

## **Supplemental materials for**

Levene LS, Baker R, Newby C, Couchman E, Freeman GK. Ongoing Decline in Continuity With GPs in English General Practices: A Longitudinal Study Across the COVID-19 Pandemic. *Ann Fam Med*. 2024;22:null-null.

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**Supplemental Table 1** Definition of key terms

Primary care	NHS England defines primary care as the ‘front door of the NHS’. (1) This sector encompasses general practice, pharmacy, dentist and optician services. These services are generally delivered outside of hospitals by doctors, nurses, midwives and other healthcare professionals. (2)
General practice	‘General practice is defined as the medical specialty that manages common and long-term illnesses in children and adults, focussing on overall health and well-being.’ This definition should be contextualised by detailing disease that is locally relevant to a particular population/community, ‘with examples that illustrate the complexity of cases managed by GPs’. (3)
Continuity	‘The extent to which a person experiences an ongoing relationship with a clinician and the coordinated clinical care that progresses smoothly as the patient moves between different parts of the health service’. May be categorised as relational, managerial or informational. (4-6)

## References

1. NHSE. Primary care services: NHS England; 2023 [Available from: <https://www.england.nhs.uk/participation/get-involved/how/primarycare/>].
2. NICE. Glossary: National Institute for Health and Care Excellence; [Available from: <https://www.nice.org.uk/glossary>].
3. Hashim MJ. A Definition of Family Medicine and General Practice. J Coll Physicians Surg Pak. 2018;28(1):76-7.
4. Hill A, Freeman, G. Promoting Continuity of Care in General Practice. RCGP; 2011.
5. The Health Foundation: Increasing Continuity of Care in General Practice: The Health Foundation; 2020 [Available from: <https://www.health.org.uk/funding-and-partnerships/programmes/increasing-continuity-of-care-in-general-practice>].
6. Haggerty J, Reid R, Freeman G, et al. Continuity of care: a multidisciplinary review. BMJ. 2003;327(7425):1219-21.

**Supplemental Table 2** List of excluded variables from longlist of potential independent variables

	<b>Reason for exclusion</b>
<b><i>General Practice Patient Survey questions</i></b>	
Q3. Generally, how easy is it to get through to someone at your surgery on the phone?	Correlation with other variables
Q12. Were you able to get an appointment to see or speak to someone?	Correlation with other variables
Q14. How long after initially contacting the surgery did you actually see or speak to them? Seen on the next day	Correlation with other variables
Q14. How long after initially contacting the surgery did you actually see or speak to them? Seen a few days later	Correlation with other variables
Q14. How long after initially contacting the surgery did you actually see or speak to them? Seen a week or more later.	Correlation with other variables
Q15. How convenient was the appointment you were able to get?	Correlation with other variables
Q18. Overall, how would you describe your experience of making an appointment? (We used the 'very good' and 'fairly good' response options combined).	Correlation with other variables
Q21a. Giving you enough time	Correlation with other variables
Q21b. Listening to you	Correlation with other variables
Q21c. Explaining tests and treatments	Correlation with other variables
Q21d. Involving you in decisions about your care.	Correlation with other variables
Q21e. Treating you with care and concern.	Correlation with other variables
Q22. Did you have confidence and trust in the GP you saw or spoke to?	Correlation with other variables
% patients with a long-standing condition	Correlation with other variables
% patients who were smokers	Correlation with other variables
<b><i>Quality and Outcomes Framework variables</i></b>	
% practice population on coronary heart disease (CHD) register	Correlation with other variables
% practice population on COPD register	Correlation with other variables
% practice population on stroke/TIA register	Correlation with other variables
% practice population on hypertension register	Correlation with other variables
% practice population on cancer register	Correlation with other variables
Sum of percentages of patients on CHD, COPD, stroke/TIA, hypertension, diabetes and cancer registers	Correlation with other variables

The inverse of DM009. The percentage of patients with diabetes, on the register, in whom the last IFCC-HbA1c is 75 mmol/mol or more in the preceding 12 months.	Correlation with other variables
CHD007. The percentage of patients with coronary heart disease who have had influenza immunisation in the preceding 1 August to 31 March	Correlation with other variables
HYP006. The percentage of patients with hypertension in whom the last blood pressure reading (measured in the preceding 12 months) is 150/90 mmHg or less.	Correlation with other variables
STIA009. The percentage of patients with stroke or TIA who have had influenza immunisation in the preceding 1 September to 31 March.	Correlation with other variables
DM003. The percentage of patients with diabetes, on the register, in whom the last blood pressure reading (measured in the preceding 12 months) is 140/80 mmHg or less.	Correlation with other variables
<b>Workforce data</b>	
Direct patient care (DPC) staff i.e. health care assistants, dispensers, paramedics, occupational therapists, other therapists, physician associates, podiatrists, pharmacists, phlebotomists, physiotherapists and others)	The data were incomplete
Administrative staff other than receptionists (including managers, secretaries, and others)	A rationale for any effect of these staff on outcomes has not been sufficiently developed.

#### Reference:

Baker R, Levene LS, Newby C, Freeman G. Does shortage of general practitioners matter? Life expectancy in English general practices. *Br J Gen Pract.* 2023. DOI: <https://doi.org/10.3399/BJGP.2023.0195>

**Supplemental Table 3** Data sources

The raw data used in this study are available from the following open access websites.

Variables	Website publishing the dataset*
continuity, region, ethnicity, % seen same day	<a href="https://gp-patient.co.uk/surveysandreports">https://gp-patient.co.uk/surveysandreports</a>
deprivation	<a href="https://fingertips.phe.org.uk/profile/general-practice-patients">https://fingertips.phe.org.uk/profile/general-practice-patients</a>
rurality, contract type, payments	<a href="https://digital.nhs.uk/data-and-information/publications/statistical/nhs-payments-to-general-practice">https://digital.nhs.uk/data-and-information/publications/statistical/nhs-payments-to-general-practice</a>
list sizes	<a href="https://digital.nhs.uk/data-and-information/publications/statistical/patients-registered-at-a-gp-practice">https://digital.nhs.uk/data-and-information/publications/statistical/patients-registered-at-a-gp-practice</a>
workforce	<a href="https://digital.nhs.uk/data-and-information/publications/statistical/general-and-personal-medical-services">https://digital.nhs.uk/data-and-information/publications/statistical/general-and-personal-medical-services</a>

\*Full methodological guidance on the datasets can be found on the websites.

**Descriptive Statistics**

**Supplemental Table 4** Descriptive statistics of all potential variables' data in all practice entities with any data\*  
(see also Figure S1)

Variable	Missing (%)	Mean	Median	Standard Deviation	25% centile	75% centile	Outliers (n)
% Asian ethnicity 2018	16.69	10.03	3.48	16.64	0.74	11.00	729

Variable	Missing (%)	Mean	Median	Standard Deviation	25% centile	75% centile	Outliers (n)
% Asian ethnicity 2019	22.22	10.15	3.59	16.60	0.83	11.26	666
% Asian ethnicity 2020	23.80	10.22	3.65	16.44	0.85	11.63	648
% Asian ethnicity 2021	30.61	11.03	4.11	17.15	0.94	12.97	574
% Asian ethnicity 2022	21.90	11.52	4.71	17.44	1.15	13.51	618
% Black ethnicity 2018	14.16	3.86	0.84	7.20	0.00	4.19	798
% Black ethnicity 2019	18.57	3.94	0.89	7.09	0.00	4.49	727
% Black ethnicity 2020	20.78	3.86	0.97	6.79	0.00	4.57	696
% Black ethnicity 2021	25.71	4.02	1.12	6.80	0.00	4.94	601
% Black ethnicity 2022	21.94	4.39	1.38	7.25	0.00	5.38	620
% Continuity 2018	15.49	29.22	27.35	14.26	18.39	38.08	79
% Continuity 2019	18.03	27.40	25.35	14.13	16.64	35.98	81
% Continuity 2020	20.64	25.12	22.76	13.82	14.68	33.50	93
% Continuity 2021	21.64	23.00	20.81	12.82	13.43	30.36	126
% Continuity 2022	24.15	18.87	16.57	12.02	10.01	25.13	166
% on disability reg 2018	12.61	4.23	3.55	3.29	1.83	5.89	198
% on disability reg 2019	15.95	4.17	3.45	3.27	1.87	5.70	226
% on disability reg 2020	18.19	4.09	3.39	3.19	1.77	5.66	202
% on disability reg 2021	20.34	4.21	3.56	3.09	1.99	5.74	192
% on disability reg 2022	21.51	4.78	4.03	3.55	2.16	6.62	163
FTE GPs/1000 pats 2018	15.34	0.56	0.53	0.44	0.40	0.69	153
FTE GPs/1000 pats 2019	17.58	0.57	0.53	0.52	0.39	0.69	166
FTE GPs/1000 pats 2020	19.65	0.62	0.54	3.30	0.40	0.71	165
FTE GPs/1000 pats 2021	20.65	0.59	0.54	0.53	0.39	0.73	166
FTE GPs/1000 pats 2022	22.06	0.59	0.54	0.38	0.39	0.74	154
IMD 2019 score	5.65	23.27	21.29	11.38	14.17	30.26	78
List size 2018	11.23	8,133.02	7,202.00	5,179.88	4,482.00	10,688.00	168
List size 2019	14.55	8,550.24	7,522.50	5,560.13	4,737.75	11,081.00	186
List size 2020	16.79	8,885.36	7,789.00	5,904.78	4,940.00	11,389.00	204
List size 2021	18.93	9,153.45	7,967.00	6,167.08	5,119.75	11,660.50	203
List size 2022	20.20	9,440.91	8,178.00	6,433.69	5,316.75	11,938.75	218
% with long term condition 2018	12.09	51.92	52.42	8.84	46.35	57.87	82
% with long term condition 2019	15.27	52.21	52.68	8.71	46.64	58.16	85
% with long term condition 2020	17.63	53.18	53.62	8.93	47.50	59.38	76
% with long term condition 2021	19.38	52.29	52.85	8.49	46.65	58.18	50
% with long term condition 2022	20.92	55.03	55.39	9.06	49.11	61.32	45

