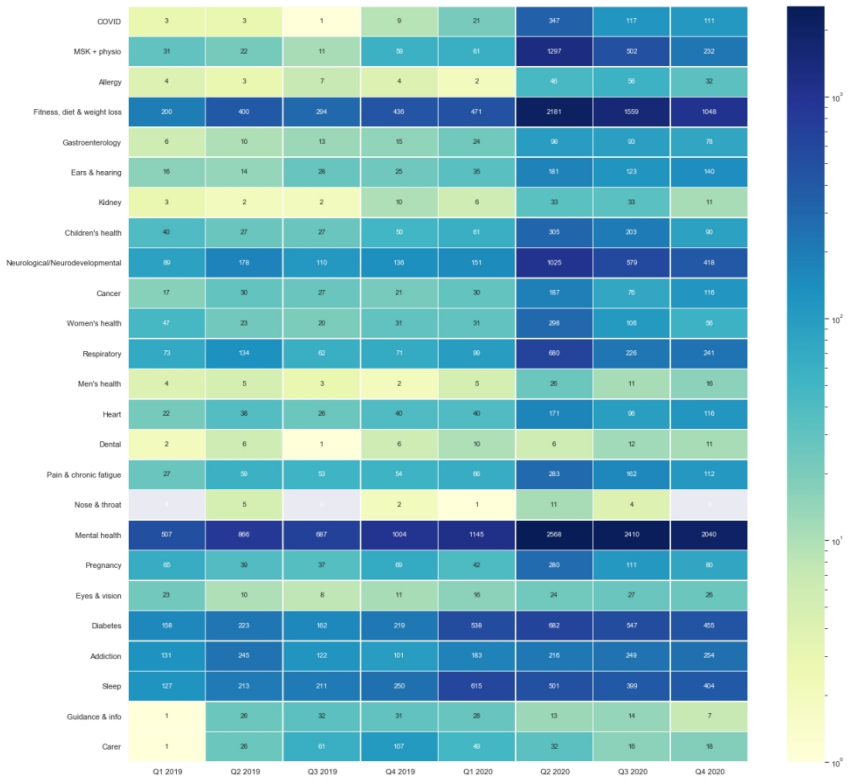
Author statement

SL, TA and LAP devised the study. RD led the data collection. LL and CC provided curation of the data. RD, SL & SS planned and conducted the statistical analysis. SL, SS, RD, LL and CC drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgments

None



How demand for digital health changed throughout the Covid-19 pandemic

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

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*

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

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1 & 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 & 5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8 & 9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7 & 8
Bias	9	Describe any efforts to address potential sources of bias	7 & 8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	N/A (time-series analysis). In absence of time-series checklist, a cohort study was the next

		(b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	best alternative.
Outcome data	15*	Report numbers of outcome events or summary measures over time	10 & 11

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10 & 11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10 & 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12 & 13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	12 & 13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

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

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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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Keywords:	COVID-19, Telemedicine < BIOTECHNOLOGY & BIOINFORMATICS, PRIMARY CARE

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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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Word count

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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 United Kingdom (UK), split over two periods, pre-COVID-19 lockdown (January 2019 to March 23rd 2020) and post-COVID-19 lockdown (March 24th 2020 to 31st December 2020).

Setting

UK

Participants

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

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 343% from 2,446 per month prior to COVID-19 lockdown measures being introduced, to 8,996 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 two-months following lockdown. Musculoskeletal conditions (2,036%), allergy (1,253%), and healthy living DHPs(1,051%) experienced the greatest increases in searches compared to 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 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.

Keywords

Digital health, COVID-19, health-apps

Strengths & limitations of this study

- This study is a first-of-its-kind in utilising real-world internet search data for 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 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.

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 United States, ambulatory care visits fell by 60% in the early phase of the pandemic [6], while in the United Kingdom (UK) alone, an estimated 1.5million elective admissions and 2.6million 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 2,400 fewer people started treatment for lung cancer in April to December 2020, compared with the same time in 2019 [10]. Similarly, an estimated 344, 1,563 and 342 avoidable deaths are expected to occur in the UK as a result of breast, colorectal and oesophageal cancers respectively, with an estimated 63,229 years of life lost as a result [11].

