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The Positive Pharmacy Care Law Revisited: an area-level analysis of the relationship between community pharmacy distribution, urbanity and deprivation in England

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The Positive Pharmacy Care Law Revisited: an area-level analysis of the relationship between community pharmacy distribution, urbanity and deprivation in England

Eman Zied Abozied¹, Luke Munford², Alison Copeland³, Adetayo Kasim⁴, Andy Husband^{4,5}, Clare

Bambra^{1,5}, Adam Todd^{4,5*}

- Population Health Science Institute, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.
- Division of Population Health, Health Services Research and Primary Care, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom
- School of Geography, Politics and Sociology, Faculty of Humanities and Social Sciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
- 4. School of Pharmacy, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.
- 5. Newcastle NIHR Patient Safety Research Collaboration, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.

Keywords: Public Health, Pharmacies, Geographic Factors, Health Services, United Kingdom

ABSTRACT:

Objectives: (i) determine geographical access to community pharmacy in England, (ii) explore the relationship between community pharmacy access and urbanity and multiple deprivation, and (iii) understand any changes in access over time.

Design: an area level analysis study exploring the relationship between spatial access to and provision of community pharmacies over the past 10 years from 2014 to 2023, deprivation and urbanicity, using GIS and descriptive statistics on a Middle layer Super Output Area level.

Primary outcome measure: access to a community pharmacy within 20 minutes walking distance.

Results: for geographical access, in 2014, 91.3% of people lived within a 20-minute walk to a community pharmacy and, in 2023, this number increased to 91.7%. There was a positive relationship between geographical community pharmacy access and urbanity and geographical community pharmacy access and urbanity and geographical community pharmacy access and deprivation. For provision, the median number of community pharmacies per 10,000 people in 2014 was 1.60 while in 2023, the number reduced to 1.51 community pharmacies per 10,000 people. The sharpest decline in community pharmacy provision was observed in the most deprived areas.

Conclusions: there is high access to community pharmacies in England with access to a community pharmacy greatest in the most deprived areas, showing that the 'positive pharmacy care law' remains. However, the 'positive pharmacy care law' is eroding as the provision of community pharmacies has reduced over time – particularly in deprived areas, with more people reliant on each community pharmacy.

STRENGTHS AND LIMITATIONS OF THIS STUDY

 Community pharmacy access was conceptualised in two ways – geographical access and community pharmacy provision per 10,000 people, enabling insights into both geographical accessibility and population wide provision.

- Middle Super Output Areas instead of Lower Super Output Areas were used as the larger MSOAs are a better conceptual representation of a person's local area or town than an LSOA.
- Straight line distances were used from the population weighted centroid of the MSOA (where most people live) to the nearest pharmacy. A distance of 1.6km was considered a 20 minute walk. We acknowledge that just because a person lives within 20 minute walking distance (1 mile) of a community pharmacy does not mean they can walk the distance due to their own abilities and other factors.
- The pharmacies per 10,000 people measure uses the mid-year population estimate from 2014-2020. For the years 2021-2023, we used the 2020 population estimate since more recent data is not available. This may lead to the overestimation of the community pharmacies per 10,000 people for years post 2020 as the real population denominator may have increased.

BACKGROUND

Community pharmacies are an important component of healthcare systems around the world and deliver a range of public health and clinical services to the general public. Examples of such services include smoking cessation, emergency hormonal contraception, hypertension screening and 'flu' vaccination programmes.^{1,2} Recent policy developments have also seen the commissioning of clinical pharmacy services to manage various common conditions. For example, in England, through a 'Pharmacy First' scheme, community pharmacies are now able to treat seven common conditions following a defined clinical pathway.³ In 2014, we established that community pharmacies followed a 'positive pharmacy care law' whereby access to community pharmacies was greatest in the most deprived communities. This was in contrast to the well-established inverse care law whereby there is less medical care where there is highest need.⁴ In related analysis, we found that community pharmacies were more accessible than other primary care providers, including general practice.⁵

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Since our discovery of the 'positive pharmacy care law' ten years ago, there have been funding cuts across the sector that have led to community pharmacy closures – with some estimations suggesting that more than 1,000 community pharmacies in England have closed in this time.⁶ Given the changing landscape of the community pharmacy network, it is important to understand if the positive pharmacy care law is still in operation, as this could have implications for the commissioning of future services. This work, therefore, seeks to address this knowledge gap and aimed to (i) determine geographical access to community pharmacy in England, (ii) explore the relationship between community pharmacy access and urbanity and multiple deprivation, and (iii) understand any changes in access over time.

METHODS

Study design

This study explores the relationship between spatial access to and provision of community pharmacies over the past 10 years from 2014 to 2023, deprivation and urbanicity, using GIS and descriptive statistics on a Middle layer Super Output Area (MSOA level).

Definitions

<u>Community Pharmacy</u>: Registered with the General Pharmaceutical Council *as premises for the compounding, procurement, storage and distribution of medicines and appliances*. In this study we excluded "internet only" pharmacies and hospital pharmacies as they are not accessible by the general community.

<u>Middle layer Super Output Areas (MSOA)</u>: A geographical area defined by the Office for National Statistics which have a minimum size of 5,000 residents and 2,000 households with an average population size of 7,800. They fit within local authority boundaries and are generally analogous to a small town.⁷

<u>Urban/rural Classification</u>: an index of five main categories – major conurbation, minor conurbation, city and town, town and fringe, and rural villages and hamlets. Every settlement with a population

over 10,000 is urban and every settlement below that is rural. Settlements are further classified using their building and population density and surrounding setting.⁸

Index of Multiple Deprivation Quintile: The Index of Multiple Deprivation (IMD) is a measure of relative deprivation for small geographic areas of the UK. Each small area is ranked based on seven domains of deprivation (Income, Employment, Education, Health, Crime, Barriers to housing and services and Living environment. IMD is split into five quintiles based on relative disadvantage, with quintile 1 being the most deprived and quintile 5 being the least deprived.⁹

Outcome

We used two measures to assess a person's access to a community pharmacy:

1. Community pharmacy provision per 10,000 people (number of pharmacies in an MSOA*10000/population of the MSOA).

2. Community pharmacy access: Whether or not the straight-line distance is within a 20-minute walk from the population weighted centroid of the MSOA (where most people live)¹⁰ to the nearest pharmacy, approximately 1 mile or 1.6 km (1=yes, 0=no).

Data sources

We used the 2011 MSOA boundaries as a base map because the 2019 IMD is based on them. We used the Ordnance Survey (OS) Points of Interest (PoI) datasets to find the locations of community pharmacies, from September release of each year from 2014 to 2023. The data was downloaded from Edina Digimap using an Educational Use license. ^{11–20} Additional data were attached to the initial base map to enable statistical analysis. We used the IMD 2019 on MSOA level compiled by mySociety²¹ which also contains region of each MSOA. We also used the Rural Urban Classification (2011) of MSOAs in England from the Office for National Statistics.²² We used the Mid-year population estimates for 2014-2020 for MSOAs²³ to calculate the provision per 10,000 people measure. To calculate the distance to the nearest pharmacy, we used the population weighted centroid of each MSOA as an

 origin point, which corresponds to the co-ordinates where the majority of people live within the MSOA.²⁴

Geographical data workflow

Base map

The MSOA boundaries were linked to IMD, urban/rural classification, region and MSOA population estimate in QGIS using a spatial join by MSOA code.

