BMJ Open

Cross-sectional analysis of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-068627
Article Type:	Original research
Date Submitted by the Author:	11-Oct-2022
Complete List of Authors:	Alturkistani, Abrar; Imperial College London, Department of Primary Care and Public Health Greenfield, Geva; Imperial College London, Department of Primary Care & Public Health Beaney, Thomas; Imperial College London, Department of Primary Care and Public Health Norton, John; National Institute for Health Research, Applied Research Collaboration Northwest London Costelloe, Ceire ; Imperial College London, Department of Primary Care and Public Health; Institute of cancer Research Division of Clinical studies
Keywords:	Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Cross-sectional analysis of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Abrar Alturkistani[1]*(https://orcid.org/0000-0001-7935-8870), Geva Greenfield[2] (https://orcid.org/0000-0001-9779-2486), Thomas Beaney[1,3](https://orcid.org/0000-0001-9709-7264), John Norton[3], Ceire E Costelloe[1,4](https://orcid.org/0000-0002-3475-7525)

[1] Global Digital Health Unit, Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[2] Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[3] National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom;

[4] Division of Clinical studies, Institute of cancer Research, London, United Kingdom; National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom

*Corresponding author

Email: Abrar.alturkistani16@imperial.ac.uk

Word count: 2849.

Keywords general practice; primary health care; patient portal; electronic health record; personal health record; GP Patient Survey.

Abstract

Objectives: To explore the characteristics of participants using the different functionalities of the services in the context of NHS General Practices.

Design: Cross-sectional study.

Participants: participants of the General Practice Patient Survey in England for the years 2018-2020.

Primary and secondary outcome measures: Online appointment booking and online repeat prescription ordering. We assessed the association between online services use and participant characteristics using two-level mixed-effects logistic regression.

Results: 1,806,977 survey participants were included in this study. 15% (n=263938) used online appointment booking in the last 12 months, and 19% (n=339449) had ordered a repeat prescription in the last 12 months. Participants with a long-term condition, on regular multiple medications, who have deafness or hearing loss and who are from the lowest deprivation quintile were more likely to have used online services. Male participants (compared to females) and participants with Black and Other ethnic background compared to White ethnic backgrounds were less likely to use online services. Participants over 85 years old were less likely to use online appointment booking and online repeat prescription ordering compared to the younger age groups.

Conclusions: Specific groups of participants used online services such as patients with long-term conditions or those with deafness or hearing loss. While online services could provide efficiency to patients and practices it is essential that alternatives continue to be provided to those that cannot use or choose not to use online services. Understanding the different patients' needs could help tailor solutions to encourage the uptake and use of the services.

Strengths and limitations of this study

1. The study used a sample from a major national survey to explore the characteristics of online services users, a service which has been highly advocated in the NHS and in other healthcare systems of the world.
2. Given the clustered nature of the data (where patients are registered to different general practices) and to account for the clustering, we used multilevel logistic regression analysis.
3. The study relied on self-reported data for online service use due to data unavailability which can lead to response bias.

BACKGROUND

Online services such as appointment booking or repeat prescription ordering are offered in 99.7% of General Practitioner (GP) practices in England [1], but patients have to request access to the service and adoption remains low (about 31% in May 2020) [1]. According to previous literature, online services, also referred to as patient portals, have the potential to promote patients' involvement in their care, reduce emergency visits and hospitalisation [2], and may improve some health outcomes through improving medication adherence [2, 3] patient knowledge about health and patient efficacy (e.g. patient's confidence in adhering to health instructions or treatment) [4]. Few studies have examined the characteristics of patients using online services and the inequalities that might exist based on patient characteristics in the context of NHS services such as ethnicity and deprivation inequalities [5-7]. Understanding patient characteristics associated with online service use may reveal barriers to use and inform service planning to increase the uptake of the services.

Studies from other countries, and a limited number of studies from the UK, suggest that [7-10] patients with low income, and ethnic minorities may be less likely to use patient portals

due to reduced access to the internet, computers and smartphones [8, 10]. This is the first study to look at online services user characteristics for both online appointment booking and repeat prescription ordering explicitly in England, where the NHS have invested in a nation-wide digital transformation programme [11]. This study aims to examine patients' characteristics associated with online appointment booking and repeat prescription service ordering.

METHODS

The methods are described using the Strengthening the reporting of observational studies in epidemiology (STROBE) checklist [12] (Supplementary Table 1).

Patient and public involvement

The NIHR Applied Research Collaboration of Northwest London Public Advisors were consulted during the study write-up and were involved appropriately in the drafting.

Study design

Cross-sectional analysis of data from the General Practice Patient Survey (GPPS) of 2018, 2019, and 2020 in England.

Variables

The outcome variables (online appointment booking use and online repeat prescription use) were based on the responses to the GPPS question: "Which of the following general practice online services have you used in the past 12 months?" [13] in which the answers "Booking appointments online", and "Ordering repeat prescriptions online" were used for this study. The GPPS also records the use of online record viewing. However, we did not include it in this study due to the limited number of participants reporting the use of the functionality (about 5% in 2020

and lower proportions in 2019 and 2018). Additionally, ten different covariates (explanatory variables) were included in the models as listed in table 1.

Table 1 The list of variables included in the two-level regression models of the study and their definitions

Variable	Categories and definition
Gender	Male, Female
Age	16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, 85 or over
Ethnicity	White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [14]) White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [14])
Survey year	2018, 2019 or 2020 (created based on the year of the survey)
Long-term conditions	Yes, No, or "I don't know/ Can't answer" answers to the question: "Do you have any long-term physical or mental health conditions, disabilities or illnesses?" [13]
Deafness or hearing loss	Yes or No answer to the question: " Which, if any, of the following long-term conditions do you have?…Deafness or hearing loss" [13]
Taking 5 or more medications on a regular basis	Yes or No answer to the question: "Do you take 5 or more medications on a regular basis?" [13]
Parent status	Yes or No answer to the question: "Are you a parent or a legal guardian for any children aged under 16 living in your home?" [13]
Carer status	Yes or No answer derived from the answers to the question: "Do you look after, or give any help or support to family members, friends, neighbours or others because of either: long-term physical or mental ill health / disability, or problems related to old age?"
Index of Multiple Deprivation (IMD) quintiles	Derived from the IMD ranking available in the dataset where the ranks were converted to quintiles according to the English indices of deprivation 2019 guidance. The IMD ranking in the dataset is based on the ranking of the postcode of the participant [15]. Derived from the IMD ranking available in the dataset where the ranks were converted to quintiles according to the

	English indices of deprivation 2019 guidance. The IMD ranking in the dataset is based on the ranking of the postcode of the participant [15].
Rurality of the General Practice	Rural or urban as defined by the ONS [16]Rural or urban as defined by the ONS [16]

Data source

The GPPS is a national, postal survey commissioned by NHS England. GPPS uses random sampling, proportionately stratified by GP practice, age, and gender. Eligibility for GPPS includes having a valid NHS number, being 16 years or older and being registered with a GP for at least 6 months. Response rates of previous surveys are considered, sending more surveys to low-response practices and fewer survey to high-response practices [17-19]. The survey was sent to 2,221,082, 2,328,560, 2,329,590 participants in the years 2018, 2019 and 2020, with response rates of 34%, 33% and 32%, respectively [17-19].

In March 2020, social restrictions were announced in England due to the COVID-19 pandemic [20]. The last data collected for the GPPS was in April 2020, however, only a small number of surveys were received post March 2020 with the GPPS indicating it was highly unlikely that the survey results were affected by the pandemic [18].

Study size

We received data from 2,246,109 participants who completed the GPPS surveys in 2018, 2019 or 2020. After removing participants that did not have complete data for the variables of interest (n=439,060, 19.5%), 1,807,049 participants were included.

Statistical methods

We first reported descriptive statistics of the participants based on their online appointment booking and repeat prescription use. We then performed multilevel mixed-effects logistic regression models: First, we created a null model with only the outcome variable and random intercept (GP practice) to understand if there was clustering due to the random intercept. We then added all patient level covariates to the model (model 2). We checked the Intraclass Correlation Coefficient (ICC) and intercepted in all models to examine the effect of clustering. We then added the GP level variable (GP rurality) in the final model (model 3) [21]. Methods of the sensitivity analyses is in the Supplementary Table 2.

RESULTS

Some of the results of this study will be presented as a conference abstract in the following year [22].

Summary statistics

1,807,049 participants were included of which 15% (n=263938) used online appointment booking (used at least once in the last 12 months), and 19% (n=339449) used online repeat prescription (used at least once in the last 12 months) (Supplementary Table 3). Most participants were female (55.1%), and in the 65-74 years age group (22%), were of white ethnic backgrounds (86.8%), and were registered at GPs in an urban area (83.1%) and half (51.1%) had a long-term condition.

About 19.5% of the total sample received from GPPS was excluded due to missing data. The proportion of participants by category were different to the complete case dataset in the

proportions for age, ethnicity (most participants were from the mixed ethnicity), survey year, long-term condition, taking five or more medications, reporting of deafness or hearing loss, and slight difference in deprivation fifths proportions (Supplementary Table 4). Descriptive statistics of the sensitivity analysis groups are displayed in Supplementary Table 5.

Patient and GP characteristics associated with online services use

Online appointment booking

Results of the two-level mixed-effects logistic regression for the online appointment booking outcome are presented in table 2. Participants with a long-term condition, taking 5 or more medications on a regular basis and who have deafness or hearing loss were more likely to use online appointment booking compared to participants without these characteristics. In the fully adjusted model for patient and GP characteristics, participants with a long-term condition had 67% greater odds of using online appointment booking (CI: 1.66-1.69) compared to participants without a long-term condition.

Males had lower odds of booking an appointment online (OR: 0.89, 95% CI: 0.88-0.90) than females. Compared to the age group (85+), the odds ratio for using online appointment booking was the highest for the age groups 25-34 and 35-44 (OR: 4.96, 95% CI: 4.78-5.14) and (OR: 4.85, 95% CI:4.68-5.03), respectively.

Participants of black and "other" ethnic backgrounds had lower odds than those of white ethnic backgrounds for using online appointment booking, whereas participants of Asian ethnic backgrounds had 11% (OR: 1.11, 95% CI: 1.09-1.13) greater odds of using online appointment booking.

Parents or legal guardians were less likely and carers of people with long-term condition or disability were more likely to book online appointments compared with non-carers.

There was an inverse association between deprivation quintile and online appointment booking. The odds for using online appointment booking increased with reducing deprivation from the second to fifth (least deprived) quintile compared to the most deprived quintile. Participants in the least deprived quintile had 54% greater odds of booking appointments online (OR: 1.54, 95% CI: 1.51-1.57) compared to those in the most deprived quintile. Participants from the survey year 2020 were the most likely to use online appointment booking compared to participants from the survey year 2018 and 2019.

Participants from GPs located in an urban setting had greater odds of booking appointments online compared to participants from GPs in a rural setting.

Model comparison: The ICC of 0.13 indicates that there is a slight similarity between values from the same group (in this case from the same GP practice) although the difference is not large because the value is close to zero.

Table 2 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey participant characteristics on Online appointment booking use in the last 12 months (level 1 , N= 1807049 participants; level 2, N=7256 general practices)

Predictors	+ GP Characteristics (Model 3) Odds Ratios	95% Confidence Interval
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.15***	(1.12, 1.19)
Long term condition- Yes	1.67***	(1.66, 1.69)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.18, 1.20)
Deafness or hearing loss-Yes (REF= No)	1.13***	(1.11, 1.15)
Gender-Male (REF= Female)	0.89***	(0.88, 0.90)
Age (REF: 85+)		
16-24	3.63***	(3.48, 3.78)
25-34	4.96***	(4.78, 5.14)
35-44	4.85***	(4.68, 5.03)
45-54	4.26***	(4.12, 4.42)
55-64	3.69***	(3.57, 3.82)
65-74	3.09***	(2.99, 3.20)

Predictors	+ GP Characteristics (Model 3) Odds Ratios	95% Confidence Interval
75-84	1.74***	(1.68, 1.80)
Ethnicity (REF: White)		
Black	0.84***	(0.81, 0.86)
Asian	1.11***	(1.09, 1.13)
Other	0.96**	(0.92, 0.99)
Mixed	1.04	(1.00, 1.08)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.92***	(0.90, 0.93)
Carer-Yes (REF= No)	1.14***	(1.13, 1.16)
Deprivation quintile (REF: 1- Most deprived)		
2	1.15***	(1.13, 1.17)
3	1.27***	(1.25, 1.29)
4	1.40***	(1.37, 1.42)
5 (least deprived)	1.54***	(1.51, 1.57)
Survey year (REF= 2018)		
2019	1.19***	(1.18, 1.20)
2020	1.52***	(1.50, 1.54)
General practice rurality-urban (REF= rural)	1.11***	(1.07, 1.16)
Model summary		
ICC	0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Online repeat prescription ordering

Results of the two-level mixed-effects logistic regression for the online repeat prescription ordering outcome are presented in table 3. Participants with a long-term condition, users of 5 or more medications on a regular basis and participants with deafness or hearing loss were all more likely to use online repeat prescription ordering compared to participants without these characteristics. The odds of using online repeat prescription ordering was 2.58 times greater (OR: 2.58, 95% CI: 2.55, 2.60) for participants with a long-term condition compared to those without a condition.

Males had 4% lower odds of ordering repeat prescriptions online (OR: 0.96, 95% CI: 0.96-0.97) than females. All age groups from 16-84 had greater odds of using online repeat prescription ordering compared to the age group 85+. However, participants from the age groups 45-54 and 55-64 had the highest odds of ordering repeat prescriptions online compared to the age group 85+ (OR: 3.18, 95% CI: 3.10-3.28) and (OR: 3.28, 95% CI: 3.20, 3.37), respectively.

Black, Asian, and Mixed had lower odds of using online repeat prescription ordering compared to the White ethnicity. Parents or legal guardians had 5% lower odds of ordering repeat prescriptions online (OR: 0.95, 95% CI: 0.94- 0.96) than non-parents. Carers of people with a long-term condition or disability had 16% greater odds of ordering repeat prescriptions online (OR: 1.16, 95% CI: 1.15- 1.17) compared to non-carers.

Participants in the deprivation quintiles 4 and 5 (least deprived) had the highest odds of using online repeat prescription ordering compared to the most deprived group (OR: 1.62, 95% CI: 1.59, 1.64) and (OR: 1.77, 95% CI: 1.74, 1.80), respectively.

Participants who completed the survey in the years 2019 and 2020 had greater odds of using online repeat prescription ordering compared to participants from the survey year 2018.

Participants from GPs located in an urban setting had lower odds of ordering repeat prescriptions online compared to participants from GPs in a rural setting.

Model comparison: the ICC was 0.08 for model 3 in table 3, which also showed that there is slight evidence that patients from the same GP may have more similar results compared to patients from other GPs. Results of the sensitivity analyses are in Supplementary Tables 6 and 7.

Table 3 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey participant characteristics on Online Repeat prescription ordering use in the last 12 months (level 1, N= 1807049 participants; level 2, N=7256 general practices)

	+ GP Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.25***	(1.22, 1.29)
Long term condition- Yes	2.58***	(2.55, 2.60)
Taking five or more medication on a regular basis-Yes (REF= No)	1.26***	(1.25, 1.28)
Deafness or hearing loss-Yes (REF= No)	1.02**	(1.00, 1.03)
Gender-Male (REF= Female)	0.96***	(0.96, 0.97)
Age (REF: 85+)		
16-24	1.71***	(1.64, 1.77)
25-34	2.17***	(2.10, 2.23)
35-44	2.69***	(2.61, 2.77)
45-54	3.18***	(3.10, 3.28)
55-64	3.28***	(3.20, 3.37)
65-74	3.01***	(2.93, 3.09)
75-84	1.68***	(1.64, 1.73)
Ethnicity (REF: White)		
Black	0.76***	(0.74, 0.78)
Asian	0.94***	(0.93, 0.96)
Other	0.78***	(0.75, 0.81)
Mixed	0.98	(0.94, 1.02)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.95***	(0.94, 0.96)
Carer-Yes (REF= No)	1.16***	(1.15, 1.17)
Deprivation quintile (REF: 1- Most deprived)		
2	1.23***	(1.21, 1.25)
3	1.44***	(1.42, 1.46)
4	1.62***	(1.59, 1.64)
5 (least deprived)	1.77***	(1.74, 1.80)
Survey year (REF= 2018)		
2019	1.18***	(1.17, 1.19)
2020	1.46***	(1.44, 1.47)
General practice rurality-urban (REF= rural)	0.88***	(0.85, 0.91)
Model Summary		
ICC	0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

DISCUSSION

Principal findings

The most notable findings of this study were that online services were predominantly used by certain groups including participants with a long-term condition, using regular multiple medications, have deafness or hearing loss, carers, and the most recent participants of the survey (2020). There was some evidence of inequality in use by some participants groups. Participants of Black, and Other ethnic backgrounds were less likely to use online services compared to people of White ethnic backgrounds. Additionally, the deprivation gradient (the association with online service use in the least deprived quintile and most deprived quintile) showed that online services use increased with reduced deprivation and that use was highest among the least deprived quintile.

Strengths and weaknesses of the study

Although online services have been offered almost universally in GPs in England since 2015, there continues to be a lack of research on the use of online services (or patient portals) in this setting [7, 23]. This study used a major national survey major national survey which uses rigorous research methodology (accounting for GP practice variation in the models and accounting for missing data in the sensitivity analyses) to explore online services user characteristics in England which can inform service planning and identify patient groups who may need support using the service.

A limitation of the study was using only complete-case data in the analyses. Participants excluded from the analyses due to missing data presented differences in the breakdown of participant characteristics. Therefore, we performed sensitivity to explore what kind of

differences might have observed if all the sample was included. Both summary statistics of the excluded sample and the sensitivity analyses indicated GPs with more missing data may be more likely to have younger age groups, greater deprivation groups, and ethnically diverse groups, all of which were associated with relatively lower odds of using online services. This introduces the possibility that some of the odd's ratios presented in the main analysis may be larger than they are in the population due to missing data bias.

As with all survey-based studies, a major limitation of the GPPS is the non-response bias. However, a study on the methodology of the GPPS, did not find evidence of non-response bias [24].We tried to alleviate non-response bias by controlling for deprivation, ethnicity, age and gender (which can often be associated with low-response rates as reported in a study examining GPPS non-response characteristics [24]).

Strengths and weaknesses in relation to other studies

This study relied on self-reported online service usage which could introduce response bias. A better way to measure use could be via the electronic patient portal log files. The log files automatically record patient portal activity and can serve as an objective method to examine patient portal use because it is not subject to recall bias and records the exposure prior to the outcome [3]. However, due to data unavailability of patient-level data of this kind at the time of the study, the GPPS records of online services use was used in this study as it has been on other England based studies exploring patient portal use [5, 6].

Discussing important differences in results

Patients from more deprived areas, and from ethnic minorities are reported to have lower uptake of patient portals in previous studies [25]. According to previous studies, deprivation and ethnicity play key roles in online services use [26-28] which was confirmed by the main analysis

and sensitivity analyses in this study. A study from the USA suggested that patients' ethnicity could be associated with less trust in patient portals [29]. Lower use of online services by participants with greater deprivation levels is repeatedly reported in the literature [30]. This may be due to lower access to the internet, smart phone, and computers among individuals from more deprived areas [7, 31].

Meaning of the study

There is evidence that online services use in England is increasing every year and it is likely to continue to be an important tool in GP settings. Understanding the needs of populations less likely to use online services may help improve the uptake of the services and meet the needs of vulnerable populations which may be more prone to have reduced access to healthcare services [32] in addition to online services. There is evidence that online services use is increasing every year and it is likely to continue to be an important tool in GP settings. Understanding the needs of populations less likely to use online services may help improve the uptake of the services and meet the needs of vulnerable populations which may be more prone to have reduced access to healthcare services [32] in addition to online services.

Possible explanations and implications for clinicians and Policymakers

The adoption of online services by those with long-term conditions is promising and can potentially contribute to improve self-management of the long-term condition [2]. However, it is also a reflection that patients with long-term conditions may generally be more likely to use healthcare services[33-35]. Practices could continue to encourage patients with long-term

conditions to sign up and use online services. However, it is essential that alternatives to online services continue to be provided to patients who are unable to use the services [33-35].

This study shows that online services use is lower among people from more deprived areas and from ethnic minorities which may introduce inequities if in-person services become out of reach. As an example, the move to telephone consultations and remote triage in GPs amidst the COVID-19 pandemic made it difficult for homeless people to access care due to not having a telephone [36]. In-person access to care is seen necessary to reach all patient groups despite access to technology in the move to remote consultations in the COVID-19 pandemic [36]. For this reason, it is important that practices continue to provide in-person services (e.g. for appointment booking and repeat prescriptions) to patients especially those less able to access remote services.

Unanswered questions and future research

Further research is needed to understand the lack of uptake of the services in some patient groups to clarify if uptake is low due to barriers or due to patient preference. In the light of the COVID-19 pandemic, where patients are asked to contact their GP remotely [37], inequities in the access and use of the online services may be responsible for dramatic inequities when it comes to situations where online services becomes the only route of accessing care [38]. Although the findings of this study should be viewed as pre-COVID-19 findings, the patterns in disparities may continue or worsen in the post-COVID-19 period amidst the move to remote GP services. Future research could focus on the effects of these services on aspects of the healthcare system such as healthcare utilisation and patients' self-management of their condition.

Funding

This article presents independent research commissioned by the National Institute for Health Research (NIHR) under the Applied Health Research (ARC) programme for Northwest London. The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. TB acknowledges support from the NIHR ARC Northwest London.

Ethical approval

This study was approved by the Imperial College Research Ethics Committee, Reference number: 20IC6303.

Author contribution

AA, GG, TB and CC created the study design, formulated the research question and finalised the study methodology. AA performed the analysis of the study. JN contributed to the introduction and discussion sections of the study. All authors reviewed and approved the submitted manuscript.

Data sharing statement

The data that support the findings of this study are available on request from Ipsos Mori but cannot be provided by the authors due to ethical restrictions. However, the aggregate level GPPS data are openly available in the GP Patient Survey webpage at https://www.gp-patient.co.uk/ [13].

Competing interests

The authors declare that they have no competing interests.

References

1. *Patient Online Management Information (POMI) - NHS Digital*. 2021; Available from: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub/patient-online-management-information-pomi.
2. ME, R., et al., *Patients with complex chronic conditions: Health care use and clinical events associated with access to a patient portal.* PloS one, 2019. **14**(6).
3. DR, M. and D. M, *Sharing Ethics Consultation Notes With Patients Through Online Portals.* AMA journal of ethics, 2020. **22**(9).
4. HR, H., et al., *Using Patient Portals to Improve Patient Outcomes: Systematic Review.* JMIR human factors, 2019. **6**(4).
5. M, G.-C., et al., *Awareness and use of online appointment booking in general practice: analysis of GP Patient Survey data.* The British journal of general practice : the journal of the Royal College of General Practitioners, 2020. **70**(suppl 1).
6. Gomez-Cano, et al., *Awareness and use of online services in general practice: analysis of GP Patient Survey data | SAPC*, in *SAPC ASM 2021*. 2021, @sapcacuk: Virtual.
7. A, A.-A., et al., *Patients' Perspectives About Factors Affecting Their Use of Electronic Personal Health Records in England: Qualitative Analysis.* Journal of medical Internet research, 2021. **23**(1).
8. S, E.-T., et al., *Barriers to Patient Portal Access and Use: Evidence from the Health Information National Trends Survey.* Journal of the American Board of Family Medicine : JABFM, 2020. **33**(6).
9. A, G., et al., *Patient Portals: Who uses them? What features do they use? And do they reduce hospital readmissions?* Applied clinical informatics, 2016. **7**(2).
10. MG, A., P. O, and L. F, *The State of Evidence in Patient Portals: Umbrella Review.* Journal of medical Internet research, 2020. **22**(11).
11. Watcher, R.M., *Making IT work: harnessing the power of health information technology to improve care in England*. 2016.
12. *STROBE Strengthening the reporting of observational studies in epidemiology*. 2021; Available from: https://www.strobe-statement.org/.
13. *GP Patient Survey: Surveys and Reports*. 2020; Available from: https://www.gp-patient.co.uk/surveysandreports.
14. *Ethnic group, national identity and religion*. 2021; Available from: https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion.
15. Ministry of Housing, C., & Local Government. *English Indices of Deprivation 2019 FAQs*. 2019; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf.
16. *2011 rural/urban classification*. 2011; Available from: https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification.

17. MORI, I. *GP Patient Survey 2019 Technical Annex*. 2019; Available from: https://gp-patient.co.uk/downloads/archive/2019/GPPS_2019_Technical_Annex_PUBLIC.pdf.
18. MORI, I. *GP Patient Survey 2020 Technical Annex*. 2020; Available from: https://gp-patient.co.uk/downloads/2020/GPPS_2020_Technical_Annex_PUBLIC.pdf.
19. MORI, I. *GP Patient Survey - Technical Annex: 2018 annual report*. August 2018; Available from: https://gp-patient.co.uk/downloads/archive/2018/GPPS%202018%20Technical%20Annex%20PUBLIC.pdf.
20. GOV.UK, *Prime Minister's statement on coronavirus (COVID-19): 23 March 2020.* 23 March 2020.
21. Kleiman, E., *Understanding and analyzing multilevel data from real-time monitoring studies: An easily- accessible tutorial using R.* 2021.
22. Alturkistani, A., et al., ***Ethnicity, deprivation, and the use of patient portals in England's general practices 2018-2020 (in-press)***. European Journal of Public Health.
23. F, M., et al., *Patients' online access to their electronic health records and linked online services: a systematic review in primary care.* The British journal of general practice : the journal of the Royal College of General Practitioners, 2015. **65**(632).
24. M, R., et al., *Reliability of patient responses in pay for performance schemes: analysis of national General Practitioner Patient Survey data in England.* BMJ (Clinical research ed.), 2009. **339**.
25. CH, H., et al., *Racial Differences in Patient Portal Activation and Research Enrollment Among Patients With Prostate Cancer.* JCO clinical cancer informatics, 2021. **5**.
26. S, S., et al., *Disparities in Electronic Health Record Patient Portal Enrollment Among Oncology Patients.* JAMA oncology, 2021. **7**(6).
27. EP, U., F. J, and Y. LM, *Disparities in Electronic Patient Portal Use in Prenatal Care: Retrospective Cohort Study.* Journal of medical Internet research, 2019. **21**(9).
28. DM, W., et al., *Exploring the Digital Divide: Age and Race Disparities in Use of an Inpatient Portal.* Telemedicine journal and e-health : the official journal of the American Telemedicine Association, 2020. **26**(5).
29. MA, C., et al., *Sociodemographic Differences and Factors Affecting Patient Portal Utilization.* Journal of racial and ethnic health disparities, 2021. **8**(4).
30. Priti, S., et al., *Outpatient Portal Use in Prenatal Care: Differential Use by Race, Risk, and Area Social Determinants of Health Factors.* medRXiv, 2021.
31. Matthew, H., et al. *Digital technology and health inequalities: a scoping review*. 2020; Available from: https://phw.nhs.wales/publications/publications1/digital-technology-and-health-inequalities-a-scoping-review/.
32. Saunders, C.L., et al., *Sociodemographic inequalities in patients' experiences of primary care: an analysis of the General Practice Patient Survey in England between 2011 and 2017:.* https://doi.org/10.1177/1355819620986814, 2021.
33. LB, S., et al., *Disease Burden and Healthcare Utilization Among Patients with Chronic Obstructive Pulmonary Disease (COPD) in England.* International journal of chronic obstructive pulmonary disease, 2022. **17**.
34. CW, l.R., et al., *Obesity and healthcare resource utilization: results from Clinical Practice Research Database (CPRD).* Obesity science & practice, 2018. **4**(5).
35. HI, W., et al., *Healthcare resource use and costs for people with type 2 diabetes mellitus with and without severe mental illness in England: longitudinal matched-cohort study using the Clinical Practice Research Datalink.* The British journal of psychiatry : the journal of mental science, 2022. **221**(1).
36. Howells, K.A., et al., *Remote primary care during the COVID-19 pandemic for people experiencing homelessness: a qualitative study.* 2022.

37. NHS. *Using the NHS and other health services during coronavirus (COVID-19)*. 2021 2 Jun 2020; Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/using-the-nhs-and-other-health-services/.
38. Ian, L., S. David, and G. Sheila, *Impact of COVID-19 on the digital divide: a rapid review.* 2021.

Supplementary material

Supplementary Table 1 STROBE 2007 checklist of items to be included in reports of observational studies in epidemiology.

Supplementary Table 2. Methods and results of the sensitivity analysis.

Supplementary Table 3. Descriptive statistics of the number and proportion of participant characteristics in the total population included in the analyses (n=1807049), categorised by online services use.

Supplementary Table 4. The breakdown of participants by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060).

Supplementary Table 5. Breakdown of the number and proportion of participant characteristics based on the categories of the proportion of missing data in the GP practice.

Supplementary Table 6. Results of model 3 of the sensitivity analysis of the online appointment booking in the last 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary Table 7. Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the last 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary material:

Supplementary Table 1 STROBE 2007 checklist [12] of items to be included in reports of observational studies in epidemiology

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
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	*5*
Bias	9	Describe any efforts to address potential sources of bias	6 & Supplementary Table 2
Study size	10	Explain how the study size was arrived at	6

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	Supplementary Table 2
		(*c*) Explain how missing data were addressed	Supplementary Table 2
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Supplementary Table 2
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	7
		(b) Give reasons for non-participation at each stage	6-7
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7 & Supplementary Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	7 & Supplementary Table 4
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	8-12
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 2, Supplementary Table 5-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-13

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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
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	16

Supplementary Table 2. Methods and results of the sensitivity analysis

Methods	In the main analyses performed in this study, only complete case participants (participants that did not have any missing data for any of the variables included in the analyses) were included. We ran sensitivity analyses to explore the effects of excluding participants with missing data. We first calculated the proportion of participants with complete data per practice using the complete dataset (n=2198821) and assigned each practice a new variable indicating the proportion of complete case participants in the practice. We then separated the complete case participants (n=1807049) into three categories based on the proportion of complete case participants in their practice. The three categories were: highest missing data group (≥75%), middle-range missing data group (26-74%), and lowest missing data group (≤25%). We then ran the same two-level mixed-effects models for each of the outcomes (online appointment booking and online repeat prescription use) separately for each of the three categories.

Results	The summary statistics of the sensitivity analysis groups are reported in table Supplementary Table 5. GPs with the highest proportion of missing data (practices with 75% or more of participants with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a greater proportion of participants from Black, Asian and Other ethnic backgrounds as well. Greater proportion or participants from the most deprived group compared to the GPs with lower missing data. Results of the sensitivity mixed-effects regression analyses for the online appointment booking outcome is in table Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the participants from the practices with the different proportion of missing data. The difference in odds ratios when comparing participants from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. These differences indicate that the characteristics of participants within each type of the GPs (based on the proportion of missing data) were more similar to each other than the other type of practices. For the repeat prescription outcome (Supplementary Table 7), differences in odds ratios were also seen for the long-term condition (answering yes), age groups, ethnicity, being a

	parent, being a carer and for the deprivation quintile. Among the highest missing data GP practice participants, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97) greater odds of online repeat prescription use compared to participants from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice participants. This indicates that deprivation has a larger impact in practices with the most missing data compared to practices with the least missing data for the online repeat prescription ordering outcome. Sensitivity analyses results reveal that some of the estimates in this study may be attenuated if missing data/non-response participants were present. However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained to be larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services between the three categories of GPs use were bigger for online repeat prescription use compared to the online appointment booking use. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GPs indicating that socioeconomic inequities may have a larger influence on online repeat

	prescription ordering than online appointment booking. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with bigger differences in the odds associated with the outcome for participants from the highest missing data GPs compared to the other GPs.