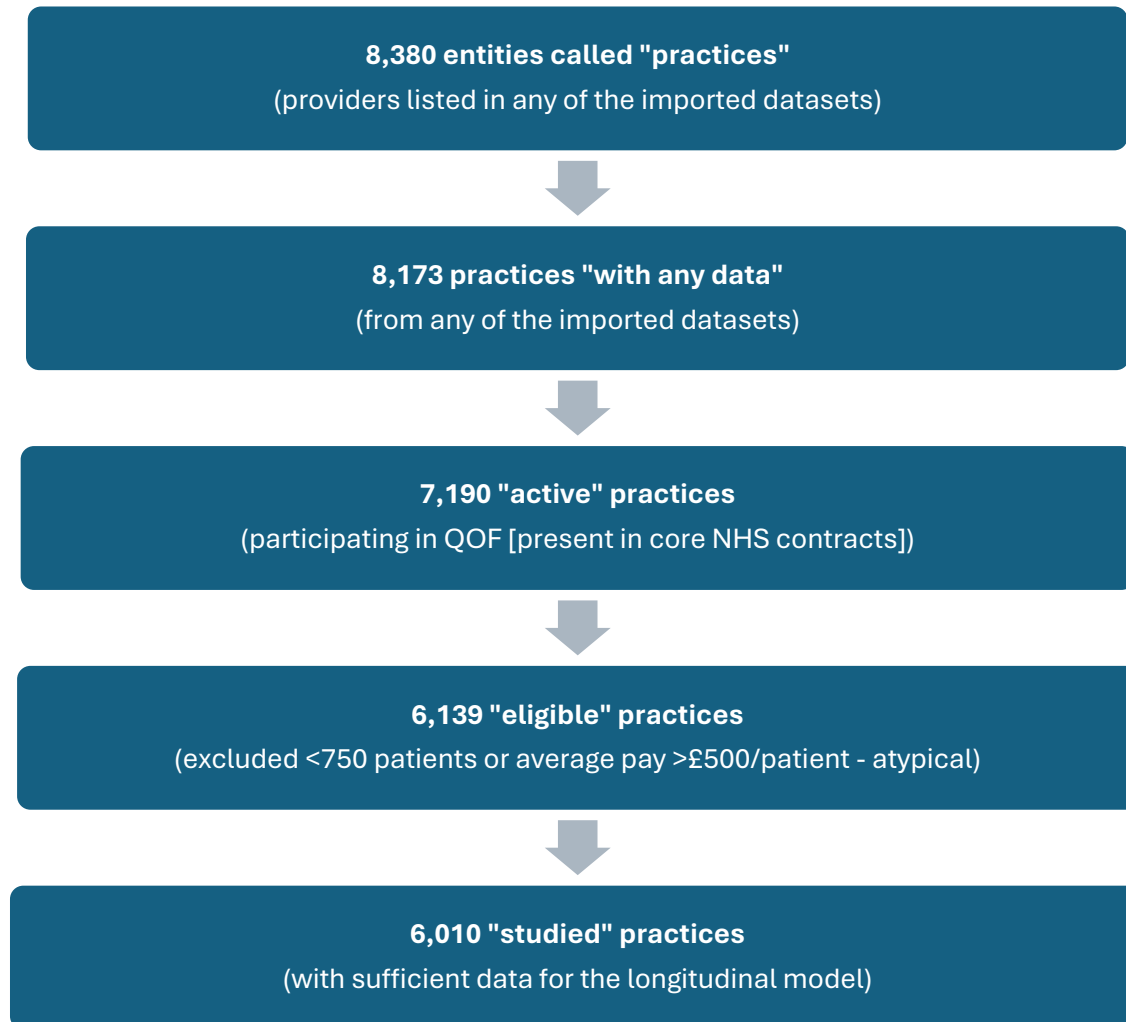
Variable	Missing (%)	Mean	Median	Standard Deviation	25% centile	75% centile	Outliers (n)
% Mixed ethnicity 2018	15.25	1.48	0.72	2.07	0.00	2.26	373
% Mixed ethnicity 2019	20.13	1.59	0.80	2.21	0.00	2.38	325
% Mixed ethnicity 2020	21.97	1.68	0.96	2.18	0.00	2.58	275
% Mixed ethnicity 2021	27.53	1.72	1.06	2.07	0.00	2.62	215
% Mixed ethnicity 2022	22.88	2.04	1.29	2.40	0.00	3.11	233
FTE Nurses/1000 pats 2018	16.08	0.27	0.24	0.22	0.16	0.33	202
FTE Nurses/1000 pats 2019	18.74	0.27	0.24	0.25	0.16	0.34	169
FTE Nurses/1000 pats 2020	21.16	0.29	0.24	1.30	0.16	0.35	154
FTE Nurses/1000 pats 2021	20.95	0.27	0.23	0.36	0.15	0.34	150
FTE Nurses/1000 pats 2022	23.28	0.27	0.23	0.30	0.15	0.34	152
% Other ethnicity 2018	13.86	2.27	0.76	3.95	0.00	2.97	574
% Other ethnicity 2019	17.80	2.51	0.96	4.16	0.00	3.45	475
% Other ethnicity 2020	20.21	2.58	1.03	4.29	0.00	3.50	454
% Other ethnicity 2021	23.90	2.62	1.18	4.08	0.00	3.57	392
% Other ethnicity 2022	22.39	2.49	1.05	3.99	0.00	3.51	390
% aged ≥75 years 2018	11.23	7.72	7.70	4.11	5.21	9.88	54
% aged ≥75 years 2019	14.55	7.85	7.82	4.01	5.28	10.09	50
% aged ≥75 years 2020	16.79	8.04	7.96	4.24	5.32	10.39	43
% aged ≥75 years 2021	18.93	8.06	7.96	4.29	5.29	10.47	42
% aged ≥75 years 2022	20.20	8.35	8.21	4.54	5.40	10.89	36
Average NHS pay per patient 2019	10.94	236.91	144.86	5,926.06	129.34	166.40	889
Average NHS pay per patient 2020	16.38	299.60	145.90	10,374.19	131.24	166.56	714
Average NHS pay per patient 2021	18.51	239.88	148.82	5,722.94	132.67	170.87	784
Average NHS pay per patient 2022	19.66	501.63	152.04	10,871.79	135.32	173.77	765
% on QOF diabetes register 2018	13.13	7.08	6.97	2.12	5.92	8.07	389
% on QOF diabetes register 2019	15.91	7.23	7.15	2.18	6.05	8.29	374
% on QOF diabetes register 2020	17.78	7.42	7.30	2.64	6.18	8.44	360
% on QOF diabetes register 2021	19.60	7.43	7.32	2.22	6.21	8.49	335
% on QOF diabetes register 2022	20.84	7.61	7.52	2.28	6.37	8.70	343
% booked & seen same day 2018	12.16	32.28	30.15	13.90	21.94	41.56	45
% booked & seen same day 2019	15.33	32.20	30.36	13.82	21.71	41.31	37
% booked & seen same day 2020	17.66	31.98	30.16	13.48	21.86	40.62	53
% booked & seen same day 2021	19.43	34.74	34.13	12.98	25.17	43.64	18
% booked & seen same day 2022	20.97	33.47	32.13	14.25	22.53	43.67	8
% White ethnicity 2018	17.47	82.35	92.63	22.61	75.57	97.72	572



Variable	Missing (%)	Mean	Median	Standard Deviation	25% centile	75% centile	Outliers (n)
% White ethnicity 2019	22.87	82.22	92.27	22.26	75.11	97.50	509
% White ethnicity 2020	23.54	81.79	91.92	22.62	74.63	97.43	492
% White ethnicity 2021	29.65	80.75	91.11	22.85	72.22	96.93	382
% White ethnicity 2022	20.96	79.84	90.15	23.50	70.86	96.73	437

\* In the study period there were 8,173 entities labelled as general practices in England with data published by either the GPPS or NHS England.