Data cleaning

Initial investigations found a discrepancy between the number of registered pharmacies listed by the General Pharmaceutical Council and community pharmacies present in the OS dataset. The General Pharmaceutical Council is responsible for the regulation of pharmacists, pharmacy technicians and pharmacy premises in England, Scotland and Wales. In the OS dataset, we found an undercount of pharmacies from 2014-2019 then an overcount from 2020 onwards. The overcount was due to hospital pharmacies included in the OS dataset and classified as community pharmacies. The data was cleaned and filtered to remove online only pharmacies and hospital pharmacies and compared to the General Pharmaceutical Council registered pharmacy list to make sure the number of pharmacies OS data was not greater than the General Pharmaceutical Council list. The data cleaning procedure is expanded on in Supplementary Material.

Spatial analysis

Two spatial analyses were undertaken in QGIS²⁵ for each year of the dataset from 2014-2023:
1. The algorithm "count points in polygon" to find the number of pharmacies per MSOA.
2. Straight line distance from population weighted centroid to the nearest pharmacy
The results of these analyses were linked to the base map and exported from QGIS to Stata²⁶.

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Statistical analysis

Two measures were generated in Stata, the provision per 10,000 people and if there was a community pharmacy within a 20-minute walk. The number of community pharmacies in an MSOA was divided by the population of that MSOA to determine the provision per 10,000 people. The straight-line distance measure was used to create the "pharmacy within a 20-minute walk" variable. If the distance was less than 1.6 km (1 mile) then the variable was coded as yes.

Descriptive statistics were extracted for the outcomes provision per 10,000 people, distance to nearest pharmacy and if there was a pharmacy within 20-minute walk. The descriptive statistics were stratified by IMD and urban/rural classification.

Patient and public involvement

No patients or members of the public were involved in the study.

RESULTS

All England

Overall, the analysis showed that, in 2014, 91.3% of people lived within a 20-minute walk to a community pharmacy and, in 2023, this number increased to 91.7%, showing an increase of 0.4 percentage points. The areas in England with a community pharmacy within a 20-minute walk in 2023 is shown visually in Figure 1, alongside community pharmacy distribution by IMD and urban rural classification. The values for community pharmacy provision per 10,000 people and spatial accessibility from years 2014 to 2023 are shown in supplementary Tables 3 and 4. Across England, the median number of community pharmacies per 10,000 people in 2014 was 1.60 while in 2023, the number reduced to 1.51 community pharmacies per 10,000 people, showing an overall decline of 0.09 of community pharmacies per 10,000 (a reduction of community pharmacies per population by 5.6%). The provision of community pharmacies per 10,000 people over time is shown visually in Figure 1.

60

2017

2018

2019

2020

2021

2022

2023

Figure 1: People living within a 20-minute walk of a community pharmacy by Index of Multiple Deprivation and Urban Rural Classification (top) and Community pharmacy provision per 10,000 people over time from 2014-2023 (bottom)

Provision and access to community pharmacy by IMD quintile

There was a positive relationship between community pharmacy provision and deprivation – the more deprived an area, the higher the community pharmacy provision (Table 1 and Figure 2). In 2014, there were 2.28 pharmacies per 10,000 people in the 20% most deprived areas and 1.37 in the 20% least deprived areas. In 2023, this provision was reduced to 2.01 pharmacies per 10,000 people in the 20% most deprived areas and 1.33 in the 20% least deprived areas. Over the study period, community pharmacy provision reduced across all deprivation quintiles, with the sharpest decline in the 20% most deprived areas (-0.27/11.8%), which was around four times the decline of provision seen in the 20% least deprived areas (-0.04/3%). Accessibility of community pharmacy by spatial access showed that, in 2014, for the most deprived 20% areas, 99.8% of people could access a community pharmacy within a 20-minute walk, compared to 89.0% for the least deprived 20% areas. There was an observed Ushaped relationship between spatial access to a community pharmacy and deprivation whereby people living in the 3rd and 4th quintiles had 88.9% and 82.5% access, respectively. The percentages of people who could access a community pharmacy within a 20-minute walk has remained stable over time and by IMD quintile (Table 2 and Figure 3).

IMD 1 IMD 2 IMD 3 IMD 4 IMD Year _ most deprived Deprived 2014 2.28 1.75 1.59 1.44 2015 2.26 1.72 1.57 1.44 2016 2.23 1.69 1.56 1.44

Table 1: Community pharmacies per 10,000 persons by IMD quintile, median

2.17

2.07

2.2

2.07

2.08

2.07

2.01

1.68

1.67

1.69

1.64

1.65

1.64

1.59

1.55

1.55

1.58

1.55

1.54

1.55

1.51

5

1.43

1.42

1.45

1.43

1.43

1.43

1.41

Least

1.37

1.36

1.36

1.35

1.34

1.37

1.37

1.36

1.37

1.33

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Total	Change	-0.27 (11.8%)	-0.16 (9%)	-0.08 (5%)	-0.03 (2%)	-0.04 (3%)
(2014 to	o 2023)					

Figure 2: Community pharmacy provision per 10,000 people between 2014 and 2023 by IMD quintile

Table 2: Percentage of people with a community pharmacy in 1 mile walk [%] per year by IMD

Year	IMD 1 – most deprived		IMD 2		IMD 3		IMD 4		IMD 5 – Least Deprived	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
2014	99.8	0.2	96.2	3.8	88.9	11.1	82.5	17.5	89.0	11.0
2015	99.7	0.3	96.3	3.7	89.0	11.0	82.6	17.4	89.1	10.9
2016	99.7	0.3	96.2	3.8	89.0	11.0	82.6	17.4	89.1	10.9
2017	99.7	0.3	96.2	3.8	89.1	10.9	82.6	17.4	89.0	11.0
2018	99.7	0.3	96.5	3.5	89.1	10.9	82.6	17.4	89.1	10.9
2019	99.9	0.1	96.5	3.5	89.3	10.7	83.4	16.6	89.8	10.2
2020	99.9	0.1	96.5	3.5	89.3	10.7	83.8	16.2	89.8	10.2
2021	99.9	0.1	96.2	3.8	89.2	10.8	83.7	16.3	89.6	10.4
2022	99.9	0.1	96.3	3.7	89.2	10.8	83.9	16.1	89.7	10.3
2023	99.9	0.1	96.3	3.7	89.2	10.8	83.7	16.3	89.4	10.6

Figure 3: Community pharmacy accessibility within 20-minute walking distance between 2014 and 2023 by IMD quintile

Urban/rural provision and community pharmacy access

In major and minor urban conurbations, the median community pharmacy provision was 1.81 pharmacies per 10,000 people in 2014 and 1.66 per 10,000 people in 2023, showing a decline of 0.15 pharmacies per 10,000 people or a reduction by 8.2%. In cities and towns, and towns and fringe, the median pharmacy provisions were similar, starting at 1.66 and 1.64 in 2014 and reducing to 1.54 and 1.56, respectively, by 2024. In villages and hamlets, the median community pharmacy provision was zero, which can be interpreted as over 50% of areas classified as villages and hamlets have no pharmacy within the MSOA (Table 3). Considering spatial access to a community pharmacy, for urban conurbations, access remained constant over time: in 2014 the access was 99.6% for major and minor

urban conurbations and 98.2% for towns and cities, while in 2023, the access was 99.6% and 98.5% for major and minor urban conurbations and towns and cities, respectively. For towns and fringe, 81.7% of people had a community pharmacy within a 20-minute walk in 2014, which increased to 85.2% in 2023. In contrast, in 2014 only 28.3% of people in villages and hamlets had a community pharmacy within a 20-minute walk, which remained relatively constant over time to 2023 (Table 4 and Figure 4).