Supplementary Table 3. Descriptive statistics of the number and proportion of participant characteristics in the total population included in the analyses (n=1807049), categorized by online services use

Characteristics	Total	Online appointment booking in the last 12 months			Online repeat prescription ordering in the last 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Gender				<0.001			0.97
Female	996544 (55.1%)	843422 (54.7%)	153122 (58.0%)		809337 (55.1%)	187207 (55.2%)	
Male	810505 (44.9%)	699689 (45.3%)	110816 (42.0%)		658263 (44.9%)	152242 (44.8%)	
Age				<0.001			<0.001
16-24	74381 (4.1%)	64513 (4.2%)	9868 (3.7%)		67069 (4.6%)	7312 (2.2%)	
25-34	159806 (8.8%)	132951 (8.6%)	26855 (10.2%)		141376 (9.6%)	18430 (5.4%)	
35-44	217687 (12.0%)	181290 (11.7%)	36397 (13.8%)		186112 (12.7%)	31575 (9.3%)	
45-54	302285 (16.7%)	253145 (16.4%)	49140 (18.6%)		243458 (16.6%)	58827 (17.3%)	

Characteristics	Total	Online appointment booking in the last 12 months			Online repeat prescription ordering in the last 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
55-64	381808 (21.1%)	321902 (20.9%)	59906 (22.7%)		295168 (20.1%)	86640 (25.5%)	
65-74	397999 (22.0%)	340484 (22.1%)	57515 (21.8%)		303875 (20.7%)	94124 (27.7%)	
75-84	211586 (11.7%)	191217 (12.4%)	20369 (7.7%)		176214 (12.0%)	35372 (10.4%)	
85+	61497 (3.4%)	57609 (3.7%)	3888 (1.5%)		54328 (3.7%)	7169 (2.1%)	
Ethnicity				<0.001			<0.001
White	1567690 (86.8%)	1340202 (86.9%)	227488 (86.2%)		1258828 (85.8%)	308862 (91.0%)	
Black	52950 (2.9%)	46120 (3.0%)	6830 (2.6%)		47195 (3.2%)	5755 (1.7%)	
Asian	137026 (7.6%)	115015 (7.5%)	22011 (8.3%)		118728 (8.1%)	18298 (5.4%)	
Other	29168 (1.6%)	24993 (1.6%)	4175 (1.6%)		25773 (1.8%)	3395 (1.0%)	
Mixed	20215 (1.1%)	16781 (1.1%)	3434 (1.3%)		17076 (1.2%)	3139 (0.9%)	
Survey year				<0.001			<0.001
2018	612084 (33.9%)	536349 (34.8%)	75735 (28.7%)		512184 (34.9%)	99900 (29.4%)	
2019	623358 (34.5%)	534321 (34.6%)	89037 (33.7%)		507522 (34.6%)	115836 (34.1%)	
2020	571607 (31.6%)	472441 (30.6%)	99166 (37.6%)		447894 (30.5%)	123713 (36.4%)	

Characteristics	Total	Online appointment booking in the last 12 months			Online repeat prescription ordering in the last 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Long-term condition				<0.001			<0.001
No	833523 (46.1%)	730177 (47.3%)	103346 (39.2%)		736861 (50.2%)	96662 (28.5%)	
I don't know/ Can't answer	49746 (2.8%)	43186 (2.8%)	6560 (2.5%)		43212 (2.9%)	6534 (1.9%)	
Yes	923780 (51.1%)	769748 (49.9%)	154032 (58.4%)		687527 (46.8%)	236253 (69.6%)	
Taking five or more medication on a regular basis				<0.001			<0.001
No	1343735 (74.4%)	1151312 (74.6%)	192423 (72.9%)		1118704 (76.2%)	225031 (66.3%)	
Yes	463314 (25.6%)	391799 (25.4%)	71515 (27.1%)		348896 (23.8%)	114418 (33.7%)	
Deafness or hearing loss				<0.001			<0.001
No	1652099 (91.4%)	1409236 (91.3%)	242863 (92.0%)		1344856 (91.6%)	307243 (90.5%)	
Yes	154950 (8.6%)	133875 (8.7%)	21075 (8.0%)		122744 (8.4%)	32206 (9.5%)	
Parent or legal guardian to				<0.001			<0.001

Characteristics	Total	Online appointment booking in the last 12 months			Online repeat prescription ordering in the last 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
a 16 year old or younger							
No	1466017 (81.1%)	1254880 (81.3%)	211137 (80.0%)		1177272 (80.2%)	288745 (85.1%)	
Yes	341032 (18.9%)	288231 (18.7%)	52801 (20.0%)		290328 (19.8%)	50704 (14.9%)	
Carer				<0.001			<0.001
No	1462467 (80.9%)	1254985 (81.3%)	207482 (78.6%)		1200653 (81.8%)	261814 (77.1%)	
Yes	344582 (19.1%)	288126 (18.7%)	56456 (21.4%)		266947 (18.2%)	77635 (22.9%)	
Deprivation quintile				<0.001			<0.001
1 (Most deprived)	338728 (18.7%)	298412 (19.3%)	40316 (15.3%)		292405 (19.9%)	46323 (13.6%)	
2	353580 (19.6%)	304870 (19.8%)	48710 (18.5%)		296229 (20.2%)	57351 (16.9%)	
3	376042 (20.8%)	322081 (20.9%)	53961 (20.4%)		304048 (20.7%)	71994 (21.2%)	
4	378002 (20.9%)	319100 (20.7%)	58902 (22.3%)		297096 (20.2%)	80906 (23.8%)	
5 (Least deprived)	360697 (20.0%)	298648 (19.4%)	62049 (23.5%)		277822 (18.9%)	82875 (24.4%)	
General practice rurality				<0.001			<0.001

Characteristics	Total	Online appointment booking in the last 12 months			Online repeat prescription ordering in the last 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Rural	306200 (16.9%)	263405 (17.1%)	42795 (16.2%)		238353 (16.2%)	67847 (20.0%)	
Urban	1500849 (83.1%)	1279706 (82.9%)	221143 (83.8%)		1229247 (83.8%)	271602 (80.0%)	

* p-value derived from chi squared test comparing online appointment booking users and non-users
† p-value derived from chi squared test comparing online repeat prescription users and non-users

Supplementary Table 4 The breakdown of participants by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060)

Characteristics	**Total in the sample received (n=2,246,109)**	**Total in the complete case dataset (n=1807049)**	**Total in the excluded sample (n=439,060)**
Online appointment booking in the last 12 months			
No	1892841 (84.3%)	1543111 (85.4%)	349730 (79.7%)
Yes	305980 (13.6%)	263938 (14.6%)	42042 (9.6%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Online repeat prescription ordering in the last 12 months			
No	1807863 (80.5%)	1467600 (81.2%)	340263 (77.5%)
Yes	390958 (17.4%)	339449 (18.8%)	51509 (11.7%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Gender			
Female	1229473 (54.7%)	996544 (55.1%)	232929 (53.1%)

Male	967079 (43.1%)	810505 (44.9%)	156574 (31.7%)
(Missing)	49557 (2.2%)	0 (0.0%)	49557 (11.3%)
Age			
16-24	87081 (3.9%)	74381 (4.1%)	12700 (2.9%)
25-34	185580 (8.3%)	159806 (8.8%)	25774 (5.9%)
35-44	256766 (11.4%)	217687 (12.0%)	39079 (8.9%)
45-54	360011 (16.0%)	302285 (16.7%)	57726 (13.1%)
55-64	454900 (20.3%)	381808 (21.1%)	73092 (16.6%)
65-74	487171 (21.7%)	397999 (22.0%)	89172 (20.3%)
75-84	287533 (12.8%)	211586 (11.7%)	75947 (17.3%)
85+	91083 (4.1%)	61497 (3.4%)	29586 (6.7%)
(Missing)	35984 (1.6%)	0 (0.0%)	35984 (8.2%)
Ethnicity			
White	1895473 (84.4%)	1567690 (86.8%)	15862 (3.6%)
Black	68812 (3.1%)	52950 (2.9%)	33583 (7.6%)
Asian	170609 (7.6%)	137026 (7.6%)	10257 (2.3%)
Other	39425 (1.8%)	29168 (1.6%)	4558 (1.0%)
Mixed	24773 (1.1%)	20215 (1.1%)	327783 (74.7%)
(Missing)	47017 (2.1%)	0 (0.0%)	47017 (10.7%)
Survey year			
2018	750619 (33.4%)	612084 (33.9%)	138535 (31.6%)
2019	763244 (34.0%)	623358 (34.5%)	139886 (31.9%)
2020	732246 (32.6%)	571607 (31.6%)	160639 (36.6%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Long term condition			
No	1022671 (45.5%)	833523 (46.1%)	189148 (43.1%)
Yes	1050129 (46.8%)	923780 (51.1%)	126349 (28.8%)
Don't know/Can't say	61802 (2.8%)	49746 (2.8%)	12056 (2.7%)
Prefer not to say	38879 (1.7%)	0 (0.0%)	38879 (8.9%)
(Missing)	72628 (3.2%)	0 (0.0%)	72628 (16.5%)
Taking five or more medication on a regular basis			
No	1632850 (72.7%)	1343735 (74.4%)	289115 (65.8%)
Yes	574749 (25.6%)	463314 (25.6%)	111435 (25.4%)

(Missing)	38510 (1.7%)	0 (0.0%)	38510 (8.8%)
Deafness or hearing loss			
No	1799633 (80.1%)	1652099 (91.4%)	147534 (33.6%)
Yes	179304 (8.0%)	154950 (8.6%)	24354 (5.5%)
(Missing)	267172 (11.9%)	0 (0.0%)	267172 (60.9%)
Parent or legal guardian to a 16 year old or younger			
No	1782911 (79.4%)	1466017 (81.1%)	316894 (72.2%)
Yes	407923 (18.2%)	341032 (18.9%)	66891 (15.2%)
(Missing)	55275 (2.5%)	0 (0.0%)	55275 (12.6%)
Carer			
No	1741536 (77.5%)	1462467 (80.9%)	279069 (63.6%)
Yes	410450 (18.3%)	344582 (19.1%)	65868 (15.0%)
(Missing)	94123 (4.2%)	0 (0.0%)	94123 (21.4%)
Deprivation fifth			
1- least deprived	437189 (19.5%)	338728 (18.7%)	98461 (22.4%)
2	444869 (19.8%)	353580 (19.6%)	91289 (20.8%)
3	464884 (20.7%)	376042 (20.8%)	88842 (20.2%)
4	461586 (20.6%)	378002 (20.9%)	83584 (19.0%)
5 - most deprived	435997 (19.4%)	360697 (20.0%)	75300 (17.2%)
(Missing)	1584 (0.1%)	0 (0.0%)	1584 (0.4%)
General practice rurality			
Rural	374466 (16.7%)	306200 (16.9%)	68266 (15.5%)
Urban	1871643 (83.3%)	1500849 (83.1%)	370794 (84.5%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Supplementary Table 5. Breakdown of the number and proportion of participant characteristics based on the categories of the proportion of missing data in the GP practice

Characteristics	Participants from practices with 25% or less participants with missing data n=474082, 1843 practices	Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices	Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices
Online services use			
Online appointment booking in the last 12 months	75194(15.9%)	176193(19.4%)	55937(13.1%)
Online repeat prescription use in the last 12 months	102332(21.6%)	176193(19.4%)	60924(14.4%)
Gender			
Female	265428 (56.0%)	503040 (55.3%)	228076 (53.8%)
Male	208654 (44.0%)	406112 (44.7%)	195739 (46.2%)
Age			
16-24	18750 (4.0%)	34473 (3.8%)	21158 (5.0%)
25-34	39537 (8.3%)	75142 (8.3%)	45127 (10.6%)
35-44	55609 (11.7%)	103244 (11.4%)	58834 (13.9%)
45-54	79934 (16.9%)	149707 (16.5%)	72644 (17.1%)
55-64	100332 (21.2%)	194450 (21.4%)	87026 (20.5%)
65-74	106927 (22.6%)	208741 (23.0%)	82331 (19.4%)
75-84	56564 (11.9%)	111123 (12.2%)	43899 (10.4%)

Characteristics	Participants from practices with 25% or less participants with missing data n=474082, 1843 practices	Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices	Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices
85+	16429 (3.5%)	32272 (3.5%)	12796 (3.0%)
Ethnicity			
White	5027 (1.1%)	17758 (2.0%)	30165 (7.1%)
Black	16190 (3.4%)	49142 (5.4%)	71694 (16.9%)
Asian	3729 (0.8%)	10722 (1.2%)	14717 (3.5%)
Other	4175 (0.9%)	8704 (1.0%)	7336 (1.7%)
Mixed	444961 (93.9%)	822826 (90.5%)	299903 (70.8%)
Survey year			
2018	166729 (35.2%)	305514 (33.6%)	139841 (33.0%)
2019	162214 (34.2%)	315671 (34.7%)	145473 (34.3%)
2020	145139 (30.6%)	287967 (31.7%)	138501 (32.7%)
Long-term condition			
No	11725 (2.5%)	24207 (2.7%)	13814 (3.3%)
I don't know/ Can't answer	220575 (46.5%)	411974 (45.3%)	200974 (47.4%)
Yes	241782 (51.0%)	472971 (52.0%)	209027 (49.3%)
Taking five or more medication on a regular basis			

Characteristics	Participants from practices with 25% or less participants with missing data n=474082, 1843 practices	Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices	Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices
No	363720 (76.7%)	674880 (74.2%)	305135 (72.0%)
Yes	110362 (23.3%)	234272 (25.8%)	118680 (28.0%)
Deafness or hearing loss			
No	433463 (91.4%)	827757 (91.0%)	390879 (92.2%)
Yes	40619 (8.6%)	81395 (9.0%)	32936 (7.8%)
Parent or legal guardian to a 16 year old or younger			
No	385230 (81.3%)	746422 (82.1%)	334365 (78.9%)
Yes	88852 (18.7%)	162730 (17.9%)	89450 (21.1%)
Carer			
No	382112 (80.6%)	732193 (80.5%)	348162 (82.1%)
Yes	91970 (19.4%)	176959 (19.5%)	75653 (17.9%)
Deprivation quintile			
1 (Most deprived)	38111 (8.0%)	146156 (16.1%)	154461 (36.4%)
2	64792 (13.7%)	174694 (19.2%)	114094 (26.9%)

Characteristics	Participants from practices with 25% or less participants with missing data n=474082, 1843 practices	Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices	Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices
3	99792 (21.0%)	199586 (22.0%)	76664 (18.1%)
4	124261 (26.2%)	203142 (22.3%)	50599 (11.9%)
5 (Least deprived)	147126 (31.0%)	185574 (20.4%)	27997 (6.6%)
General practice rurality			
Rural	116101 (24.5%)	165787 (18.2%)	24312 (5.7%)
Urban	357981 (75.5%)	743365 (81.8%)	399503 (94.3%)

Supplementary Table 6 Results of model 3 of the sensitivity analysis of the online appointment booking in the last 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, Participants from practices with 25% or less participants with missing data n=474082, 1843 practices		Model 3, Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices		Model 3, Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.16***	(1.10, 1.23)	1.14***	(1.10, 1.19)	1.16***	(1.10, 1.22)
Long term condition- Yes	1.78***	(1.75, 1.81)	1.69***	(1.67, 1.72)	1.49***	(1.46, 1.53)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.17, 1.22)	1.20***	(1.18, 1.22)	1.20***	(1.17, 1.23)
Deafness or hearing loss-Yes (REF= No)	1.15***	(1.11, 1.19)	1.12***	(1.09, 1.14)	1.12***	(1.08, 1.16)
Gender-Male (REF= Female)	0.88***	(0.86, 0.89)	0.88***	(0.87, 0.89)	0.91***	(0.89, 0.93)
Age (REF: 85+)						
16-24	3.39***	(3.14, 3.66)	3.76***	(3.55, 3.98)	3.50***	(3.21, 3.82)
25-34	4.69***	(4.37, 5.03)	5.17***	(4.91, 5.45)	4.66***	(4.30, 5.06)
35-44	4.63***	(4.32, 4.96)	5.13***	(4.87, 5.40)	4.46***	(4.11, 4.83)
45-54	4.28***	(4.01, 4.57)	4.51***	(4.29, 4.74)	3.75***	(3.46, 4.06)

Predictors	Model 3, Participants from practices with 25% or less participants with missing data n=474082, 1843 practices		Model 3, Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices		Model 3, Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
55-64	3.80***	(3.56, 4.05)	3.94***	(3.75, 4.13)	3.07***	(2.84, 3.32)
65-74	3.27***	(3.07, 3.49)	3.32***	(3.16, 3.48)	2.35***	(2.18, 2.54)
75-84	1.81***	(1.69, 1.93)	1.83***	(1.74, 1.93)	1.43***	(1.32, 1.55)
Ethnicity (REF: White)						
Black	0.75***	(0.69, 0.81)	0.83***	(0.79, 0.87)	0.87***	(0.83, 0.90)
Asian	1.04	(1.00, 1.09)	1.10***	(1.07, 1.14)	1.14***	(1.10, 1.17)
Other	0.86**	(0.79, 0.95)	0.92**	(0.87, 0.98)	1.01	(0.96, 1.06)
Mixed	1.01	(0.93, 1.10)	1.01	(0.95, 1.07)	1.09**	(1.02, 1.16)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.91***	(0.89, 0.93)	0.90***	(0.88, 0.92)	0.96***	(0.93, 0.98)
Carer-Yes (REF= No)	1.11***	(1.09, 1.13)	1.15***	(1.13, 1.17)	1.17***	(1.14, 1.19)
Deprivation quintile (REF: 1-Most deprived)						
2	1.15***	(1.11, 1.20)	1.14***	(1.12, 1.17)	1.16***	(1.13, 1.19)
3	1.23***	(1.19, 1.28)	1.29***	(1.26, 1.32)	1.27***	(1.23, 1.30)
4	1.38***	(1.33, 1.44)	1.40***	(1.37, 1.43)	1.36***	(1.31, 1.41)
5 (least deprived)	1.54***	(1.48, 1.60)	1.52***	(1.49, 1.56)	1.53***	(1.46, 1.60)

10.1136/bmjopen-2023-080277 on 12 October 2023. Downloaded from

Predictors	Model 3, Participants from practices with 25% or less participants with missing data n=474082, 1843 practices		Model 3, Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices		Model 3, Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Survey year (REF= 2018)						
2019	1.16***	(1.14, 1.18)	1.18***	(1.17, 1.20)	1.25***	(1.22, 1.28)
2020	1.46***	(1.43, 1.49)	1.52***	(1.50, 1.54)	1.61***	(1.57, 1.65)
General practice rurality-Urban (REF= Rural)	1.22***	(1.10, 1.23)	1.11***	(1.10, 1.19)	1.10	(0.97, 1.24)
Model summary						
Interclass correlation coefficient (ICC)	0.13		0.12		0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Supplementary Table 7 Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the last 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, Participants from practices with 25% or less participants with missing data n=474082, 1843 practices		Model 3, Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices		Model 3, Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.25***	(1.18, 1.32)	1.25***	(1.20, 1.30)	1.24***	(1.17, 1.31)
Long term condition- Yes	2.71***	(2.66, 2.75)	2.56***	(2.52, 2.59)	2.42***	(2.37, 2.47)
Taking five or more medication on a regular basis- Yes (REF= No)	1.26***	(1.24, 1.29)	1.26***	(1.24, 1.28)	1.29***	(1.26, 1.32)
Deafness or hearing loss-Yes (REF= No)	1.02	(1.00, 1.05)	1.02	(1.00, 1.04)	1.01	(0.98, 1.04)
Gender-Male (REF= Female)	0.96***	(0.94, 0.97)	0.96***	(0.95, 0.97)	0.98***	(0.96, 1.00)
Age (REF: 85+)						
16-24	1.64***	(1.53, 1.75)	1.76***	(1.67, 1.85)	1.62***	(1.50, 1.76)
25-34	2.16***	(2.04, 2.29)	2.22***	(2.13, 2.32)	1.98***	(1.85, 2.13)
35-44	2.67***	(2.52, 2.82)	2.82***	(2.70, 2.94)	2.37***	(2.21, 2.54)
45-54	3.25***	(3.09, 3.42)	3.29***	(3.16, 3.42)	2.82***	(2.65, 3.01)
55-64	3.35***	(3.18, 3.52)	3.43***	(3.31, 3.56)	2.81***	(2.64, 3.00)
65-74	3.11***	(2.97, 3.27)	3.15***	(3.03, 3.27)	2.48***	(2.33, 2.64)
75-84	1.73***	(1.65, 1.82)	1.75***	(1.68, 1.82)	1.43***	(1.34, 1.53)
Ethnicity (REF: White)						
Black	0.77***	(0.71, 0.84)	0.73***	(0.70, 0.77)	0.81***	(0.77, 0.84)
Asian	0.88***	(0.84, 0.92)	0.94***	(0.91, 0.97)	1.01	(0.98, 1.04)
Other	0.79***	(0.71, 0.87)	0.76***	(0.72, 0.81)	0.82***	(0.77, 0.86)

Predictors	Model 3, Participants from practices with 25% or less participants with missing data n=474082, 1843 practices		Model 3, Participants from practices with 26%-74% of participants with missing data n=909152, 3361 practices		Model 3, Participants from practices with 75% or more participants with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Mixed	0.96	(0.89, 1.05)	0.98	(0.93, 1.05)	0.99	(0.92, 1.07)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.93***	(0.91, 0.96)	0.94***	(0.92, 0.96)	0.99	(0.96, 1.02)
Carer-Yes (REF= No)	1.13***	(1.11, 1.16)	1.15***	(1.14, 1.17)	1.19***	(1.17, 1.22)
Deprivation quintile (REF: 1-Most deprived)						
2	1.21***	(1.17, 1.26)	1.22***	(1.19, 1.25)	1.22***	(1.19, 1.26)
3	1.37***	(1.32, 1.42)	1.43***	(1.40, 1.46)	1.43***	(1.39, 1.47)
4	1.54***	(1.48, 1.59)	1.59***	(1.55, 1.62)	1.67***	(1.62, 1.73)
5 (least deprived)	1.65***	(1.59, 1.71)	1.74***	(1.70, 1.78)	1.89***	(1.82, 1.97)
Survey year (REF= 2018)						
2019	1.16***	(1.13, 1.18)	1.17***	(1.15, 1.19)	1.26***	(1.24, 1.29)
2020	1.40***	(1.38, 1.43)	1.46***	(1.44, 1.48)	1.54***	(1.51, 1.58)
General practice rurality-Urban (REF= Rural)	0.94**	(0.89, 0.99)	0.90***	(0.87, 0.94)	0.97	(0.88, 1.07)
Model summary						
Interclass correlation coefficient (ICC)	0.07		0.07		0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

BMJ Open

Cross-sectional analysis of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-068627.R1
Article Type:	Original research
Date Submitted by the Author:	24-Mar-2023
Complete List of Authors:	Alturkistani, Abrar; Imperial College London, Department of Primary Care and Public Health Greenfield, Geva; Imperial College London, Department of Primary Care & Public Health Beaney, Thomas; Imperial College London, Department of Primary Care and Public Health Norton, John; National Institute for Health Research, Applied Research Collaboration Northwest London Costelloe, Ceire ; Imperial College London, Department of Primary Care and Public Health; Institute of cancer Research Division of Clinical studies
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Public health
Keywords:	Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Cross-sectional analysis of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Abrar Alturkistani[1]*(https://orcid.org/0000-0001-7935-8870), Geva Greenfield[2] (https://orcid.org/0000-0001-9779-2486), Thomas Beaney[1,3](https://orcid.org/0000-0001-9709-7264), John Norton[3], Ceire E Costelloe[1,4](https://orcid.org/0000-0002-3475-7525)

[1] Global Digital Health Unit, Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[2] Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[3] National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom;

[4] Division of Clinical studies, Institute of cancer Research, London, United Kingdom; National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom

*Corresponding author

Email: Abrar.alturkistani16@imperial.ac.uk

Word count: 3718.

Keywords general practice; primary health care; patient portal; electronic health record; personal health record; GP Patient Survey.

Abstract

Objectives: To explore the characteristics of the General Practice Patient Survey (GPPS) respondents using the different functionalities of the online services in the context of England's

National Health Service (NHS) General Practices. We hypothesised that use of online services would vary according to patient sociodemographic factors.

Design: Cross-sectional study using respondent-level data from the GPPS in England of the years 2018, 2019 and 2020. We assessed the association between online services use and respondent characteristics using two-level mixed-effects logistic regression.

Participants: Survey respondents of the GPPS 2018-2020.

Primary and secondary outcome measures: Online appointment booking and online repeat prescription ordering.

Results: 1,806,977 survey respondents were included in this study. 15% (n=263938) used online appointment booking in the previous 12 months, and 19% (n=339449) had ordered a repeat prescription in the previous 12 months. Respondents with a long-term condition, on regular multiple medications, who have deafness or hearing loss and who are from the lowest deprivation quintile were more likely to have used online services. Male respondents (compared to females) and respondents with Black and Other ethnic background compared to White ethnic backgrounds were less likely to use online services. Respondents over 85 years old were less likely to use online appointment booking and online repeat prescription ordering compared to the younger age groups.

Conclusions: Specific groups of respondents were more likely to use online services such as patients with long-term conditions or those with deafness or hearing loss. While online services could provide efficiency to patients and practices it is essential that alternatives continue to be provided to those that cannot use or choose not to use online services. Understanding the different patients' needs could help tailor solutions to encourage the uptake and use of the services.

Strengths and limitations of this study

1. The study used a sample from a major national survey which follows a rigorous methodology in its data collection to explore the characteristics of online services users, a service which has been highly advocated in the NHS and in other healthcare systems of the world.
2. Given the clustered nature of the data (where patients are registered to different general practices) and to account for the clustering, we used multilevel logistic regression analysis.
3. The study relied on self-reported data for online service use due to data unavailability which can lead to response bias.

BACKGROUND

Online services such as online appointment booking or repeat prescription ordering are offered in 99.7% of General Practitioner (GP) practices in England [1], but patients have to request access to the service and adoption remains low (about 31% in May 2020) [1]. According to previous literature, online services, also referred to as patient portals, have the potential to promote patients' involvement in their care, reduce emergency visits and hospitalisation [2], and may improve some health outcomes through improving medication adherence [2, 3] patients' knowledge about health and patient efficacy (e.g. patient's confidence in adhering to health instructions or treatment) [4]. Few studies have examined the characteristics of patients using online services and the inequalities that might exist based on patient characteristics in the context of the National Health Service (NHS) of England such as ethnicity and deprivation inequalities

[5-7]. Understanding patient characteristics associated with online service use may reveal barriers to use and inform service planning to increase the uptake of the services.

Studies from other countries, and a limited number of studies from the UK, suggest that [7-10] patients with low income, and ethnic minorities may be less likely to use patient portals due to reduced access to the internet, computers and smartphones [8, 10]. This is the first study to look at online services user characteristics for both online appointment booking and repeat prescription ordering explicitly in England, where the NHS have invested in a nation-wide digital transformation programme [11]. This study aims to examine patients' characteristics associated with online appointment booking and repeat prescription service ordering.

Healthcare systems are characterized as complex systems and healthcare innovations often face multi-faceted challenges in diffusion ("passive spread") and adoption due to the nature of complex systems [12]. A major theory considered in healthcare innovation adoption is the digital divide theory which considers the inequality that occurs when people without access to technology (that is physical access but also access to the knowledge and skills to use the technology) are excluded from the benefits that technology has to offer [13, 14]. In consideration of the digital divide theory [13, 14], we hypothesized that those of older age (patients 35 years old and older) of lower socioeconomic status and respondents of minority ethnic groups would be less likely to use online services. Additionally, in consideration of patients' health status, we hypothesized that respondents with long-term or chronic conditions (but not those who are very ill) may be more likely to use online services because of their increased need to access and use the services such as appointment booking and repeat prescription.

METHODS

Patient and public involvement

The NIHR Applied Research Collaboration of Northwest London Public Advisors were consulted during the study write-up and were involved appropriately in the drafting.

Study design

Cross-sectional analysis of respondent-level data from the General Practice Patient Survey (GPPS) of 2018, 2019, and 2020 in England. The respondent-level data was pseudonymised and researchers' did not have access to respondents' name, address, NHS number or date of birth. Respondent-level data is only presented aggregately to protect respondents' privacy as agreed in the ethical approval of the study (20IC6303). Data collection for each survey was between January and March for the years 2018 and 2019 and between January and April for 2020. Respondents of the survey have the right to withdraw their consent before the data is processed [15].

Variables

The outcome variables (online appointment booking use and online repeat prescription use) were based on the responses to the GPPS question: "Which of the following general practice online services have you used in the past 12 months?" [16] in which the answers "Booking appointments online", and "Ordering repeat prescriptions online" were used for this study. The GPPS also records the use of online record viewing. However, we did not include it in this study due to the limited number of respondents reporting the use of the functionality (about 5% in 2020 and lower proportions in 2019 and 2018). Additionally, ten different covariates (explanatory variables) were included in the models as listed in table 1. The list of variables were chosen

based on factors that are known to be associated with patient portal use in the literature such as long-term condition status, deafness or hearing loss, parent and carer status and based on data availability such as taking 5 or more medications regularly (another indicator for healthcare status).

Table 1 The list of variables included in the two-level regression models of the study and their definitions

Variable	Categories and definition
Gender	Male, Female
Age	16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, 85 or over (as categorised by the survey)
Ethnicity	White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [17]) White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [17])
Survey year	2018, 2019 or 2020 (created based on the year of the survey)
Long-term conditions	Yes, No, or "I don't know/ Can't answer" answers to the question: "Do you have any long-term physical or mental health conditions, disabilities or illnesses?" [16]
Deafness or hearing loss	Yes or No answer to the question: " Which, if any, of the following long-term conditions do you have?…Deafness or hearing loss" [16]
Taking 5 or more medications on a regular basis	Yes or No answer to the question: "Do you take 5 or more medications on a regular basis?" [16]
Parent status	Yes or No answer to the question: "Are you a parent or a legal guardian for any children aged under 16 living in your home?" [16]
Carer status	Yes or No answer derived from the answers to the question: "Do you look after, or give any help or support to family members, friends, neighbours or others because of either: long-term physical or mental ill health / disability, or problems related to old age?"
Index of Multiple Deprivation (IMD) quintiles	A variable provided by GPPS based Derived from the ONS score indicating deprivation banding based on patients' postcode where the ranks were converted to quintiles according to the English indices of deprivation 2019 guidance [18].
Rurality of the General Practice	A variable provided by GPPS based on the GP practice's postcode categorised as Rural or urban as defined by the ONS [19]Rural or urban as defined by the ONS [19]

Data source

The GPPS is a national, postal survey commissioned by NHS England. GPPS uses random sampling, proportionately stratified by GP practice, age, and gender. Eligibility for GPPS includes having a valid NHS number, being 16 years or older and being registered with a GP practice for at least 6 months. Response rates of previous surveys are considered, sending more surveys to low-response practices and fewer survey to high-response practices [20-22]. The survey was sent to 2,221,082, 2,328,560, 2,329,590 respondents in the years 2018, 2019 and 2020, with response rates of 34%, 33% and 32%, respectively [20-22].