**Supplemental Figure 1** Numbers of practices at each stage of the analysis  
(see also Methods)



**Supplemental Table 5** Expanded Table 1 - descriptive statistics of numeric variables used in model

<b>Numeric Variable</b>	<b>% missing*</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Median</b>	<b>25%</b>	<b>75%</b>
Continuity (% patients) 2018	1.71	29.29	14.08	27.50	18.62	38.01
Continuity (% patients) 2019	1.38	27.54	14.04	25.46	16.93	36.05
Continuity (% patients) 2020	1.94	25.25	13.76	22.87	14.86	33.65
Continuity (% patients) 2021	1.50	23.13	12.81	21.00	13.56	30.50
Continuity (% patients) 2022	2.87	18.96	12.05	16.66	10.07	25.24
IMD	0.00	23.28	11.60	21.24	14.01	30.40
White ethnicity ((% patients) 2018	6.27	82.55	22.56	92.79	75.93	97.77
White ethnicity ((% patients) 2019	9.24	82.39	22.25	92.44	75.76	97.55
White ethnicity ((% patients) 2020	7.41	81.96	22.56	92.09	74.87	97.47
White ethnicity ((% patients) 2021	12.79	80.80	22.88	91.20	72.27	97.02
White ethnicity ((% patients) 2022	0.02	79.90	23.52	90.31	71.01	96.77
List size 2018	0.00	8,648.67	5,115.24	7,711.00	4,996.00	11,110.00
List size 2019	0.00	8,945.87	5,484.19	7,907.00	5,164.50	11,394.00
List size 2020	0.00	9,207.57	5,803.96	8,052.00	5,298.50	11,684.50

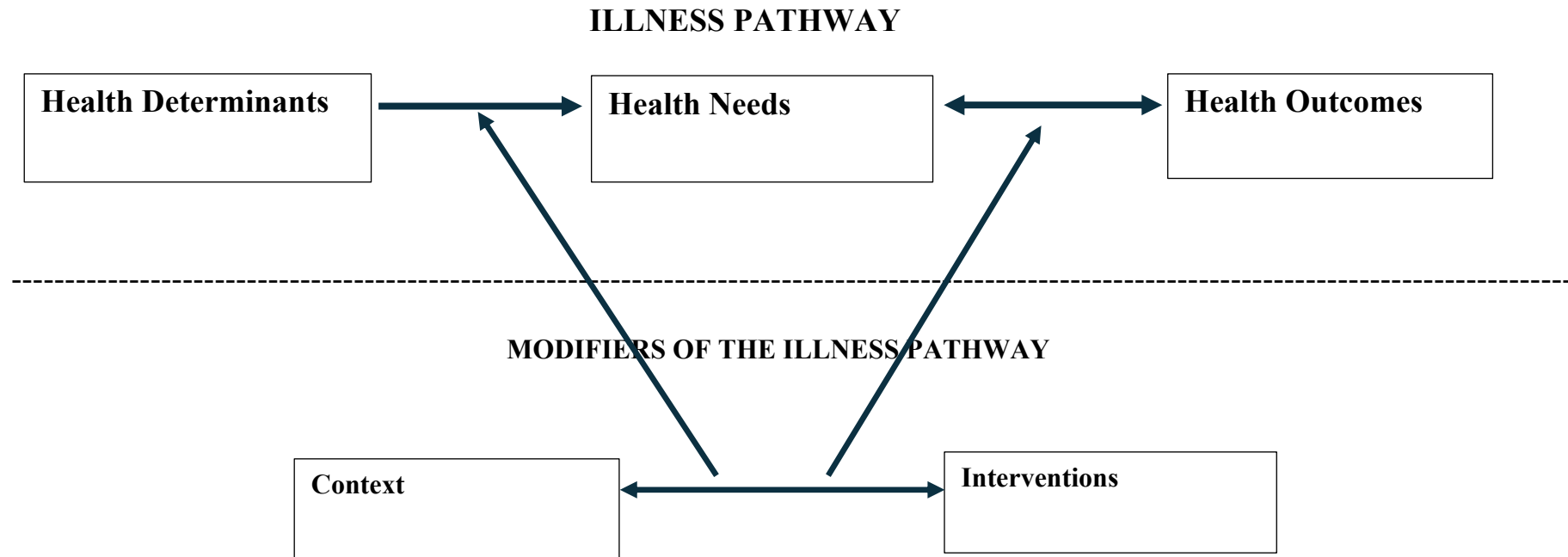
<b>Numeric Variable</b>	<b>% missing*</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Median</b>	<b>25%</b>	<b>75%</b>
List size 2021	0.00	9,358.48	6,040.94	8,147.00	5,377.50	11,825.00
List size 2022	0.00	9,583.90	6,284.75	8,308.00	5,475.00	12,028.00
Av pay per patient (£) 2019	0.00	158.34	45.87	146.40	131.79	167.55
Av pay per patient (£) 2020	0.00	158.53	46.09	146.52	132.33	166.76
Av pay per patient (£) 2021	0.00	162.69	49.82	149.66	134.34	171.44
Av pay per patient (£) 2022	0.00	164.67	48.92	152.85	136.97	173.84
FTE GPs/1000 2018	0.57	0.56	0.26	0.53	0.40	0.69
FTE GPs/1000 2019	0.78	0.57	0.27	0.53	0.40	0.70
FTE GPs/1000 2020	0.68	0.58	0.26	0.54	0.40	0.71
FTE GPs/1000 2021	0.26	0.58	0.28	0.54	0.39	0.73
FTE GPs/1000 2022	1.61	0.59	0.30	0.55	0.39	0.74
FTE nurses/1000 2018	1.37	0.26	0.15	0.24	0.16	0.33
FTE nurses/1000 2019	2.02	0.27	0.15	0.24	0.16	0.34
FTE nurses/1000 2020	2.44	0.27	0.15	0.24	0.16	0.35
FTE nurses/1000 2021	0.62	0.26	0.15	0.23	0.15	0.34

<b>Numeric Variable</b>	<b>% missing*</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Median</b>	<b>25%</b>	<b>75%</b>
FTE nurses/1000 2022	3.13	0.26	0.17	0.23	0.15	0.34
Seen same day ((% patients) 2018	0.02	32.33	13.84	30.13	21.98	41.60
Seen same day ((% patients) 2019	0.02	32.23	13.83	30.32	21.74	41.33
Seen same day ((% patients) 2020	0.00	32.05	13.49	30.17	21.90	40.70
Seen same day ((% patients) 2021	0.00	34.82	12.98	34.23	25.23	43.68
Seen same day ((% patients) 2022	0.00	33.55	14.24	32.16	22.60	43.74

\*6,139 eligible practices

**Supplemental Figure 2: Configuration of the population health framework**

This was used to categorise variables and their possible relationships.



The conceptual framework has two components: (1) an illness pathway and (2) modifiers of the illness pathway. The illness pathway starts with health determinants, which generate health needs, which then predict health-related outcomes. Two groups of modifying variables, context (factors not directly causing illness) and interventions (e.g., primary care structures and processes, including appointment availability, that link to service-related intermediate outcomes such as LCoC), can alter the trajectory of population groups along the illness pathway.

Our variables focused largely on the interactions between and within the two categories of modifiers of the illness pathway, context, and interventions.

Reference: Levene LS, Bankart J, Walker N, Wilson A, Baker R. How health care may modify the effects of illness determinants on population outcomes: the Leicester SEARCH conceptual framework for primary care. BJGP Open 2018; DOI: 10.3399/bjgpopen18X101603

## **Additional detail about variables**

### **Continuity of care**

The study population was English general practices (collections of patients), not individual patients, i.e., a population level study, using published practice level data (described in Methods and the data sources). Thus, certain CoC measures used elsewhere, which can only be generated from anonymized individual patient level data (e.g., Usual Provider of Care Index [UPCI], Herfindahl Hirschman Index [HHI] and the Bice-Boxerman Index [BBI]), were not feasible for this study of practice populations.