Year	Major Minor U Conurbat	and rban tions	Cities Towns	and	Town Fringe	and	Villages and Hamlets	
2014		1.81		1.66		1.64	C)
2015		1.78		1.64		1.64	C)
2016		1.76		1.62		1.63	C)
2017		1.73		1.63		1.62	C)
2018		1.70		1.59		1.59	C)
2019		1.79		1.62		1.62	C)
2020		1.70		1.59		1.57	C)
2021		1.70		1.58		1.57	C)
2022		1.70		1.59		1.57	C)
2023		1.66		1.54		1.56	C)
Total Change	-	0.15		-0.12	-	0.08	C)

Table 3: Community pharmacies per 10,000 persons by urban/rural category, median

Table 4: Percentage of people with a community pharmacy in 1 mile walk [%] per year by Urban/Rural

classification								
Year	Major aı Urban Conurbat	nd Minor tions	Cities and	Cities and Towns		d Fringe	Villages and Hamlets	
	Yes	No	Yes	No	Yes	No	Yes	No
2014	99.6	0.4	98.2	1.8	81.7	18.3	28.6	71.4
2015	99.6	0.4	98.3	1.7	82.4	17.6	28.1	71.9
2016	99.6	0.4	98.3	1.7	82.4	17.6	28.1	71.9
2017	99.6	0.4	98.2	1.8	82.7	17.3	28.3	71.7
2018	99.6	0.4	98.1	1.9	82.9	17.1	28.4	71.6
2019	99.7	0.3	98.6	1.4	85.4	14.6	27.9	72.1
2020	99.7	0.3	98.6	1.4	85.4	14.6	28.6	71.4
2021	99.7	0.3	98.6	1.4	84.5	15.5	28.3	71.7
2022	99.7	0.3	98.6	1.4	85.0	15.0	28.3	71.7
2023	99.6	0.4	98.5	1.5	85.2	14.8	28.3	71.7

Figure 4: Percentage of people with a pharmacy within a 20-minute walk between 2014 and 2023 by Urban/Rural classification

There is a positive relationship between urbanicity and deprivation, whereby as urbanicity increases deprivation also increases (supplementary Table 2). Overall, deprived areas have higher provision of community pharmacies per 10,000 people and have greater spatial access to community pharmacies across all urban/rural classifications (supplementary Table 8). For example, in the most rural deprived areas, 50% of people have access to a community pharmacy within a 20-minute walk and there are 2.08 community pharmacies per 10,000 people. In the least deprived rural areas, only 32.2% of people have a community pharmacy within a 20-minute walk and there are within the MSOA.

DISCUSSION

 This paper identifies several important findings: firstly, there is high access to community pharmacies in all areas of England, with over 90% of the population living within a 20-minute walk of a community pharmacy; secondly, the 'positive pharmacy care law' still stands ten years on as there is greatest access to community pharmacies in the most deprived and urban areas; and thirdly, even though geographical access has remained constant, the reduction in the number of community pharmacies in England means that each community pharmacy serves a higher number of people with the greatest decline in provision in the most deprived areas (the 20% most deprived areas experienced a decrease from 2.28 pharmacies per 10,000 people in 2014 to 2.01 pharmacies per 10,000 people in 2023).

Policy Implications

The work shows that the 'positive pharmacy care law' is still in existence, although it appears to be eroding given the provision of community pharmacies has reduced – particularly in deprived areas

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where people more are reliant on each community pharmacy. Commissioning healthcare and public health services through community pharmacies still has scope to reach people in the greatest need. In view of this, the development of new community pharmacy services, particularly those designed to increase access to tackle inequalities in health outcomes, are warranted. Good examples in this regard are the current services of influenza and covid-19 vaccinations or services to promote early cancer detection through screening and direct referral interventions. ^{27,28}

There is now a greater reliance on community pharmacies per 10,000 population and this is greatest in deprived areas – this puts pressure onto services and staff. Indeed, due to the nature to the NHS Community Pharmacy Contractual Framework in England and the tiered levels of services, there is potential that there will be less capacity to provide the additional enhanced clinical services for community pharmacies located in the most deprived areas. For example, dispensing medication is considered a core 'essential' service that must be provided by all community pharmacies while other services, such as smoking cessation, vaccination and hypertension screening are additional services that can be offered by the community pharmacy, providing there is sufficient resource (staff to deliver the services and infrastructure to provide the services). Reviewing the NHS Community Pharmacy Contractual Framework in England to ensure there is not tension between delivering core essential services and enhanced clinical services appears to be warranted. Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

Community pharmacies have recently highlighted workforce challenges and staff shortages, which have been linked to a lack of funding.²⁹ Indeed, there has been debate about the challenges of community pharmacy funding, with the sector in England recently holding a national day of protest.³⁰ These disputes are also mirrored across Europe, with pharmacists in France recently holding a national strike day in relation to the challenges associated with funding.³¹ If the policy directives of allowing community pharmacies to deliver more clinical services to support other primary care organisations are to reach their full potential, it is important that appropriate funding arrangements are in place to achieve this.

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Strengths and weaknesses

In this study, we conceptualised access to a community pharmacy in two ways: firstly, the pharmacy provision in a person's "local area" and secondly, the distance to the closest pharmacy for most of the population. To facilitate this, there are some methodological changes from our original 2014 study around conceptualisation of "local area" and the distance calculation to the community pharmacy. For this work, we used Middle layer Super Output Areas (MSOAs) rather than Lower layer Super Output Areas (LSOAs) to represent a person's local area. We believe that the larger MSOAs are a better conceptual representation of a person's local area or town than an LSOA, so if a community pharmacy is no longer in their MSOA it means that access is more difficult since travelling to another MSOA may be perceived as leaving their local area. To find the percentage of the population that can access a pharmacy, the 2014 study used a catchment area approach by creating a 1.6 km buffer around each pharmacy and calculating the percentage of the population covered by the buffer. Instead, we used a distance approach from the population weighted centroid (usually located in the largest population centre) of the MSOA to the nearest pharmacy, and if the distance was less than 1.6 km, we concluded that the people of that MSOA have access to a community pharmacy within a 20 minute-walk. This approach is conceptually very similar but less computationally difficult than a catchment area approach. As in the 2014 paper, we used a straight-line distance to conceptualise spatial access since this approach is less computationally intensive than street network distance. While this may be acknowledged as a limitation, previous work has shown that added accuracy from using street network distance has been found to be insignificant in most cases.^{32,33} We also acknowledge that just because a person lives within 20 minute walking distance (1 mile) of a community pharmacy does not necessarily mean they can walk the distance; there could be a number of physical, mental and cultural factors that impact on an individual's walking ability.