In March 2020, social restrictions were announced in England due to the COVID-19 pandemic [23]. The last data collected for the GPPS was in April 2020, however, only a small number of surveys were received post March 2020 with the GPPS indicating it was highly unlikely that the survey results were affected by the pandemic [21].

Study size

We received data from 2,246,109 respondents who completed the GPPS surveys in 2018, 2019 or 2020. After removing respondents that did not have complete data for the variables of interest (n=439,060, 19.5%), 1,807,049 respondents were included.

Statistical methods

We first reported descriptive statistics of the respondents based on their online appointment booking and repeat prescription use. We then performed multilevel mixed-effects logistic regression models: First, we created a null model with only the outcome variable and random intercept (GP practice) to understand if there was clustering due to the random intercept. We then

added all patient level covariates to the model (model 2) (most of the variable in the final model were patient-level variables). We checked the Intraclass Correlation Coefficient (ICC) and intercepted in all models to examine the effect of clustering. We then added the GP practice level variable (GP practice rurality) in the final model (model 3) [24]. Methods of the sensitivity analyses is in the Supplementary Table 1. The statistical analysis was performed in RStudio software version 1.4.1717.

The Strengthening the reporting of observational studies in epidemiology (STROBE) checklist was completed to review the methods of the study [25] (Supplementary Table 2).

RESULTS

Some of the results of this study were presented in a conference abstract [26].

Summary statistics

1,807,049 respondents were included of which 15% (n=263938) used online appointment booking (used at least once in the previous 12 months), and 19% (n=339449) used online repeat prescription (used at least once in the previous 12 months) (Supplementary Table 3). Most respondents were female (55.1%), and in the 65-74 years age group (22%), were of white ethnic backgrounds (86.8%), and were registered at GP practices in an urban area (83.1%) and half (51.1%) had a long-term condition.

About 19.5% of the total sample received from GPPS was excluded due to missing data. The proportion of respondents by category in the excluded respondents were different to the complete case dataset in the proportions for age, ethnicity (most respondents were from the mixed ethnicity), survey year, long-term condition, taking five or more medications, reporting of

deafness or hearing loss, and slight difference in deprivation fifths proportions (Supplementary Table 4).

Descriptive statistics of the sensitivity analysis groups are displayed in Supplementary Table 5. GP practices with the highest proportion of missing data (practices with 75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a higher proportion of respondents from Black, Asian and Other ethnic backgrounds as well as higher proportion or respondents from the most deprived group compared to the GP practices with lower missing data.

Patient and GP practice characteristics associated with online services use

Online appointment booking

Results of the two-level mixed-effects logistic regression for the online appointment booking outcome are presented in table 2. Respondents with a long-term condition, taking 5 or more medications on a regular basis and who have deafness or hearing loss were more likely to use online appointment booking compared to respondents without these characteristics. In the fully adjusted model for patient and GP practice characteristics, respondents with a long-term condition had 67% greater odds of using online appointment booking (OR: 1.67, CI: 1.66-1.69) compared to respondents without a long-term condition.

Respondents of black and "other" ethnic backgrounds had lower odds than those of white ethnic backgrounds for using online appointment booking, whereas respondents of Asian ethnic

backgrounds had 11% (OR: 1.11, 95% CI: 1.09-1.13) greater odds of using online appointment booking.

There was an inverse association between deprivation quintile and online appointment booking. The odds for using online appointment booking increased with reducing deprivation from the second to fifth (least deprived) quintile compared to the most deprived quintile. Respondents in the least deprived quintile had 54% greater odds of booking appointments online (OR: 1.54, 95% CI: 1.51-1.57) compared to those in the most deprived quintile. Respondents from the survey year 2020 were the most likely to use online appointment booking compared to respondents from the survey year 2018 and 2019.

Respondents from GP practices located in an urban setting had greater odds of booking appointments online compared to respondents from GP practices in a rural setting.

Model comparison: The ICC of 0.13 indicates that there is a slight similarity between values from the same group (in this case from the same GP practice) although the difference is not large because the value is close to zero.

Sensitivity analysis: Results of the sensitivity analysis for online appointment booking are in the Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality.

Table 2 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online appointment booking use in the previous 12 months (level 1 , N= 1807049 respondents; level 2, N=7256 general practices)

Predictors	+ GP practice Characteristics (Model 3) Odds Ratios	95% Confidence Interval
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.15***	(1.12, 1.19)
Long term condition- Yes	1.67***	(1.66, 1.69)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.18, 1.20)
Deafness or hearing loss-Yes (REF= No)	1.13***	(1.11, 1.15)
Gender-Male (REF= Female)	0.89***	(0.88, 0.90)
Age (REF: 85+)		
16-24	3.63***	(3.48, 3.78)
25-34	4.96***	(4.78, 5.14)
35-44	4.85***	(4.68, 5.03)
45-54	4.26***	(4.12, 4.42)
55-64	3.69***	(3.57, 3.82)
65-74	3.09***	(2.99, 3.20)
75-84	1.74***	(1.68, 1.80)
Ethnicity (REF: White)		
Black	0.84***	(0.81, 0.86)
Asian	1.11***	(1.09, 1.13)
Other	0.96**	(0.92, 0.99)
Mixed	1.04	(1.00, 1.08)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.92***	(0.90, 0.93)
Carer-Yes (REF= No)	1.14***	(1.13, 1.16)
Deprivation quintile (REF: 1- Most deprived)		
2	1.15***	(1.13, 1.17)
3	1.27***	(1.25, 1.29)
4	1.40***	(1.37, 1.42)
5 (least deprived)	1.54***	(1.51, 1.57)
Survey year (REF= 2018)		
2019	1.19***	(1.18, 1.20)
2020	1.52***	(1.50, 1.54)
General practice rurality-urban (REF= rural)	1.11***	(1.07, 1.16)
Model summary		
ICC	0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Online repeat prescription ordering

Results of the two-level mixed-effects logistic regression for the online repeat prescription ordering outcome are presented in table 3. Respondents with a long-term condition, users of 5 or more medications on a regular basis and respondents with deafness or hearing loss were all more likely to use online repeat prescription ordering compared to respondents without these characteristics. The odds of using online repeat prescription ordering was 2.58 times greater (OR: 2.58, 95% CI: 2.55, 2.60) for respondents with a long-term condition compared to those without a condition.

Black, Asian, and Mixed had lower odds of using online repeat prescription ordering compared to the White ethnicity.

Respondents in the deprivation quintiles 4 and 5 (least deprived) had the highest odds of using online repeat prescription ordering compared to the most deprived group (OR: 1.62, 95% CI: 1.59, 1.64) and (OR: 1.77, 95% CI: 1.74, 1.80), respectively.

Respondents who completed the survey in the years 2019 and 2020 had greater odds of using online repeat prescription ordering compared to respondents from the survey year 2018.

Respondents from GP practices located in an urban setting had lower odds of ordering repeat prescriptions online compared to respondents from GP practices in a rural setting.

Model comparison: the ICC was 0.08 for model 3 in table 3, which also showed that there is slight evidence that patients from the same GP practices may have more similar results compared to patients from other GP practices.

Sensitivity analysis results: Results of the sensitivity analysis for the repeat prescription outcome are in supplementary table 7. Differences (compared to the main analysis) in odds ratios were seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a

carer and for the deprivation quintile. Among respondents from practices with 75% or more respondents with missing data, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97) higher odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents.

Table 3 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online Repeat prescription ordering use in the previous 12 months (level 1, N= 1807049 respondents; level 2, N=7256 general practices)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.25***	(1.22, 1.29)
Long term condition- Yes	2.58***	(2.55, 2.60)
Taking five or more medication on a regular basis-Yes (REF= No)	1.26***	(1.25, 1.28)
Deafness or hearing loss-Yes (REF= No)	1.02**	(1.00, 1.03)
Gender-Male (REF= Female)	0.96***	(0.96, 0.97)
Age (REF: 85+)		
16-24	1.71***	(1.64, 1.77)
25-34	2.17***	(2.10, 2.23)
35-44	2.69***	(2.61, 2.77)
45-54	3.18***	(3.10, 3.28)
55-64	3.28***	(3.20, 3.37)
65-74	3.01***	(2.93, 3.09)
75-84	1.68***	(1.64, 1.73)
Ethnicity (REF: White)		
Black	0.76***	(0.74, 0.78)
Asian	0.94***	(0.93, 0.96)
Other	0.78***	(0.75, 0.81)
Mixed	0.98	(0.94, 1.02)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.95***	(0.94, 0.96)
Carer-Yes (REF= No)	1.16***	(1.15, 1.17)
Deprivation quintile (REF: 1- Most deprived)		
2	1.23***	(1.21, 1.25)
3	1.44***	(1.42, 1.46)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
4	1.62***	(1.59, 1.64)
5 (least deprived)	1.77***	(1.74, 1.80)
Survey year (REF= 2018)		
2019	1.18***	(1.17, 1.19)
2020	1.46***	(1.44, 1.47)
General practice rurality-urban (REF= rural)	0.88***	(0.85, 0.91)
Model Summary		
ICC	0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

DISCUSSION

Principal findings

Overall, the findings of the study indicate that indicators of increased healthcare need and socioeconomic disadvantage predicted variations in the use of online services and use of the services increased over the three years studied. Some of the findings agreed with what we hypothesized such as patients with long-term conditions being more likely to use online services and respondents of lower socioeconomic status and minority ethnic groups being less likely to use online services. However, contrary to our hypothesis, not all respondents older than 35 were less likely to use online services as use varied by age group and respondents of the age groups 35-84 were all more likely to use online services compared to respondents of the age group 85 years old and older.

Strengths and weaknesses of the study

Although online services have been offered almost universally in GP practices in England since 2015, there continues to be a lack of research on the use of online services (or patient portals) in

this setting [7, 27]. This study used a major national survey which uses rigorous research methodology in its data collection process and used suitable analysis methodology for processing the data (accounting for GP practice variation in the models and accounting for missing data in the sensitivity analyses) to explore online services user characteristics in England which can inform service planning and identify patient groups who may need support using the service.

We accounted for clustering in our data presenting patient-level data in which patients belonged to different GP practices, by using multilevel logistic regression model which is an analysis methodology that takes into account the hierarchy in the data [28]. Clustering by GP practice was important not only because patients from the same GP practice may be more similar to each other, but patient portal functionalities and promotion of online services (such as providing training, posters, emails and reminders) to use online services may vary from one GP practice to another [29].

A limitation of the study was using only complete-case data in the analyses. Respondents excluded from the analyses due to missing data presented differences in the breakdown of respondent characteristics. Therefore, we performed sensitivity to explore what kind of differences might have observed if all the sample was included. Both summary statistics of the excluded sample and the sensitivity analyses indicated GP practices with more missing data may be more likely to have younger age groups, greater deprivation groups, and ethnically diverse groups, all of which were associated with relatively lower odds of using online services. This introduces the possibility that some of the odd's ratios presented in the main analysis may be larger than they are in the population due to missing data bias.

However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the

effects. For example, odds ratios that were larger than one in the main analyses remained to be larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services between the three categories of GP practices use were bigger for online repeat prescription use compared to the online appointment booking use. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GP practices indicating that socioeconomic inequities may have a larger influence on online repeat prescription ordering than online appointment booking. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with bigger differences in the odds associated with the outcome for respondents from the highest missing data GP practices compared to the other GP practices.

As with all survey-based studies, a major limitation of the GPPS is the non-response bias. However, a study on the methodology of the GPPS, did not find evidence of non-response bias [30]. We tried to alleviate non-response bias by controlling for deprivation, ethnicity, age and gender (which can often be associated with low-response rates as reported in a study examining GPPS non-response characteristics [30]).

Strengths and weaknesses in relation to other studies

This study relied on self-reported online service usage which could introduce response bias [31]. A better way to measure use could be via the electronic patient portal log files. The log files automatically record patient portal activity and can serve as an objective method to examine patient portal use because it is not subject to recall bias and records the exposure prior to the outcome [3]. However, due to data unavailability of patient-level data of this kind at the time of

the study, the GPPS records of online services use was used in this study as it has been on other England based studies exploring patient portal use [5, 6].

Discussing important differences in results

Patients from more deprived areas, and from ethnic minorities are reported to have lower uptake of patient portals in previous studies [32]. According to previous studies, deprivation and ethnicity play key roles in online services use [33-35] which was confirmed by the main analysis and sensitivity analyses in this study. A study from the USA suggested that patients' ethnicity could be associated with less trust in patient portals [36]. Lower use of online services by respondents with greater deprivation levels is repeatedly reported in the literature [37]. This may be due to lower access to the internet, smart phone, and computers among individuals from more deprived areas [7, 38].

Meaning of the study

There is evidence that online services use in England is increasing every year and it is likely to continue to be an important tool in GP practice settings. Understanding the needs of populations less likely to use online services may help improve the uptake of the services and meet the needs of vulnerable populations which may be more prone to have reduced access to healthcare services [39] in addition to online services.

According to the theory of the digital divide, [13, 14], using technologies such as patient portals may require more than just access to a computer, skills such as digital literacy and eHealth literacy may be essential to enable the use of these services. Education is also considered a detrimental factor contributing to the digital divide [40]. While the literature on social theories could help interpret the behavior of patients using healthcare information system technologies,

the quantitative nature of the study does not allow us to dig deep into the social constructs that drive these behaviors. However, such theories can help us understand the mechanisms, and that may be involved in leading some individuals to adopt the technologies. For example, we are aware that socioeconomic factors play a role in patient portal use, which may be associated with the factors that were not studied in the study, such as access to the internet, access to digital technologies. Additionally, although we estimated that younger populations would be more likely to use and have access to technologies, we could not see that pattern in the study may be because young people are less likely to need the healthcare system and services such as appointment booking and repeat prescription requests. We can already see the complex mechanisms that may be involved in driving individuals to use an adult electronic patient which may be driven by social factors beyond this study.

Possible explanations and implications for clinicians and Policymakers

The adoption of online services by those with long-term conditions is promising and can potentially contribute to improve self-management of the long-term condition [2]. However, it is also a reflection that patients with long-term conditions may generally be more likely to use healthcare services[41-43]. Practices could continue to encourage patients with long-term conditions to sign up and use online services. However, it is essential that alternatives to online services continue to be provided to patients who are unable to use the services [41-43].

This study shows that online services use is lower among people from more deprived areas and from ethnic minorities which may introduce inequities if in-person services become out of reach. As an example, the move to telephone consultations and remote triage in GP practices amidst the COVID-19 pandemic made it difficult for homeless people to access care due to not having a

telephone [44]. In-person access to care is seen necessary to reach all patient groups despite access to technology in the move to remote consultations in the COVID-19 pandemic [44]. For this reason, it is important that practices continue to provide in-person services (e.g. for appointment booking and repeat prescriptions) to patients especially those less able to access remote services. Training to use online services may be a solution to increase adoption which is already provided in some GP practices [29] and we can continue to recommend it

Unanswered questions and future research

Further research is needed to understand the lack of uptake of the services in some patient groups to clarify if uptake is low due to barriers or due to patient preference. In the light of the COVID-19 pandemic, where patients are asked to contact their GP practice remotely [45], inequities in the access and use of the online services may be responsible for dramatic inequities when it comes to situations where online services becomes the only route of accessing care [46]. Although the findings of this study should be viewed as pre-COVID-19 findings, the patterns in disparities may continue or worsen in the post-COVID-19 period amidst the move to remote GP services.

Future research could focus on the effects of these services on aspects of the healthcare system such as healthcare utilisation and patients' self-management of their condition. Our future research aim is to use electronic health records to estimate patient portal use in GP practices in England as opposed to self-report of patients and examine outcomes such as healthcare utilization and health outcomes in association with patient portal use to test patient portal's influence on health and the healthcare system in general.

Funding

This article presents independent research commissioned by the National Institute for Health Research (NIHR) under the Applied Health Research (ARC) programme for Northwest London. The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. TB acknowledges support from the NIHR ARC Northwest London.

Ethical approval

This study was approved by the Imperial College Research Ethics Committee, Reference number: 20IC6303. Respondents of the survey provide informed consent to take part in the research by taking part in the survey and have the right to withdraw their consent before the data is processed.

Author contribution

AA, GG, TB and CC created the study design, formulated the research question and finalised the study methodology. AA performed the analysis of the study. JN contributed to the introduction and discussion sections of the study. All authors reviewed and approved the submitted manuscript.

Data sharing statement

The data that support the findings of this study are available on request from Ipsos Mori but cannot be provided by the authors due to ethical restrictions. However, the aggregate level GPPS data are openly available in the GP Patient Survey webpage at https://www.gp-patient.co.uk/ [16].

Competing interests

The authors declare that they have no competing interests.

References

1. Patient Online Management Information (POMI) - NHS Digital. @NHSDigital; 2021; Available from: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub/patient-online-management-information-pomi.
2. ME R, J H, RJ B, R N, I G, J H, et al. Patients with complex chronic conditions: Health care use and clinical events associated with access to a patient portal. PloS one. 2019 06/19/2019;14(6). PMID: 31216295. doi: 10.1371/journal.pone.0217636.
3. DR M, M D. Sharing Ethics Consultation Notes With Patients Through Online Portals. AMA journal of ethics. 2020 09/01/2020;22(9). PMID: 33009775. doi: 10.1001/amajethics.2020.784.
4. HR H, KT G, CA S, HN M, SJ K, S C, et al. Using Patient Portals to Improve Patient Outcomes: Systematic Review. JMIR human factors. 2019 12/19/2019;6(4). PMID: 31855187. doi: 10.2196/15038.
5. M G-C, H A, J C, A E, J D, L P, et al. Awareness and use of online appointment booking in general practice: analysis of GP Patient Survey data. The British journal of general practice : the journal of the Royal College of General Practitioners. 2020 2020 Jun;70(suppl 1). PMID: 32554662. doi: 10.3399/bjgp20X711365.
6. Gomez-Cano, J M, R W, J L, G A. Awareness and use of online services in general practice: analysis of GP Patient Survey data | SAPC. SAPC ASM 2021; 2021-06-08T14:38+01:00; Virtual: @sapcacuk; 2021.
7. A A-A, Z S, BM B, M H, PH G. Patients' Perspectives About Factors Affecting Their Use of Electronic Personal Health Records in England: Qualitative Analysis. Journal of medical Internet research. 2021 01/13/2021;23(1). PMID: 33439126. doi: 10.2196/17500.
8. S E-T, A M, S C, EJ P-S. Barriers to Patient Portal Access and Use: Evidence from the Health Information National Trends Survey. Journal of the American Board of Family Medicine : JABFM. 2020 Nov-Dec 2020;33(6). PMID: 33219074. doi: 10.3122/jabfm.2020.06.190402.
9. A G, A S, J T, M W. Patient Portals: Who uses them? What features do they use? And do they reduce hospital readmissions? Applied clinical informatics. 2016 06/06/2016;7(2). PMID: 27437056. doi: 10.4338/ACI-2016-01-RA-0003.
10. MG A, O P, F L. The State of Evidence in Patient Portals: Umbrella Review. Journal of medical Internet research. 2020 11/11/2020;22(11). PMID: 33174851. doi: 10.2196/23851.
11. Watcher RM. Making IT work: harnessing the power of health information technology to improve care in England. 2016 7 September 2016. Report No.
12. T G, G R, F M, P B, O K. Diffusion of innovations in service organizations: systematic review and recommendations. The Milbank quarterly. 2004 2004;82(4). PMID: 15595944. doi: 10.1111/j.0887-378X.2004.00325.x.
13. Serafino P. Exploring the UK's digital divide - Office for National Statistics. s; 2019; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/articles/exploringtheuksdigitaldivide/2019-03-04.

14. Dijk Jv. A Framework For Digital Divide Research. The Electronic Journal of Communication. 2002;12(1 & 2).
15. GP Patient Survey Confidentiality and data protection. 2023; Available from: https://www.gp-patient.co.uk/confidentiality.
16. GP Patient Survey: Surveys and Reports. Ipsos MORI; 2020; Available from: https://www.gp-patient.co.uk/surveysandreports.
17. Ethnic group, national identity and religion. Office for National Statistics; 2021; Available from: https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion.
18. Ministry of Housing C, & Local Government. English Indices of Deprivation 2019 FAQs. 2019; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf.
19. 2011 rural/urban classification. 2011; Available from: https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification.
20. MORI I. GP Patient Survey 2019 Technical Annex. 2019; Available from: https://gp-patient.co.uk/downloads/archive/2019/GPPS_2019_Technical_Annex_PUBLIC.pdf.
21. MORI I. GP Patient Survey 2020 Technical Annex. 2020; Available from: https://gp-patient.co.uk/downloads/2020/GPPS_2020_Technical_Annex_PUBLIC.pdf.
22. MORI I. GP Patient Survey - Technical Annex: 2018 annual report. August 2018; Available from: https://gp-patient.co.uk/downloads/archive/2018/GPPS%202018%20Technical%20Annex%20PUBLIC.pdf.
23. GOV.UK. Prime Minister's statement on coronavirus (COVID-19): 23 March 2020. 23 March 2020.
24. Kleiman E. Understanding and analyzing multilevel data from real-time monitoring studies: An easily- accessible tutorial using R. 2021. doi: doi:10.31234/osf.io/xf2pw.
25. STROBE Strengthening the reporting of observational studies in epidemiology. 2021; Available from: https://www.strobe-statement.org/.
26. Alturkistani A, Greenfield G, Beaney T, Norton J, Costelloe CE, editors. Ethnicity, deprivation, and the use of patient portals in England's general practices 2018-2020: Abrar Alturkistani. European Journal of Public Health; 2022: Oxford academic.
27. F M, S dL, A S, A M, JC W, T Q, et al. Patients' online access to their electronic health records and linked online services: a systematic review in primary care. The British journal of general practice : the journal of the Royal College of General Practitioners. 2015 2015 Mar;65(632). PMID: 25733435. doi: 10.3399/bjgp15X683941.
28. Modelling CfM. What are multilevel models and why should I use them? : University of Bristol; 2023.
29. England N. GP online services case studies. 2023.
30. M R, M E, G L, J B, RA P, P S, et al. Reliability of patient responses in pay for performance schemes: analysis of national General Practitioner Patient Survey data in England. BMJ (Clinical research ed). 2009 09/29/2009;339. PMID: 19808811. doi: 10.1136/bmj.b3851.
31. J S, P B, B G, SW M, N R, AM R, et al. Cuts to local government spending, multimorbidity and health-related quality of life: A longitudinal ecological study in England. The Lancet regional health Europe. 2022 06/10/2022;19. PMID: 36039277. doi: 10.1016/j.lanepe.2022.100436.
32. CH H, M J, CG A, OA B, R D, P A, et al. Racial Differences in Patient Portal Activation and Research Enrollment Among Patients With Prostate Cancer. JCO clinical cancer informatics. 2021 2021 Jun;5. PMID: 34328797. doi: 10.1200/CCI.20.00131.

33. S S, M G, N N, BW M, AY O, A L, et al. Disparities in Electronic Health Record Patient Portal Enrollment Among Oncology Patients. JAMA oncology. 2021 06/01/2021;7(6). PMID: 33830178. doi: 10.1001/jamaoncol.2021.0540.
34. EP U, J F, LM Y. Disparities in Electronic Patient Portal Use in Prenatal Care: Retrospective Cohort Study. Journal of medical Internet research. 2019 09/23/2019;21(9). PMID: 31586367. doi: 10.2196/14445.
35. DM W, JL H, N F, TR H, AS M. Exploring the Digital Divide: Age and Race Disparities in Use of an Inpatient Portal. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2020 2020 May;26(5). PMID: 31313977. doi: 10.1089/tmj.2019.0065.
36. MA C, ER L, J M, KM K, MM S, T M, et al. Sociodemographic Differences and Factors Affecting Patient Portal Utilization. Journal of racial and ethnic health disparities. 2021 2021 Aug;8(4). PMID: 32839896. doi: 10.1007/s40615-020-00846-z.
37. Priti S, Pallavi J, Evan M, Naleef F. Outpatient Portal Use in Prenatal Care: Differential Use by Race, Risk, and Area Social Determinants of Health Factors. medRXiv. 2021 2021-05-26. doi: 10.1101/2021.05.25.21257657.
38. Matthew H, David M, Harry E, Alisha D. Digital technology and health inequalities: a scoping review. Cardiff: Public Health Wales NHS Trust; 2020; Available from: https://phw.nhs.wales/publications/publications1/digital-technology-and-health-inequalities-a-scoping-review/.
39. Saunders CL, Flynn S, Massou E, Lyratzopoulos G, Abel G, Burt J. Sociodemographic inequalities in patients' experiences of primary care: an analysis of the General Practice Patient Survey in England between 2011 and 2017:. https://doiorg/101177/1355819620986814. 2021 2021-01-31. doi: 10.1177_1355819620986814.
40. G W. COVID-19 and the digital divide in the UK. The Lancet Digital health. 2020 2020 Aug;2(8). PMID: 32835198. doi: 10.1016/S2589-7500(20)30169-2.
41. LB S, DA L, C B, GA A, KJ R, AS I. Disease Burden and Healthcare Utilization Among Patients with Chronic Obstructive Pulmonary Disease (COPD) in England. International journal of chronic obstructive pulmonary disease. 2022 03/03/2022;17. PMID: 35264848. doi: 10.2147/COPD.S336158.
42. CW lR, B C, E N, A B. Obesity and healthcare resource utilization: results from Clinical Practice Research Database (CPRD). Obesity science & practice. 2018 08/21/2018;4(5). PMID: 30338111. doi: 10.1002/osp4.291.
43. HI W, L H, R J, T D, RIG H, SL P, et al. Healthcare resource use and costs for people with type 2 diabetes mellitus with and without severe mental illness in England: longitudinal matched-cohort study using the Clinical Practice Research Datalink. The British journal of psychiatry : the journal of mental science. 2022 2022 Jul;221(1). PMID: 35049484. doi: 10.1192/bjp.2021.131.
44. Howells KA, Amp M, Burrows M, Brown J, Brennan R, Dickinson J, et al. Remote primary care during the COVID-19 pandemic for people experiencing homelessness: a qualitative study. 2022 2022-03-03. doi: 10.3399/BJGP.2021.0596.
45. NHS. Using the NHS and other health services during coronavirus (COVID-19). @nhsuk; 2021 [updated 2 Jun 2020]; Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/using-the-nhs-and-other-health-services/.
46. Ian L, David S, Sheila G. Impact of COVID-19 on the digital divide: a rapid review. 2021 2021-10-01. doi: 10.1136/bmjopen-2021-053440.

Supplementary material

Supplementary Table 1 Methods of the sensitivity analysis.

Supplementary Table 2. STROBE 2007 checklist of items to be included in reports of observational studies in epidemiology.

Supplementary Table 3. Descriptive statistics of the number and proportion of respondent characteristics in the total population included in the analyses (n=1807049), categorised by online services use.

Supplementary Table 4. The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060).

Supplementary Table 5. Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice.

Supplementary Table 6. Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary Table 7. Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary material:

Supplementary Table 1. Methods of the sensitivity analysis

Methods	In the main analyses performed in this study, only complete case respondents (respondents that did not have any missing data for any of the variables included in the analyses) were included. We ran sensitivity analyses to explore the effects of excluding respondents with missing data. We first calculated the proportion of respondents with complete data per practice using the complete dataset (n=2198821) and assigned each practice a new variable indicating the proportion of complete case respondents in the practice. We then separated the complete case respondents (n=1807049) into three categories based on the proportion of complete case respondents in their practice. The three categories were: highest missing data group (≥75%), middle-range missing data group (26-74%), and lowest missing data group (≤25%). We then ran the same two-level mixed-effects models for each of the outcomes (online appointment booking and online repeat prescription use) separately for each of the three categories.