At practice population level in England, the only CoC measure(s) available to us is/are derived from General Practice Patient Survey (GPPS) published data, which are collected only in the UK. GPPS measures have been extensively used in UK general practice studies, including several which we have authored. The GPPS has published detailed technical information on how their measures are developed and validated (see Technical Annexes in reference 26).

Some studies have used only responses to one of the two GPPS continuity-related questions (see references 27 and 28), instead of the product of both (as we did). However, we were interested in practices' overall achievement in delivering continuity. Each of the two questions looks at distinct and narrower, but complementary, facets: do patients have a preferred GP and, if so, how frequently do they see this GP? Multiplying them provided a more comprehensive measure of how much continuity was achieved in the practice. This approach has been used in previous studies, including those we have had published, and was described over 10 years ago in authoritative publications (references 4, 5).

Even if UPC, HHI or BBI had been used in this study, it could be argued that they would have offered a rather narrow view of what constitutes relationship continuity. In contrast, we used a GPPS-derived variable that also considers the qualitative aspect of relationship continuity. A measure based on patient perceptions and preferences may have greater face validity than one based solely on records (i.e. was there a therapeutic relationship or does it just reflect that a patient and a specific clinician (who may not be the preferred clinician) were seeing each other more frequently?). Unfortunately, none of the current and readily available measures of relationship continuity are absolutely ideal: all have their strengths and limitations. Our pragmatic choice was determined by needing to meet the study's aims and by what was available at practice population level.

### **IMD**



The Index of Multiple Deprivation (IMD), last updated in 2019, combines “baskets” of indicators from seven domains (income, employment, education, skills and training, health and disability, crime, barriers to housing and services, and living environment), then combined according to their respective weights to produce an overall relative measure. IMD is produced for 32,844 small areas (Lower-layer Super Output Areas) in England, with an average population of 1,500 (reference 40). Practice IMD scores were obtained from Profiles (reference 35); these were estimated by taking a weighted average of the IMD scores for each small area in which a given practice had registered patients.

### **NHS Regions**

NHS England has organized England into seven regions:

1. East of England
2. London
3. Midlands
4. North East and Yorkshire
5. North West
6. South East
7. South West

Each regional team is responsible for the quality, financial and operational performance of all NHS organisations in its region and is backed by NHS England’s corporate teams. Regional teams have also supported the development of integrated care systems (ICS).

### **NHS Primary Care Contracts**

It is compulsory for every individual GP or partnership of GPs running an NHS-commissioned general practice to hold an NHS GP contract. Contracts set out:

1. Mandatory requirements and services for all general practices, and
1. Provisions for several types of other services that practices may additionally and optionally provide.

NHS commissioners in England use three different types of GP contract arrangements:

- 1 General Medical Services (GMS) is the national standard GP contract. It is negotiated annually between NHS England and the General Practice Committee of the British Medical Association, which represents GPs in England. Commissioners (national or local) then use it to contract local general practices in an area.
- 2 Personal Medical Services (PMS) is another form of core contract. Unlike the GMS contract, it is negotiated locally between local commissioners or NHS England and general practices. PMS is more flexible than GMS, enabling requirements to be tailored to local needs while keeping within national guidelines and legislation. However, the PMS contract is being phased out.
- 3 Alternative Provider Medical Services (APMS) offer even greater flexibility by allowing contracts with organizations (such as private companies or third sector providers) other than general practitioners/partnerships of GPs to provide primary care services, and by allowing the commissioning of other types of primary care services. An example would be a social enterprise contracted to provide primary health care to homeless people or asylum seekers. Very few practices in England hold an APMS contract.

(Reference 45)

The NHS financial year runs from April 1 to March 31 in the following year. In our analyses, the numeric variable payments, whose data were collected over the financial year period, were assigned to the latter year.

### **GPPS response rates**

Data published by the General Practice Patient Survey (GPPS) was used for the following variables in the model: continuity, region, ethnicity, and % seen same day (see Methods). The national averages for response rates to the GPPS ranged between 23.7% and 29.1% in 2018-2022:

- 2018: 27.4%
- 2019: 23.7%
- 2020: 28.6%
- 2021: 28.7%
- 2022: 29.1%

Response rates can vary, depending on factors such as practice location, patient demographics, and survey methodology. Low response rates increase the risk of non-response bias. However:

- The GPPS has developed sophisticated weighting strategies for producing results, using practice population characteristics such as age and ethnicity, to reduce non-response bias (see NHS England. General Practice Patient Survey. Surveys, reports and materials. Online: <https://www.gp-patient.co.uk/surveysandreports> - and click on technical annex section 6.5 for a detailed discussion of the weighting strategy).
- Published independent studies have assessed the validity and reliability of the GPPS' output. These studies did not uncover any serious problems (references 28,46-48).
- GPPS data have been used in previous studies (references 20,25,27).
- A study compared continuity levels as measured by UPCI and GPPS (one question - %frequency of seeing preferred GP) and found these to correlate well (reference 28).
- Whatever measure of continuity is used, all UK studies are consistent in showing a persistent decline across all types of general practices.

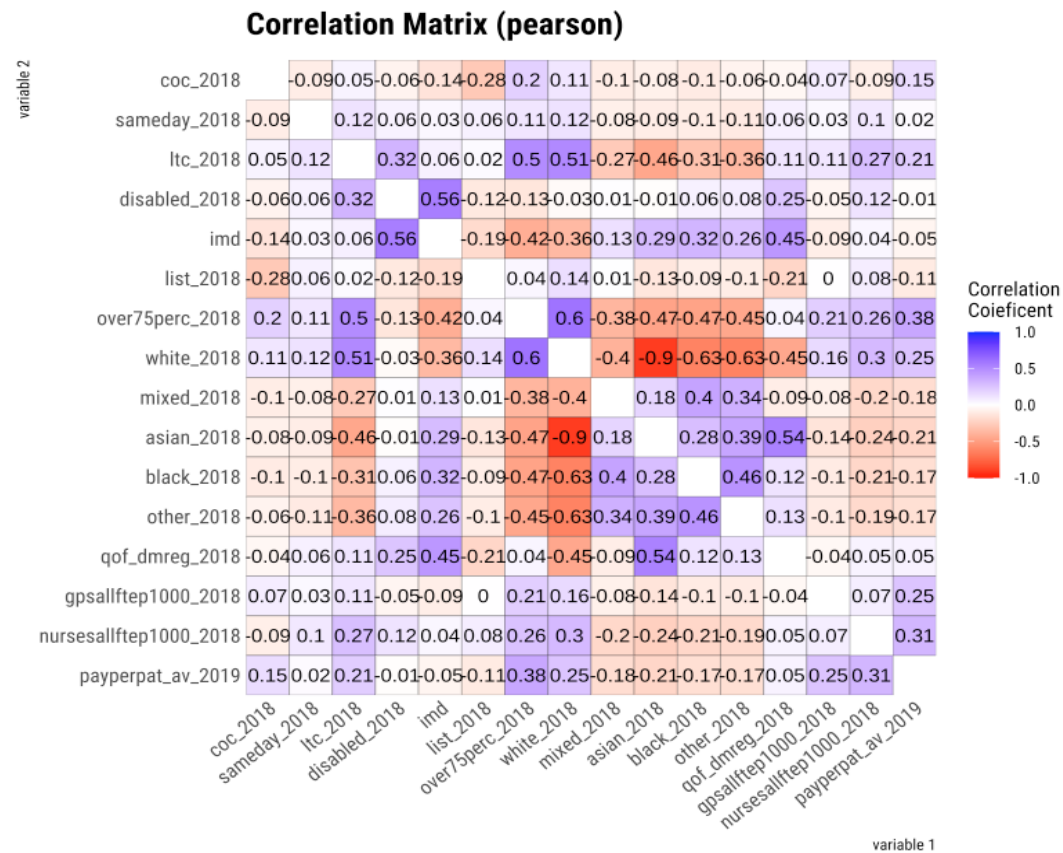
### Supplemental Figures 3-7 Correlation matrices for 2018-2022

To reduce the risk of multicollinearity, we checked for correlations between all potential independent variables prior to fitting our model. Where the correlation coefficient was  $>0.40$ , we excluded one of the pair of variables, based on conceptual importance and whether other strong correlations with other independent variables were present (see Methods).