The study also has some methodological limitations around data availability. The MSOA boundaries used in the analysis are from 2011 rather than the latest from 2021; this approach was used to enable

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the linkage of the latest IMD 2019 and 2011 urban-rural classification data. In addition, the pharmacy per 10,000 people measure uses the mid-year population estimate from 2014-2020. For the years 2021-2023, we used the 2020 population estimate since more recent data is not available. This may lead to the overestimation of the community pharmacies per 10,000 people for years post 2020 as the real population denominator may have increased.

Conclusion

There is high access to community pharmacies in England with access to a community pharmacy greatest in the most deprived areas, showing that the 'positive pharmacy care law' remains. However, the 'positive pharmacy care law' is eroding as the provision of community pharmacies has reduced over time – particularly in deprived areas, with more people reliant on each community pharmacy. Reinvestment in the community pharmacy network will help reduce inequalities in access to health care.

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Competing Interest Statement

None declared

CRediT author statement

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Eman Zied Abozied: Methodology, Formal analysis, Investigation, Data Curation, Writing - Original Draft

Luke Munford: Investigation, Methodology, Investigation, Writing - Original Draft

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Data sharing statement

All of the primary data sources used to compile the database for this study are referenced within the manuscript. We are unable to share licensed data, but open data are available from the corresponding author on reasonable request.

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Figure 2: Community pharmacy provision per 10,000 people between 2014 and 2023 by IMD quintile



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Figure 3: Community pharmacy accessibility within 20-minute walking distance between 2014 and 2023 by IMD quintile

431x193mm (130 x 130 DPI)





387x193mm (130 x 130 DPI)

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Supplementary material

Relationship between Deprivation and urbanicity

Code	Number	Classification
A1	2,399	Major and Minor Urban Conurbations
B1	249	
C1	2,938	City and Town
C2	13	City and Town in Sparse Setting
D1	588	Town and Fringe
D2	20	Town and Fringe in Sparse Setting
E1	539	Villages and Hamlets
E2	45	Villages and Hamlets in Sparse Setting

Supplemer	ntary Tabl	e 2: Rela	tionship	between	IM[) and	d Urban/	Rural Cla	ssificatio	n groups	i		
	IMD 1 deprive	– most d	2		3			4		5		Total	
	Ν	%	N	%	Ν		%	Ν	%	N	%		
A1/B1	795	58.5	664	48.9		499	36.7	342	25.2	348	25.6	2648	39.0
C1/C2	539	39.7	571	42.0		579	42.6	571	42.0	691	50.8	2951	43.5
D1/D2	22	1.6	68	5.0		115	8.5	198	14.6	205	15.1	608	9.0
E1/E2	2	0.1	55	4.1		165	12.2	247	18.2	115	8.5	584	8.6
Total	1358		1358		1	358		1358		1359		6791	

Descriptive Statistics for All of England:

Supplementary	/ Table 3: All of E	ngland Pharmacy provi	sion	
Year	Total # open	MSOAs with at least 1 pharmacy	Median pharmacies per 10,000 people	Median distance to pharmacy
2014	11776	5366	1.60	0.456
2015	11617	5369	1.59	0.454
2016	11453	5379	1.57	0.454
2017	11283	5386	1.56	0.454
2018	11249	5380	1.54	0.455
2019	11214	5451	1.58	0.447
2020	10749	5431	1.54	0.448
2021	10795	5427	1.54	0.452
2022	10749	5431	1.54	0.452
2023	10494	5388	1.51	0.454
Total Change	-1,282/- 10.8%	+22/+0.40%	-0.09/5.6%	+0.02

Supplementa Pharmacy in	iry Table 4: Percenta 1 mile walk in all of E	ge of people witr England
Year	[% (N)]	
	Yes	No
2014	91.3 (6200)	8.7 (59
2015	91.3 (6203)	8.7 (58
2016	91.3 (6203)	8.7 (58
2017	91.3 (6203)	8.7 (58
2018	91.3 (6203)	8.7 (58
2019	91.8 (6231)	8.2 (56
2020	91.8 (6236)	8.2 (55
2021	91.7 (6227)	8.3 (56
2022	91.8 (6234)	8.2 (55
2023	91.7 (6228)	8.3 (56

Provision by deprivation:

Supplementary Table 5: distance to nearest pharmacy from population centroid of MSOA in km by IMD quintile, median

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quintile) meala					
Year	IMD 1 - most deprived	IMD 2	IMD 3	IMD 4	IMD 5 – Least Deprived
2014	0.358	0.404	0.467	0.557	0.561
2015	0.357	0.404	0.464	0.558	0.561
2016	0.357	0.404	0.464	0.553	0.562
2017	0.358	0.406	0.462	0.552	0.558
2018	0.359	0.408	0.463	0.553	0.558
2019	0.356	0.398	0.459	0.558	0.548
2020	0.356	0.401	0.459	0.539	0.548
2021	0.362	0.403	0.460	0.549	0.550
2022	0.362	0.403	0.464	0.541	0.549
2023	0.365	0.403	0.463	0.551	0.553

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Provision by urban/rural classification:

Supplementary Table 6: dis MSOA in km by urban/rural	tance to neare category, med	est pharmacy f Jian	rom populatio	n centroid of
Year	A1/B1	C1/C2	D1/D2	E1/E2
2014	0.384	0.459	0.529	3.18
2015	0.384	0.455	0.524	3.21
2016	0.384	0.456	0.519	3.19
2017	0.384	0.457	0.516	3.18
2018	0.385	0.458	0.519	3.17
2019	0.378	0.453	0.505	3.16
2020	0.380	0.456	0.512	3.16
2021	0.379	0.457	0.511	3.15
2022	0.381	0.461	0.509	3.19
2023	0.379	0.454	0.507	3.15

Supplementary Tab	ole 7: Provision and a	ccess using 2 urban/r	ural categories inste	ad of 4
Year	Distance Urban (5599) (A-C)	Distance Rural (1192) (D-E)	Per 10000 Urban (5599) (A-C)	Per 10000 Rural (1192) (D-E)
2014	0.419	1.167	1.70	1.29
2015	0.418	1.163	1.68	1.28
2016	0.419	1.161	1.66	1.29
2017	0.419	1.138	1.66	1.29
2018	0.421	1.139	1.64	1.27
2019	0.413	1.083	1.67	1.29
2020	0.415	1.069	1.63	1.26
2021	0.418	1.083	1.64	1.26
2022	0.418	1.082	1.63	1.26
2023	0.422	1.082	1.59	1.26