Supplementary Table 2 STROBE 2007 checklist [12] of items to be included in reports of observational studies in epidemiology

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
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	*5*
Bias	9	Describe any efforts to address potential sources of bias	6 & Supplementary Table 2
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	Supplementary Table 2
		(*c*) Explain how missing data were addressed	Supplementary Table 2

		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Supplementary Table 2
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	7
		(b) Give reasons for non-participation at each stage	6-7
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7 & Supplementary Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Data collection times are summarized under study design subsection
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supplementary Table 3 (check categories of survey year)
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Supplementary Table 3
		Cross-sectional study—Report numbers of outcome events or summary measures	7 & Supplementary Table 4
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	8-12
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 2, Supplementary Table 5-7
Discussion			

Key results	18	Summarise key results with reference to study objectives	12-13
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
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	16

Supplementary Table 3. Descriptive statistics of the number and proportion of respondent characteristics in the total population included in the analyses (n=1807049), categorized by online services use

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Gender				<0.001			0.97
Female	996544 (55.1%)	843422 (54.7%)	153122 (58.0%)		809337 (55.1%)	187207 (55.2%)	
Male	810505 (44.9%)	699689 (45.3%)	110816 (42.0%)		658263 (44.9%)	152242 (44.8%)	
Age				<0.001			<0.001
16-24	74381 (4.1%)	64513 (4.2%)	9868 (3.7%)		67069 (4.6%)	7312 (2.2%)	
25-34	159806 (8.8%)	132951 (8.6%)	26855 (10.2%)		141376 (9.6%)	18430 (5.4%)	
35-44	217687 (12.0%)	181290 (11.7%)	36397 (13.8%)		186112 (12.7%)	31575 (9.3%)	
45-54	302285 (16.7%)	253145 (16.4%)	49140 (18.6%)		243458 (16.6%)	58827 (17.3%)	

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
55-64	381808 (21.1%)	321902 (20.9%)	59906 (22.7%)		295168 (20.1%)	86640 (25.5%)	
65-74	397999 (22.0%)	340484 (22.1%)	57515 (21.8%)		303875 (20.7%)	94124 (27.7%)	
75-84	211586 (11.7%)	191217 (12.4%)	20369 (7.7%)		176214 (12.0%)	35372 (10.4%)	
85+	61497 (3.4%)	57609 (3.7%)	3888 (1.5%)		54328 (3.7%)	7169 (2.1%)	
Ethnicity				<0.001			<0.001
White	1567690 (86.8%)	1340202 (86.9%)	227488 (86.2%)		1258828 (85.8%)	308862 (91.0%)	
Black	52950 (2.9%)	46120 (3.0%)	6830 (2.6%)		47195 (3.2%)	5755 (1.7%)	
Asian	137026 (7.6%)	115015 (7.5%)	22011 (8.3%)		118728 (8.1%)	18298 (5.4%)	
Other	29168 (1.6%)	24993 (1.6%)	4175 (1.6%)		25773 (1.8%)	3395 (1.0%)	
Mixed	20215 (1.1%)	16781 (1.1%)	3434 (1.3%)		17076 (1.2%)	3139 (0.9%)	
Survey year				<0.001			<0.001
2018	612084 (33.9%)	536349 (34.8%)	75735 (28.7%)		512184 (34.9%)	99900 (29.4%)	
2019	623358 (34.5%)	534321 (34.6%)	89037 (33.7%)		507522 (34.6%)	115836 (34.1%)	
2020	571607 (31.6%)	472441 (30.6%)	99166 (37.6%)		447894 (30.5%)	123713 (36.4%)	

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Long-term condition				<0.001			<0.001
No	833523 (46.1%)	730177 (47.3%)	103346 (39.2%)		736861 (50.2%)	96662 (28.5%)	
I don't know/ Can't answer	49746 (2.8%)	43186 (2.8%)	6560 (2.5%)		43212 (2.9%)	6534 (1.9%)	
Yes	923780 (51.1%)	769748 (49.9%)	154032 (58.4%)		687527 (46.8%)	236253 (69.6%)	
Taking five or more medication on a regular basis				<0.001			<0.001
No	1343735 (74.4%)	1151312 (74.6%)	192423 (72.9%)		1118704 (76.2%)	225031 (66.3%)	
Yes	463314 (25.6%)	391799 (25.4%)	71515 (27.1%)		348896 (23.8%)	114418 (33.7%)	
Deafness or hearing loss				<0.001			<0.001
No	1652099 (91.4%)	1409236 (91.3%)	242863 (92.0%)		1344856 (91.6%)	307243 (90.5%)	
Yes	154950 (8.6%)	133875 (8.7%)	21075 (8.0%)		122744 (8.4%)	32206 (9.5%)	
Parent or legal guardian to				<0.001			<0.001

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
a 16 year old or younger							
No	1466017 (81.1%)	1254880 (81.3%)	211137 (80.0%)		1177272 (80.2%)	288745 (85.1%)	
Yes	341032 (18.9%)	288231 (18.7%)	52801 (20.0%)		290328 (19.8%)	50704 (14.9%)	
Carer				<0.001			<0.001
No	1462467 (80.9%)	1254985 (81.3%)	207482 (78.6%)		1200653 (81.8%)	261814 (77.1%)	
Yes	344582 (19.1%)	288126 (18.7%)	56456 (21.4%)		266947 (18.2%)	77635 (22.9%)	
Deprivation quintile				<0.001			<0.001
1 (Most deprived)	338728 (18.7%)	298412 (19.3%)	40316 (15.3%)		292405 (19.9%)	46323 (13.6%)	
2	353580 (19.6%)	304870 (19.8%)	48710 (18.5%)		296229 (20.2%)	57351 (16.9%)	
3	376042 (20.8%)	322081 (20.9%)	53961 (20.4%)		304048 (20.7%)	71994 (21.2%)	
4	378002 (20.9%)	319100 (20.7%)	58902 (22.3%)		297096 (20.2%)	80906 (23.8%)	
5 (Least deprived)	360697 (20.0%)	298648 (19.4%)	62049 (23.5%)		277822 (18.9%)	82875 (24.4%)	
General practice rurality				<0.001			<0.001

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Rural	306200 (16.9%)	263405 (17.1%)	42795 (16.2%)		238353 (16.2%)	67847 (20.0%)	
Urban	1500849 (83.1%)	1279706 (82.9%)	221143 (83.8%)		1229247 (83.8%)	271602 (80.0%)	

* p-value derived from chi squared test comparing online appointment booking users and non-users
† p-value derived from chi squared test comparing online repeat prescription users and non-users

Supplementary Table 4 The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060)

Characteristics	**Total in the sample received (n=2,246,109)**	**Total in the complete case dataset (n=1807049)**	**Total in the excluded sample (n=439,060)**
Online appointment booking in the previous 12 months			
No	1892841 (84.3%)	1543111 (85.4%)	349730 (79.7%)
Yes	305980 (13.6%)	263938 (14.6%)	42042 (9.6%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Online repeat prescription ordering in the previous 12 months			
No	1807863 (80.5%)	1467600 (81.2%)	340263 (77.5%)
Yes	390958 (17.4%)	339449 (18.8%)	51509 (11.7%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Gender			
Female	1229473 (54.7%)	996544 (55.1%)	232929 (53.1%)

Male	967079 (43.1%)	810505 (44.9%)	156574 (31.7%)
(Missing)	49557 (2.2%)	0 (0.0%)	49557 (11.3%)
Age			
16-24	87081 (3.9%)	74381 (4.1%)	12700 (2.9%)
25-34	185580 (8.3%)	159806 (8.8%)	25774 (5.9%)
35-44	256766 (11.4%)	217687 (12.0%)	39079 (8.9%)
45-54	360011 (16.0%)	302285 (16.7%)	57726 (13.1%)
55-64	454900 (20.3%)	381808 (21.1%)	73092 (16.6%)
65-74	487171 (21.7%)	397999 (22.0%)	89172 (20.3%)
75-84	287533 (12.8%)	211586 (11.7%)	75947 (17.3%)
85+	91083 (4.1%)	61497 (3.4%)	29586 (6.7%)
(Missing)	35984 (1.6%)	0 (0.0%)	35984 (8.2%)
Ethnicity			
White	1895473 (84.4%)	1567690 (86.8%)	15862 (3.6%)
Black	68812 (3.1%)	52950 (2.9%)	33583 (7.6%)
Asian	170609 (7.6%)	137026 (7.6%)	10257 (2.3%)
Other	39425 (1.8%)	29168 (1.6%)	4558 (1.0%)
Mixed	24773 (1.1%)	20215 (1.1%)	327783 (74.7%)
(Missing)	47017 (2.1%)	0 (0.0%)	47017 (10.7%)
Survey year			
2018	750619 (33.4%)	612084 (33.9%)	138535 (31.6%)
2019	763244 (34.0%)	623358 (34.5%)	139886 (31.9%)
2020	732246 (32.6%)	571607 (31.6%)	160639 (36.6%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Long term condition			
No	1022671 (45.5%)	833523 (46.1%)	189148 (43.1%)
Yes	1050129 (46.8%)	923780 (51.1%)	126349 (28.8%)
Don’t know/Can’t say	61802 (2.8%)	49746 (2.8%)	12056 (2.7%)
Prefer not to say	38879 (1.7%)	0 (0.0%)	38879 (8.9%)
(Missing)	72628 (3.2%)	0 (0.0%)	72628 (16.5%)
Taking five or more medication on a regular basis			
No	1632850 (72.7%)	1343735 (74.4%)	289115 (65.8%)
Yes	574749 (25.6%)	463314 (25.6%)	111435 (25.4%)

(Missing)	38510 (1.7%)	0 (0.0%)	38510 (8.8%)
Deafness or hearing loss			
No	1799633 (80.1%)	1652099 (91.4%)	147534 (33.6%)
Yes	179304 (8.0%)	154950 (8.6%)	24354 (5.5%)
(Missing)	267172 (11.9%)	0 (0.0%)	267172 (60.9%)
Parent or legal guardian to a 16 year old or younger			
No	1782911 (79.4%)	1466017 (81.1%)	316894 (72.2%)
Yes	407923 (18.2%)	341032 (18.9%)	66891 (15.2%)
(Missing)	55275 (2.5%)	0 (0.0%)	55275 (12.6%)
Carer			
No	1741536 (77.5%)	1462467 (80.9%)	279069 (63.6%)
Yes	410450 (18.3%)	344582 (19.1%)	65868 (15.0%)
(Missing)	94123 (4.2%)	0 (0.0%)	94123 (21.4%)
Deprivation fifth			
1- least deprived	437189 (19.5%)	338728 (18.7%)	98461 (22.4%)
2	444869 (19.8%)	353580 (19.6%)	91289 (20.8%)
3	464884 (20.7%)	376042 (20.8%)	88842 (20.2%)
4	461586 (20.6%)	378002 (20.9%)	83584 (19.0%)
5 - most deprived	435997 (19.4%)	360697 (20.0%)	75300 (17.2%)
(Missing)	1584 (0.1%)	0 (0.0%)	1584 (0.4%)
General practice rurality			
Rural	374466 (16.7%)	306200 (16.9%)	68266 (15.5%)
Urban	1871643 (83.3%)	1500849 (83.1%)	370794 (84.5%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Supplementary Table 5. Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Online services use			
Online appointment booking in the previous 12 months	75194(15.9%)	176193(19.4%)	55937(13.1%)
Online repeat prescription use in the previous 12 months	102332(21.6%)	176193(19.4%)	60924(14.4%)
Gender			
Female	265428 (56.0%)	503040 (55.3%)	228076 (53.8%)
Male	208654 (44.0%)	406112 (44.7%)	195739 (46.2%)
Age			
16-24	18750 (4.0%)	34473 (3.8%)	21158 (5.0%)
25-34	39537 (8.3%)	75142 (8.3%)	45127 (10.6%)
35-44	55609 (11.7%)	103244 (11.4%)	58834 (13.9%)
45-54	79934 (16.9%)	149707 (16.5%)	72644 (17.1%)
55-64	100332 (21.2%)	194450 (21.4%)	87026 (20.5%)
65-74	106927 (22.6%)	208741 (23.0%)	82331 (19.4%)
75-84	56564 (11.9%)	111123 (12.2%)	43899 (10.4%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
85+	16429 (3.5%)	32272 (3.5%)	12796 (3.0%)
Ethnicity			
White	5027 (1.1%)	17758 (2.0%)	30165 (7.1%)
Black	16190 (3.4%)	49142 (5.4%)	71694 (16.9%)
Asian	3729 (0.8%)	10722 (1.2%)	14717 (3.5%)
Other	4175 (0.9%)	8704 (1.0%)	7336 (1.7%)
Mixed	444961 (93.9%)	822826 (90.5%)	299903 (70.8%)
Survey year			
2018	166729 (35.2%)	305514 (33.6%)	139841 (33.0%)
2019	162214 (34.2%)	315671 (34.7%)	145473 (34.3%)
2020	145139 (30.6%)	287967 (31.7%)	138501 (32.7%)
Long-term condition			
No	11725 (2.5%)	24207 (2.7%)	13814 (3.3%)
I don't know/ Can't answer	220575 (46.5%)	411974 (45.3%)	200974 (47.4%)
Yes	241782 (51.0%)	472971 (52.0%)	209027 (49.3%)
Taking five or more medication on a regular basis			

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
No	363720 (76.7%)	674880 (74.2%)	305135 (72.0%)
Yes	110362 (23.3%)	234272 (25.8%)	118680 (28.0%)
Deafness or hearing loss			
No	433463 (91.4%)	827757 (91.0%)	390879 (92.2%)
Yes	40619 (8.6%)	81395 (9.0%)	32936 (7.8%)
Parent or legal guardian to a 16 year old or younger			
No	385230 (81.3%)	746422 (82.1%)	334365 (78.9%)
Yes	88852 (18.7%)	162730 (17.9%)	89450 (21.1%)
Carer			
No	382112 (80.6%)	732193 (80.5%)	348162 (82.1%)
Yes	91970 (19.4%)	176959 (19.5%)	75653 (17.9%)
Deprivation quintile			
1 (Most deprived)	38111 (8.0%)	146156 (16.1%)	154461 (36.4%)
2	64792 (13.7%)	174694 (19.2%)	114094 (26.9%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
3	99792 (21.0%)	199586 (22.0%)	76664 (18.1%)
4	124261 (26.2%)	203142 (22.3%)	50599 (11.9%)
5 (Least deprived)	147126 (31.0%)	185574 (20.4%)	27997 (6.6%)
General practice rurality			
Rural	116101 (24.5%)	165787 (18.2%)	24312 (5.7%)
Urban	357981 (75.5%)	743365 (81.8%)	399503 (94.3%)

Supplementary Table 6 Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.16***	(1.10, 1.23)	1.14***	(1.10, 1.19)	1.16***	(1.10, 1.22)
Long term condition- Yes	1.78***	(1.75, 1.81)	1.69***	(1.67, 1.72)	1.49***	(1.46, 1.53)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.17, 1.22)	1.20***	(1.18, 1.22)	1.20***	(1.17, 1.23)
Deafness or hearing loss-Yes (REF= No)	1.15***	(1.11, 1.19)	1.12***	(1.09, 1.14)	1.12***	(1.08, 1.16)
Gender-Male (REF= Female)	0.88***	(0.86, 0.89)	0.88***	(0.87, 0.89)	0.91***	(0.89, 0.93)
Age (REF: 85+)						
16-24	3.39***	(3.14, 3.66)	3.76***	(3.55, 3.98)	3.50***	(3.21, 3.82)
25-34	4.69***	(4.37, 5.03)	5.17***	(4.91, 5.45)	4.66***	(4.30, 5.06)
35-44	4.63***	(4.32, 4.96)	5.13***	(4.87, 5.40)	4.46***	(4.11, 4.83)
45-54	4.28***	(4.01, 4.57)	4.51***	(4.29, 4.74)	3.75***	(3.46, 4.06)

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
55-64	3.80***	(3.56, 4.05)	3.94***	(3.75, 4.13)	3.07***	(2.84, 3.32)
65-74	3.27***	(3.07, 3.49)	3.32***	(3.16, 3.48)	2.35***	(2.18, 2.54)
75-84	1.81***	(1.69, 1.93)	1.83***	(1.74, 1.93)	1.43***	(1.32, 1.55)
Ethnicity (REF: White)						
Black	0.75***	(0.69, 0.81)	0.83***	(0.79, 0.87)	0.87***	(0.83, 0.90)
Asian	1.04	(1.00, 1.09)	1.10***	(1.07, 1.14)	1.14***	(1.10, 1.17)
Other	0.86**	(0.79, 0.95)	0.92**	(0.87, 0.98)	1.01	(0.96, 1.06)
Mixed	1.01	(0.93, 1.10)	1.01	(0.95, 1.07)	1.09**	(1.02, 1.16)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.91***	(0.89, 0.93)	0.90***	(0.88, 0.92)	0.96***	(0.93, 0.98)
Carer-Yes (REF= No)	1.11***	(1.09, 1.13)	1.15***	(1.13, 1.17)	1.17***	(1.14, 1.19)
Deprivation quintile (REF: 1-Most deprived)						
2	1.15***	(1.11, 1.20)	1.14***	(1.12, 1.17)	1.16***	(1.13, 1.19)
3	1.23***	(1.19, 1.28)	1.29***	(1.26, 1.32)	1.27***	(1.23, 1.30)
4	1.38***	(1.33, 1.44)	1.40***	(1.37, 1.43)	1.36***	(1.31, 1.41)
5 (least deprived)	1.54***	(1.48, 1.60)	1.52***	(1.49, 1.56)	1.53***	(1.46, 1.60)

10.1136/bmjopen-2022-068827 on 12 October 2023. Downloaded from

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Survey year (REF= 2018)						
2019	1.16***	(1.14, 1.18)	1.18***	(1.17, 1.20)	1.25***	(1.22, 1.28)
2020	1.46***	(1.43, 1.49)	1.52***	(1.50, 1.54)	1.61***	(1.57, 1.65)
General practice rurality-Urban (REF= Rural)	1.22***	(1.10, 1.23)	1.11***	(1.10, 1.19)	1.10	(0.97, 1.24)
Model summary						
Interclass correlation coefficient (ICC)	0.13		0.12		0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Supplementary Table 7 Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.25***	(1.18, 1.32)	1.25***	(1.20, 1.30)	1.24***	(1.17, 1.31)
Long term condition- Yes	2.71***	(2.66, 2.75)	2.56***	(2.52, 2.59)	2.42***	(2.37, 2.47)
Taking five or more medication on a regular basis- Yes (REF= No)	1.26***	(1.24, 1.29)	1.26***	(1.24, 1.28)	1.29***	(1.26, 1.32)
Deafness or hearing loss-Yes (REF= No)	1.02	(1.00, 1.05)	1.02	(1.00, 1.04)	1.01	(0.98, 1.04)
Gender-Male (REF= Female)	0.96***	(0.94, 0.97)	0.96***	(0.95, 0.97)	0.98***	(0.96, 1.00)
Age (REF: 85+)						
16-24	1.64***	(1.53, 1.75)	1.76***	(1.67, 1.85)	1.62***	(1.50, 1.76)
25-34	2.16***	(2.04, 2.29)	2.22***	(2.13, 2.32)	1.98***	(1.85, 2.13)
35-44	2.67***	(2.52, 2.82)	2.82***	(2.70, 2.94)	2.37***	(2.21, 2.54)
45-54	3.25***	(3.09, 3.42)	3.29***	(3.16, 3.42)	2.82***	(2.65, 3.01)
55-64	3.35***	(3.18, 3.52)	3.43***	(3.31, 3.56)	2.81***	(2.64, 3.00)
65-74	3.11***	(2.97, 3.27)	3.15***	(3.03, 3.27)	2.48***	(2.33, 2.64)
75-84	1.73***	(1.65, 1.82)	1.75***	(1.68, 1.82)	1.43***	(1.34, 1.53)
Ethnicity (REF: White)						
Black	0.77***	(0.71, 0.84)	0.73***	(0.70, 0.77)	0.81***	(0.77, 0.84)
Asian	0.88***	(0.84, 0.92)	0.94***	(0.91, 0.97)	1.01	(0.98, 1.04)
Other	0.79***	(0.71, 0.87)	0.76***	(0.72, 0.81)	0.82***	(0.77, 0.86)

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Mixed	0.96	(0.89, 1.05)	0.98	(0.93, 1.05)	0.99	(0.92, 1.07)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.93***	(0.91, 0.96)	0.94***	(0.92, 0.96)	0.99	(0.96, 1.02)
Carer-Yes (REF= No)	1.13***	(1.11, 1.16)	1.15***	(1.14, 1.17)	1.19***	(1.17, 1.22)
Deprivation quintile (REF: 1-Most deprived)						
2	1.21***	(1.17, 1.26)	1.22***	(1.19, 1.25)	1.22***	(1.19, 1.26)
3	1.37***	(1.32, 1.42)	1.43***	(1.40, 1.46)	1.43***	(1.39, 1.47)
4	1.54***	(1.48, 1.59)	1.59***	(1.55, 1.62)	1.67***	(1.62, 1.73)
5 (least deprived)	1.65***	(1.59, 1.71)	1.74***	(1.70, 1.78)	1.89***	(1.82, 1.97)
Survey year (REF= 2018)						
2019	1.16***	(1.13, 1.18)	1.17***	(1.15, 1.19)	1.26***	(1.24, 1.29)
2020	1.40***	(1.38, 1.43)	1.46***	(1.44, 1.48)	1.54***	(1.51, 1.58)
General practice rurality-Urban (REF= Rural)	0.94**	(0.89, 0.99)	0.90***	(0.87, 0.94)	0.97	(0.88, 1.07)
Model summary						
Interclass correlation coefficient (ICC)	0.07		0.07		0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

BMJ Open

Cross-sectional analyses of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-068627.R2
Article Type:	Original research
Date Submitted by the Author:	12-Jul-2023
Complete List of Authors:	Alturkistani, Abrar; Imperial College London, Department of Primary Care and Public Health Greenfield, Geva; Imperial College London, Department of Primary Care & Public Health Beaney, Thomas; Imperial College London, Department of Primary Care and Public Health Norton, John; National Institute for Health Research, Applied Research Collaboration Northwest London Costelloe, Ceire ; Imperial College London, Department of Primary Care and Public Health; Institute of cancer Research Division of Clinical studies
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Public health
Keywords:	Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Cross-sectional analyses of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Abrar Alturkistani[1]*(https://orcid.org/0000-0001-7935-8870), Geva Greenfield[2] (https://orcid.org/0000-0001-9779-2486), Thomas Beaney[1,3](https://orcid.org/0000-0001-9709-7264), John Norton[3], Ceire E Costelloe[1,4](https://orcid.org/0000-0002-3475-7525)

[1] Global Digital Health Unit, Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[2] Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[3] National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom;

[4] Division of Clinical studies, Institute of cancer Research, London, United Kingdom; National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom

*Corresponding author

Email: Abrar.alturkistani16@imperial.ac.uk

Word count: 4527.

Keywords general practice; primary health care; patient portal; electronic health record; personal health record; GP Patient Survey.

Abstract

Objectives: To explore the characteristics of the General Practice Patient Survey (GPPS) respondents using the different functionalities of the online services in the context of England's

National Health Service (NHS) General Practices. We hypothesised that use of online services would vary according to patient sociodemographic factors.

Design: Cross-sectional study using respondent-level data from the GPPS in England of the years 2018, 2019 and 2020. We assessed the association between online services use and respondent characteristics using two-level mixed-effects logistic regression.

Participants: Survey respondents of the GPPS 2018-2020.

Primary and secondary outcome measures: Online appointment booking and online repeat prescription ordering.

Results: 1,806,977 survey respondents were included in this study. 15% (n=263938) used online appointment booking in the previous 12 months, and 19% (n=339449) had ordered a repeat prescription in the previous 12 months. Respondents with a long-term condition, on regular multiple medications, who have deafness or hearing loss and who are from the lowest deprivation quintile were more likely to have used online services. Male respondents (compared to females) and respondents with Black and Other ethnic background compared to White ethnic backgrounds were less likely to use online services. Respondents over 85 years old were less likely to use online appointment booking and online repeat prescription ordering compared to the younger age groups.

Conclusions: Specific groups of respondents were more likely to use online services such as patients with long-term conditions or those with deafness or hearing loss. While online services could provide efficiency to patients and practices it is essential that alternatives continue to be provided to those that cannot use or choose not to use online services. Understanding the different patients' needs could inform solutions to encourage the uptake and use of the services.

Strengths and limitations of this study

Strengths

1. The study used a sample from a major national survey which has developed a robust methodology in its data collection to explore the characteristics of online services users, a service which has been highly advocated in the NHS and in other healthcare systems of the world.
2. Given the clustered nature of the data (where patients are registered to different general practices) and to account for the clustering, we used multilevel logistic regression analysis.

Limitation

1. The study relied on self-reported data for online service use due to data unavailability which can lead to response bias.

BACKGROUND

Online services such as online appointment booking or repeat prescription ordering are offered in 99.7% of General Practitioner (GP) practices in England [1], but patients have to request access to the service and adoption remains low (about 31% in May 2020) [1]. According to previous literature, online services, also referred to as patient portals, have the potential to promote patients' involvement in their care, reduce emergency visits and hospitalisation [2], and may improve some health outcomes through improving medication adherence [2, 3] patients' knowledge about health and patient efficacy (e.g. patient's confidence in adhering to health instructions or treatment) [4]. Few studies have examined the characteristics of patients using online services and the inequalities that might exist based on patient characteristics in the context

of the National Health Service (NHS) of England such as ethnicity and deprivation inequalities [5-7]. Understanding patient characteristics associated with online service use may reveal barriers to use and inform service planning to increase the uptake of the services.

Studies from other countries, and a limited number of studies from the UK, suggest that [7-10] patients with low income, and ethnic minorities may be less likely to use patient portals due to reduced access to the internet, computers and smartphones [8, 10]. This is the first study to look at online services user characteristics for both online appointment booking and repeat prescription ordering explicitly in England, where the NHS have invested in a nation-wide digital transformation programme [11]. This study aims to examine patients' characteristics associated with online appointment booking and repeat prescription service ordering.

Healthcare systems are characterized as complex systems and healthcare innovations often face multi-faceted challenges in diffusion ("passive spread") and adoption due to the nature of complex systems [12]. A major theory considered in healthcare innovation adoption is the digital divide theory which highlights the inequality that arises when people without access to technology (that is physical access but also access to the knowledge and skills to use the technology) are excluded from the benefits that technology has to offer [13-15]. In consideration of the digital divide theory [13-15], we hypothesized that those of older age (patients 35 years old and older) of lower socioeconomic status and respondents of minority ethnic groups would be less likely to use online services. We hypothesized the younger age group (younger than 35 years old) to be more likely to use online services due to the high adoption of technology in this age group and their familiarity with the use of internet [16]. We hypothesized that individuals of lower socioeconomic status and minority ethnicities to be less likely to use online services as this has been reported in several studies looking into the use of patient portals and patient

characteristics [8, 17-19]. Additionally, in consideration of patients' health status, we hypothesized that respondents with long-term or chronic conditions (but not those who are very ill) may be more likely to use online services because of their increased need to access and use the services such as appointment booking and repeat prescription. Additionally, patients with long-term conditions have certain physical limitation and socio-economic circumstances that could also influence their ability to access healthcare services in person.

METHODS

Patient and public involvement

This study had limited involvement from from the NIHR Applied Research Collaboration of Northwest London Public Advisors whom were consulted during the study write-up and were involved appropriately in the drafting.

Study design

Cross-sectional analyses of respondent-level data obtained from the General Practice Patient Survey (GPPS) of 2018, 2019, and 2020 in England. The respondent-level data were pseudonymised. The researchers' did not have access to the respondents' identifies: name, address, NHS number and date of birth. Respondent-level data are only presented aggregately to protect respondents' privacy as agreed in the ethical approval of the study (20IC6303). Data collection for each survey was between January and March for the years 2018 and 2019 and between January and April for 2020. Respondents of the survey had the right to withdraw their consent before their data were processed [20].

Variables

Outcome variables

The outcome variables (online appointment booking use and online repeat prescription use) were based on the responses to the GPPS question: "Which of the following general practice online services have you used in the past 12 months?" [21] in which the answers "Booking appointments online", and "Ordering repeat prescriptions online" were used for this study. We compared the characteristics of those who replied "yes" to the question to those who replied "no" to the question. The answers "yes" and "no" were provided by the GPPS for each of the options: "Booking appointments online", and "Ordering repeat prescriptions online". The GPPS also records the use of online record viewing. However, we did not include it in this study due to the limited number of respondents reporting the use of the functionality (about 5% in 2020 and lower proportions in 2019 and 2018).

Explanatory variables

Ten different covariates (explanatory variables) were included in the models as listed in table 1. Variables were selected based on factors that are known to be associated with patient portal use in the literature such as long-term condition status, deafness or hearing loss, and parent and carer status, and based on data availability such as taking 5 or more medications regularly (another indicator for healthcare status).

Table 1 The list of variables included in the two-level regression models of the study and their definitions.

Variable	Categories and definition
Gender	Male, Female
Age (bands)	16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, 85 or over (as categorised by the survey)
Ethnicity	White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [22]) White, mixed,

	Asian, black, other (5 broad groups derived from 18 ethnicity categories published by the Office of National Statistics (ONS) categories [22])
Survey year	2018, 2019 or 2020 (created based on the year of the survey)
Long-term conditions	Yes, No, or "I don't know/ Can't answer" answers to the question: "Do you have any long-term physical or mental health conditions, disabilities or illnesses?" [21]
Deafness or hearing loss	Yes or No answer to the question: " Which, if any, of the following long-term conditions do you have?…Deafness or hearing loss" [21]
Taking 5 or more medications on a regular basis	Yes or No answer to the question: "Do you take 5 or more medications on a regular basis?" [21]
Parent status	Yes or No answer to the question: "Are you a parent or a legal guardian for any children aged under 16 living in your home?" [21]
Carer status	Yes or No answer derived from the answers to the question: "Do you look after, or give any help or support to family members, friends, neighbours or others because of either: long-term physical or mental ill health / disability, or problems related to old age?"
Index of Multiple Deprivation (IMD) quintiles	The GPPS provided a variable called deprivation rank for all respondents included in the survey which was defined as: ONS IMD score - deprivation banding based on patient postcode. We converted the ONS IMD scores provided by GPPS to IMD quintiles using the English indices of deprivation 2019 guidance [23]. We chose the deprivation quintile instead of deciles or IMD ranking to reduce the number of categories in the model while accounting for a potential predictor of online services use (deprivation) [24] and to duplicate the same categories used in previous GPPS analyses [5, 6, 24].
Rurality of the General Practice	A variable provided by GPPS based on the GP practice's postcode categorised as Rural or urban as defined by the ONS [25] rural or urban as defined by the ONS [25]

Data source

The GPPS is a national, postal survey commissioned by NHS England. GPPS uses random sampling, proportionately stratified by GP practice, age, and gender. Eligibility for GPPS includes having a valid NHS number, being 16 years or older and being registered with a GP practice for at least 6 months. Response rates of previous surveys are considered, sending more

surveys to low-response practices and fewer surveys to high-response practices [26-28]. The survey was sent to 2,221,068, 2,328,560, 2,329,590 respondents in the years 2018, 2019 and 2020, with response rates of 34%, 33% and 32%, respectively [26-28].

In March 2020, social restrictions were announced in England due to the COVID-19 pandemic [29]. The last data collected for the GPPS was in April 2020, however, only a small number of surveys were received post March 2020 with the GPPS indicating it was highly unlikely that the survey results were affected by the pandemic [27].

Study population

We obtained data from respondents who completed the GPPS surveys in 2018, 2019 and 2020 and only included the respondents who answered either "yes" or "no" to using online appointment booking and/or online repeat prescription ordering as described in the variables section above. We then removed respondents who did not have complete data for the variables of interests.

Statistical analyses

We first reported descriptive statistics of the respondents based on their online appointment booking and repeat prescription use. All of the included variables in this study were categorical. We first tabulated each exploratory variable by the outcome variables and compared using Chi square test. We then performed univariate analysis between each of the explanatory variables and the outcome variable to check if they converge and to examine the coefficients. Collinearity was avoided by using the same set of variables used in previous studies analysing online services use using GPPS data [5], and checking for collinearity after the analysis was completed. To perform multilevel mixed-effects logistic regression models: First, we created null models with only the outcome variables and random intercepts (GP practices) to understand if there was clustering due

to the random intercepts. We then added all patient level covariates to the models (model 2) (most of the variable in the final models were patient-level variables). We checked the Intraclass Correlation Coefficient (ICC) and intercepted in all models to examine the effect of clustering. We then added the GP practice level variable (GP practice rurality) in the final models (model 3) [30]. After completing all analyses we also performed model diagnostics to check the best fit model and checked for multicollinearity by calculating the variable inflation factor (VIF). Model diagnostics was performed by calculating Bayesian information criterion (BIC) and comparing the BIC of the different versions of the models. The model with the lowest BIC was considered the best fit model [31]. VIF that was lower than 5 was considered not indicating collinearity [32]. The statistical analyses were performed in RStudio software version 1.4.1717.

Sensitivity analyses

Methods of the sensitivity analyses is in the Supplementary Table 1. Because only complete case participants were included in this study, we ran a sensitivity analysis to predict the outcome this decision may have had on the main analyses. To do this, we first categorized GP practices according to the proportion of complete case participants available. The outcome of this categorization resulted in three groups: highest missing data group (75% of the participants in these practices had missing data), middle-range missing data group (26-74% of the participants in these practices had missing data), and lowest missing data group (25% or less of the participants in these practices had missing data). We then categorized the complete-case participants according to the proportion of missing data in their GP practices using the three categories (highest, middle-range and lowest missing data groups) and then ran the same analyses described in the statistical analyses sub-section above.

The Strengthening the reporting of observational studies in epidemiology (STROBE) checklist was completed to review the methods of the study [33] (Supplementary Table 2).

RESULTS

Some of the results of this study were presented in a conference abstract [34].

Sample size

We received data from 2,246,109 respondents who completed the GPPS surveys in 2018, 2019 or 2020. After removing respondents that did not have complete data for the variables of interest (n=439,060, 19.5%), 1,807,049 respondents were included.

Summary statistics

1,807,049 respondents were included of which 15% (n=263938) used online appointment booking (used at least once in the previous 12 months), and 19% (n=339449) used online repeat prescription (used at least once in the previous 12 months) (Table 2). Most respondents were female (55.1%), and in the 65-74 years age group (22%), were of white ethnic backgrounds (86.8%), and were registered at GP practices in an urban area (83.1%) and half (51.1%) had a long-term condition.