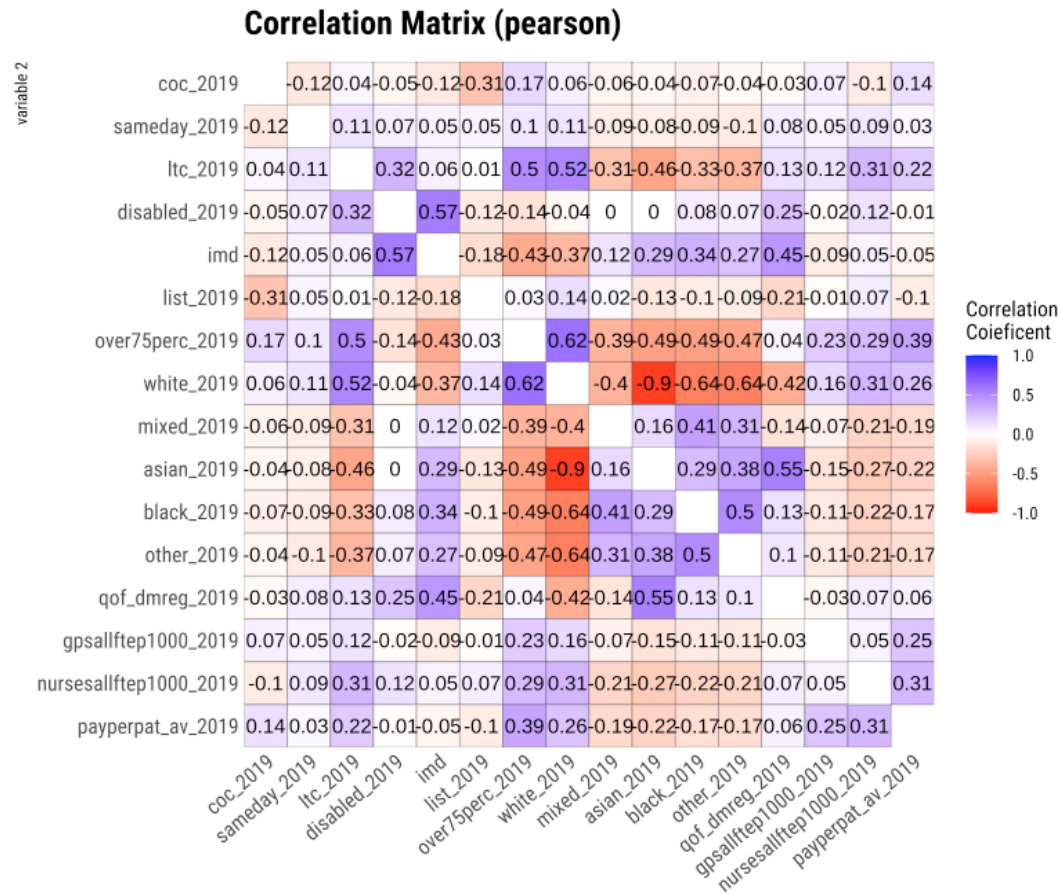
#### Abbreviations of variable names

coc	continuity of care (%)
sameday	booked and seen on same day (%)
ltc	self-reported with long term condition (%)
disabled	self-reported registered as disabled (%)
imd	deprivation
list	number of patients registered in a general practice
over75perc	patients registered in a practice aged 75 or more (%)
white	registered patients with White ethnicity (%)
mixed	registered patients with mixed ethnicity (%)
asian	registered patients with Asian ethnicity (%)
black	registered patients with Black ethnicity (%)
other	registered patients with Other ethnicity (%)
qof_dmreg	registered patients aged 16 or more on a practice diabetes register (%)
gpsallftep1000	number of FTE GPs (all types) per 1000 patients
nursesallftep1000	number of FTE nurses (all types) per 1000 patients
payperpat_av	average NHS payments per registered patient