Decade Snapshot 2023



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Supplementary	/ Table 8: % A	Access (within 1 mile walk) in	n 2023		
IMD Quintile	All	Major and Minor Urban	Cities and	Town and	Villages and
	England	Conurbations	Towns	Fringe	Hamlets
1 – most	99.9	100.0	99.8	100.0	50.0
deprived					
2	96.3	99.8	99.8	85.3	30.9
3	89.2	99.4	99.5	92.2	20.6
4	83.7	99.1	97.2	84.3	30.8
5 – least	89.4	99.1	96.7	80.5	32.2
deprived					
Median pharm	acies per 10,	000 in 2023			
IMD Quintile	All	Major and Minor Urban	Cities and	Town and	Villages and
	England	Conurbations	Towns	Fringe	Hamlets
1 – most	2.01	2.00	2.08	1.64	2.08
deprived					
2	1.59	1.61	1.66	1.88	1.00
3	1.51	1.61	1.63	1.92	0
4	1.41	1.60	1.43	1.53	0
5 – least	1.33	1.49	1.32	1.41	0
deprived					

Pharmacies Data Cleaning Supplement

The aim of this section is to outline the data investigation and cleaning procedure for the Ordnance Survey Points of Interest dataset¹ to harmonise it with the list of registered pharmacies by the General Pharmaceutical Service.²

The Ordnance Survey Dataset

This dataset covers the entire United Kingdom, so the first step was to filter the points of interest to those in England only. There were approximately 3 million points of interest per year in England. The points of interest are organised by a general category, for example, "Health and Education" then a further class name – in our case "Chemists and Pharmacies". Each point of interest also has its name, spatial co-ordinates, address and data source registered in the dataset. We used the data from September of each year 2014-2023.

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General Pharmaceutical Services

The General Pharmaceutical Services in England collects information about community pharmacy contractors and dispensing of prescription items. Pharmacy premises must be registered and reviewed every year, so the number of pharmacies in the dataset is the definitive number in England in each financial year. We excluded distance selling pharmacies since they are not necessarily physically accessible like a community pharmacy. The data is available for the financial year (April to April) from 2015/16 to 2022/23.

Supplementary Tab	ole 9: Comparia	son between th	ne Ordnance	Survey Datas	et and G	General
Pharmaceutical Serv	vices Dataset					
	Number of reg	gistered	Number of	pharmacies in	Differen	ce
	pharmacies in	GPS excluding	the OS Data	aset using	betweer	n OS
	distance sellin	g	"Chemists a	and	and GPS	
			Pharmacies	" Class Name		
Year		Year on year		Year on year	N	%
		change		change		
2014			10750		-	-
2015			10868		-	-
2016	11822		10858		-964	-8.2
2017	11586	-236	10843	-15	-743	-6.4
2018	11616	+30	10715	-128	-901	-7.8
2019	11511	-105	11238	+523	-273	-2.4
2020	11436	-75	11508	+270	72	0.6
2021	11264	-172	11205	-303	-59	-0.5
2022	11147	-117	11085	-120	-62	-0.6
2023	11016	-131	10804	-281	-212	-1.9

Table 1 illustrates the number of registered community pharmacies, and the number of pharmacies present in the OS dataset when using the "chemists and pharmacies" class name. We expected that there would be differences in the numbers in both datasets due to the difference in the data collection period (rolling financial year vs one snapshot in September). We also expected missing data in the OS dataset as they state that the dataset is not a complete record of all points of interest. While there is no absolute cut off, it is generally posited that around 5% missingness can be ignored in spatial datasets with minimal risk of bias.^{3,4}

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However, the issue here is not the overall percentage of missing data, rather the *pattern* of missingness and how it relates to the registered pharmacies in the GPS dataset. For the community pharmacies, there has been a steady decline since 2016 (barring a slight increase in 2018). In the Ordnance Survey dataset, there are an additional 523 and 270 pharmacies added in 2019 and 2020 respectively. There is also a significant undercount between 2016 and 2019 – the missing data percentage is inconsistent across years. More importantly, this does not reflect the year-on-year change as shown in the GPS dataset – there was no big increase of pharmacies between 2019 and 2022, rather the opposite.

We think there are two issues in the dataset:

- There is an undercount between 2016 2018 the pharmacies may be in the dataset but not under the "Chemists and Pharmacies" class name
- 2. Pharmacies were either added to the dataset or reclassified in 2019 this does not reflect an actual increase in pharmacies in reality.

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Data cleaning approach

The data cleaning and validation process has two main aims – firstly, to determine if there are pharmacies present in the dataset that are not counted, and to find the reason for the additional pharmacies from 2019 onwards. Once determined, the data cleaning process should be applied to each year's dataset for consistency, even if the missing data percentage is below 5%.

1. Finding the missing pharmacies in the dataset

Firstly, we investigated whether some pharmacies are present in the data but are misclassified (not under the "chemists and pharmacies" class name) using SQL filtering in QGIS.

"classname"='Chemists and Pharmacies' OR "name" ILIKE '%pharmacy%' OR "name" ILIKE

'%chemist%'

This code selects everything that is within the class name 'Chemists and Pharmacies' or which has

pharmacy or chemist in the name of the point of interest. In 2016 this returned 12055 records, almost

Asda Instore Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Phakeys Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Radford Road Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Total Health Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services

2000 additional records. On closer inspection, we find that some pharmacies are misclassified – for

example here as 'Parenting and Childcare Services'

We also find that some points of interest are clearly not community pharmacies, despite having pharmacy or chemist in the name:

Some of the points are duplicated in address or co-ordinates – or one premises has two functions (e.g., a pharmacy onsite and a cosmetics store) so has two entries

5	Superdrug Pharmacy	05280364	Education and Health	Health Practitioners and Establishments	Chemists and Pharmacies	430328.70000000001	433539.2999999999
3	Superdrug Pharmacy	09480677	Retail	Household, Office, Leisure and Garden	Cosmetics, Toiletries, Perfumes and Hairdressing Supplies	430324.00000000000	433530.0000000000

Data Cleaning

After selecting everything that might be a pharmacy, we manually filtered the results to remove

Mid Sussex Maths & Chemistry Tutoring	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Chemistry	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Chemistry Lessons London	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Professional Maths & Chemistry Tuition	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Inorganic Chemistry Laboratory, John B. Gooden	03200269	Attractions	Tourism	Unspecified and Other Attractions
Royal Society of Chemistrys Publishing Operation Blue Plaque	03200269	Attractions	Tourism	Unspecified and Other Attractions
John Beckwith, the Oldest Chemists Shop, Edmund Lawrence, and W. P. Lawrence Blue Plaque	03200269	Attractions	Tourism	Unspecified and Other Attractions
Vet Pharmacy	05260323	Education and Health	Animal Welfare	Veterinary Pharmacies
Vet-medic Pharmacy	05260323	Education and Health	Animal Welfare	Veterinary Pharmacies

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entries that were likely not a pharmacy, for example, bus stops, cafes, or schools. We also removed duplicate geometries and exact addresses. We kept pharmacies classified under "Ambulance and Medical Transportation Services", "Medical Equipment, Supplies and Pharmaceuticals" and "Cosmetics, Toiletries, Perfumes and Hairdressing Supplies" if there was Chemist/Pharmacy in the name.

Reasons for additional pharmacies from 2019 onwards 2.