Table 2. Descriptive statistics of the number and proportion of respondent characteristics in the total population included in the analyses (n=1807049), categorized by online services use

CharacteristicsTotal	Online appointment booking in the previous 12 months	Online repeat prescription ordering in the previous 12 months

	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Gender				<0.001			0.97
Female	996544 (55.1%)	843422 (54.7%)	153122 (58.0%)		809337 (55.1%)	187207 (55.2%)	
Male	810505 (44.9%)	699689 (45.3%)	110816 (42.0%)		658263 (44.9%)	152242 (44.8%)	
Age (bands)				<0.001			<0.001
16-24	74381 (4.1%)	64513 (4.2%)	9868 (3.7%)		67069 (4.6%)	7312 (2.2%)	
25-34	159806 (8.8%)	132951 (8.6%)	26855 (10.2%)		141376 (9.6%)	18430 (5.4%)	
35-44	217687 (12.0%)	181290 (11.7%)	36397 (13.8%)		186112 (12.7%)	31575 (9.3%)	
45-54	302285 (16.7%)	253145 (16.4%)	49140 (18.6%)		243458 (16.6%)	58827 (17.3%)	
55-64	381808 (21.1%)	321902 (20.9%)	59906 (22.7%)		295168 (20.1%)	86640 (25.5%)	
65-74	397999 (22.0%)	340484 (22.1%)	57515 (21.8%)		303875 (20.7%)	94124 (27.7%)	
75-84	211586 (11.7%)	191217 (12.4%)	20369 (7.7%)		176214 (12.0%)	35372 (10.4%)	
85+	61497 (3.4%)	57609 (3.7%)	3888 (1.5%)		54328 (3.7%)	7169 (2.1%)	
Ethnicity				<0.001			<0.001
White	1567690 (86.8%)	1340202 (86.9%)	227488 (86.2%)		1258828 (85.8%)	308862 (91.0%)	
Black	52950 (2.9%)	46120 (3.0%)	6830 (2.6%)		47195 (3.2%)	5755 (1.7%)	
Asian	137026 (7.6%)	115015 (7.5%)	22011 (8.3%)		118728 (8.1%)	18298 (5.4%)	
Other	29168 (1.6%)	24993 (1.6%)	4175 (1.6%)		25773 (1.8%)	3395 (1.0%)	
Mixed	20215 (1.1%)	16781 (1.1%)	3434 (1.3%)		17076 (1.2%)	3139 (0.9%)	
Survey year				<0.001			<0.001
2018	612084 (33.9%)	536349 (34.8%)	75735 (28.7%)		512184 (34.9%)	99900 (29.4%)	

2019	623358 (34.5%)	534321 (34.6%)	89037 (33.7%)		507522 (34.6%)	115836 (34.1%)	
2020	571607 (31.6%)	472441 (30.6%)	99166 (37.6%)		447894 (30.5%)	123713 (36.4%)	
Long-term condition				<0.001			<0.001
No	833523 (46.1%)	730177 (47.3%)	103346 (39.2%)		736861 (50.2%)	96662 (28.5%)	
I don't know/ Can't answer	49746 (2.8%)	43186 (2.8%)	6560 (2.5%)		43212 (2.9%)	6534 (1.9%)	
Yes	923780 (51.1%)	769748 (49.9%)	154032 (58.4%)		687527 (46.8%)	236253 (69.6%)	
Taking five or more medication on a regular basis				<0.001			<0.001
No	1343735 (74.4%)	1151312 (74.6%)	192423 (72.9%)		1118704 (76.2%)	225031 (66.3%)	
Yes	463314 (25.6%)	391799 (25.4%)	71515 (27.1%)		348896 (23.8%)	114418 (33.7%)	
Deafness or hearing loss				<0.001			<0.001
No	1652099 (91.4%)	1409236 (91.3%)	242863 (92.0%)		1344856 (91.6%)	307243 (90.5%)	
Yes	154950 (8.6%)	133875 (8.7%)	21075 (8.0%)		122744 (8.4%)	32206 (9.5%)	
Parent or legal guardian to a 16 year old or younger				<0.001			<0.001
No	1466017 (81.1%)	1254880 (81.3%)	211137 (80.0%)		1177272 (80.2%)	288745 (85.1%)	
Yes	341032 (18.9%)	288231 (18.7%)	52801 (20.0%)		290328 (19.8%)	50704 (14.9%)	
Carer				<0.001			<0.001
No	1462467 (80.9%)	1254985 (81.3%)	207482 (78.6%)		1200653 (81.8%)	261814 (77.1%)	

Yes	344582 (19.1%)	288126 (18.7%)	56456 (21.4%)	266947 (18.2%)	77635 (22.9%)	
Deprivation quintile				<0.001		<0.001
1 (Most deprived)	338728 (18.7%)	298412 (19.3%)	40316 (15.3%)	292405 (19.9%)	46323 (13.6%)	
2	353580 (19.6%)	304870 (19.8%)	48710 (18.5%)	296229 (20.2%)	57351 (16.9%)	
3	376042 (20.8%)	322081 (20.9%)	53961 (20.4%)	304048 (20.7%)	71994 (21.2%)	
4	378002 (20.9%)	319100 (20.7%)	58902 (22.3%)	297096 (20.2%)	80906 (23.8%)	
5 (Least deprived)	360697 (20.0%)	298648 (19.4%)	62049 (23.5%)	277822 (18.9%)	82875 (24.4%)	
General practice rurality				<0.001		<0.001
Rural	306200 (16.9%)	263405 (17.1%)	42795 (16.2%)	238353 (16.2%)	67847 (20.0%)	
Urban	1500849 (83.1%)	1279706 (82.9%)	221143 (83.8%)	1229247 (83.8%)	271602 (80.0%)	

* p-value derived from chi squared test comparing online appointment booking users and non-users

† p-value derived from chi squared test comparing online repeat prescription users and non-users

About 19.5% of the total sample received from GPPS was excluded due to missing data. The proportion of respondents by category in the excluded respondents were different to the complete case dataset in the proportions for age, ethnicity (most respondents were from the mixed ethnicity), survey year, long-term condition, taking five or more medications, reporting of deafness or hearing loss, and slight difference in deprivation fifths proportions (Supplementary Table 3). However, when comparing the complete case sample to the total sample received, the differences in proportions between the two categories are very small and vary between 1-2% (Supplementary Table 3).

Descriptive statistics of the sensitivity analysis groups are displayed in Supplementary Table 4.

GP practices with the highest proportion of missing data (practices with 75% or more of

respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a higher proportion of respondents from Black, Asian and Other ethnic backgrounds as well as higher proportion or respondents from the most deprived group compared to the GP practices with lower missing data.

Patient and GP practice characteristics associated with online services' use

The results of the univariate analysis are in the supplementary table 5.

Online appointment booking

Results of the two-level mixed-effects logistic regression for the online appointment booking outcome are presented in table 2. Respondents with a long-term condition, taking 5 or more medications on a regular basis and who have deafness or hearing loss were more likely to use online appointment booking compared to respondents without these characteristics. In the fully adjusted model for patient and GP practice characteristics, respondents with a long-term condition had 67% greater odds of using online appointment booking (OR: 1.67, CI: 1.66-1.69) compared to respondents without a long-term condition.

Respondents of black and "other" ethnic backgrounds had lower odds than those of white ethnic backgrounds for using online appointment booking, whereas respondents of Asian ethnic backgrounds had 11% (OR: 1.11, 95% CI: 1.09-1.13) greater odds of using online appointment booking.

There was an inverse association between deprivation quintile and online appointment booking. The odds for using online appointment booking increased with reducing deprivation from the second to fifth (least deprived) quintile compared to the most deprived quintile. Respondents in

the least deprived quintile had 54% greater odds of booking appointments online (OR: 1.54, 95% CI: 1.51-1.57) compared to those in the most deprived quintile. Respondents from the survey year 2020 were the most likely to use online appointment booking compared to respondents from the survey year 2018 and 2019.

Respondents from GP practices located in an urban setting had greater odds of booking appointments online compared to respondents from GP practices in a rural setting.

Model comparison: The ICC of 0.13 indicates that there is a slight similarity between values from the same group (in this case from the same GP practice) although the difference is not large because the value is close to zero.

Sensitivity analysis

Results of the sensitivity analysis for online appointment booking are in the Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GP practices indicating that socioeconomic inequities may have a larger influence on online repeat prescription ordering than online appointment booking. Most of the odds ratios that were statistically significant remained significant for the different analyses by practice size except for the ethnicity categories including: Asian, Other and Mixed categories

which may reflect the differences in ethnic representation in each of the sensitivity analyses categories.

Table 2 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online appointment booking use in the previous 12 months (level 1 , N= 1807049 respondents; level 2, N=7256 general practices)

Predictors	+ GP practice Characteristics (Model 3) Odds Ratios	95% Confidence Interval
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.15***	(1.12, 1.19)
Long term condition- Yes	1.67***	(1.66, 1.69)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.18, 1.20)
Deafness or hearing loss-Yes (REF= No)	1.13***	(1.11, 1.15)
Gender-Male (REF= Female)	0.89***	(0.88, 0.90)
Age (bands) (REF: 85+)		
16-24	3.63***	(3.48, 3.78)
25-34	4.96***	(4.78, 5.14)
35-44	4.85***	(4.68, 5.03)
45-54	4.26***	(4.12, 4.42)
55-64	3.69***	(3.57, 3.82)
65-74	3.09***	(2.99, 3.20)
75-84	1.74***	(1.68, 1.80)
Ethnicity (REF: White)		
Black	0.84***	(0.81, 0.86)
Asian	1.11***	(1.09, 1.13)
Other	0.96**	(0.92, 0.99)
Mixed	1.04	(1.00, 1.08)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.92***	(0.90, 0.93)
Carer-Yes (REF= No)	1.14***	(1.13, 1.16)
Deprivation quintile (REF: 1- Most deprived)		
2	1.15***	(1.13, 1.17)
3	1.27***	(1.25, 1.29)
4	1.40***	(1.37, 1.42)
5 (least deprived)	1.54***	(1.51, 1.57)
Survey year (REF= 2018)		
2019	1.19***	(1.18, 1.20)
2020	1.52***	(1.50, 1.54)
General practice rurality-urban (REF= rural)	1.11***	(1.07, 1.16)
Model summary		
ICC	0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Online repeat prescription ordering

Results of the two-level mixed-effects logistic regression for the online repeat prescription ordering outcome are presented in table 3. Respondents with a long-term condition, users of 5 or more medications on a regular basis and respondents with deafness or hearing loss were all more likely to use online repeat prescription ordering compared to respondents without these characteristics. The odds of using online repeat prescription ordering were 2.58 times greater (OR: 2.58, 95% CI: 2.55, 2.60) for respondents with a long-term condition compared to those without a condition.

Black, Asian, and Mixed had lower odds of using online repeat prescription ordering compared to the White ethnicity.

Respondents in the deprivation quintiles 4 and 5 (least deprived) had the highest odds of using online repeat prescription ordering compared to the most deprived group (OR: 1.62, 95% CI: 1.59, 1.64) and (OR: 1.77, 95% CI: 1.74, 1.80), respectively.

Respondents who completed the survey in the years 2019 and 2020 had greater odds of using online repeat prescription ordering compared to respondents from the survey year 2018.

Respondents from GP practices located in an urban setting had lower odds of ordering repeat prescriptions online compared to respondents from GP practices in a rural setting.

Model comparison: the ICC was 0.08 for model 3 in table 3, which also showed that there is slight evidence that patients from the same GP practices may have more similar results compared to patients from other GP practices.

Sensitivity analysis results: Results of the sensitivity analysis for the repeat prescription outcome are in supplementary table 7. Differences (compared to the main analysis) in odds ratios were seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the deprivation quintile. Among respondents from practices with 75% or more respondents with missing data, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97) higher odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with bigger differences in the odds associated with the outcome for respondents from the highest missing data GP practices compared to the other GP practices.

The VIF values for all explanatory variables in our fixed-effects logistic regression models for both outcomes (online appointment booking and online repeat prescription ordering) were below the threshold of 5 (ranging from 1 to 1.8) indicating that there is no evidence of multicollinearity among the explanatory variables. In terms of model diagnostics, BIC values of each of the models (null model, model 2 and model 3) were compared to each other to make sure that the model presented is the best fit model (the model with the lowest BIC). The values of BIC for all the models for each outcome are summarized below:

Value of BIC for the online appointment booking outcome models:

Null model: BIC= 1434808

Model 2: BIC= 1398822

Model 3: BIC= 1398807

Value of BIC for the online repeat prescription ordering outcome models:

Null model: BIC= 1692919

Model 2: BIC= 1601232

Model 3: BIC= 1601182

Table 3 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online Repeat prescription ordering use in the previous 12 months (level 1, N= 1807049 respondents; level 2, N=7256 general practices)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.25***	(1.22, 1.29)
Long term condition- Yes	2.58***	(2.55, 2.60)
Taking five or more medication on a regular basis-Yes (REF= No)	1.26***	(1.25, 1.28)
Deafness or hearing loss-Yes (REF= No)	1.02**	(1.00, 1.03)
Gender-Male (REF= Female)	0.96***	(0.96, 0.97)
Age (bands) (REF: 85+)		
16-24	1.71***	(1.64, 1.77)
25-34	2.17***	(2.10, 2.23)
35-44	2.69***	(2.61, 2.77)
45-54	3.18***	(3.10, 3.28)
55-64	3.28***	(3.20, 3.37)
65-74	3.01***	(2.93, 3.09)
75-84	1.68***	(1.64, 1.73)
Ethnicity (REF: White)		
Black	0.76***	(0.74, 0.78)
Asian	0.94***	(0.93, 0.96)
Other	0.78***	(0.75, 0.81)
Mixed	0.98	(0.94, 1.02)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.95***	(0.94, 0.96)
Carer-Yes (REF= No)	1.16***	(1.15, 1.17)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Deprivation quintile (REF: 1- Most deprived)		
2	1.23***	(1.21, 1.25)
3	1.44***	(1.42, 1.46)
4	1.62***	(1.59, 1.64)
5 (least deprived)	1.77***	(1.74, 1.80)
Survey year (REF= 2018)		
2019	1.18***	(1.17, 1.19)
2020	1.46***	(1.44, 1.47)
General practice rurality-urban (REF= rural)	0.88***	(0.85, 0.91)
Model Summary		
ICC	0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

DISCUSSION

Principal findings

Overall, the findings of the study indicate that indicators of increased healthcare need and socioeconomic disadvantage predicted variations in the use of online services and use of the services increased over the three years studied. Our findings partly confirmed out hypotheses in that patients with long-term conditions were more likely to use online services and respondents of lower socioeconomic status and minority ethnic groups were less likely to use online services. However, our findings did not support our hypothesis that not all respondents older than 35 were less likely to use online services, as use varied by age group. Respondents of the age groups 35-84 were all more likely to use online services compared to respondents of the age group 85 years old and older.

Strengths and weaknesses of the study

Strengths

This study used a major national survey which uses robust research methodology in its data collection process and used suitable analysis methodology for processing the data (accounting for GP practice variation in the models and accounting for missing data in the sensitivity analyses). The study explored online services user characteristics in England which can inform service planning and identify patient groups who may need support using the service.

We accounted for clustering in our data presenting patient-level data in which patients belonged to different GP practices, by using multilevel logistic regression model which is an analysis methodology that takes into account the hierarchy in the data [35]. Clustering by GP practice was important not only because patients from the same GP practice may be more similar to each other, but patient portal functionalities and promotion of online services (such as providing training, posters, emails and reminders) to use online services may vary from one GP practice to another [36].

Limitations

A limitation of the study was using only complete-case data in the analyses, which risks sample bias. Respondents excluded from the analyses due to missing data presented differences in the breakdown of respondent characteristics. Therefore, we performed sensitivity to explore what kind of differences might have observed if all the sample was included. Both summary statistics of the excluded sample and the sensitivity analyses indicated GP practices with more missing data may be more likely to have younger age groups, greater deprivation groups, and ethnically diverse groups, all of which were associated with relatively lower odds of using online services.

This introduces the possibility that some of the odd's ratios presented in the main analysis may be overestimated in the population due to missing data bias.

However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services use between the three categories of GP practices were bigger for online repeat prescription use compared to the online appointment booking use.

As with all survey-based studies, a major limitation of the GPPS is the non-response bias. However, a study on the methodology of the GPPS, did not find evidence of non-response bias [37]. We tried to alleviate non-response bias by controlling for deprivation, ethnicity, age and gender (which can often be associated with low-response rates as reported in a study examining GPPS non-response characteristics [37]).

Strengths and weaknesses in relation to other studies

This study relied on self-reported online service usage which could introduce response bias [38]. A better way to measure use of outcomes such as online appointment booking and repeat prescription ordering could be via the electronic patient portal log files. The log files automatically record patient portal activity and can serve as an objective method to examine patient portal use because it is not subject to recall bias and records the exposure prior to the outcome [3]. However, due to data unavailability of patient-level data of this kind at the time of the study, the GPPS records of online services use was used in this study as it has been on other England based studies exploring online services use [5, 6].

Discussing important differences in results

Patients from more deprived areas, and from ethnic minorities are reported to have lower uptake of patient portals in previous studies [39]. According to previous studies, deprivation and ethnicity play key roles in online services use [40-42] which was confirmed by the main analysis and sensitivity analyses in this study. A study from the USA suggested that patients' ethnicity could be associated with less trust in patient portals [18]. Lower use of online services by respondents with greater deprivation levels is repeatedly reported in the literature [19]. This may be due to lower access to the internet, smart phone, and computers among individuals from more deprived areas [7, 43].

Meaning of the study

There is evidence that online services use in England is increasing every year and it is likely to continue to be an important tool in GP practice settings. Although online services have been offered almost universally in GP practices in England since 2015, there continues to be a lack of research on the use of online services (or patient portals) in this setting [7, 44]. Understanding the needs of populations less likely to use online services may help to improve the uptake of these services and to better meet the needs of vulnerable populations which are more likely to have reduced access to healthcare services [45] in addition to online services.

According to the theory of the digital divide, [14, 15], using technologies such as patient portals may require more than just having access to a computer. Skills such as digital literacy and eHealth literacy may be essential to enable the use of these services. Lack of education is also considered a detrimental factor contributing to the digital divide [46]. While our study did not directly investigate the mechanisms of the digital divide, it provides valuable insight into the

disparities that may exist in the use of online services. Factors that we found to be associated with reduced likelihood of using online services such as measures of lower socioeconomic status may be associated with factors such as limited digital skills and inadequate access to technology [13]. Efforts to understand the specific challenges faced by different patient groups in accessing and using online services, healthcare staff and policymakers can help develop tailored strategies to bridge the digital divide [47] and promote equitable access to online services. Further investigation including both quantitative and qualitative approaches can help us to better understand the mechanisms, and what may be involved in leading some individuals to adopt the technologies.

We estimated that younger populations would be more likely to use and have access to technologies, we could not see that pattern in the study may be because young people are less likely to need the healthcare system and services, such as appointment booking and repeat prescription requests. Additionally, this may be due to the complex mechanisms that may be involved in individuals opting to use online services which may be driven by social factors beyond this study.

Possible explanations and implications for clinicians and Policymakers

The adoption of online services by those with long-term conditions is promising and can potentially contribute to improving self-management of the long-term condition [2]. However, it is also a reflection that patients with long-term conditions may generally be more likely to use healthcare services [48-50]. Practices could continue to encourage and support patients with long-term conditions to sign up and use online services. However, it is essential that alternatives to online services continue to be provided to patients who are unable to use the services [48-50].

This study shows that online services use is lower among people from more deprived areas and from ethnic minorities which may increase inequities if in-person services become further out of reach. As an example, the move to telephone consultations and remote triage in GP practices amidst the COVID-19 pandemic made it difficult for homeless people to access care due to not having a telephone [51]. In-person access to care is seen necessary to reach all patient groups despite access to technology in the move to remote consultations in the COVID-19 pandemic [51]. For this reason, it is important that practices continue to provide in-person services (e.g. for appointment booking and repeat prescriptions) to patients especially those less able to access remote services. Training GP practice staff to promote the use online services may be a solution to increase adoption which is already provided in some GP practices [36] and we can continue to recommend it.

Unanswered questions and future research

Further research is needed to understand the lack of uptake of the services in some patient groups to clarify if uptake is low due to barriers or due to patient preference. During the COVID-19 pandemic, when patients are asked to contact their GP practice remotely [52], inequities in the access and use of the online services may have exacerbated inequities in situations where online services became the only route to access care [53]. Although the findings of this study relate to pre-COVID-19, the patterns in disparities may persist or worsen in the post-COVID-19 period amidst the move to increased remote GP services.

Future research could explore how remote services might affect aspects of the healthcare system such as healthcare utilisation and patients' self-management of their conditions. Our future research aim is to study patient portal use in GP practices in England using electronic health

records instead of relaying on patients' self-report. We will explore the influence of patient portal use on health outcomes and healthcare utilization to better understand its impact on health and the healthcare system.

Funding

This article presents independent research commissioned by the National Institute for Health Research (NIHR) under the Applied Health Research (ARC) programme for Northwest London. The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. TB acknowledges support from the NIHR ARC Northwest London.

Ethical approval

This study was approved by the Imperial College Research Ethics Committee, Reference number: 20IC6303. Respondents of the survey provided informed consent to take part in the research by allowing us to use their anonymised survey data, but they had the right to withdraw their consent before these data were processed.

Author contribution

AA, GG, TB and CC created the study design, formulated the research question and finalised the study methodology. AA performed the analysis of the study. JN contributed to the introduction and discussion sections of the study. All authors reviewed and approved the submitted manuscript.

Data sharing statement

The data that support the findings of this study are available on request from Ipsos Mori but cannot be provided by the authors due to ethical restrictions. However, the aggregate level GPPS data are openly available in the GP Patient Survey webpage at https://www.gp-patient.co.uk/ [21].

Competing interests

The authors declare that they have no competing interests.

References

1. Patient Online Management Information (POMI) - NHS Digital. @NHSDigital; 2021; Available from: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub/patient-online-management-information-pomi.
2. ME Reed, J Huang, RJ Brand, R Neugebauer, I Graetz, J Hsu, et al. Patients with complex chronic conditions: Health care use and clinical events associated with access to a patient portal. PloS one. 2019 06/19/2019;14(6). PMID: 31216295. doi: 10.1371/journal.pone.0217636.
3. DR Mangino, M Danis. Sharing Ethics Consultation Notes With Patients Through Online Portals. AMA journal of ethics. 2020 09/01/2020;22(9). PMID: 33009775. doi: 10.1001/amajethics.2020.784.
4. HR Han, KT Gleason, CA Sun, HN Miller, SJ Kang, S Chow, et al. Using Patient Portals to Improve Patient Outcomes: Systematic Review. JMIR human factors. 2019 12/19/2019;6(4). PMID: 31855187. doi: 10.2196/15038.
5. M Gomez-Cano, H Atherton, J Campbell, A Eccles, J Dale, L Poltawski, et al. Awareness and use of online appointment booking in general practice: analysis of GP Patient Survey data. The British journal of general practice : the journal of the Royal College of General Practitioners. 2020 2020 Jun;70(suppl 1). PMID: 32554662. doi: 10.3399/bjgp20X711365.
6. Gomez-Cano, J MCampbell, R Winder, J Lambert, G Abel. Awareness and use of online services in general practice: analysis of GP Patient Survey data | SAPC. SAPC ASM 2021; 2021-06-08T14:38+01:00; Virtual: @sapcacuk; 2021.
7. A Abd-Alrazaq, Z Safi, BM Bewick, M Househ, PH Gardner. Patients' Perspectives About Factors Affecting Their Use of Electronic Personal Health Records in England: Qualitative Analysis. Journal of medical Internet research. 2021 01/13/2021;23(1). PMID: 33439126. doi: 10.2196/17500.
8. S El-Toukhy, A Méndez, S Collins, EJ Pérez-Stable. Barriers to Patient Portal Access and Use: Evidence from the Health Information National Trends Survey. Journal of the American Board of Family Medicine : JABFM. 2020 Nov-Dec 2020;33(6). PMID: 33219074. doi: 10.3122/jabfm.2020.06.190402.
9. A Griffin, A Skinner, J Thornhill, M Weinberger. Patient Portals: Who uses them? What features do they use? And do they reduce hospital readmissions? Applied clinical informatics. 2016 06/06/2016;7(2). PMID: 27437056. doi: 10.4338/ACI-2016-01-RA-0003.

10. MG Antonio, O Petrovskaya, F Lau. The State of Evidence in Patient Portals: Umbrella Review. Journal of medical Internet research. 2020 11/11/2020;22(11). PMID: 33174851. doi: 10.2196/23851.
11. Watcher Robert M. Making IT work: harnessing the power of health information technology to improve care in England. 2016 7 September 2016. Report No.
12. T Greenhalgh, G Robert, F Macfarlane, P Bate, O Kyriakidou. Diffusion of innovations in service organizations: systematic review and recommendations. The Milbank quarterly. 2004 2004;82(4). PMID: 15595944. doi: 10.1111/j.0887-378X.2004.00325.x.
13. AJ van Deursen, JA van Dijk. The first-level digital divide shifts from inequalities in physical access to inequalities in material access. New media & society. 2019 2019 Feb;21(2). PMID: 30886536. doi: 10.1177/1461444818797082.
14. Serafino Paola. Exploring the UK's digital divide - Office for National Statistics. s; 2019; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/articles/exploringtheuksdigitaldivide/2019-03-04.
15. Dijk Jan van. A Framework For Digital Divide Research. The Electronic Journal of Communication. 2002;12(1 & 2).
16. Internet access – households and individuals, Great Britain: 2020 Internet access in Great Britain, including how many people have internet access, what they use it for and online shopping.: Office for National Statistics; 2020; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2020#internet-access-households-and-individuals-data.
17. N Dixit, Y Van Sebille, GB Crawford, PK Ginex, PF Ortega, RJ Chan. Disparities in telehealth use: How should the supportive care community respond? Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer. 2021 10/19/2021. PMID: 34668075. doi: 10.1007/s00520-021-06629-4.
18. MA Clarke, ER Lyden, J Ma, KM King, MM Siahpush, T Michaud, et al. Sociodemographic Differences and Factors Affecting Patient Portal Utilization. Journal of racial and ethnic health disparities. 2021 2021 Aug;8(4). PMID: 32839896. doi: 10.1007/s40615-020-00846-z.
19. Priti Singh, Pallavi Jonnalagadda, Evan Morgan, Naleef Fareed. Outpatient Portal Use in Prenatal Care: Differential Use by Race, Risk, and Area Social Determinants of Health Factors. medRXiv. 2021 2021-05-26. doi: 10.1101/2021.05.25.21257657.
20. GP Patient Survey Confidentiality and data protection. 2023; Available from: https://www.gp-patient.co.uk/confidentiality.
21. GP Patient Survey: Surveys and Reports. Ipsos MORI; 2020; Available from: https://www.gp-patient.co.uk/surveysandreports.
22. Ethnic group, national identity and religion. Office for National Statistics; 2021; Available from: https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion.
23. Ministry of Housing Communities, & Local Government. English Indices of Deprivation 2019 FAQs. 2019; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf.
24. J Burt, C Lloyd, J Campbell, M Roland, G Abel. Variations in GP-patient communication by ethnicity, age, and gender: evidence from a national primary care patient survey. The British journal of general practice : the journal of the Royal College of General Practitioners. 2016 2016 Jan;66(642). PMID: 26541182. doi: 10.3399/bjgp15X687637.

25. 2011 rural/urban classification. 2011; Available from: https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification.
26. MORI Ipsos. GP Patient Survey 2019 Technical Annex. 2019; Available from: https://gp-patient.co.uk/downloads/archive/2019/GPPS_2019_Technical_Annex_PUBLIC.pdf.
27. MORI Ipsos. GP Patient Survey 2020 Technical Annex. 2020; Available from: https://gp-patient.co.uk/downloads/2020/GPPS_2020_Technical_Annex_PUBLIC.pdf.
28. MORI Ipsos. GP Patient Survey - Technical Annex: 2018 annual report. August 2018; Available from: https://gp-patient.co.uk/downloads/archive/2018/GPPS%202018%20Technical%20Annex%20PUBLIC.pdf.
29. GOV.UK. Prime Minister's statement on coronavirus (COVID-19): 23 March 2020. 23 March 2020.
30. Kleiman Evan. Understanding and analyzing multilevel data from real-time monitoring studies: An easily- accessible tutorial using R. 2021. doi: doi:10.31234/osf.io/xf2pw.
31. Boykin Allison Ames, Ezike Nnamdi C., Myers Aaron J. Model-data fit evaluation: posterior checks and Bayesian model selection. International Encyclopedia of Education: Elsevier Science; 2023. p. 279-89.
32. JH Kim. Multicollinearity and misleading statistical results. Korean journal of anesthesiology. 2019 2019 Dec;72(6). PMID: 31304696. doi: 10.4097/kja.19087.
33. STROBE Strengthening the reporting of observational studies in epidemiology. 2021; Available from: https://www.strobe-statement.org/.
34. Alturkistani A., Greenfield G., Beaney T ., Norton J., Costelloe C E., editors. Ethnicity, deprivation, and the use of patient portals in England's general practices 2018-2020: Abrar Alturkistani. European Journal of Public Health; 2022: Oxford academic.
35. Modelling Centre for Multilevel. What are multilevel models and why should I use them? : University of Bristol; 2023.
36. England NHS. GP online services case studies. 2023.
37. M Roland, M Elliott, G Lyratzopoulos, J Barbiere, RA Parker, P Smith, et al. Reliability of patient responses in pay for performance schemes: analysis of national General Practitioner Patient Survey data in England. BMJ (Clinical research ed). 2009 09/29/2009;339. PMID: 19808811. doi: 10.1136/bmj.b3851.
38. J Stokes, P Bower, B Guthrie, SW Mercer, N Rice, AM Ryan, et al. Cuts to local government spending, multimorbidity and health-related quality of life: A longitudinal ecological study in England. The Lancet regional health Europe. 2022 06/10/2022;19. PMID: 36039277. doi: 10.1016/j.lanepe.2022.100436.
39. CH Halbert, M Jefferson, CG Allen, OA Babatunde, R Drake, P Angel, et al. Racial Differences in Patient Portal Activation and Research Enrollment Among Patients With Prostate Cancer. JCO clinical cancer informatics. 2021 2021 Jun;5. PMID: 34328797. doi: 10.1200/CCI.20.00131.
40. S Sinha, M Garriga, N Naik, BW McSteen, AY Odisho, A Lin, et al. Disparities in Electronic Health Record Patient Portal Enrollment Among Oncology Patients. JAMA oncology. 2021 06/01/2021;7(6). PMID: 33830178. doi: 10.1001/jamaoncol.2021.0540.
41. EP Ukoha, J Feinglass, LM Yee. Disparities in Electronic Patient Portal Use in Prenatal Care: Retrospective Cohort Study. Journal of medical Internet research. 2019 09/23/2019;21(9). PMID: 31586367. doi: 10.2196/14445.
42. DM Walker, JL Hefner, N Fareed, TR Huerta, AS McAlearney. Exploring the Digital Divide: Age and Race Disparities in Use of an Inpatient Portal. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2020 2020 May;26(5). PMID: 31313977. doi: 10.1089/tmj.2019.0065.