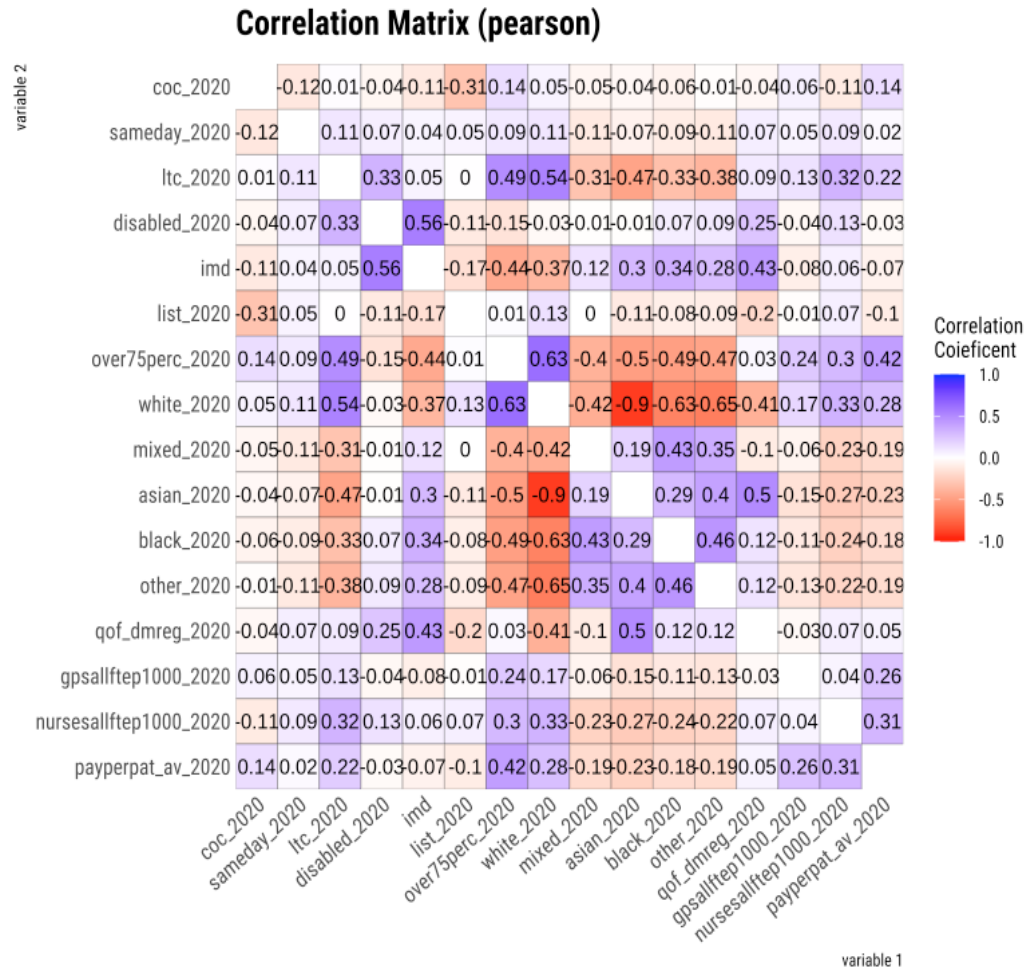
2018



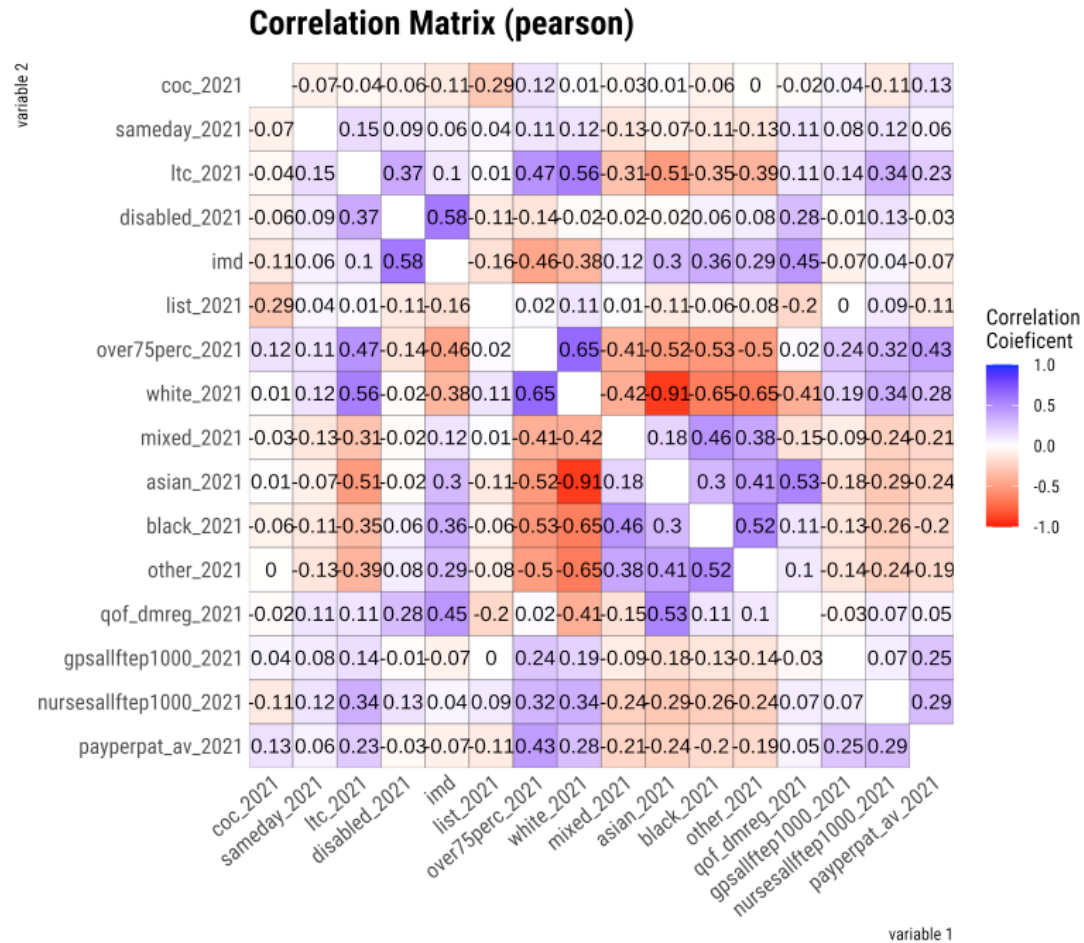
2019



2020

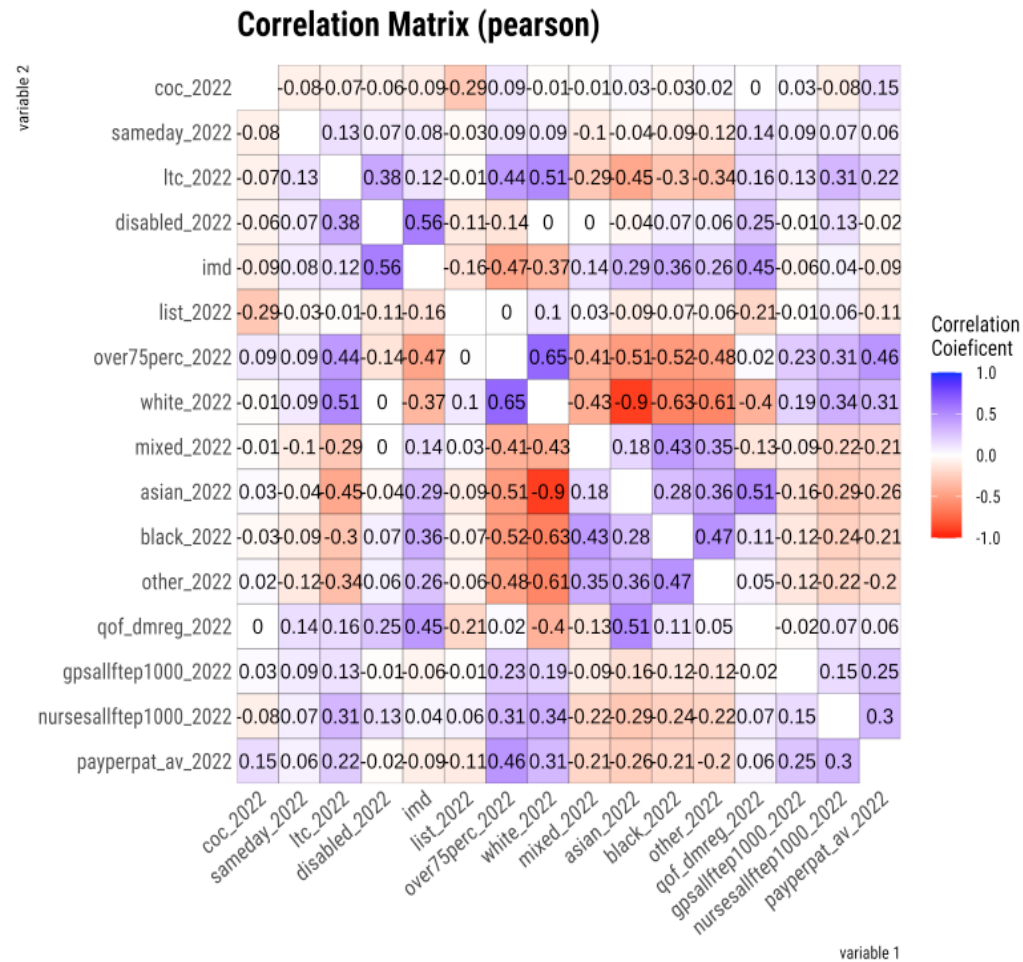


2021





2022



### **The coefficient of variation (CV)**

(used in Figure 3)

We wanted to examine longitudinal trends in the variability of our outcome, LCoC. The coefficient of variation (CV), expressed as a percentage, is a valuable tool, if used with normally distributed variables and if interpreted judiciously. Higher CV values, indicating a relatively greater standard deviation value compared against the mean value, represent relatively wider variations of measured variables' distributions. The

CV has been used in epidemiological and healthcare research to explore the variability of factors such as disease prevalence, treatment response, and biomarker levels.

The following statistical textbooks describe CV in more detail:

- Spiegel MR, Schiller JJ, Srinivasan. Fundamentals of Statistics. New York: McGraw-Hill 2012.
- Devore JJ, Berk RG. Modern Mathematical Statistics with Applications (2nd edition). New York; Springer 2012.
- Shechtman O. The Coefficient of Variation as an Index of Measurement Reliability. In: S., Williams, G. (eds) Methods of Clinical Epidemiology. Springer Series on Epidemiology and Public Health. Berlin :Springer, 2013. [https://doi.org/10.1007/978-3-642-37131-8\\_4](https://doi.org/10.1007/978-3-642-37131-8_4)

We have used CV in our previous longitudinal study of continuity (reference 25).

**Supplemental Table 6 Cross-sectional multivariate robust regression models 2018-2022, with %LCoC as the dependent variable**

Predictors	%LCoC 2018			%LCoC 2019			%LCoC 2020			%LCoC 2021			%LCoC 2022		
	Estimates	95% CI	p	Estimates	95% CI	p	Estimates	95% CI	p	Estimates	95% CI	p	Estimates	95% CI	p
(Intercept)	28.62	25.21 – 32.03	<0.001	30.33	26.84 – 33.82	<0.001	30.23	27.02 – 33.45	<0.001	24.77	21.70 – 27.84	<0.001	23.20	20.67 – 25.73	<0.001
Deprivation (IMD)	-0.13	-0.17 – -0.09	<0.001	-0.12	-0.15 – -0.08	<0.001	-0.12	-0.16 – -0.08	<0.001	-0.12	-0.16 – -0.09	<0.001	-0.10	-0.13 – -0.07	<0.001
<i>London = reference region</i>															
South West	5.26	3.62 – 6.89	<0.001	5.35	3.71 – 6.99	<0.001	4.76	3.19 – 6.33	<0.001	3.53	2.03 – 5.03	<0.001	2.88	1.56 – 4.21	<0.001
South East	2.95	1.53 – 4.36	<0.001	3.21	1.76 – 4.66	<0.001	2.80	1.36 – 4.23	<0.001	2.25	0.91 – 3.58	0.001	0.78	-0.36 – 1.93	0.180
Midlands	-0.00	-1.22 – 1.22	1.000	0.23	-1.00 – 1.46	0.718	0.43	-0.76 – 1.62	0.482	-0.45	-1.58 – 0.67	0.430	-0.94	-1.95 – 0.06	0.065
East of England	0.32	-1.15 – 1.79	0.667	-0.45	-1.91 – 1.01	0.547	-0.02	-1.41 – 1.37	0.982	-1.00	-2.31 – 0.31	0.135	-1.37	-2.50 – -0.24	0.018
NorthWest	1.46	0.07 – 2.85	0.039	2.19	0.80 – 3.59	0.002	1.93	0.54 – 3.31	0.006	1.65	0.35 – 2.94	0.013	0.11	-1.00 – 1.22	0.843
North East and Yorkshire	0.42	-0.98 – 1.82	0.558	0.62	-0.76 – 2.00	0.382	1.01	-0.31 – 2.33	0.133	0.25	-0.99 – 1.49	0.695	0.05	-1.03 – 1.13	0.934
<i>Rural = reference location</i>															
Urban location	-2.82	-4.10 – -1.55	<0.001	-2.97	-4.27 – -1.68	<0.001	-2.46	-3.71 – -1.21	<0.001	-1.90	-3.11 – -0.70	0.002	-1.66	-2.68 – -0.64	0.001
% White ethnicity 2018	0.04	0.02 – 0.06	<0.001												
List size 2018	-0.00	-0.00 – -0.00	<0.001												
FTE GPs/1000 pats 2018	0.79	-0.63 – 2.21	0.278												
FTE nurses/1000 pats 2018	-12.39	-15.08 – -9.71	<0.001												
<i>Reference contract: APMS</i>															
contract 2019 [GMS]	10.01	8.09 – 11.92	<0.001	9.44	7.42 – 11.47	<0.001									
contract 2019 [PMS]	8.68	6.70 – 10.66	<0.001	8.02	5.92 – 10.13	<0.001									
NHS Pay per pat (£) 2019	0.03	0.02 – 0.04	<0.001	0.03	0.02 – 0.04	<0.001									