As outlined in table 1, there was a large increase of pharmacies in 2019 and 2020 which was not reflected in the GPS registered pharmacies dataset. To address this, we reached out to the Ordnance Survey Points of Interest team about the discrepancy. They informed us that after a data respecification in 2019 onwards "additional NHS-run pharmacies which were found in hospitals and surgeries were added. This increased the number of chemist and pharmacies by around 600 records." Additionally, after the 2019 respecification, there was more attention paid to misclassification and duplicates. We took this feedback into account and found that there were indeed pharmacies in hospitals included in the dataset which were not present before 2020, which we removed for years 2020-2023. We also found very few duplicates and misclassifications in the data from 2020 onwards, compared to 2014.

Final Result

Final Result						
Supplementary Table 10) : Compariso	n between the (Ordnance Sur	rvey Dataset and	d General	
Pharmaceutical Services	Dataset afte	r data cleaning				
	Number of	registered	Number of	pharmacies in	Differen	ce
	pharmacies	in GPS	the OS Data	aset after	betweer	n OS
	excluding d	istance selling	cleaning an	d validation	and GPS	
Year		Year on year		Year on year	N	%
		change		change		
2014			11776		-	-
2015			11617		-	-
2016	11822		11453			
2017	11586	-236	11283	-170	-303	2.6%
2018	11616	+30	11249	-34	-367	3.1%
2019	11511	-105	11214	-35	-297	2.6%
2020	11436	-75	10749	-465	-687	6.0%
2021	11264	-172	10795	+46	-469	4.2%

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2022	11147	-117	10749	-46	-398	3.6%
2023	11016	-131	10494	-255	-522	4.7%
Total Change since						
2016	-806		-789			

The final count after cleaning has addressed both issues of the undercount/missing data before 2019 and the overcount after 2019. The missing data is now between 2.6-6% which is a more acceptable percentage and trend than +0.6 to -8.2% missingness. We believe this approach is robust as we dealt with the missing data in a systematic way year on year and we consulted with the Ordnance Survey on their treatment of the data. The year on year change and total change is now closer to the trend shown by the registered pharmacies in the GPS dataset.

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The Positive Pharmacy Care Law Revisited: an area-level analysis of the relationship between community pharmacy distribution, urbanity and deprivation in England

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Primary Subject Heading :	Public health
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The Positive Pharmacy Care Law Revisited: an area-level analysis of the relationship between community pharmacy distribution, urbanity and deprivation in England

Eman Zied Abozied¹, Luke Munford², Alison Copeland³, Adetayo Kasim^{4,6}, Andy Husband^{4,5}, Clare

Bambra^{1,5}, Adam Todd^{4,5}

- Population Health Science Institute, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.
- Division of Population Health, Health Services Research and Primary Care, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom and NIHR Applied Research Collaboration Greater Manchester (ARC-GM)
- School of Geography, Politics and Sociology, Faculty of Humanities and Social Sciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
- 4. School of Pharmacy, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.
- Newcastle NIHR Patient Safety Research Collaboration, Newcastle University, Newcastle upon Tyne, NE1 7RU United Kingdom.
- 6. Research Statistics, GlaxoSmithKline, London, United Kingdom.

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ABSTRACT:

Objectives: (i) determine geographical access to community pharmacy in England, (ii) explore the relationship between community pharmacy access and urbanity and multiple deprivation, and (iii) understand any changes in access over time.

Design: an area level spatial analysis study exploring the relationship between spatial access to and availability of community pharmacies over the past 10 years from 2014 to 2023, deprivation and urbanicity, using GIS and descriptive statistics on a Middle layer Super Output Area level.

Primary outcome measure: availability per 10,000 people of a community pharmacy in their local area. *Results:* for geographical access, in 2014, 91.3% of people lived within a 20-minute walk to a community pharmacy and, in 2023, this number increased to 91.7%. There was a positive relationship between geographical community pharmacy access and urbanity and geographical community pharmacy access and urbanity and geographical community pharmacy access and urbanity and geographical community pharmacy access and deprivation. For availability, the median number of community pharmacies per 10,000 people in 2014 was 1.60 while in 2023, the number reduced to 1.51 community pharmacies per 10,000 people. The most deprived areas were more likely to lose a pharmacy, compared to the least deprived areas (OR 1.65 [1.38, 1.98]).

Conclusions: there is high access to community pharmacies in England with access to a community pharmacy greatest in the most deprived areas, showing that the 'positive pharmacy care law' remains. However, the 'positive pharmacy care law' is eroding as the availability of community pharmacies has reduced over time – particularly in deprived areas, with more people reliant on each community pharmacy.

STRENGTHS AND LIMITATIONS OF THIS STUDY

 Community pharmacy access was conceptualised in two ways to enable insights into both geographical accessibility and population wide availability.

- Middle Super Output Areas were used as a better conceptual representation of a person's local area or town than a Lower Super Output Area
- We acknowledge the limitation that just because a person lives within 20-minute walking distance (1 mile) of a community pharmacy does not mean they can walk the distance due to their own abilities and other factors.
- Mid-year population estimates are not yet available after 2020, so this may lead to the overestimation of the community pharmacies per 10,000 people for years post 2020 as the real population denominator may have increased.

BACKGROUND

Community pharmacies are an important component of healthcare systems around the world and deliver a range of public health and clinical services to the general public. Examples of such services include smoking cessation, emergency hormonal contraception, hypertension screening and 'flu' vaccination programmes.^{1,2} Recent policy developments have also seen the commissioning of clinical pharmacy services to manage various common conditions. For example, in England, through a 'Pharmacy First' scheme, community pharmacies are now able to treat seven common conditions following a defined clinical pathway.³ In 2014, we established that, in England, community pharmacies followed a 'positive pharmacy care law'⁴ whereby the availability of community pharmacies was greatest in the most deprived communities (defined through area-level multiple deprivation). This was in contrast to the well-established 'inverse care law' for other health care services in England and internationally whereby there is less provision in the most deprived areas even though they have the highest health needs (i.e. a higher morbidity burden).⁵ In related analysis, we found that more people lived within a 20 minute walk to community pharmacies than other primary care providers, including general practice.⁶ The positive pharmacy care supported the idea of using community pharmacies as a way to promote health and wellbeing interventions to local communities.⁷

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Since our discovery of the 'positive pharmacy care law' ten years ago, there have been funding cuts across the sector that have led to community pharmacy closures – with some estimations suggesting that more than 1,000 community pharmacies in England have closed in this time.⁸ Given the changing landscape of the community pharmacy network, it is important to understand if the positive pharmacy care law is still in operation, as this could have implications for the commissioning of future services. This work, therefore, seeks to address this knowledge gap and aimed to (i) determine geographical access to community pharmacy in England, (ii) explore the relationship between community pharmacy access and urbanity and multiple deprivation, and (iii) understand any changes in access over time.

METHODS

Study design

This study explores the relationship between spatial access to and availability of community pharmacies over the past 10 years from 2014 to 2023, deprivation and urbanicity, using GIS and statistical analysis on a Middle layer Super Output Area (MSOA level).

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Definitions

<u>Community Pharmacy</u>: Registered with the General Pharmaceutical Council *as premises for the compounding, procurement, storage and distribution of medicines and appliances*. In this study we excluded "internet only" pharmacies and hospital pharmacies as they are not accessible by the general community.