43. Matthew Honeyman, David Maguire, Harry Evans, Alisha Davies. Digital technology and health inequalities: a scoping review. Cardiff: Public Health Wales NHS Trust; 2020; Available from: https://phw.nhs.wales/publications/publications1/digital-technology-and-health-inequalities-a-scoping-review/.
44. F Mold, S de Lusignan, A Sheikh, A Majeed, JC Wyatt, T Quinn, et al. Patients' online access to their electronic health records and linked online services: a systematic review in primary care. The British journal of general practice : the journal of the Royal College of General Practitioners. 2015 2015 Mar;65(632). PMID: 25733435. doi: 10.3399/bjgp15X683941.
45. Saunders Catherine L, Flynn Sarah, Massou Efthalia, Lyratzopoulos Georgios, Abel Gary, Burt Jenni. Sociodemographic inequalities in patients' experiences of primary care: an analysis of the General Practice Patient Survey in England between 2011 and 2017:. https://doiorg/101177/1355819620986814. 2021 2021-01-31. doi: 10.1177_1355819620986814.
46. G Watts. COVID-19 and the digital divide in the UK. The Lancet Digital health. 2020 2020 Aug;2(8). PMID: 32835198. doi: 10.1016/S2589-7500(20)30169-2.
47. L Husain, T Greenhalgh, G Hughes, T Finlay, J Wherton. Desperately Seeking Intersectionality in Digital Health Disparity Research: Narrative Review to Inform a Richer Theorization of Multiple Disadvantage. Journal of medical Internet research. 2022 12/07/2022;24(12). PMID: 36383632. doi: 10.2196/42358.
48. LB Sansbury, DA Lipson, C Bains, GA Anley, KJ Rothnie, AS Ismaila. Disease Burden and Healthcare Utilization Among Patients with Chronic Obstructive Pulmonary Disease (COPD) in England. International journal of chronic obstructive pulmonary disease. 2022 03/03/2022;17. PMID: 35264848. doi: 10.2147/COPD.S336158.
49. CW le Roux, B Chubb, E Nørtoft, A Borglykke. Obesity and healthcare resource utilization: results from Clinical Practice Research Database (CPRD). Obesity science & practice. 2018 08/21/2018;4(5). PMID: 30338111. doi: 10.1002/osp4.291.
50. HI Wang, L Han, R Jacobs, T Doran, RIG Holt, SL Prady, et al. Healthcare resource use and costs for people with type 2 diabetes mellitus with and without severe mental illness in England: longitudinal matched-cohort study using the Clinical Practice Research Datalink. The British journal of psychiatry : the journal of mental science. 2022 2022 Jul;221(1). PMID: 35049484. doi: 10.1192/bjp.2021.131.
51. Howells Kelly Ann, Amp Mat, Burrows Martin, Brown Jo, Brennan Rachel, Dickinson Joanne, et al. Remote primary care during the COVID-19 pandemic for people experiencing homelessness: a qualitative study. 2022 2022-03-03. doi: 10.3399/BJGP.2021.0596.
52. NHS. Using the NHS and other health services during coronavirus (COVID-19). @nhsuk; 2021 [updated 2 Jun 2020]; Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/using-the-nhs-and-other-health-services/.
53. Ian Litchfield, David Shukla, Sheila Greenfield. Impact of COVID-19 on the digital divide: a rapid review. 2021 2021-10-01. doi: 10.1136/bmjopen-2021-053440.

Supplementary material

Supplementary Table 1 Methods and results of the sensitivity analysis.

Supplementary Table 2. STROBE 2007 checklist of items to be included in reports of observational studies in epidemiology.

Supplementary Table 3. The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060).Supplementary Table 4. Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice.

Supplementary Table 5. Table presenting summaries of the univariate analyses for each of the outcomes.

Supplementary Table 6. Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary Table 7. Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary material:

Supplementary Table 1. Methods and results of the sensitivity analysis

Methods	In the main analyses performed in this study, only complete case respondents (respondents that did not have any missing data for any of the variables included in the analyses) were included. We ran sensitivity analyses to explore the effects of excluding respondents with missing data. We first calculated the proportion of respondents with complete data per practice using the complete dataset (n=2198821) and assigned each practice a new variable indicating the proportion of complete case respondents in the practice. We then separated the complete case respondents (n=1807049) into three categories based on the proportion of complete case respondents in their practice. The three categories were: highest missing data group (≥75%), middle-range missing data group (26-74%), and lowest missing data group (≤25%). We then ran the same two-level mixed-effects models for each of the outcomes (online appointment booking and online repeat prescription use) separately for each of the three categories.
Results	The summary statistics of the sensitivity analysis groups are reported in table Supplementary Table 5. GPs with the highest proportion of missing data (practices with

	75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a greater proportion of respondents from Black, Asian and Other ethnic backgrounds as well. Greater proportion or respondents from the most deprived group compared to the GPs with lower missing data. Results of the sensitivity mixed-effects regression analyses for the online appointment booking outcome is in table Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. These differences indicate that the characteristics of respondents within each type of the GPs (based on the proportion of missing data) were more similar to each other than the other type of practices. For the repeat prescription outcome (Supplementary Table 7), differences in odds ratios were also seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the deprivation quintile. Among the highest missing data GP practice respondents, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97)

	greater odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents. This indicates that deprivation has a larger impact in practices with the most missing data compared to practices with the least missing data for the online repeat prescription ordering outcome. Sensitivity analyses results reveal that some of the estimates in this study may be attenuated if missing data/non-response respondents were present. However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained to be larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services between the three categories of GPs use were bigger for online repeat prescription use compared to the online appointment booking use. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GPs indicating that socioeconomic inequities may have a larger influence on online repeat prescription ordering than online appointment booking. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with

	bigger differences in the odds associated with the outcome for respondents from the highest missing data GPs compared to the other GPs.

Supplementary Table 2 STROBE 2007 checklist [12] of items to be included in reports of observational studies in epidemiology

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	9 & Supplementary Table 1

Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	Supplementary Table 1
		(*c*) Explain how missing data were addressed	Supplementary Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Supplementary Table 1
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	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-13
		(b) Indicate number of participants with missing data for each variable of interest	13 & Supplementary Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Data collection times are summarized under study design subsection
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supplementary Table 3 (check categories of survey year)
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Supplementary Table 3
		Cross-sectional study—Report numbers of outcome events or summary measures	13 & table 3
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	14-18, Supplementary Table 5
		(*b*) Report category boundaries when continuous variables were categorized	Table 1

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 1, Supplementary Table 6-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	20
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	21-22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	23-24
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	26

Supplementary Table 3 The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060)

Characteristics	Total in the sample received (n=2,246,109)	Total in the complete case dataset (n=1807049)	Total in the excluded sample (n=439,069)
Online appointment booking in the previous 12 months			
No	1892841 (84.3%)	1543111 (85.4%)	349730 (79.7%)
Yes	305980 (13.6%)	263938 (14.6%)	42042 (9.6%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Online repeat prescription ordering in the previous 12 months			
No	1807863 (80.5%)	1467600 (81.2%)	340263 (77.5%)
Yes	390958 (17.4%)	339449 (18.8%)	51509 (11.7%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Gender			

Female	1229473 (54.7%)	996544 (55.1%)	232929 (51.1%)
Male	967079 (43.1%)	810505 (44.9%)	156574 (34.7%)
(Missing)	49557 (2.2%)	0 (0.0%)	49557 (11.3%)
Age			
16-24	87081 (3.9%)	74381 (4.1%)	12700 (2.9%)
25-34	185580 (8.3%)	159806 (8.8%)	25774 (5.9%)
35-44	256766 (11.4%)	217687 (12.0%)	39079 (8.9%)
45-54	360011 (16.0%)	302285 (16.7%)	57726 (13.2%)
55-64	454900 (20.3%)	381808 (21.1%)	73092 (16.6%)
65-74	487171 (21.7%)	397999 (22.0%)	89172 (20.3%)
75-84	287533 (12.8%)	211586 (11.7%)	75947 (17.3%)
85+	91083 (4.1%)	61497 (3.4%)	29586 (6.7%)
(Missing)	35984 (1.6%)	0 (0.0%)	35984 (8.2%)
Ethnicity			
White	1895473 (84.4%)	1567690 (86.8%)	15862 (3.6%)
Black	68812 (3.1%)	52950 (2.9%)	33583 (7.6%)
Asian	170609 (7.6%)	137026 (7.6%)	10257 (2.3%)
Other	39425 (1.8%)	29168 (1.6%)	4558 (1.0%)
Mixed	24773 (1.1%)	20215 (1.1%)	327783 (74.7%)
(Missing)	47017 (2.1%)	0 (0.0%)	47017 (10.7%)
Survey year			
2018	750619 (33.4%)	612084 (33.9%)	138535 (31.6%)
2019	763244 (34.0%)	623358 (34.5%)	139886 (31.9%)
2020	732246 (32.6%)	571607 (31.6%)	160639 (36.6%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Long term condition			
No	1022671 (45.5%)	833523 (46.1%)	189148 (43.1%)
Yes	1050129 (46.8%)	923780 (51.1%)	126349 (28.8%)
Don’t know/Can’t say	61802 (2.8%)	49746 (2.8%)	12056 (2.7%)
Prefer not to say	38879 (1.7%)	0 (0.0%)	38879 (8.9%)
(Missing)	72628 (3.2%)	0 (0.0%)	72628 (16.5%)
Taking five or more medication on a regular basis			
No	1632850 (72.7%)	1343735 (74.4%)	289115 (65.8%)

Yes	574749 (25.6%)	463314 (25.6%)	111435 (21.4%)
(Missing)	38510 (1.7%)	0 (0.0%)	38510 (8.8%)
Deafness or hearing loss			
No	1799633 (80.1%)	1652099 (91.4%)	147534 (33.6%)
Yes	179304 (8.0%)	154950 (8.6%)	24354 (5.5%)
(Missing)	267172 (11.9%)	0 (0.0%)	267172 (60.9%)
Parent or legal guardian to a 16 year old or younger			
No	1782911 (79.4%)	1466017 (81.1%)	316894 (72.2%)
Yes	407923 (18.2%)	341032 (18.9%)	66891 (15.2%)
(Missing)	55275 (2.5%)	0 (0.0%)	55275 (12.6%)
Carer			
No	1741536 (77.5%)	1462467 (80.9%)	279069 (63.6%)
Yes	410450 (18.3%)	344582 (19.1%)	65868 (15.0%)
(Missing)	94123 (4.2%)	0 (0.0%)	94123 (21.4%)
Deprivation fifth			
1- least deprived	437189 (19.5%)	338728 (18.7%)	98461 (22.4%)
2	444869 (19.8%)	353580 (19.6%)	91289 (20.8%)
3	464884 (20.7%)	376042 (20.8%)	88842 (20.2%)
4	461586 (20.6%)	378002 (20.9%)	83584 (19.0%)
5 - most deprived	435997 (19.4%)	360697 (20.0%)	75300 (17.2%)
(Missing)	1584 (0.1%)	0 (0.0%)	1584 (0.4%)
General practice rurality			
Rural	374466 (16.7%)	306200 (16.9%)	68266 (15.5%)
Urban	1871643 (83.3%)	1500849 (83.1%)	370794 (84.5%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Supplementary Table 4 Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Online services use			
Online appointment booking in the previous 12 months	75194(15.9%)	176193(19.4%)	55937(13.1%)
Online repeat prescription use in the previous 12 months	102332(21.6%)	176193(19.4%)	60924(14.4%)
Gender			
Female	265428 (56.0%)	503040 (55.3%)	228076 (53.8%)
Male	208654 (44.0%)	406112 (44.7%)	195739 (46.2%)
Age			
16-24	18750 (4.0%)	34473 (3.8%)	21158 (5.0%)
25-34	39537 (8.3%)	75142 (8.3%)	45127 (10.6%)
35-44	55609 (11.7%)	103244 (11.4%)	58834 (13.9%)
45-54	79934 (16.9%)	149707 (16.5%)	72644 (17.1%)
55-64	100332 (21.2%)	194450 (21.4%)	87026 (20.5%)
65-74	106927 (22.6%)	208741 (23.0%)	82331 (19.4%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
75-84	56564 (11.9%)	111123 (12.2%)	43899 (10.4%)
85+	16429 (3.5%)	32272 (3.5%)	12796 (3.0%)
Ethnicity			
White	5027 (1.1%)	17758 (2.0%)	30165 (7.1%)
Black	16190 (3.4%)	49142 (5.4%)	71694 (16.9%)
Asian	3729 (0.8%)	10722 (1.2%)	14717 (3.5%)
Other	4175 (0.9%)	8704 (1.0%)	7336 (1.7%)
Mixed	444961 (93.9%)	822826 (90.5%)	299903 (70.8%)
Survey year			
2018	166729 (35.2%)	305514 (33.6%)	139841 (33.0%)
2019	162214 (34.2%)	315671 (34.7%)	145473 (34.3%)
2020	145139 (30.6%)	287967 (31.7%)	138501 (32.7%)
Long-term condition			
No	11725 (2.5%)	24207 (2.7%)	13814 (3.3%)
I don't know/ Can't answer	220575 (46.5%)	411974 (45.3%)	200974 (47.4%)
Yes	241782 (51.0%)	472971 (52.0%)	209027 (49.3%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Taking five or more medication on a regular basis			
No	363720 (76.7%)	674880 (74.2%)	305135 (72.0%)
Yes	110362 (23.3%)	234272 (25.8%)	118680 (28.0%)
Deafness or hearing loss			
No	433463 (91.4%)	827757 (91.0%)	390879 (92.2%)
Yes	40619 (8.6%)	81395 (9.0%)	32936 (7.8%)
Parent or legal guardian to a 16 year old or younger			
No	385230 (81.3%)	746422 (82.1%)	334365 (78.9%)
Yes	88852 (18.7%)	162730 (17.9%)	89450 (21.1%)
Carer			
No	382112 (80.6%)	732193 (80.5%)	348162 (82.1%)
Yes	91970 (19.4%)	176959 (19.5%)	75653 (17.9%)
Deprivation quintile			
1 (Most deprived)	38111 (8.0%)	146156 (16.1%)	154461 (36.4%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
2	64792 (13.7%)	174694 (19.2%)	114094 (26.9%)
3	99792 (21.0%)	199586 (22.0%)	76664 (18.1%)
4	124261 (26.2%)	203142 (22.3%)	50599 (11.9%)
5 (Least deprived)	147126 (31.0%)	185574 (20.4%)	27997 (6.6%)
General practice rurality			
Rural	116101 (24.5%)	165787 (18.2%)	24312 (5.7%)
Urban	357981 (75.5%)	743365 (81.8%)	399503 (94.3%)

Supplementary Table 5. Table presenting summaries of the univariate analyses for each of the outcomes:

Summary of univariate analysis for the online appointment booking outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.10	0.01	1.07 - 1.13	**<0.001**
Long term condition- Yes	1.50	0.01	1.48 - 1.51	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.16	0.01	1.15 - 1.17	**<0.001**
Deafness or hearing loss-Yes (REF= No)	0.94	0.01	0.92 - 0.95	**<0.001**
Gender-Male (REF= Female)	0.88	0.01	0.87 - 0.89	**<0.001**
Age bands (REF: 85+)				
16-24	2.32	0.05	2.24 - 2.41	**<0.001**
25-34	3.05	0.05	2.94 - 3.15	**<0.001**
35-44	3.00	0.05	2.9 - 3.11	**<0.001**
45-54	2.96	0.05	2.87 - 3.06	**<0.001**
55-64	2.88	0.05	2.79 - 2.98	**<0.001**
65-74	2.62	0.04	2.53 - 2.71	**<0.001**
	1.61	0.03	1.56 - 1.67	**<0.001**
Ethnicity (REF: White)				

Black	0.81	0.01	0.79 - 0.84	**<0.001**
Asian	1.10	0.01	1.08 - 1.12	**<0.001**
Other	0.94	0.02	0.91 - 0.97	**<0.001**
Mixed	1.11	0.02	1.07 - 1.16	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	1.06	0.01	1.05 - 1.07	**<0.001**
Carer-Yes (REF= No)	1.21	0.01	1.2 - 1.22	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.11	0.01	1.1 - 1.13	**<0.001**
3	1.19	0.01	1.18 - 1.21	**<0.001**
4	1.28	0.01	1.26 - 1.3	**<0.001**
5 (least deprived)	1.38	0.01	1.36 - 1.41	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.2	**<0.001**
2020	1.50	0.01	1.48 - 1.51	**<0.001**
General practice rurality-urban (REF= rural)	1.07	0.02	1.03 - 1.11	**<0.001**

Summary of univariate analysis for the repeat prescription ordering outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.21	0.02	1.18 - 1.24	**<0.001**
Long term condition- Yes	2.70	0.01	2.68 - 2.73	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.72	0.01	1.7 - 1.74	**<0.001**
Deafness or hearing loss-Yes (REF= No)	1.13	0.01	1.12 - 1.14	**<0.001**
Gender-Male (REF= Female)	1.01	0.00	1 - 1.02	**0.007**
Age bands (REF: 85+)				
16-24	0.87	0.02	0.84 - 0.9	**<0.001**
25-34	1.06	0.02	1.03 - 1.09	**<0.001**
35-44	1.37	0.02	1.33 - 1.4	**<0.001**
45-54	1.91	0.03	1.86 - 1.96	**<0.001**
55-64	2.31	0.03	2.25 - 2.37	**<0.001**
65-74	2.41	0.03	2.35 - 2.47	**<0.001**
Ethnicity (REF: White)				
Black	0.66	0.01	0.64 - 0.68	**<0.001**
Asian	0.77	0.01	0.76 - 0.78	**<0.001**

Other	0.66	0.01	0.65 - 0.68	**<0.001**
Mixed	0.84	0.02	0.82 - 0.87	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.73	0.00	0.72 - 0.73	**<0.001**
Carer-Yes (REF= No)	1.32	0.01	1.3 - 1.33	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.18	0.01	1.16 - 1.2	**<0.001**
3	1.35	0.01	1.33 - 1.37	**<0.001**
4	1.50	0.01	1.48 - 1.52	**<0.001**
5 (least deprived)	1.60	0.01	1.58 - 1.63	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.19	**<0.001**
2020	1.43	0.01	1.42 - 1.44	**<0.001**
General practice rurality-urban (REF= rural)	0.78	0.01	0.76 - 0.8	**<0.001**

Supplementary Table 6 Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.16***	(1.10, 1.23)	1.14***	(1.10, 1.19)	1.16***	(1.10, 1.22)
Long term condition- Yes	1.78***	(1.75, 1.81)	1.69***	(1.67, 1.72)	1.49***	(1.46, 1.53)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.17, 1.22)	1.20***	(1.18, 1.22)	1.20***	(1.17, 1.23)
Deafness or hearing loss-Yes (REF= No)	1.15***	(1.11, 1.19)	1.12***	(1.09, 1.14)	1.12***	(1.08, 1.16)
Gender-Male (REF= Female)	0.88***	(0.86, 0.89)	0.88***	(0.87, 0.89)	0.91***	(0.89, 0.93)
Age (REF: 85+)						

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
16-24	3.39***	(3.14, 3.66)	3.76***	(3.55, 3.98)	3.50***	(3.21, 3.82)
25-34	4.69***	(4.37, 5.03)	5.17***	(4.91, 5.45)	4.66***	(4.30, 5.06)
35-44	4.63***	(4.32, 4.96)	5.13***	(4.87, 5.40)	4.46***	(4.11, 4.83)
45-54	4.28***	(4.01, 4.57)	4.51***	(4.29, 4.74)	3.75***	(3.46, 4.06)
55-64	3.80***	(3.56, 4.05)	3.94***	(3.75, 4.13)	3.07***	(2.84, 3.32)
65-74	3.27***	(3.07, 3.49)	3.32***	(3.16, 3.48)	2.35***	(2.18, 2.54)
75-84	1.81***	(1.69, 1.93)	1.83***	(1.74, 1.93)	1.43***	(1.32, 1.55)
Ethnicity (REF: White)						
Black	0.75***	(0.69, 0.81)	0.83***	(0.79, 0.87)	0.87***	(0.83, 0.90)
Asian	1.04	(1.00, 1.09)	1.10***	(1.07, 1.14)	1.14***	(1.10, 1.17)
Other	0.86**	(0.79, 0.95)	0.92**	(0.87, 0.98)	1.01	(0.96, 1.06)
Mixed	1.01	(0.93, 1.10)	1.01	(0.95, 1.07)	1.09**	(1.02, 1.16)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.91***	(0.89, 0.93)	0.90***	(0.88, 0.92)	0.96***	(0.93, 0.98)
Carer-Yes (REF= No)	1.11***	(1.09, 1.13)	1.15***	(1.13, 1.17)	1.17***	(1.14, 1.19)
Deprivation quintile (REF: 1-Most deprived)						
2	1.15***	(1.11, 1.20)	1.14***	(1.12, 1.17)	1.16***	(1.13, 1.19)

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
3	1.23***	(1.19, 1.28)	1.29***	(1.26, 1.32)	1.27***	(1.23, 1.30)
4	1.38***	(1.33, 1.44)	1.40***	(1.37, 1.43)	1.36***	(1.31, 1.41)
5 (least deprived)	1.54***	(1.48, 1.60)	1.52***	(1.49, 1.56)	1.53***	(1.46, 1.60)
Survey year (REF= 2018)						
2019	1.16***	(1.14, 1.18)	1.18***	(1.17, 1.20)	1.25***	(1.22, 1.28)
2020	1.46***	(1.43, 1.49)	1.52***	(1.50, 1.54)	1.61***	(1.57, 1.65)
General practice rurality-Urban (REF= Rural)	1.22***	(1.10, 1.23)	1.11***	(1.10, 1.19)	1.10	(0.97, 1.24)
Model summary						
Interclass correlation coefficient (ICC)	0.13		0.12		0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

10.1136/bmjopen-2022-068827 on 12 October 2023. Downloaded from

Supplementary Table 7 Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.25***	(1.18, 1.32)	1.25***	(1.20, 1.30)	1.21***	(1.17, 1.31)
Long term condition- Yes	2.71***	(2.66, 2.75)	2.56***	(2.52, 2.59)	2.42***	(2.37, 2.47)
Taking five or more medication on a regular basis- Yes (REF= No)	1.26***	(1.24, 1.29)	1.26***	(1.24, 1.28)	1.29***	(1.26, 1.32)
Deafness or hearing loss-Yes (REF= No)	1.02	(1.00, 1.05)	1.02	(1.00, 1.04)	1.01	(0.98, 1.04)
Gender-Male (REF= Female)	0.96***	(0.94, 0.97)	0.96***	(0.95, 0.97)	0.98**	(0.96, 1.00)
Age (REF: 85+)						
16-24	1.64***	(1.53, 1.75)	1.76***	(1.67, 1.85)	1.62***	(1.50, 1.76)
25-34	2.16***	(2.04, 2.29)	2.22***	(2.13, 2.32)	1.98***	(1.85, 2.13)
35-44	2.67***	(2.52, 2.82)	2.82***	(2.70, 2.94)	2.37***	(2.21, 2.54)
45-54	3.25***	(3.09, 3.42)	3.29***	(3.16, 3.42)	2.82***	(2.65, 3.01)
55-64	3.35***	(3.18, 3.52)	3.43***	(3.31, 3.56)	2.81***	(2.64, 3.00)
65-74	3.11***	(2.97, 3.27)	3.15***	(3.03, 3.27)	2.48***	(2.33, 2.64)
75-84	1.73***	(1.65, 1.82)	1.75***	(1.68, 1.82)	1.43***	(1.34, 1.53)
Ethnicity (REF: White)						

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Black	0.77***	(0.71, 0.84)	0.73***	(0.70, 0.77)	0.8***	(0.77, 0.84)
Asian	0.88***	(0.84, 0.92)	0.94***	(0.91, 0.97)	1.01	(0.98, 1.04)
Other	0.79***	(0.71, 0.87)	0.76***	(0.72, 0.81)	0.8***	(0.77, 0.86)
Mixed	0.96	(0.89, 1.05)	0.98	(0.93, 1.05)	0.99	(0.92, 1.07)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.93***	(0.91, 0.96)	0.94***	(0.92, 0.96)	0.99	(0.96, 1.02)
Carer-Yes (REF= No)	1.13***	(1.11, 1.16)	1.15***	(1.14, 1.17)	1.19***	(1.17, 1.22)
Deprivation quintile (REF: 1-Most deprived)						
2	1.21***	(1.17, 1.26)	1.22***	(1.19, 1.25)	1.22***	(1.19, 1.26)
3	1.37***	(1.32, 1.42)	1.43***	(1.40, 1.46)	1.43***	(1.39, 1.47)
4	1.54***	(1.48, 1.59)	1.59***	(1.55, 1.62)	1.67***	(1.62, 1.73)
5 (least deprived)	1.65***	(1.59, 1.71)	1.74***	(1.70, 1.78)	1.89***	(1.82, 1.97)
Survey year (REF= 2018)						
2019	1.16***	(1.13, 1.18)	1.17***	(1.15, 1.19)	1.26***	(1.24, 1.29)
2020	1.40***	(1.38, 1.43)	1.46***	(1.44, 1.48)	1.54***	(1.51, 1.58)
General practice rurality-Urban (REF= Rural)	0.94**	(0.89, 0.99)	0.90***	(0.87, 0.94)	0.97	(0.88, 1.07)
Model summary						
Interclass correlation coefficient (ICC)	0.07		0.07		0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

BMJ Open

Cross-sectional analyses of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-068627.R3
Article Type:	Original research
Date Submitted by the Author:	17-Aug-2023
Complete List of Authors:	Alturkistani, Abrar; Imperial College London, Department of Primary Care and Public Health Greenfield, Geva; Imperial College London, Department of Primary Care & Public Health Beaney, Thomas; Imperial College London, Department of Primary Care and Public Health Norton, John; National Institute for Health Research, Applied Research Collaboration Northwest London Costelloe, Ceire ; Imperial College London, Department of Primary Care and Public Health; Institute of cancer Research Division of Clinical studies
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Public health
Keywords:	Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Cross-sectional analyses of online appointment booking and repeat prescription ordering user characteristics in General Practices of England in the years 2018-2020

Abrar Alturkistani[1]*(https://orcid.org/0000-0001-7935-8870), Geva Greenfield[2] (https://orcid.org/0000-0001-9779-2486), Thomas Beaney[1,3](https://orcid.org/0000-0001-9709-7264), John Norton[3], Ceire E Costelloe[1,4](https://orcid.org/0000-0002-3475-7525)

[1] Global Digital Health Unit, Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[2] Department of Primary Care and Public Health, Imperial College London, London, United Kingdom

[3] National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom;

[4] Division of Clinical studies, Institute of cancer Research, London, United Kingdom; National Institute for Health Research Applied Research Collaboration Northwest London, Imperial College London, London, United Kingdom

*Corresponding author

Email: Abrar.alturkistani16@imperial.ac.uk

Word count: 4651.

Keywords general practice; primary health care; patient portal; electronic health record; personal health record; GP Patient Survey.

Abstract

Objectives: To explore the characteristics of the General Practice Patient Survey (GPPS) respondents using the different functionalities of the online services in the context of England's National Health Service (NHS) General Practices. We hypothesised that respondents who are

older, with lower socioeconomic status, and non-White ethnicity would be less likely to use online services, while long-term conditions might increase their usage.

Design: Cross-sectional study using respondent-level data from the GPPS in England of the years 2018, 2019 and 2020. We assessed the association between online services use and respondent characteristics using two-level mixed-effects logistic regression.

Participants: Survey respondents of the GPPS 2018-2020.

Primary outcome measures: Online appointment booking and online repeat prescription ordering.

Results: 1,806,977 survey respondents were included in this study. 15% (n=263938) used online appointment booking in the previous 12 months, and 19% (n=339449) had ordered a repeat prescription in the previous 12 months. Respondents with a long-term condition, on regular multiple medications, who have deafness or hearing loss and who are from the lowest deprivation quintile were more likely to have used online services. Male respondents (compared to females) and respondents with Black and Other ethnicity compared to White ethnicity were less likely to use online services. Respondents over 85 years old were less likely to use online appointment booking and online repeat prescription ordering compared to the younger age groups.

Conclusions: Specific groups of respondents were more likely to use online services such as patients with long-term conditions or those with deafness or hearing loss. While online services could provide efficiency to patients and practices it is essential that alternatives continue to be provided to those that cannot use or choose not to use online services. Understanding the different patients' needs could inform solutions to increase the uptake and use of the services.

Strengths and limitations of this study

Strengths

1. The study used a sample from a major national survey which has developed a robust methodology in its data collection to explore the characteristics of online services users, a service which has been highly advocated in the NHS and in other healthcare systems of the world.
2. Given the clustered nature of the data (where patients are registered to different general practices) and to account for the clustering, we used multilevel logistic regression analysis.

Limitation

1. The study used only complete-case data in the analyses, which risked sample bias.
2. The study relied on self-reported data for online service use due to data unavailability which can lead to response bias.

BACKGROUND

Online services such as online appointment booking or repeat prescription ordering are offered in 99.7% of General Practitioner (GP) practices in England [1], but patients have to request access to the service and adoption remains low (about 50% in May 2023) [1]. According to previous literature, online services, also referred to as patient portals, have the potential to promote patients' involvement in their care, reduce emergency visits and hospitalisation [2], and may improve some health outcomes through improving medication adherence [2, 3] patients' knowledge about health and patient efficacy (e.g. patient's confidence in adhering to health

instructions or treatment) [4]. Few studies have examined the characteristics of patients using online services and the inequalities that might exist based on patient characteristics in the context of the National Health Service (NHS) of England such as ethnicity and deprivation inequalities [5-7]. Understanding patient characteristics associated with online service use may reveal barriers to use and may inform service planning to increase the uptake of these services.

Studies from other countries, and a limited number of studies from the UK, suggest that [7-10] patients with low income, and with non-White ethnicity may be less likely to use patient portals due to reduced access to the internet, computers and smartphones [8, 10]. This is the first study to look at online services user characteristics for both online appointment booking and repeat prescription ordering explicitly in England, where the NHS have invested in a nation-wide digital transformation programme [11].

Healthcare systems are characterised as complex systems and healthcare innovations often face multi-faceted challenges in diffusion ("passive spread") and adoption due to the nature of complex systems [12]. A major theory considered in healthcare innovation adoption is the digital divide theory which highlights the inequality that arises when people without access to technology (that is physical access but also access to the knowledge and skills to use the technology) are excluded from the benefits that technology has to offer [13-15]. In consideration of the digital divide theory [13-15], we formulated several hypotheses based on respondent characteristics and knowledge from previous literature. We hypothesised that:

1. That the younger age group (younger than 35 years old) to be more likely to use online services due to the high adoption of technology in this age group and their familiarity with the use of internet [16].

2. That individuals of lower socioeconomic status and minority ethnicities to be less likely to use online services as this has been reported in several studies looking into the use of patient portals and patient characteristics [8, 17-19].
3. In consideration of individuals' health status, we hypothesised that respondents with long-term or chronic conditions (but not those who are very ill) may be more likely to use online services because of their increased need to access and use the services such as appointment booking and repeat prescription. Additionally, people with long-term conditions have certain physical limitation and socio-economic circumstances that could be associated with their ability to access healthcare services in person.

Thus, we aimed to examine which respondent characteristics were associated with online appointment booking and repeat prescription service ordering and test the hypotheses that we formulated.

METHODS

Patient and public involvement

This study had limited involvement from the NIHR Applied Research Collaboration of Northwest London Public Advisors, whom were consulted during the study write-up and were involved appropriately in the drafting.

Study design

Cross-sectional analyses of respondent-level data obtained from the General Practice Patient Survey (GPPS) of 2018, 2019, and 2020 in England. The respondent-level data were

pseudonymised. The researchers did not have access to the respondents' identifies: name, address, NHS number and date of birth. Respondent-level data are only presented aggregately to protect respondents' privacy as agreed in the ethical approval of the study (20IC6303). Data collection for each survey was between January and March for the years 2018 and 2019 and between January and April for 2020. Respondents in the survey had the right to withdraw their consent before their data were processed [20].