% booked & seen same day 2018	-0.08	-0.11 – -0.05	<0.001						
% White ethnicity 2019			0.01	-0.01 – 0.03	0.208				
List size 2019			-0.00	-0.00 – -0.00	<0.001				
FTE GPs/1000 pats 2019			0.33	-0.89 – 1.55	0.596				
FTE nurses/1000 pats 2019			-13.30	-16.06 – -10.54	<0.001				
% booked & seen same day 2019			-0.10	-0.13 – -0.08	<0.001				
% White ethnicity 2020				0.01	-0.01 – 0.03	0.518			
List size 2020				-0.00	-0.00 – -0.00	<0.001			
FTE GPs/1000 pats 2020				0.04	-1.23 – 1.30	0.955			
FTE nurses/1000 pats 2020				-13.71	-16.41 – -11.01	<0.001			
contract 2020 [GMS]				7.50	5.73 – 9.27	<0.001			
contract 2020 [PMS]				6.21	4.37 – 8.05	<0.001			
NHS Pay per pat (£) 2020				0.03	0.02 – 0.04	<0.001			
% booked & seen same day 2020				-0.11	-0.13 – -0.08	<0.001			
% White ethnicity 2021							-0.02	-0.04 – -0.01	0.008
List size 2021							-0.00	-0.00 – -0.00	<0.001
FTE GPs/1000 pats 2021							0.42	-0.74 – 1.59	0.477
FTE nurses/1000 pats 2021							-9.87	-12.51 – -7.23	<0.001
contract 2021 [GMS]							9.29	7.67 – 10.92	<0.001
contract 2021 [PMS]							8.35	6.65 – 10.06	<0.001
NHS Pay per pat (£) 2021							0.02	0.01 – 0.03	<0.001
% booked & seen same day 2021							-0.04	-0.07 – -0.02	0.001

% White ethnicity 2022						-0.05	-0.06 – -0.03	<0.001
List size 2022						-0.00	-0.00 – -0.00	<0.001
FTE GPs/1000 pats 2022						0.28	-0.72 – 1.27	0.585
FTE nurses/1000 pats 2022						-5.91	-7.84 – -3.98	<0.001
contract 2022 [GMS]						5.51	4.29 – 6.73	<0.001
contract 2022 [PMS]						5.05	3.75 – 6.35	<0.001
NHS Pay per pat (£) 2022						0.03	0.02 – 0.04	<0.001
% booked & seen same day 2022						-0.06	-0.08 – -0.04	<0.001
Observations	5556	5362	5414	5234	5771			
R <sup>2</sup> / R <sup>2</sup> adjusted	0.192 / 0.190	0.200 / 0.198	0.207 / 0.205	0.175 / 0.172	0.175 / 0.172			

**Supplemental Table 7** Full multilevel mixed effects model 2018-2022 – without and with time interactions

Dependent variable = %practice patients reporting LCoC (% with preferred GP x % able to see preferred GP)

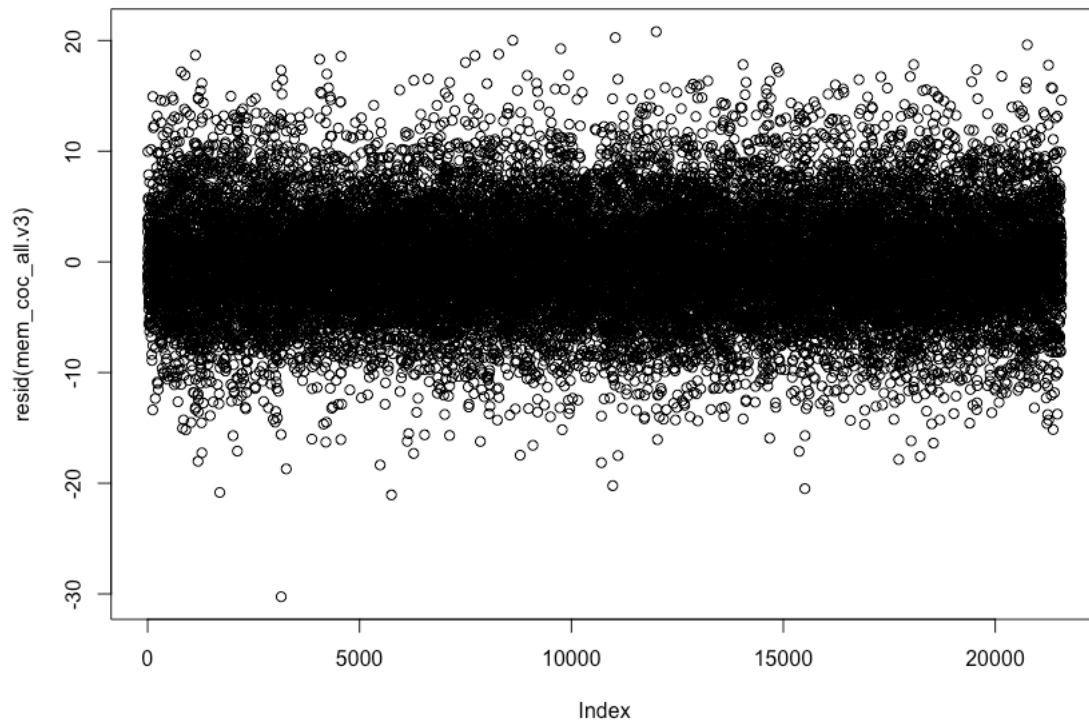
A positive coefficient indicated a slower rate of decline over time, whereas a negative coefficient indicated a faster rate of decline over time.

Predictors	Fixed effects			Interactions with time		
	Estimates	95% CI	p	Estimates	95% CI	p
(Intercept)	6.00	3.88 – 8.13	<b>&lt;0.001</b>			
Time Year	0.18	-0.32 – 0.68	0.484			
Baseline LCoC (2018)	0.99	0.97 – 1.01	<b>&lt;0.001</b>	-0.08	-0.09 – -0.07	<b>&lt;0.001</b>
IMD	-0.00009	-0.03 – 0.03	0.996	-0.007	-0.011 – 0.003	0.074
Reference region = London						
Region [South West]	1.31	-0.04 – 2.66	0.057	-0.26	-0.58 – 0.06	0.106
Region [South East]	1.54	0.36 – 2.72	<b>0.011</b>	-0.32	-0.60 – -0.04	<b>0.023</b>
Region [Midlands]	1.26	0.17 – 2.34	<b>0.023</b>	-0.59	-0.84 – -0.33	<b>&lt;0.001</b>
Region [East of England]	0.34	-0.92 – 1.61	0.594	-0.41	-0.70 – -0.11	<b>0.007</b>
Region [North West]	1.65	0.43 – 2.86	<b>0.008</b>	-0.57	-0.85 – -0.28	<b>&lt;0.001</b>
Region [North East and Yorks]	0.40	-0.79 – 1.60	0.508	-0.24	-0.52 – 0.05	0.102
Reference rurality = Urban						
Rurality [Rural]	0.31	-0.69 – 1.30	0.546	-0.01	-0.24 – 0.23	0.956
% White ethnicity	0.01	-0.009 – 0.03	0.110	-0.012	-0.014 – -0.010	<b>&lt;0.001</b>
list (thousands)	-0.21	-0.26 – -0.15	<b>&lt;0.001</b>	0.003	-0.01 – 0.02	0.684
GPs /1000 patients	-0.46	-1.55 – 0.63	0.404	0.38	0.11 – 0.65	<b>0.005</b>
Nurses /1000 patients	-3.89	-6.09 – -1.68	<b>0.001</b>	0.45	-0.10 – 0.99	0.109
Reference contract 2020= GMS						
APMS Contract 2020	-1.29	-3.54 – 0.96	0.262	0.25	-0.29 – 0.80	0.358
PMS Contract 2020	-0.59	-1.30 – 0.11	0.097	0.21	0.05 – 0.38	<b>0.011</b>
Pay/pat (£10s)	0.02	-0.05 – 0.10	0.559	0.01	-0.01 – 0.03	0.384
% seen same day	-0.01	-0.03 – 0.01	0.198	0.008	0.005 – 0.011	<b>0.003</b>
Random Effects						
$\sigma^2$	30.47					
$\tau_{00 \text{ practice.id}}$	32.17					
ICC	0.51					
$N_{\text{practice.id}}$	6010					