<u>Middle layer Super Output Areas (MSOA)</u>: A geographical area defined by the Office for National Statistics which have a minimum size of 5,000 residents and 2,000 households with an average population size of 7,800. They fit within local authority boundaries and are generally analogous to a small town.⁹

<u>Urban/rural Classification</u>: an index of eight main categories – major conurbation, minor conurbation, city and town, town and fringe, and rural villages and hamlets which we consolidated to four

categories (Table S1). Every settlement with a population over 10,000 is urban and every settlement below that is rural. Settlements are further classified using their building and population density and surrounding setting.¹⁰

Index of Multiple Deprivation Quintile: The Index of Multiple Deprivation (IMD) is a measure of relative deprivation for small geographic areas of the UK. Each small area is ranked based on seven domains of deprivation (Income, Employment, Education, Health, Crime, Barriers to housing and services and Living environment). IMD is split into five quintiles based on relative disadvantage, with quintile 1 being the most deprived and quintile 5 being the least deprived.¹¹

Outcome

We used three measures to assess a person's access to a community pharmacy:

1. Community pharmacy availability per 10,000 people (number of pharmacies in an MSOA*10000/population of the MSOA).

2. Community pharmacy access: Whether or not the straight-line distance is within a 20-minute walk from the population weighted centroid of the MSOA (where most people live)¹² to the nearest pharmacy, approximately 1 mile or 1.6 km (1=yes, 0=no).

3. Community Pharmacy change over time: Whether or not a community has lost a pharmacy between 2023 and 2014 based on the availability measure. A negative value means there is a loss, which is then operationalised as a binary variable (0 = gain or no change, 1= loss)

Data sources

We used the 2011 MSOA boundaries as a base map because the 2019 IMD is based on them. We used the Ordnance Survey (OS) Points of Interest (PoI) datasets to find the locations of community pharmacies, from September release of each year from 2014 to 2023. The data was downloaded from Edina Digimap using an Educational Use license. ^{13–22} Additional data were attached to the initial base map to enable statistical analysis. We used the IMD 2019 on MSOA level compiled by mySociety²³

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which also contains region of each MSOA, the Rural Urban Classification (2011) of MSOAs in England from the Office for National Statistics.²⁴ and the Mid-year population estimates for 2014-2020 for MSOAs²⁵ to calculate the availability per 10,000 people measure. To calculate the distance to the nearest pharmacy, we used the population weighted centroid of each MSOA as an origin point, which corresponds to the co-ordinates where the majority of people live within the MSOA.²⁶ For the age and ethnicity structure at the first time point, we used data from the 2011 census from the NOMIS database.^{27, 28}

Geographical data workflow

Base map

The MSOA boundaries were linked to IMD, urban/rural classification, region and MSOA population estimate in Quantum Geographic Information System (QGIS) Software²⁹ using a spatial join by MSOA ID code.

Data cleaning

Initial investigations found a discrepancy between the number of registered pharmacies listed by the General Pharmaceutical Council and community pharmacies present in the OS dataset. The General Pharmaceutical Council is responsible for the regulation of pharmacists, pharmacy technicians and pharmacy premises in England, Scotland and Wales. In the OS dataset, we found an undercount of pharmacies from 2014-2019 then an overcount from 2020 onwards. The overcount was due to hospital pharmacies included in the OS dataset and classified as community pharmacies. The data was cleaned and filtered to remove online only pharmacies and hospital pharmacies and compared to the General Pharmaceutical Council registered pharmacy list to make sure the number of pharmacies OS data was not greater than the General Pharmaceutical Council list. The data cleaning procedure is expanded on in Supplementary Material Tables S7 and S8.

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Spatial analysis

Two spatial analyses were undertaken in QGIS for each year of the dataset from 2014-2023:

1. The algorithm "count points in polygon" to find the number of pharmacies (represented as points) within the MSOA boundary polygon.

2. Straight line distance from population weighted centroid (the area where most people live) to the nearest pharmacy

The results of these analyses were linked to the base map and exported from QGIS to Stata³⁰.

Statistical analysis

Two measures were generated in Stata, the availability per 10,000 people and if there was a community pharmacy within a 20-minute walk. The number of community pharmacies in an MSOA was divided by the population of that MSOA to determine the availability per 10,000 people. The population denominator changes year on year to reflect population dynamics. The straight-line distance measure was used to create the "pharmacy within a 20-minute walk" variable. If the distance was less than 1.6 km (1 mile) then the variable was coded as yes.

Descriptive statistics were extracted for the outcomes availability per 10,000 people, distance to nearest pharmacy and if there was a pharmacy within 20-minute walk. The descriptive statistics were stratified by IMD and urban/rural classification. All MSOAs had complete information on population, IMD and urban/rural classification, so no missing data treatment was needed.

Logistic regression was used to explore the association between the change over time in pharmacy availability and deprivation. We controlled for urban/rural classification, region, age structure (using median age) and ethnicity structure (proportion of people identifying as white).

Patient and public involvement

No patients or members of the public were involved in the study.

RESULTS

All England

Overall, the analysis showed that, in 2014, 91.3% of people lived within a 20-minute walk to a community pharmacy and, in 2023, this number is 91.7%, showing that this measure has remained stable. The areas in England with a community pharmacy within a 20-minute walk in 2023 is shown visually in Figure 1, alongside community pharmacy distribution by IMD and urban rural classification. The values for community pharmacy availability per 10,000 people and spatial accessibility from years 2014 to 2023 are shown in Tables S3 and S4. Across England, the median number of community pharmacies per 10,000 people in 2014 was 1.60 [1.57, 1.64] while in 2023, the number reduced to 1.51 [1.49, 1.54] community pharmacies per 10,000 people, showing an overall decline of 0.09 of community pharmacies per 10,000 (a reduction of community pharmacies per population by 5.6%). The availability of community pharmacies per 10,000 people over time is shown visually in Figure 2. **Figure 1:** People living within a 20-minute walk of a community pharmacy by Index of Multiple Deprivation and Urban Rural Classification (top) and Community pharmacy availability per 10,000 people over time from 2014-2023 (bottom)

Availability and access to community pharmacy by IMD quintile

There was a positive relationship between community pharmacy availability and deprivation – the more deprived an area, the higher the community pharmacy availability (Table 1 and Figure 2). In 2014, there were 2.28 [2.12, 2.39] pharmacies per 10,000 people in the 20% most deprived areas and 1.37 [1.34, 1.44] in the 20% least deprived areas. In 2023, this availability was reduced to 2.01 [1.87, 2.17] pharmacies per 10,000 people in the 20% most deprived areas and 1.33 [1.29, 1.38] in the 20% least deprived areas. Over the study period, community pharmacy availability reduced across all deprivation quintiles, with the sharpest decline in the 20% most deprived areas (-0.27/11.8%), which was around four times the decline of availability seen in the 20% least deprived areas (-0.04/3%). Accessibility of community pharmacy by spatial access showed that, in 2014, for the most deprived 20% areas, 99.8% of people could access a community pharmacy within a 20-minute walk, compared

to 89.0% for the least deprived 20% areas. There was an observed U-shaped relationship between spatial access to a community pharmacy and deprivation whereby people living in the 3rd and 4th quintiles had 88.9% and 82.5% access, respectively. The percentages of people who could access a community pharmacy within a 20-minute walk has remained stable over time and by IMD quintile (Table 2 and Figure 3).