Given the increasing barriers to both accessing and utilising 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. Utilising 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 March 23rd 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.

DHP search data & categorisation

ORCHA are the world's largest independent reviewer of digital health products (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 (CCGs) and integrated care systems (ICSs) 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 United Kingdom 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 1st January 2019 to 31st December 2020, was collected using Google Analytics. We removed 2,486 searches which were exclusively alpha-numeric, 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 5,276 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 multi-disciplinary 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 utilized 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 finalized. 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 Supplementary 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. Firstly, we utilised 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 two-year period of investigation. This figure was the cut off for classification as it was at this point that clear typos and alpha-numeric 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 United Kingdom on March 23rd 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) pre and post-March 23rd 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, USA), with all statistical analyses conducted using Stata 14.

Ethical approval

We used the ethical approval decision tool provided by the University of Manchester [17] and following discussion among the scientific steering committee for the study, ethical approval was not sought. The reason being that the study falls under market research using secondary data, which was completely anonymous data, with no confidential, personal or sensitive information and therefore no possible risk of disclosures. Additionally, we received explicit consent from the data controller to access and utilize the data, with all users of the ORCHA health-app library also consenting to the use of this data for the purpose of research, as detailed in the privacy policy provided to users.

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 (January 1st 2019 to March 23rd 2020), 36,685 searches for DHPs were undertaken using ORCHA Digital Health Libraries, equivalent to 2,446 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 (March 24th 2020 onwards), a total of 89,955 searches for DHPs took place, equivalent to 8,996 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 vs post COVID-19 lockdown), as demonstrated in Table 1. COVID-19, MSK & physiotherapy, allergy, and fitness/diet and weight loss DHPs experienced ~4622%, ~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.

Table 1: Comparison of search frequency pre & post Covid-19 lockdown measures, by condition area.

Category	Searches per month Pre-Lockdown[1] (mean=)	Searches per month Post-Lockdown[2] (mean=)	Increase (%)	Significance*
COVID	4	197	4622.4%	p<0.01
MSK + physio	34	683	2035.5%	p<0.01
Allergy	4	45	1253.1%	p<0.01
Fitness, diet & weight loss	320	1663	1050.8%	p<0.01
Gastroenterology	12	92	767.6%	p<0.01
Ears & 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 & 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 & chronic fatigue	49	191	389.6%	p<0.01
Nose & 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 & 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 & info	21	16	74.3%	p=0.64
Carer	45	28	63.2%	p=0.14
Combined	2256	8920	395%	N/A

[1]Start January 2019 > March 23rd 2020 (~15 months)

[2]Start March 24th 2020 > End December 2020 (~9 months)

**Significance determined using two-staged Poisson test*

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, and 14/25 (56%) experienced search volumes more than 100% greater than pre-lockdown levels.

Figure 1: How interest in digital health changed throughout the Covid-19 pandemic

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 digital-health products (DHPs) under real-world conditions. Utilising two-years of retrospective data (January 2019 to December 2020) from the world's largest formulary of DHPs, available to healthcare providers and members of the public in the United Kingdom, we observed a significant increase in searches for DHPs. Searches for DHPs increased by 343% from an average 2,446 per month prior to COVID-19 lockdown measures being introduced, to an average 8,996 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 & physiotherapy (2,036%), allergy (1,253%), and fitness, diet and weight loss DHPs (1,051%) 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.

Strengths and limitations

The strengths of this analysis include the fact that the dataset utilised includes over 125,000 searches for DHPs by members of the public from the United Kingdom, over a two-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 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 limitations of this analysis which must also be considered when interpreting the findings. Firstly, 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. Secondly, while every attempt was made to ensure that the conditions under consideration were varied and representative, utilizing 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 multi-disciplinary, it is possible that DHPs could have been mis-classified 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 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 2,446 per month prior to COVID-19 lockdown measures, to 8,996 per month in the nine-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 HCPs [18-20], 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 [21-23], and promotion of this relatively new therapeutic medium by health authorities. Previous studies, including two conducted by the authors of this study [24,25] have shown that recommendations from health authorities to use digital health products, including the NHS and the National Institute for Health and Care Excellence (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 (DTAC) [26], and revisions to the NICE evidence standards framework (ESF) [14]. As such, at least some of the increases seen here may have been attributable to latent shifts in attitudes towards digital health, albeit 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 United Kingdom, leisure facilities, organized 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 organized 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 three-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 centered around addiction, as observed in this study.