Variables

Outcome variables

The outcome variables (online appointment booking use and online repeat prescription use) were based on the responses to the GPPS question: "Which of the following general practice online services have you used in the past 12 months?" [21] in which the answers "Booking appointments online", and "Ordering repeat prescriptions online" were used for this study. We compared the characteristics of those who replied "yes" to the question to those who replied "no" to the question. The answers "yes" and "no" were provided by the GPPS for each of the options: "Booking appointments online", and "Ordering repeat prescriptions online". The GPPS also records the use of online record viewing. However, we did not include it in this study due to the limited number of respondents reporting the use of the functionality (about 5% in 2020 and lower proportions in 2019 and 2018).

Explanatory variables

Ten different covariates (explanatory variables) were included in the models as listed in table 1. Variables were selected based on:

1. Factors that have been identified in the literature as being associated with patient portal use, such as long-term condition status, deafness or hearing loss, and parent and carer status, and
2. Data availability such as taking 5 or more medications regularly (another indicator for healthcare status).

Table 1 The list of variables included in the two-level regression models of the study and their definitions.

Variable	Categories and definition
Gender	Male, Female
Age (bands)	16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, 85 or over (as categorised by the survey)
Ethnicity	White, mixed, Asian, black, other (derived from 18 ethnicity categories of the Office of National Statistics (ONS) categories [22]) White, mixed, Asian, black, other (5 broad groups derived from 18 ethnicity categories published by the Office of National Statistics (ONS) categories [22])
Survey year	2018, 2019 or 2020 (created based on the year of the survey)
Long-term conditions	Yes, No, or "I don't know/ Can't answer" answers to the question: "Do you have any long-term physical or mental health conditions, disabilities or illnesses?" [21]
Deafness or hearing loss	Yes or No answer to the question: " Which, if any, of the following long-term conditions do you have?…Deafness or hearing loss" [21]
Taking 5 or more medications on a regular basis	Yes or No answer to the question: "Do you take 5 or more medications on a regular basis?" [21]
Parent status	Yes or No answer to the question: "Are you a parent or a legal guardian for any children aged under 16 living in your home?" [21]
Carer status	Yes or No answer derived from the answers to the question: "Do you look after, or give any help or support to family members, friends, neighbours or others because of either: long-term physical or mental ill health / disability, or problems related to old age?"
Index of Multiple Deprivation (IMD) quintiles	The GPPS provided a variable called deprivation rank for all respondents included in the survey which was defined as: ONS IMD score - deprivation banding based on respondents' postcode. We converted the ONS IMD scores provided by GPPS to IMD quintiles using the English indices of deprivation 2019 guidance [23]. We chose the deprivation quintile instead of deciles or IMD ranking to reduce the number of categories in the model

	while accounting for a potential predictor of online services use (deprivation) [24] and to duplicate the same categories used in previous GPPS analyses [5, 6, 24].
Rurality of the General Practice	A variable provided by GPPS based on the GP practice's postcode categorised as Rural or urban as defined by the ONS [25] rural or urban as defined by the ONS [25]

Data source

The GPPS is a national, postal survey commissioned by NHS England. GPPS uses random sampling, proportionately stratified by GP practice, age, and gender. Eligibility for GPPS includes having a valid NHS number, being 16 years or older and being registered with a GP practice for at least 6 months. Response rates of previous surveys are considered, sending more surveys to low-response practices and fewer surveys to high-response practices [26-28]. The survey was sent to 2,221,068, 2,328,560, 2,329,590 respondents in the years 2018, 2019 and 2020, with response rates of 34%, 33% and 32%, respectively [26-28].

In March 2020, social restrictions were announced in England due to the COVID-19 pandemic [29]. The last data collected for the GPPS was in April 2020, however, only a small number of surveys were received post March 2020 with the GPPS indicating it was highly unlikely that the survey results were affected by the pandemic [27].

Study population

We obtained data from respondents who completed the GPPS surveys in 2018, 2019 and 2020 and only included the respondents who answered either "yes" or "no" to using online appointment booking and/or online repeat prescription ordering as described in the variables section above. We then removed respondents who did not have complete data for the variables of interest.

Statistical analyses

We first reported descriptive statistics of the respondents based on their online appointment booking and repeat prescription use. All of the included variables in this study were categorical. We first tabulated each exploratory variable by the outcome variables and compared using Chi square test. We then performed univariate analysis between each of the explanatory variables and the outcome variable to check if they converge and to examine the coefficients. Collinearity was avoided by using the same set of variables used in previous studies analysing online services use using GPPS data [5], and checking for collinearity after the analysis was completed. To perform multilevel mixed-effects logistic regression models: First, we created null models with only the outcome variables and random intercepts (GP practices) to understand if there was clustering due to the random intercepts. We then added all respondent level covariates to the models (model 2) (most of the variable in the final models were respondent level variables). We checked the Intraclass Correlation Coefficient (ICC) and intercepted in all models to examine the effect of clustering. We then added the GP practice level variable (GP practice rurality) in the final models (model 3) [30]. After completing all analyses, we also performed model diagnostics to check the best fit model and checked for multicollinearity by calculating the variable inflation factor (VIF). Model diagnostics was performed by calculating Bayesian information criterion (BIC) and comparing the BIC of the different versions of the models. The model with the lowest BIC was considered the best fit model [31]. VIF values greater than 5 indicated collinearity [32]. The statistical analyses were performed using RStudio software version 1.4.1717.

Sensitivity analyses

The methods used in the sensitivity analyses are described in Supplementary Table 1. Because this study included only complete case participants, we ran a sensitivity analysis to predict the outcome this decision may have had on the main analyses. To do this, we first categorised GP practices, according to the proportion of complete case participants available, into three groups: highest missing data group (75% of the participants in these practices had missing data), middle-range missing data group (26-74% of the participants in these practices had missing data), and lowest missing data group (25% or less of the participants in these practices had missing data). We next categorised the complete-case participants according to the proportion of missing data in their GP practices using the three categories (highest, middle-range and lowest missing data groups) and then ran the same analyses described in the statistical analyses sub-section above. We completed the Strengthening the reporting of observational studies in epidemiology (STROBE) checklist to review the methods of the study [33] (Supplementary Table 2).

RESULTS

Some of the results of this study were presented in a conference abstract [34].

Sample size

We received data from 2,246,109 respondents who completed the GPPS surveys in 2018, 2019 or 2020. After removing respondents that did not have complete data for the variables of interest (n=439,060), 1,807,049 (80.5%) respondents were included.

Summary statistics

1,807,049 respondents were included of which 15% (n=263938) used online appointment booking (used at least once in the previous 12 months), and 19% (n=339449) used online repeat prescription (used at least once in the previous 12 months). Of the respondents, 55.1% were female, 22% in the 65-74 years age group, 86.8% self-identified as having White ethnicity, 83.1% were registered at GP practices in an urban area, and half (51.1%) had a self-reported long-term condition (Table 2).

Table 2. Descriptive statistics of the number and proportion of respondent characteristics in the total population included in the analyses (n=1807049), categorised by online services use

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1807049)	No (N=1543111)	Yes (N=263938)	p-value*	No (N=1467600)	Yes (N=339449)	p-value†
Gender				<0.001			0.97
Female	996544 (55.1%)	843422 (54.7%)	153122 (58.0%)		809337 (55.1%)	187207 (55.2%)	
Male	810505 (44.9%)	699689 (45.3%)	110816 (42.0%)		658263 (44.9%)	152242 (44.8%)	
Age (bands)				<0.001			<0.001
16-24	74381 (4.1%)	64513 (4.2%)	9868 (3.7%)		67069 (4.6%)	7312 (2.2%)	
25-34	159806 (8.8%)	132951 (8.6%)	26855 (10.2%)		141376 (9.6%)	18430 (5.4%)	
35-44	217687 (12.0%)	181290 (11.7%)	36397 (13.8%)		186112 (12.7%)	31575 (9.3%)	
45-54	302285 (16.7%)	253145 (16.4%)	49140 (18.6%)		243458 (16.6%)	58827 (17.3%)	
55-64	381808 (21.1%)	321902 (20.9%)	59906 (22.7%)		295168 (20.1%)	86640 (25.5%)	
65-74	397999 (22.0%)	340484 (22.1%)	57515 (21.8%)		303875 (20.7%)	94124 (27.7%)	

75-84	211586 (11.7%)	191217 (12.4%)	20369 (7.7%)	176214 (12.0%)	35372 (10.4%)	
85+	61497 (3.4%)	57609 (3.7%)	3888 (1.5%)	54328 (3.7%)	7169 (2.1%)	
Ethnicity			<0.001			<0.001
White	1567690 (86.8%)	1340202 (86.9%)	227488 (86.2%)	1258828 (85.8%)	308862 (91.0%)	
Black	52950 (2.9%)	46120 (3.0%)	6830 (2.6%)	47195 (3.2%)	5755 (1.7%)	
Asian	137026 (7.6%)	115015 (7.5%)	22011 (8.3%)	118728 (8.1%)	18298 (5.4%)	
Other	29168 (1.6%)	24993 (1.6%)	4175 (1.6%)	25773 (1.8%)	3395 (1.0%)	
Mixed	20215 (1.1%)	16781 (1.1%)	3434 (1.3%)	17076 (1.2%)	3139 (0.9%)	
Survey year			<0.001			<0.001
2018	612084 (33.9%)	536349 (34.8%)	75735 (28.7%)	512184 (34.9%)	99900 (29.4%)	
2019	623358 (34.5%)	534321 (34.6%)	89037 (33.7%)	507522 (34.6%)	115836 (34.1%)	
2020	571607 (31.6%)	472441 (30.6%)	99166 (37.6%)	447894 (30.5%)	123713 (36.4%)	
Long-term condition			<0.001			<0.001
No	833523 (46.1%)	730177 (47.3%)	103346 (39.2%)	736861 (50.2%)	96662 (28.5%)	
I don't know/ Can't answer	49746 (2.8%)	43186 (2.8%)	6560 (2.5%)	43212 (2.9%)	6534 (1.9%)	
Yes	923780 (51.1%)	769748 (49.9%)	154032 (58.4%)	687527 (46.8%)	236253 (69.6%)	
Taking five or more medication on a regular basis			<0.001			<0.001
No	1343735 (74.4%)	1151312 (74.6%)	192423 (72.9%)	1118704 (76.2%)	225031 (66.3%)	
Yes	463314 (25.6%)	391799 (25.4%)	71515 (27.1%)	348896 (23.8%)	114418 (33.7%)	
Deafness or hearing loss			<0.001			<0.001

No	1652099 (91.4%)	1409236 (91.3%)	242863 (92.0%)		1344856 (91.6%)	307243 (90.5%)
Yes	154950 (8.6%)	133875 (8.7%)	21075 (8.0%)		122744 (8.4%)	32206 (9.5%)
Parent or legal guardian to a 16 year old or younger				<0.001		<0.001
No	1466017 (81.1%)	1254880 (81.3%)	211137 (80.0%)		1177272 (80.2%)	288745 (85.1%)
Yes	341032 (18.9%)	288231 (18.7%)	52801 (20.0%)		290328 (19.8%)	50704 (14.9%)
Carer				<0.001		<0.001
No	1462467 (80.9%)	1254985 (81.3%)	207482 (78.6%)		1200653 (81.8%)	261814 (77.1%)
Yes	344582 (19.1%)	288126 (18.7%)	56456 (21.4%)		266947 (18.2%)	77635 (22.9%)
Deprivation quintile				<0.001		<0.001
1 (Most deprived)	338728 (18.7%)	298412 (19.3%)	40316 (15.3%)		292405 (19.9%)	46323 (13.6%)
2	353580 (19.6%)	304870 (19.8%)	48710 (18.5%)		296229 (20.2%)	57351 (16.9%)
3	376042 (20.8%)	322081 (20.9%)	53961 (20.4%)		304048 (20.7%)	71994 (21.2%)
4	378002 (20.9%)	319100 (20.7%)	58902 (22.3%)		297096 (20.2%)	80906 (23.8%)
5 (Least deprived)	360697 (20.0%)	298648 (19.4%)	62049 (23.5%)		277822 (18.9%)	82875 (24.4%)
General practice rurality				<0.001		<0.001
Rural	306200 (16.9%)	263405 (17.1%)	42795 (16.2%)		238353 (16.2%)	67847 (20.0%)
Urban	1500849 (83.1%)	1279706 (82.9%)	221143 (83.8%)		1229247 (83.8%)	271602 (80.0%)

* p-value derived from chi squared test comparing online appointment booking users and non-users

† p-value derived from chi squared test comparing online repeat prescription users and non-users

About 19.5% of the total population sample received from GPPS was excluded due to missing data. The proportion of respondents by category in the excluded respondents were different to the complete case dataset in the proportions for age, ethnicity (most respondents were from the mixed ethnicity), survey year, long-term condition, taking five or more medications, reporting of deafness or hearing loss, and slight difference in deprivation fifths proportions (Supplementary Table 3). However, when comparing the complete case sample to the total sample received, the differences in proportions between the two categories are very small and vary between 1 and -2% (Supplementary Table 3).

Descriptive statistics of the sensitivity analysis groups are displayed in Supplementary Table 4. GP practices with the highest proportion of missing data (practices with 75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a higher proportion of respondents with Black, Asian and Other ethnicities, as well as higher proportion or respondents from the most deprived group compared to the GP practices with lower missing data.

Respondent and GP practice characteristics associated with online services' use

The results of the univariate analysis are in the supplementary table 5.

Online appointment booking

Results of the two-level mixed-effects logistic regression for the online appointment booking outcome are presented in table 3. Respondents with a long-term condition, taking 5 or more medications on a regular basis and who have deafness or hearing loss were more likely to use online appointment booking compared to respondents without these characteristics. In the fully adjusted model for respondent and GP practice characteristics, respondents with a long-term condition had 67% greater odds of using online appointment booking (OR: 1.67, CI: 1.66-1.69) compared to respondents without a long-term condition.

Respondents with black and "other" ethnicity had lower odds than those with White ethnicity for using online appointment booking, whereas respondents with Asian ethnicity had 11% (OR: 1.11, 95% CI: 1.09-1.13) greater odds of using online appointment booking.

There was an inverse association between deprivation quintile and online appointment booking. The odds for using online appointment booking increased with reducing deprivation from the second to fifth (least deprived) quintiles compared to the most deprived quintile. Respondents in the least deprived quintile had 54% greater odds of booking appointments online (OR: 1.54, 95% CI: 1.51-1.57) compared to those in the most deprived quintile. Respondents from the survey year 2020 were the most likely to use online appointment booking compared to respondents from the survey year 2018 and 2019.

Respondents from GP practices located in an urban setting had 11% greater odds of booking appointments online compared to respondents from GP practices in a rural setting (OR: 1.11, 96% CI: 1.07-1.16).

Model comparison: The ICC of 0.13 indicates that there is a slight similarity between values from the same group (in this case from the same GP practice) although the difference is not large because the value is close to zero.

Table 3 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online appointment booking use in the previous 12 months (level 1 , N= 1807049 respondents; level 2, N=7256 general practices)

Predictors	+ GP practice Characteristics (Model 3) Odds Ratios	95% Confidence Interval
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.15***	(1.12, 1.19)
Long term condition- Yes	1.67***	(1.66, 1.69)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.18, 1.20)
Deafness or hearing loss-Yes (REF= No)	1.13***	(1.11, 1.15)
Gender-Male (REF= Female)	0.89***	(0.88, 0.90)
Age (bands) (REF: 85+)		
16-24	3.63***	(3.48, 3.78)
25-34	4.96***	(4.78, 5.14)
35-44	4.85***	(4.68, 5.03)
45-54	4.26***	(4.12, 4.42)
55-64	3.69***	(3.57, 3.82)
65-74	3.09***	(2.99, 3.20)
75-84	1.74***	(1.68, 1.80)
Ethnicity (REF: White)		
Black	0.84***	(0.81, 0.86)
Asian	1.11***	(1.09, 1.13)
Other	0.96**	(0.92, 0.99)
Mixed	1.04	(1.00, 1.08)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.92***	(0.90, 0.93)
Carer-Yes (REF= No)	1.14***	(1.13, 1.16)
Deprivation quintile (REF: 1- Most deprived)		
2	1.15***	(1.13, 1.17)
3	1.27***	(1.25, 1.29)
4	1.40***	(1.37, 1.42)
5 (least deprived)	1.54***	(1.51, 1.57)
Survey year (REF= 2018)		
2019	1.19***	(1.18, 1.20)
2020	1.52***	(1.50, 1.54)
General practice rurality-urban (REF= rural)	1.11***	(1.07, 1.16)

Predictors	+ GP practice Characteristics (Model 3) Odds Ratios	95% Confidence Interval
Model summary		
ICC	0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Sensitivity analyses

Results of the sensitivity analysis for online appointment booking are in the Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. The differences between the odds ratios based on the deprivation quintile for online repeat prescription were also bigger than online appointment booking in all the categories of GP practices. Most of the odds ratios that were statistically significant remained significant for the different analyses by practice size, except for the ethnicity groups including: Asian, Other and Mixed categories which may reflect the differences in ethnic representation in each of the sensitivity analyses categories.

Online repeat prescription ordering

Results of the two-level mixed-effects logistic regression for the online repeat prescription ordering outcome are presented in table 4. Respondents with a long-term condition, users of 5 or more medications on a regular basis and respondents with deafness or hearing loss were all more likely to use online repeat prescription ordering compared to respondents without these

characteristics. The odds of using online repeat prescription ordering were 2.58 times greater (OR: 2.58, 95% CI: 2.55, 2.60) for respondents with a long-term condition compared to those without a condition.

Black, Asian, and Mixed ethnicities had lower odds of using online repeat prescription ordering compared to the White ethnicity.

Respondents in the deprivation quintiles 4 and 5 (least deprived) had the highest odds of using online repeat prescription ordering compared to the most deprived group (OR: 1.62, 95% CI: 1.59, 1.64) and (OR: 1.77, 95% CI: 1.74, 1.80), respectively.

Respondents who completed the survey in the years 2019 and 2020 had greater odds of using online repeat prescription ordering compared to respondents from the survey year 2018.

Respondents from GP practices located in an urban setting had lower odds of ordering repeat prescriptions online compared to respondents from GP practices in a rural setting.

Model comparison:

The ICC was 0.08 for model 3 in table 4, which also showed that there is slight evidence that respondents from the same GP practices may have more similar results compared to respondents from other GP practices.

Table 4 Two-level Mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on Online Repeat prescription ordering use in the previous 12 months (level 1, N= 1807049 respondents; level 2, N=7256 general practices)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)		
Long term condition- I don't know/ Can't say	1.25***	(1.22, 1.29)
Long term condition- Yes	2.58***	(2.55, 2.60)

	+ GP Practice Characteristics (Model 3)	
Predictors	**Odds Ratios**	**95% Confidence Interval**
Taking five or more medication on a regular basis-Yes (REF= No)	1.26***	(1.25, 1.28)
Deafness or hearing loss-Yes (REF= No)	1.02**	(1.00, 1.03)
Gender-Male (REF= Female)	0.96***	(0.96, 0.97)
Age (bands) (REF: 85+)		
16-24	1.71***	(1.64, 1.77)
25-34	2.17***	(2.10, 2.23)
35-44	2.69***	(2.61, 2.77)
45-54	3.18***	(3.10, 3.28)
55-64	3.28***	(3.20, 3.37)
65-74	3.01***	(2.93, 3.09)
75-84	1.68***	(1.64, 1.73)
Ethnicity (REF: White)		
Black	0.76***	(0.74, 0.78)
Asian	0.94***	(0.93, 0.96)
Other	0.78***	(0.75, 0.81)
Mixed	0.98	(0.94, 1.02)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.95***	(0.94, 0.96)
Carer-Yes (REF= No)	1.16***	(1.15, 1.17)
Deprivation quintile (REF: 1- Most deprived)		
2	1.23***	(1.21, 1.25)
3	1.44***	(1.42, 1.46)
4	1.62***	(1.59, 1.64)
5 (least deprived)	1.77***	(1.74, 1.80)
Survey year (REF= 2018)		
2019	1.18***	(1.17, 1.19)
2020	1.46***	(1.44, 1.47)
General practice rurality-urban (REF= rural)	0.88***	(0.85, 0.91)
Model Summary		
ICC	0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Sensitivity analyses:

Results of the sensitivity analysis for the repeat prescription outcome are in supplementary table 7. Differences (compared to the main analysis) in odds ratios were seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the

deprivation quintile. Among respondents from practices with 75% or more respondents with missing data, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97) higher odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with bigger differences in the odds associated with the outcome for respondents from the highest missing data GP practices compared to the other GP practices.

Model diagnostics:

The VIF values for all explanatory variables in our fixed-effects logistic regression models for both outcomes (online appointment booking and online repeat prescription ordering) were below the threshold of 5 (ranging from 1 to 1.8) indicating that there is no evidence of multicollinearity among the explanatory variables. In terms of model diagnostics, BIC values of each of the models (null model, model 2 and model 3) were compared to each other to make sure that the model presented is the best fit model (the model with the lowest BIC). The values of BIC for all the models for each outcome are summarised in table 5 below:

Table 5 Model diagnostics results (namely BIC: Bayesian information criterion) for both outcomes and for each of the models (null model, model 2 and model 3)

Model	Value of BIC for the online appointment booking outcome models	Value of BIC for the online repeat prescription ordering outcome models
Null model	1434808	1692919
Model 2	1398822	1601232

Model 3	1398807	1601182

DISCUSSION

Principal findings

Overall, the findings of the study indicate that indicators of increased healthcare need and socioeconomic disadvantage predicted variations in the use of two types of online services and use of these services increased over the three years studied. Contrary to our hypothesis about age, we observed different variability in the relationship between age and online services use. Respondents younger than 35 years old were not the only highest users of online services as respondents of the age groups 35-84 were all more likely to use online services compared to respondents of the age group 85 years old and older. Our findings partially confirmed our hypotheses regarding lower socioeconomic status and minority ethnicities aligning with our expectations that these respondent groups were less likely to use online services. A notable alignment with our hypothesis was observed in the relationship between online services use and long-term conditions. Respondents with long-term conditions were more likely to use online services both online appointment booking and repeat prescription ordering.

Strengths and weaknesses of the study

Strengths

This study used a major national survey which uses robust research methodology in its data collection process and used suitable analysis methodology for processing the data (accounting for GP practice variation in the models and accounting for missing data in the sensitivity

analyses). The study explored online services user characteristics in England which can inform service planning and can identify patient groups who may need support using these services.

We accounted for clustering in our data presenting respondent level data in which respondents' belonged to different GP practices, by using multilevel logistic regression model which is an analysis methodology that takes into account the hierarchy in the data [35]. Clustering by GP practice was important not only because respondents from the same GP practice may be more similar to each other, but patient portal functionalities and promotion of online services (such as providing training, posters, emails and reminders) to use online services may vary from one GP practice to another [36].

Limitations

A limitation of the study was using only complete-case data in the analyses, which risked sample bias. Respondents excluded from the analyses due to missing data presented differences in the breakdown of respondent characteristics. Therefore, we performed sensitivity to explore what kind of differences might have observed if there were no exclusions. Comparing summary statistics of the excluded sample and the sensitivity analyses showed that GP practices with more missing data were more likely to have younger age groups, greater deprivation groups, and ethnically diverse groups, all of which were associated with relatively lower odds of using online services. This introduces the possibility that some of the odd's ratios presented in the main analysis may be overestimated in the population due to missing data bias.

However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that

differences in online services use between the three categories of GP practices were bigger for online repeat prescription use compared to the online appointment booking use.

As with all survey-based studies, a major potential limitation of the GPPS is non-response bias. However, a study on the methodology of the GPPS, did not find evidence of non-response bias [37]. We tried to alleviate non-response bias by controlling for deprivation, ethnicity, age, and gender (which can often be associated with low-response rates as reported in a study examining GPPS non-response characteristics [37]).

Strengths and weaknesses in relation to other studies

This study relied on self-reported online service usage which could introduce response bias [38]. A potentially better way to measure use of online appointment booking and repeat prescription ordering could be via the electronic patient portal log files. The log files automatically record patient portal activity and can serve as an objective method to examine patient portal use because these are not subject to recall bias and record the exposure prior to the outcome [3]. However, due to data unavailability of patient-level data of this kind at the time of the study, the GPPS records of online services use were used in this study in other England based studies exploring online services' use [5, 6].

Discussing important differences in results

People from more deprived areas, and from ethnic minorities were reported to have lower uptake of patient portals in previous studies [39]. According to previous studies, deprivation and ethnicity play key roles in online services use [40-42] which were confirmed by the main analysis and sensitivity analyses in this study. A survey study from the USA suggested that respondents' ethnicity could be associated with less trust in patient portals [18]. Reduced use of online services by respondents with greater deprivation levels has been reported multiple times

in the literature [19]. This may be due to worse access to the internet, smart phone, and computers among individuals from more deprived areas [7, 43].

Meaning of the study

There is evidence that online services use in England is increasing every year and it is likely to continue to be an important tool in GP practice settings. Although online services have been offered almost universally in GP practices in England since 2015, there continues to be a lack of research on the use of online services (or patient portals) in primary care [7, 44]. Understanding the needs of populations less likely to use online services may help to improve the uptake of these services and to better meet the needs of vulnerable populations which are more likely to have reduced access to healthcare services [45] in addition to online services.

According to the theory of the digital divide, [14, 15], using technologies such as patient portals may require more than just having access to a computer. Skills such as digital literacy and eHealth literacy may be essential to enable the use of these services. Lack of education is also considered a detrimental factor contributing to the digital divide [46]. While our study did not directly investigate the mechanisms of the digital divide, it provides valuable insight into the disparities that may exist in the use of online services. Factors associated with reduced use of online services, like lower socioeconomic status indicators, may relate to challenges such as limited digital skills and inadequate access to technology [13]. Understanding the specific challenges faced by different patient groups in accessing and using online services can help healthcare staff and policymakers to develop tailored strategies to bridge the digital divide [47] and to ensure fair access to online services. Further investigation, employing quantitative and qualitative approaches, can enhance our understanding of the mechanisms influencing individual technology adoption.

We hypothesised that younger populations would be more likely to use and have access to technologies, but we could not see that pattern in the study, possibly because young people are less likely to need the healthcare system and services, such as appointment booking and repeat prescription requests. Additionally, this may be due to the complex mechanisms that may be involved in individuals opting to use online services which may be driven by social factors not included in this study.

Possible explanations and implications for clinicians and policymakers

The adoption of online services by those with long-term conditions is promising and can potentially contribute to improving self-management of long-term conditions [2]. However, there is evidence that people with long-term conditions may generally be more likely to use healthcare services [48-50]. Practices should continue to encourage and support people with long-term conditions to sign up and use online services. However, it is essential that alternatives to online services continue to be provided to people who are unwilling or unable to use these services [48-50].

This study shows that online services' use is lower among people from more deprived areas and from ethnic minorities, which may increase inequities if in-person services become further out of reach. As an example, the move to telephone consultations and remote triage in GP practices amidst the COVID-19 pandemic made it difficult for homeless people to access care, due to not having a telephone or if having a telephone, not being able to pay for the call [51]. However, the study only interviewed 21 people experiencing homelessness and may not be representative of experience of all people under similar circumstance in England [51]. In-person access to care is seen as necessary to reach all patient groups, despite using access to technology to support

moves to increased remote consultations in the COVID-19 pandemic [51]. For this reason, it is important that practices continue to provide in-person access (e.g. for appointment booking and repeat prescriptions) to patients especially those less able to access remote services. Training GP practice staff to promote and to support the increased use of online services is already occurring in some GP practices [36] and we can continue to recommend providing training to increase use.

Unanswered questions and future research

Further research is needed to understand low uptake of online services in some patient groups, and to clarify if this is due to barriers or due to peoples' preference. During the COVID-19 pandemic, when patients are asked to contact their GP practice remotely [52], variable access and use of the online services may have exacerbated inequities in situations where online services became the only route to access care [53]. Although this study's findings relate to the pre-COVID-19 period, the patterns in disparities may have persisted or worsened in the post-COVID-19 period amidst the move to increasing the delivery of GP services remotely.

Future research could explore how remote services might affect aspects of the healthcare system such as healthcare utilisation and patients' self-management of their conditions. Our future research aim is to study patient portal use in GP practices in England using electronic health records instead of relying on individuals' self-reporting. We will explore the association between patient portal use and health outcomes and on healthcare utilisation to better understand its impact on health and the healthcare system.

Funding

This article presents independent research commissioned by the National Institute for Health Research (NIHR) under the Applied Health Research (ARC) programme for Northwest London.

The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. TB acknowledges support from the NIHR ARC Northwest London.

Ethical approval

This study was approved by the Imperial College Research Ethics Committee, Reference number: 20IC6303. Respondents of the survey provided informed consent to take part in the research by allowing us to use their anonymised survey data, but they had the right to withdraw their consent before these data were processed.

Author contribution

AA, GG, TB and CC created the study design, formulated the research question and finalised the study methodology. AA performed the analysis of the study. JN contributed to the introduction and discussion sections of the study. All authors reviewed and approved the submitted manuscript.

Data sharing statement

The data that support the findings of this study are available on request from Ipsos Mori but cannot be provided by the authors due to ethical restrictions. However, the aggregate level GPPS data are openly available in the GP Patient Survey webpage at https://www.gp-patient.co.uk/ [21].

Competing interests

The authors declare that they have no competing interests.

References

1. Patient Online Management Information (POMI) - NHS Digital. @NHSDigital; 2021; Available from: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub/patient-online-management-information-pomi.
2. ME R, J H, RJ B, R N, I G, J H, et al. Patients with complex chronic conditions: Health care use and clinical events associated with access to a patient portal. PloS one. 2019 06/19/2019;14(6). PMID: 31216295. doi: 10.1371/journal.pone.0217636.
3. DR M, M D. Sharing Ethics Consultation Notes With Patients Through Online Portals. AMA journal of ethics. 2020 09/01/2020;22(9). PMID: 33009775. doi: 10.1001/amajethics.2020.784.
4. HR H, KT G, CA S, HN M, SJ K, S C, et al. Using Patient Portals to Improve Patient Outcomes: Systematic Review. JMIR human factors. 2019 12/19/2019;6(4). PMID: 31855187. doi: 10.2196/15038.
5. M G-C, H A, J C, A E, J D, L P, et al. Awareness and use of online appointment booking in general practice: analysis of GP Patient Survey data. The British journal of general practice : the journal of the Royal College of General Practitioners. 2020 2020 Jun;70(suppl 1). PMID: 32554662. doi: 10.3399/bjgp20X711365.
6. Gomez-Cano, J M, R W, J L, G A. Awareness and use of online services in general practice: analysis of GP Patient Survey data. SAPC ASM 2021; 2021-06-08T14:38+01:00; Virtual: @sapcacuk; 2021.
7. A A-A, Z S, BM B, M H, PH G. Patients' Perspectives About Factors Affecting Their Use of Electronic Personal Health Records in England: Qualitative Analysis. Journal of medical Internet research. 2021 01/13/2021;23(1). PMID: 33439126. doi: 10.2196/17500.
8. S E-T, A M, S C, EJ P-S. Barriers to Patient Portal Access and Use: Evidence from the Health Information National Trends Survey. Journal of the American Board of Family Medicine : JABFM. 2020 Nov-Dec 2020;33(6). PMID: 33219074. doi: 10.3122/jabfm.2020.06.190402.
9. A G, A S, J T, M W. Patient Portals: Who uses them? What features do they use? And do they reduce hospital readmissions? Applied clinical informatics. 2016 06/06/2016;7(2). PMID: 27437056. doi: 10.4338/ACI-2016-01-RA-0003.
10. MG A, O P, F L. The State of Evidence in Patient Portals: Umbrella Review. Journal of medical Internet research. 2020 11/11/2020;22(11). PMID: 33174851. doi: 10.2196/23851.
11. Watcher RM. Making IT work: harnessing the power of health information technology to improve care in England. 2016 7 September 2016. Report No.
12. T G, G R, F M, P B, O K. Diffusion of innovations in service organizations: systematic review and recommendations. The Milbank quarterly. 2004 2004;82(4). PMID: 15595944. doi: 10.1111/j.0887-378X.2004.00325.x.
13. AJ vD, JA vD. The first-level digital divide shifts from inequalities in physical access to inequalities in material access. New media & society. 2019 2019 Feb;21(2). PMID: 30886536. doi: 10.1177/1461444818797082.
14. Serafino P. Exploring the UK's digital divide - Office for National Statistics. s; 2019; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/articles/exploringtheuksdigitaldivide/2019-03-04.
15. Dijk Jv. A Framework For Digital Divide Research. The Electronic Journal of Communication. 2002;12(1 & 2).
16. Internet access – households and individuals, Great Britain: 2020 Internet access in Great Britain, including how many people have internet access, what they use it for and online shopping.: Office for National Statistics; 2020; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetands

ocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2020#internet-access-households-and-individuals-data.