Observations	21565
Marginal $R^2$ / Conditional $R^2$	0.658 / 0.834

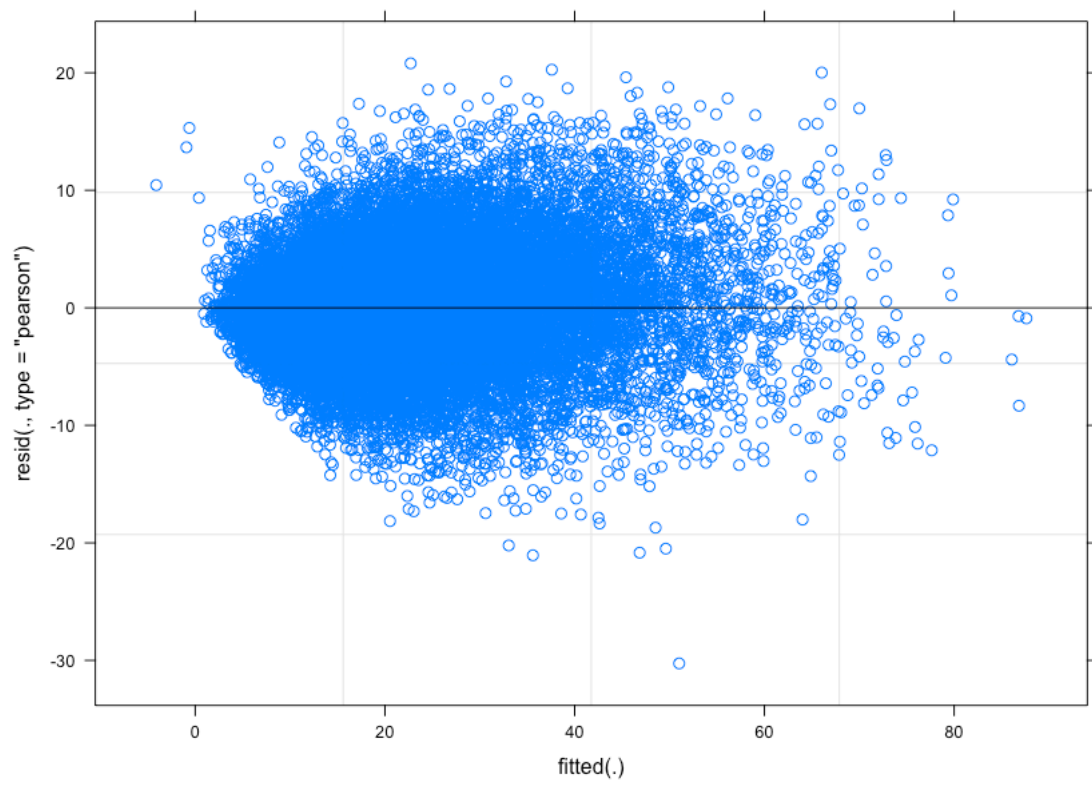
## Diagnostic checks

**Supplemental Figure 8** Testing linearity in the multilevel mixed effects model

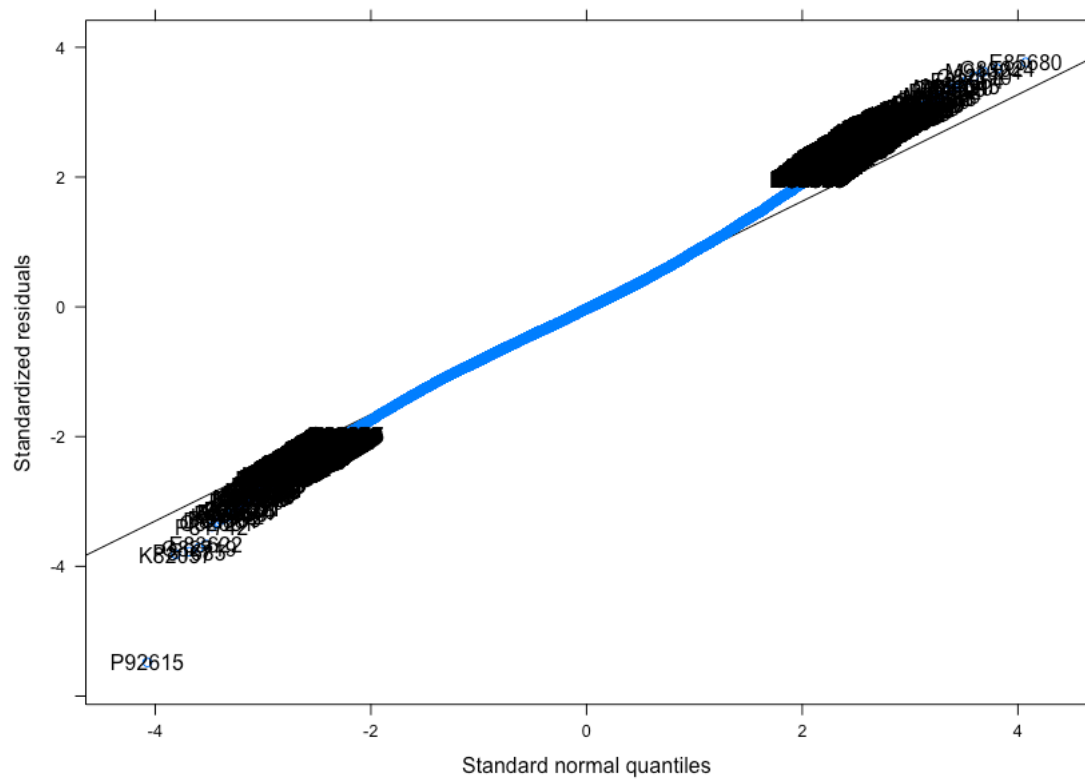




**Supplemental Figure 9** Homogeneity of variance in the multilevel mixed effects model



**Supplemental Figure 10** Distribution of standardized residuals in the multilevel mixed effects model\*



\*Assumption: The residuals of the model are normally distributed

**Supplemental Table 8** Estimated marginal effects of continuity with time interaction (model scale) averaged across independent variable levels\*, by year

<b>Year</b>	<b>Estimated mean change in continuity (model scale)<sup>1</sup></b>	<b>95% confidence intervals</b>
2018	-5475	-5881, -5069
2019	-5478	-5884, -5072
2020	-5481	-5887, -5074
2021	-5484	-5890, -5077
2022	-5486	-5893, -5080

<sup>1</sup>Negative values indicate a decline. Calculated using the “emmeans” package in R. The marginal effects values represent predicted values on the scale of the model and do **not** directly correspond to the actual continuity of care percentage values (0-100%).

\*Variable levels

<b>Independent numeric variable</b>	<b>Level<sup>1</sup></b>
Baseline % continuity (2018)	29.3
IMD	22.8
% White ethnicity	81.5
List size (1000s)	9.51
Av payments/patient (£10s)	16.2
FTE GPs/1,000	0.583
FTE nurses/1,000	0.262
%seen same day	33.2

<sup>1</sup>Results of the numeric variables’ levels were averaged over the 3 categorical variables’ levels (Region, Rurality, Contract type).

**Supplemental Table 9** Multicollinearity check

<b>Variable</b>	<b>Generalized Variance Inflation Factor = <math>VIF^{(1/(2 \cdot Df))}</math></b>
Continuity 2018	1.93
IMD	2.33
Region	1.90
Rurality	2.30
% White ethnicity	2.60
List (thousands)	2.20
GPs per 1000 patients	2.29
Nurses per 1000 patients	2.51
Contract 2020	1.88
Payperpat (£10s)	2.54
% Seen same day	2.40
Time_Year: continuity 2018	3.01
Time_Year: IMD	3.54
Time_Year: Region	2.05
Time_Year: Rurality	3.72
Time_Year: % White ethnicity	5.66
Time_Year: list (thousands)	2.95
Time_Year: GPs per1000	3.36
Time_Year: Nurses_per1000	3.30
Time_Year: Contract_2020	3.96
Time_Year: Payperpat (£10s)	5.43
Time_Year: % Seen same day	3.70