What does this mean for clinical practice?

Whilst 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 realized 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 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 fulfill 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 normalize, 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 HCP, 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 two-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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Ethical approval

We used the ethical approval decision tool provided by the University of Manchester [17] and following discussion among the scientific steering committee for the study, ethical approval was not sought. The reason being that the study falls under market research using secondary data, which was completely anonymous data, with no confidential, personal or sensitive information and therefore no possible risk of disclosures. Additionally, we received explicit consent from the data controller to access and utilize the data, with all users of the ORCHA health-app library also consenting to the use of this data for the purpose of research, as detailed in the privacy policy provided to users.

Availability of data and materials

The data that support the findings of this study can be made available upon request

Conflicts of interest

The authors declare that they have no conflicts of interest.

Funding

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Author statement

SL, TA and LAP devised the study. RD led the data collection. LL and CC provided curation of the data. RD, SL & SS planned and conducted the statistical analysis. SL, SS, RD, LL and CC drafted the manuscript. All authors read and approved the final manuscript.

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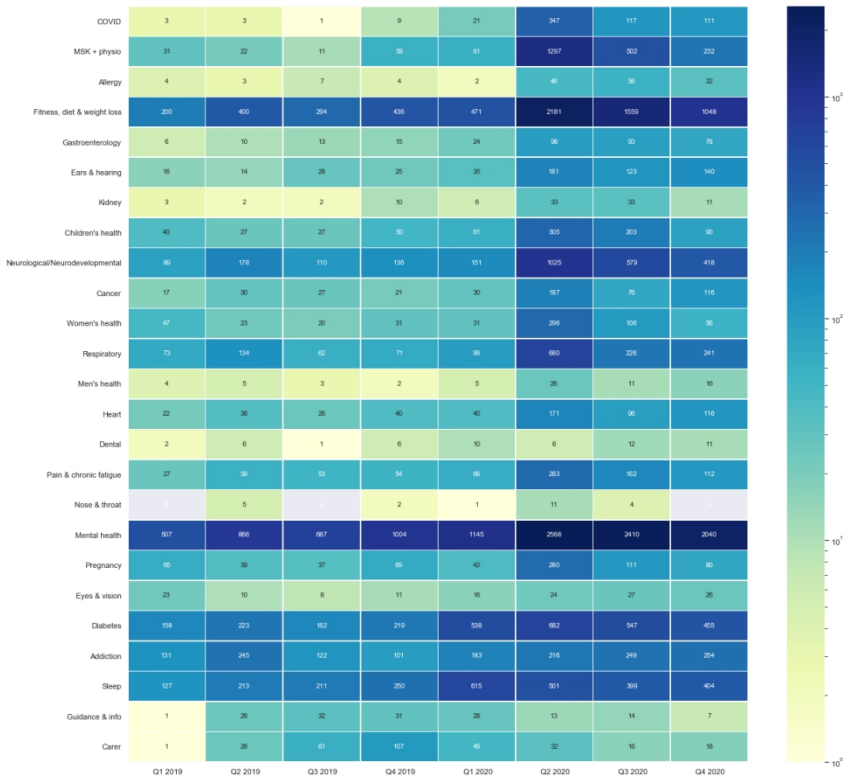
None



How demand for digital health changed throughout the Covid-19 pandemic

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

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*

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

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1 & 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 & 5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8 & 9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7 & 8
Bias	9	Describe any efforts to address potential sources of bias	7 & 8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	N/A (time-series analysis). In absence of time-series checklist, a cohort study was the next

		(b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	best alternative.
Outcome data	15*	Report numbers of outcome events or summary measures over time	10 & 11

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10 & 11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10 & 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12 & 13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	12 & 13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

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