17. N D, Y VS, GB C, PK G, PF O, RJ C. Disparities in telehealth use: How should the supportive care community respond? Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer. 2021 10/19/2021. PMID: 34668075. doi: 10.1007/s00520-021-06629-4.

18. MA C, ER L, J M, KM K, MM S, T M, et al. Sociodemographic Differences and Factors Affecting Patient Portal Utilization. Journal of racial and ethnic health disparities. 2021 2021 Aug;8(4). PMID: 32839896. doi: 10.1007/s40615-020-00846-z.

19. Priti S, Pallavi J, Evan M, Naleef F. Outpatient Portal Use in Prenatal Care: Differential Use by Race, Risk, and Area Social Determinants of Health Factors. medRXiv. 2021 2021-05-26. doi: 10.1101/2021.05.25.21257657.

20. GP Patient Survey Confidentiality and data protection. 2023; Available from: https://www.gp-patient.co.uk/confidentiality.

21. GP Patient Survey: Surveys and Reports. Ipsos MORI; 2020; Available from: https://www.gp-patient.co.uk/surveysandreports.

22. Ethnic group, national identity and religion. Office for National Statistics; 2021; Available from: https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion.

23. Ministry of Housing C, & Local Government. English Indices of Deprivation 2019 FAQs. 2019; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf.

24. J B, C L, J C, M R, G A. Variations in GP-patient communication by ethnicity, age, and gender: evidence from a national primary care patient survey. The British journal of general practice : the journal of the Royal College of General Practitioners. 2016 2016 Jan;66(642). PMID: 26541182. doi: 10.3399/bjgp15X687637.

25. 2011 rural/urban classification. 2011; Available from: https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification.

26. MORI I. GP Patient Survey 2019 Technical Annex. 2019; Available from: https://gp-patient.co.uk/downloads/archive/2019/GPPS_2019_Technical_Annex_PUBLIC.pdf.

27. MORI I. GP Patient Survey 2020 Technical Annex. 2020; Available from: https://gp-patient.co.uk/downloads/2020/GPPS_2020_Technical_Annex_PUBLIC.pdf.

28. MORI I. GP Patient Survey - Technical Annex: 2018 annual report. August 2018; Available from: https://gp-patient.co.uk/downloads/archive/2018/GPPS%202018%20Technical%20Annex%20PUBLIC.pdf.

29. GOV.UK. Prime Minister's statement on coronavirus (COVID-19): 23 March 2020. 23 March 2020.

30. Kleiman E. Understanding and analyzing multilevel data from real-time monitoring studies: An easily- accessible tutorial using R. 2021. doi: doi:10.31234/osf.io/xf2pw.

31. Boykin AA, Ezike NC, Myers AJ. Model-data fit evaluation: posterior checks and Bayesian model selection. International Encyclopedia of Education: Elsevier Science; 2023. p. 279-89.

32. JH K. Multicollinearity and misleading statistical results. Korean journal of anesthesiology. 2019 2019 Dec;72(6). PMID: 31304696. doi: 10.4097/kja.19087.

33. STROBE Strengthening the reporting of observational studies in epidemiology. 2021; Available from: https://www.strobe-statement.org/.

34. Alturkistani A, Greenfield G, Beaney T, Norton J, Costelloe CE, editors. Ethnicity, deprivation, and the use of patient portals in England's general practices 2018-2020: Abrar Alturkistani. European Journal of Public Health; 2022: Oxford academic.
35. Modelling CfM. What are multilevel models and why should I use them? : University of Bristol; 2023.
36. England N. GP online services case studies. 2023.
37. M R, M E, G L, J B, RA P, P S, et al. Reliability of patient responses in pay for performance schemes: analysis of national General Practitioner Patient Survey data in England. BMJ (Clinical research ed). 2009 09/29/2009;339. PMID: 19808811. doi: 10.1136/bmj.b3851.
38. J S, P B, B G, SW M, N R, AM R, et al. Cuts to local government spending, multimorbidity and health-related quality of life: A longitudinal ecological study in England. The Lancet regional health Europe. 2022 06/10/2022;19. PMID: 36039277. doi: 10.1016/j.lanepe.2022.100436.
39. CH H, M J, CG A, OA B, R D, P A, et al. Racial Differences in Patient Portal Activation and Research Enrollment Among Patients With Prostate Cancer. JCO clinical cancer informatics. 2021 2021 Jun;5. PMID: 34328797. doi: 10.1200/CCI.20.00131.
40. S S, M G, N N, BW M, AY O, A L, et al. Disparities in Electronic Health Record Patient Portal Enrollment Among Oncology Patients. JAMA oncology. 2021 06/01/2021;7(6). PMID: 33830178. doi: 10.1001/jamaoncol.2021.0540.
41. EP U, J F, LM Y. Disparities in Electronic Patient Portal Use in Prenatal Care: Retrospective Cohort Study. Journal of medical Internet research. 2019 09/23/2019;21(9). PMID: 31586367. doi: 10.2196/14445.
42. DM W, JL H, N F, TR H, AS M. Exploring the Digital Divide: Age and Race Disparities in Use of an Inpatient Portal. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2020 2020 May;26(5). PMID: 31313977. doi: 10.1089/tmj.2019.0065.
43. Matthew H, David M, Harry E, Alisha D. Digital technology and health inequalities: a scoping review. Cardiff: Public Health Wales NHS Trust; 2020; Available from: https://phw.nhs.wales/publications/publications1/digital-technology-and-health-inequalities-a-scoping-review/.
44. F M, S dL, A S, A M, JC W, T Q, et al. Patients' online access to their electronic health records and linked online services: a systematic review in primary care. The British journal of general practice : the journal of the Royal College of General Practitioners. 2015 2015 Mar;65(632). PMID: 25733435. doi: 10.3399/bjgp15X683941.
45. Saunders CL, Flynn S, Massou E, Lyratzopoulos G, Abel G, Burt J. Sociodemographic inequalities in patients' experiences of primary care: an analysis of the General Practice Patient Survey in England between 2011 and 2017:. https://doiorg/101177/1355819620986814. 2021 2021-01-31. doi: 10.1177_1355819620986814.
46. G W. COVID-19 and the digital divide in the UK. The Lancet Digital health. 2020 2020 Aug;2(8). PMID: 32835198. doi: 10.1016/S2589-7500(20)30169-2.
47. L H, T G, G H, T F, J W. Desperately Seeking Intersectionality in Digital Health Disparity Research: Narrative Review to Inform a Richer Theorization of Multiple Disadvantage. Journal of medical Internet research. 2022 12/07/2022;24(12). PMID: 36383632. doi: 10.2196/42358.
48. LB S, DA L, C B, GA A, KJ R, AS I. Disease Burden and Healthcare Utilization Among Patients with Chronic Obstructive Pulmonary Disease (COPD) in England. International journal of chronic obstructive pulmonary disease. 2022 03/03/2022;17. PMID: 35264848. doi: 10.2147/COPD.S336158.
49. CW lR, B C, E N, A B. Obesity and healthcare resource utilization: results from Clinical Practice Research Database (CPRD). Obesity science & practice. 2018 08/21/2018;4(5). PMID: 30338111. doi: 10.1002/osp4.291.

50. HI W, L H, R J, T D, RIG H, SL P, et al. Healthcare resource use and costs for people with type 2 diabetes mellitus with and without severe mental illness in England: longitudinal matched-cohort study using the Clinical Practice Research Datalink. The British journal of psychiatry : the journal of mental science. 2022 2022 Jul;221(1). PMID: 35049484. doi: 10.1192/bjp.2021.131.

51. Howells KA, Amp M, Burrows M, Brown J, Brennan R, Dickinson J, et al. Remote primary care during the COVID-19 pandemic for people experiencing homelessness: a qualitative study. 2022 2022-03-03. doi: 10.3399/BJGP.2021.0596.

52. NHS. Using the NHS and other health services during coronavirus (COVID-19). @nhsuk; 2021 [updated 2 Jun 2020]; Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/using-the-nhs-and-other-health-services/.

53. Ian L, David S, Sheila G. Impact of COVID-19 on the digital divide: a rapid review. 2021 2021-10-01. doi: 10.1136/bmjopen-2021-053440.

Supplementary material

Supplementary Table 1 Methods and results of the sensitivity analysis.

Supplementary Table 2. STROBE 2007 checklist of items to be included in reports of observational studies in epidemiology.

Supplementary Table 3. The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060).Supplementary Table 4. Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice.

Supplementary Table 5. Table presenting summaries of the univariate analyses for each of the outcomes.

Supplementary Table 6. Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice.

Supplementary Table 7. Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Supplementary material:

Supplementary Table 1. Methods and results of the sensitivity analysis

Methods	In the main analyses performed in this study, only complete case respondents (respondents that did not have any missing data for any of the variables included in the analyses) were included. We ran sensitivity analyses to explore the effects of excluding respondents with missing data. We first calculated the proportion of respondents with complete data per practice using the complete dataset (n=2198821) and assigned each practice a new variable indicating the proportion of complete case respondents in the practice. We then separated the complete case respondents (n=1807049) into three categories based on the proportion of complete case respondents in their practice. The three categories were: highest missing data group (≥75%), middle-range missing data group (26-74%), and lowest missing data group (≤25%). We then ran the same two-level mixed-effects models for each of the outcomes (online appointment booking and online repeat prescription use) separately for each of the three categories.
Results	The summary statistics of the sensitivity analysis groups are reported in table Supplementary Table 5. GPs with the highest proportion of missing data (practices with

	75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a greater proportion of respondents from Black, Asian and Other ethnic backgrounds as well. Greater proportion or respondents from the most deprived group compared to the GPs with lower missing data. Results of the sensitivity mixed-effects regression analyses for the online appointment booking outcome is in table Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. These differences indicate that the characteristics of respondents within each type of the GPs (based on the proportion of missing data) were more similar to each other than the other type of practices. For the repeat prescription outcome (Supplementary Table 7), differences in odds ratios were also seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the deprivation quintile. Among the highest missing data GP practice respondents, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97)

	greater odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents. This indicates that deprivation has a larger impact in practices with the most missing data compared to practices with the least missing data for the online repeat prescription ordering outcome. Sensitivity analyses results reveal that some of the estimates in this study may be attenuated if missing data/non-response respondents were present. However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained to be larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services between the three categories of GPs use were bigger for online repeat prescription use compared to the online appointment booking use. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GPs indicating that socioeconomic inequities may have a larger influence on online repeat prescription ordering than online appointment booking. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with

	bigger differences in the odds associated with the outcome for respondents from the highest missing data GPs compared to the other GPs.

Supplementary Table 2 STROBE 2007 checklist [12] of items to be included in reports of observational studies in epidemiology

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	9 & Supplementary Table 1

Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	Supplementary Table 1
		(*c*) Explain how missing data were addressed	Supplementary Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Supplementary Table 1
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	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-13
		(b) Indicate number of participants with missing data for each variable of interest	13 & Supplementary Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Data collection times are summarized under study design subsection
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supplementary Table 3 (check categories of survey year)
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Supplementary Table 3
		Cross-sectional study—Report numbers of outcome events or summary measures	13 & table 3
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	14-18, Supplementary Table 5
		(*b*) Report category boundaries when continuous variables were categorized	Table 1

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 1, Supplementary Table 6-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	20
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	21-22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	23-24
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	26

Supplementary Table 3 The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060)

Characteristics	Total in the sample received (n=2,246,109)	Total in the complete case dataset (n=1807049)	Total in the excluded sample (n=439,069)
Online appointment booking in the previous 12 months			
No	1892841 (84.3%)	1543111 (85.4%)	349730 (79.7%)
Yes	305980 (13.6%)	263938 (14.6%)	42042 (9.6%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Online repeat prescription ordering in the previous 12 months			
No	1807863 (80.5%)	1467600 (81.2%)	340263 (77.5%)
Yes	390958 (17.4%)	339449 (18.8%)	51509 (11.7%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Gender			

Female	1229473 (54.7%)	996544 (55.1%)	232929 (51.1%)
Male	967079 (43.1%)	810505 (44.9%)	156574 (34.7%)
(Missing)	49557 (2.2%)	0 (0.0%)	49557 (11.3%)
Age			
16-24	87081 (3.9%)	74381 (4.1%)	12700 (2.9%)
25-34	185580 (8.3%)	159806 (8.8%)	25774 (5.9%)
35-44	256766 (11.4%)	217687 (12.0%)	39079 (8.9%)
45-54	360011 (16.0%)	302285 (16.7%)	57726 (13.2%)
55-64	454900 (20.3%)	381808 (21.1%)	73092 (16.6%)
65-74	487171 (21.7%)	397999 (22.0%)	89172 (20.3%)
75-84	287533 (12.8%)	211586 (11.7%)	75947 (17.3%)
85+	91083 (4.1%)	61497 (3.4%)	29586 (6.7%)
(Missing)	35984 (1.6%)	0 (0.0%)	35984 (8.2%)
Ethnicity			
White	1895473 (84.4%)	1567690 (86.8%)	15862 (3.6%)
Black	68812 (3.1%)	52950 (2.9%)	33583 (7.6%)
Asian	170609 (7.6%)	137026 (7.6%)	10257 (2.3%)
Other	39425 (1.8%)	29168 (1.6%)	4558 (1.0%)
Mixed	24773 (1.1%)	20215 (1.1%)	327783 (74.7%)
(Missing)	47017 (2.1%)	0 (0.0%)	47017 (10.7%)
Survey year			
2018	750619 (33.4%)	612084 (33.9%)	138535 (31.6%)
2019	763244 (34.0%)	623358 (34.5%)	139886 (31.9%)
2020	732246 (32.6%)	571607 (31.6%)	160639 (36.6%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Long term condition			
No	1022671 (45.5%)	833523 (46.1%)	189148 (43.1%)
Yes	1050129 (46.8%)	923780 (51.1%)	126349 (28.8%)
Don’t know/Can’t say	61802 (2.8%)	49746 (2.8%)	12056 (2.7%)
Prefer not to say	38879 (1.7%)	0 (0.0%)	38879 (8.9%)
(Missing)	72628 (3.2%)	0 (0.0%)	72628 (16.5%)
Taking five or more medication on a regular basis			
No	1632850 (72.7%)	1343735 (74.4%)	289115 (65.8%)

Yes	574749 (25.6%)	463314 (25.6%)	111435 (21.4%)
(Missing)	38510 (1.7%)	0 (0.0%)	38510 (8.8%)
Deafness or hearing loss			
No	1799633 (80.1%)	1652099 (91.4%)	147534 (33.6%)
Yes	179304 (8.0%)	154950 (8.6%)	24354 (5.5%)
(Missing)	267172 (11.9%)	0 (0.0%)	267172 (60.9%)
Parent or legal guardian to a 16 year old or younger			
No	1782911 (79.4%)	1466017 (81.1%)	316894 (72.2%)
Yes	407923 (18.2%)	341032 (18.9%)	66891 (15.2%)
(Missing)	55275 (2.5%)	0 (0.0%)	55275 (12.6%)
Carer			
No	1741536 (77.5%)	1462467 (80.9%)	279069 (63.6%)
Yes	410450 (18.3%)	344582 (19.1%)	65868 (15.0%)
(Missing)	94123 (4.2%)	0 (0.0%)	94123 (21.4%)
Deprivation fifth			
1- least deprived	437189 (19.5%)	338728 (18.7%)	98461 (22.4%)
2	444869 (19.8%)	353580 (19.6%)	91289 (20.8%)
3	464884 (20.7%)	376042 (20.8%)	88842 (20.2%)
4	461586 (20.6%)	378002 (20.9%)	83584 (19.0%)
5 - most deprived	435997 (19.4%)	360697 (20.0%)	75300 (17.2%)
(Missing)	1584 (0.1%)	0 (0.0%)	1584 (0.4%)
General practice rurality			
Rural	374466 (16.7%)	306200 (16.9%)	68266 (15.5%)
Urban	1871643 (83.3%)	1500849 (83.1%)	370794 (84.5%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Supplementary Table 4 Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Online services use			
Online appointment booking in the previous 12 months	75194(15.9%)	176193(19.4%)	55937(13.1%)
Online repeat prescription use in the previous 12 months	102332(21.6%)	176193(19.4%)	60924(14.4%)
Gender			
Female	265428 (56.0%)	503040 (55.3%)	228076 (53.8%)
Male	208654 (44.0%)	406112 (44.7%)	195739 (46.2%)
Age			
16-24	18750 (4.0%)	34473 (3.8%)	21158 (5.0%)
25-34	39537 (8.3%)	75142 (8.3%)	45127 (10.6%)
35-44	55609 (11.7%)	103244 (11.4%)	58834 (13.9%)
45-54	79934 (16.9%)	149707 (16.5%)	72644 (17.1%)
55-64	100332 (21.2%)	194450 (21.4%)	87026 (20.5%)
65-74	106927 (22.6%)	208741 (23.0%)	82331 (19.4%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
75-84	56564 (11.9%)	111123 (12.2%)	43899 (10.4%)
85+	16429 (3.5%)	32272 (3.5%)	12796 (3.0%)
Ethnicity			
White	5027 (1.1%)	17758 (2.0%)	30165 (7.1%)
Black	16190 (3.4%)	49142 (5.4%)	71694 (16.9%)
Asian	3729 (0.8%)	10722 (1.2%)	14717 (3.5%)
Other	4175 (0.9%)	8704 (1.0%)	7336 (1.7%)
Mixed	444961 (93.9%)	822826 (90.5%)	299903 (70.8%)
Survey year			
2018	166729 (35.2%)	305514 (33.6%)	139841 (33.0%)
2019	162214 (34.2%)	315671 (34.7%)	145473 (34.3%)
2020	145139 (30.6%)	287967 (31.7%)	138501 (32.7%)
Long-term condition			
No	11725 (2.5%)	24207 (2.7%)	13814 (3.3%)
I don't know/ Can't answer	220575 (46.5%)	411974 (45.3%)	200974 (47.4%)
Yes	241782 (51.0%)	472971 (52.0%)	209027 (49.3%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Taking five or more medication on a regular basis			
No	363720 (76.7%)	674880 (74.2%)	305135 (72.0%)
Yes	110362 (23.3%)	234272 (25.8%)	118680 (28.0%)
Deafness or hearing loss			
No	433463 (91.4%)	827757 (91.0%)	390879 (92.2%)
Yes	40619 (8.6%)	81395 (9.0%)	32936 (7.8%)
Parent or legal guardian to a 16 year old or younger			
No	385230 (81.3%)	746422 (82.1%)	334365 (78.9%)
Yes	88852 (18.7%)	162730 (17.9%)	89450 (21.1%)
Carer			
No	382112 (80.6%)	732193 (80.5%)	348162 (82.1%)
Yes	91970 (19.4%)	176959 (19.5%)	75653 (17.9%)
Deprivation quintile			
1 (Most deprived)	38111 (8.0%)	146156 (16.1%)	154461 (36.4%)

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
2	64792 (13.7%)	174694 (19.2%)	114094 (26.9%)
3	99792 (21.0%)	199586 (22.0%)	76664 (18.1%)
4	124261 (26.2%)	203142 (22.3%)	50599 (11.9%)
5 (Least deprived)	147126 (31.0%)	185574 (20.4%)	27997 (6.6%)
General practice rurality			
Rural	116101 (24.5%)	165787 (18.2%)	24312 (5.7%)
Urban	357981 (75.5%)	743365 (81.8%)	399503 (94.3%)

Supplementary Table 5. Table presenting summaries of the univariate analyses for each of the outcomes:

Summary of univariate analysis for the online appointment booking outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.10	0.01	1.07 - 1.13	**<0.001**
Long term condition- Yes	1.50	0.01	1.48 - 1.51	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.16	0.01	1.15 - 1.17	**<0.001**
Deafness or hearing loss-Yes (REF= No)	0.94	0.01	0.92 - 0.95	**<0.001**
Gender-Male (REF= Female)	0.88	0.01	0.87 - 0.89	**<0.001**
Age bands (REF: 85+)				
16-24	2.32	0.05	2.24 - 2.41	**<0.001**
25-34	3.05	0.05	2.94 - 3.15	**<0.001**
35-44	3.00	0.05	2.9 - 3.11	**<0.001**
45-54	2.96	0.05	2.87 - 3.06	**<0.001**
55-64	2.88	0.05	2.79 - 2.98	**<0.001**
65-74	2.62	0.04	2.53 - 2.71	**<0.001**
	1.61	0.03	1.56 - 1.67	**<0.001**
Ethnicity (REF: White)				

Black	0.81	0.01	0.79 - 0.84	**<0.001**
Asian	1.10	0.01	1.08 - 1.12	**<0.001**
Other	0.94	0.02	0.91 - 0.97	**<0.001**
Mixed	1.11	0.02	1.07 - 1.16	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	1.06	0.01	1.05 - 1.07	**<0.001**
Carer-Yes (REF= No)	1.21	0.01	1.2 - 1.22	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.11	0.01	1.1 - 1.13	**<0.001**
3	1.19	0.01	1.18 - 1.21	**<0.001**
4	1.28	0.01	1.26 - 1.3	**<0.001**
5 (least deprived)	1.38	0.01	1.36 - 1.41	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.2	**<0.001**
2020	1.50	0.01	1.48 - 1.51	**<0.001**
General practice rurality-urban (REF= rural)	1.07	0.02	1.03 - 1.11	**<0.001**

Summary of univariate analysis for the repeat prescription ordering outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.21	0.02	1.18 - 1.24	**<0.001**
Long term condition- Yes	2.70	0.01	2.68 - 2.73	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.72	0.01	1.7 - 1.74	**<0.001**
Deafness or hearing loss-Yes (REF= No)	1.13	0.01	1.12 - 1.14	**<0.001**
Gender-Male (REF= Female)	1.01	0.00	1 - 1.02	**0.007**
Age bands (REF: 85+)				
16-24	0.87	0.02	0.84 - 0.9	**<0.001**
25-34	1.06	0.02	1.03 - 1.09	**<0.001**
35-44	1.37	0.02	1.33 - 1.4	**<0.001**
45-54	1.91	0.03	1.86 - 1.96	**<0.001**
55-64	2.31	0.03	2.25 - 2.37	**<0.001**
65-74	2.41	0.03	2.35 - 2.47	**<0.001**
Ethnicity (REF: White)				
Black	0.66	0.01	0.64 - 0.68	**<0.001**
Asian	0.77	0.01	0.76 - 0.78	**<0.001**

Other	0.66	0.01	0.65 - 0.68	**<0.001**
Mixed	0.84	0.02	0.82 - 0.87	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.73	0.00	0.72 - 0.73	**<0.001**
Carer-Yes (REF= No)	1.32	0.01	1.3 - 1.33	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.18	0.01	1.16 - 1.2	**<0.001**
3	1.35	0.01	1.33 - 1.37	**<0.001**
4	1.50	0.01	1.48 - 1.52	**<0.001**
5 (least deprived)	1.60	0.01	1.58 - 1.63	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.19	**<0.001**
2020	1.43	0.01	1.42 - 1.44	**<0.001**
General practice rurality-urban (REF= rural)	0.78	0.01	0.76 - 0.8	**<0.001**

Supplementary Table 6 Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.16***	(1.10, 1.23)	1.14***	(1.10, 1.19)	1.16***	(1.10, 1.22)
Long term condition- Yes	1.78***	(1.75, 1.81)	1.69***	(1.67, 1.72)	1.49***	(1.46, 1.53)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.17, 1.22)	1.20***	(1.18, 1.22)	1.20***	(1.17, 1.23)
Deafness or hearing loss-Yes (REF= No)	1.15***	(1.11, 1.19)	1.12***	(1.09, 1.14)	1.12***	(1.08, 1.16)
Gender-Male (REF= Female)	0.88***	(0.86, 0.89)	0.88***	(0.87, 0.89)	0.91***	(0.89, 0.93)
Age (REF: 85+)						

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
16-24	3.39***	(3.14, 3.66)	3.76***	(3.55, 3.98)	3.50***	(3.21, 3.82)
25-34	4.69***	(4.37, 5.03)	5.17***	(4.91, 5.45)	4.66***	(4.30, 5.06)
35-44	4.63***	(4.32, 4.96)	5.13***	(4.87, 5.40)	4.46***	(4.11, 4.83)
45-54	4.28***	(4.01, 4.57)	4.51***	(4.29, 4.74)	3.75***	(3.46, 4.06)
55-64	3.80***	(3.56, 4.05)	3.94***	(3.75, 4.13)	3.07***	(2.84, 3.32)
65-74	3.27***	(3.07, 3.49)	3.32***	(3.16, 3.48)	2.35***	(2.18, 2.54)
75-84	1.81***	(1.69, 1.93)	1.83***	(1.74, 1.93)	1.43***	(1.32, 1.55)
Ethnicity (REF: White)						
Black	0.75***	(0.69, 0.81)	0.83***	(0.79, 0.87)	0.87***	(0.83, 0.90)
Asian	1.04	(1.00, 1.09)	1.10***	(1.07, 1.14)	1.14***	(1.10, 1.17)
Other	0.86**	(0.79, 0.95)	0.92**	(0.87, 0.98)	1.01	(0.96, 1.06)
Mixed	1.01	(0.93, 1.10)	1.01	(0.95, 1.07)	1.09**	(1.02, 1.16)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.91***	(0.89, 0.93)	0.90***	(0.88, 0.92)	0.96***	(0.93, 0.98)
Carer-Yes (REF= No)	1.11***	(1.09, 1.13)	1.15***	(1.13, 1.17)	1.17***	(1.14, 1.19)
Deprivation quintile (REF: 1-Most deprived)						
2	1.15***	(1.11, 1.20)	1.14***	(1.12, 1.17)	1.16***	(1.13, 1.19)

Predictors	Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
3	1.23***	(1.19, 1.28)	1.29***	(1.26, 1.32)	1.27***	(1.23, 1.30)
4	1.38***	(1.33, 1.44)	1.40***	(1.37, 1.43)	1.36***	(1.31, 1.41)
5 (least deprived)	1.54***	(1.48, 1.60)	1.52***	(1.49, 1.56)	1.53***	(1.46, 1.60)
Survey year (REF= 2018)						
2019	1.16***	(1.14, 1.18)	1.18***	(1.17, 1.20)	1.25***	(1.22, 1.28)
2020	1.46***	(1.43, 1.49)	1.52***	(1.50, 1.54)	1.61***	(1.57, 1.65)
General practice rurality-Urban (REF= Rural)	1.22***	(1.10, 1.23)	1.11***	(1.10, 1.19)	1.10	(0.97, 1.24)
Model summary						
Interclass correlation coefficient (ICC)	0.13		0.12		0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

10.1136/bmjopen-2022-068827 on 12 October 2023. Downloaded from

Supplementary Table 7 Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.25***	(1.18, 1.32)	1.25***	(1.20, 1.30)	1.21***	(1.17, 1.31)
Long term condition- Yes	2.71***	(2.66, 2.75)	2.56***	(2.52, 2.59)	2.42***	(2.37, 2.47)
Taking five or more medication on a regular basis- Yes (REF= No)	1.26***	(1.24, 1.29)	1.26***	(1.24, 1.28)	1.29***	(1.26, 1.32)
Deafness or hearing loss-Yes (REF= No)	1.02	(1.00, 1.05)	1.02	(1.00, 1.04)	1.01	(0.98, 1.04)
Gender-Male (REF= Female)	0.96***	(0.94, 0.97)	0.96***	(0.95, 0.97)	0.98**	(0.96, 1.00)
Age (REF: 85+)						
16-24	1.64***	(1.53, 1.75)	1.76***	(1.67, 1.85)	1.62***	(1.50, 1.76)
25-34	2.16***	(2.04, 2.29)	2.22***	(2.13, 2.32)	1.98***	(1.85, 2.13)
35-44	2.67***	(2.52, 2.82)	2.82***	(2.70, 2.94)	2.37***	(2.21, 2.54)
45-54	3.25***	(3.09, 3.42)	3.29***	(3.16, 3.42)	2.82***	(2.65, 3.01)
55-64	3.35***	(3.18, 3.52)	3.43***	(3.31, 3.56)	2.81***	(2.64, 3.00)
65-74	3.11***	(2.97, 3.27)	3.15***	(3.03, 3.27)	2.48***	(2.33, 2.64)
75-84	1.73***	(1.65, 1.82)	1.75***	(1.68, 1.82)	1.43***	(1.34, 1.53)
Ethnicity (REF: White)						

Predictors	Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices		Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices		Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices	
	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval	Odds Ratios	95% Confidence Interval
Black	0.77***	(0.71, 0.84)	0.73***	(0.70, 0.77)	0.8***	(0.77, 0.84)
Asian	0.88***	(0.84, 0.92)	0.94***	(0.91, 0.97)	1.01	(0.98, 1.04)
Other	0.79***	(0.71, 0.87)	0.76***	(0.72, 0.81)	0.8***	(0.77, 0.86)
Mixed	0.96	(0.89, 1.05)	0.98	(0.93, 1.05)	0.99	(0.92, 1.07)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.93***	(0.91, 0.96)	0.94***	(0.92, 0.96)	0.99	(0.96, 1.02)
Carer-Yes (REF= No)	1.13***	(1.11, 1.16)	1.15***	(1.14, 1.17)	1.19***	(1.17, 1.22)
Deprivation quintile (REF: 1-Most deprived)						
2	1.21***	(1.17, 1.26)	1.22***	(1.19, 1.25)	1.22***	(1.19, 1.26)
3	1.37***	(1.32, 1.42)	1.43***	(1.40, 1.46)	1.43***	(1.39, 1.47)
4	1.54***	(1.48, 1.59)	1.59***	(1.55, 1.62)	1.67***	(1.62, 1.73)
5 (least deprived)	1.65***	(1.59, 1.71)	1.74***	(1.70, 1.78)	1.89***	(1.82, 1.97)
Survey year (REF= 2018)						
2019	1.16***	(1.13, 1.18)	1.17***	(1.15, 1.19)	1.26***	(1.24, 1.29)
2020	1.40***	(1.38, 1.43)	1.46***	(1.44, 1.48)	1.54***	(1.51, 1.58)
General practice rurality-Urban (REF= Rural)	0.94**	(0.89, 0.99)	0.90***	(0.87, 0.94)	0.97	(0.88, 1.07)
Model summary						
Interclass correlation coefficient (ICC)	0.07		0.07		0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001