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2014		2	.28	1.7	5	1.5	9	1.4	.4		1.37
2015		2	.26	1.72	2	1.5	7	1.4	4		1.36
2016		2	.23	1.69	9	1.5	6	1.4	4		1.36
.017		2	.17	1.6	8	1.5	5	1.4	3		1.35
018		2	.07	1.6	7	1.5	5	1.4	2		1.34
2019			2.2	1.69	9	1.5	8	1.4	5		1.37
2020		2	.07	1.64	4	1.5	5	1.4	3		1.37
2021		2	.08	1.6	5	1.5	4	1.4	3		1.36
2022		2	.07	1.64	4	1.5	5	1.4	3		1.37
2023		2	.01	1.5	9	1.5	1	1.4	1		1.33
⁻ otal Change 2014 to 2023)	-	0.27 (11.8	3%)	-0.16 (9%	5)	-0.08 (5%	6)	-0.03 (2%	6)	-0.04	(3%
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Year	IMD 1 deprive	– most d	IMD 2		IMD 3		IMD 4		IMD 5 – Least Deprived	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
2014	99.8	0.2	96.2	3.8	88.9	11.1	82.5	17.5	89.0	11.0
2015	99.7	0.3	96.3	3.7	89.0	11.0	82.6	17.4	89.1	10.9
2016	99.7	0.3	96.2	3.8	89.0	11.0	82.6	17.4	89.1	10.9
2017	99.7	0.3	96.2	3.8	89.1	10.9	82.6	17.4	89.0	11.0
2018	99.7	0.3	96.5	3.5	89.1	10.9	82.6	17.4	89.1	10.9
2019	99.9	0.1	96.5	3.5	89.3	10.7	83.4	16.6	89.8	10.2
2020	99.9	0.1	96.5	3.5	89.3	10.7	83.8	16.2	89.8	10.2
2021	99.9	0.1	96.2	3.8	89.2	10.8	83.7	16.3	89.6	10.4
2022	99.9	0.1	96.3	3.7	89.2	10.8	83.9	16.1	89.7	10.3
2023	99.9	0.1	96.3	3.7	89.2	10.8	83.7	16.3	89.4	10.6

Urban/rural availability and community pharmacy access

In major and minor urban conurbations, the median community pharmacy availability was 1.81 [1.70, 1.94] pharmacies per 10,000 people in 2014 and 1.66 [1.60, 1.74] per 10,000 people in 2023, showing a decline of 0.15 pharmacies per 10,000 people or a reduction by 8.2%. In cities and towns, and towns and fringe, the median pharmacy availabilities were similar, starting at 1.66 [1.61, 1.71] and 1.64 [1.54, 1.70] in 2014 and reducing to 1.54 [1.49, 1.58] and 1.56 [1.51, 1.62], respectively, by 2023. In villages and hamlets, the median community pharmacy availability was zero, which can be interpreted as over 50% of areas classified as villages and hamlets have no pharmacy within the MSOA (Table 3). Considering spatial access to a community pharmacy, for urban conurbations, access remained constant over time: in 2014 the access was 99.6% for major and minor urban conurbations and 98.2% for towns and cities, while in 2023, the access was 99.6% and 98.5% for major and minor urban conurbations and eties, respectively. For towns and fringe, 81.7% of people had a community pharmacy within a 20-minute walk in 2014, which increased to 85.2% in 2023. In contrast, in 2014 only 28.3% of people in villages and hamlets had a community pharmacy within a 20-minute walk, which remained relatively constant over time to 2023 (Table S5 and Figure 4).

Table 3: Community pharmacies per 10,000 persons by urban/rural category, median

Year	Major and Minor Urban Conurbations	Cities and Towns	Town and Fringe	Villages and Hamlets
2014	1.81	1.66	1.64	0
2015	1.78	1.64	1.64	0
2016	1.76	1.62	1.63	0
2017	1.73	1.63	1.62	0
2018	1.70	1.59	1.59	0
2019	1.79	1.62	1.62	0
2020	1.70	1.59	1.57	0
2021	1.70	1.58	1.57	0
2022	1.70	1.59	1.57	0
2023	1.66	1.54	1.56	0
Total Change	-0.15	-0.12	-0.08	0

Figure 4: Percentage of people with a pharmacy within a 20-minute walk between 2014 and 2023 by Urban/Rural classification

There is a positive relationship between urbanicity and deprivation, whereby as urbanicity increases deprivation also increases (Table S2). Overall, deprived areas have higher availability of community pharmacies per 10,000 people and have greater spatial access to community pharmacies across all urban/rural classifications (Table S6). For example, in the most rural deprived areas, 50% of people have access to a community pharmacy within a 20-minute walk and there are 2.08 community pharmacies per 10,000 people. In the least deprived rural areas, only 32.2% of people have a community pharmacy within a 20-minute walk and there are community pharmacies within the MSOA.

Change over time and the association with deprivation

 Table 4: Logistic regression showing unadjusted and adjusted odds ratios for the association between loss of a pharmacy and deprivation quintile

Change between 2014-2023	Odds Ratio	Std. err.	t	P>t	[95% CI]
Unadjusted					
IMD Quintile (relative to 5; least deprived quintile)					
4	1.06	0.08	0.77	0.44	[0.91, 1.23]
3	1.15	0.09	1.82	0.07	[0.99, 1.34]
2	1.40	0.11	4.33	0.00	[1.20, 1.63]
1 (most deprived)	1.79	0.14	7.40	0.00	[1.53, 2.08]
Adjusted					
IMD Quintile (relative to 5; least deprived quintile)					
4	1.11	0.09	1.31	0.19	[0.95, 1.29]
3	1.16	0.09	1.86	0.06	[0.99, 1.35]
2	1.31	0.11	3.27	0.00	[1.12, 1.54]
1 (most deprived)	1.65	0.15	5.45	0.00	[1.38, 1.98]
Urban/Rural (relative to Major and Minor Urban Conurbations)					
City and Town	1.03	0.06	0.48	0.63	[0.91, 1.17]
Town and Fringe	1.88	0.19	6.07	0.00	[1.53, 2.30]
Villages	0.63	0.07	-4.31	0.00	[0.51, 0.78]
Region (Relative to North)			2		
Midlands	1.25	0.09	2.91	0.00	[1.07, 1.45]
South	1.31	0.09	4.06	0.00	[1.15, 1.49]
Median Are	0.97	0.01	5 10	0.00	[0 06 0 09]
Proportion of	0.31	0.01	-3.10	0.00	[0.30, 0.30]

Table 4 shows the results of the logistic regression which explored the association between the loss of pharmacy availability per 10,000 people and area level deprivation. The model was adjusted for age structure, ethnicity structure, urban/rural classification and region.

Compared to the 20% least deprived areas, the 20% most deprived areas (IMD quintile 1) were more likely to lose a pharmacy (OR 1.65 [1.38, 1.98]). IMD quintile 2 were also more likely to lose a

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pharmacy (OR 1.31 [1.12, 1.54], compared to the least deprived quintile (IMD quintile 5). There was no effect in the less deprived quintiles (IMD quintiles 3 and 4). Sensitivity analysis (in Tables S9 and S10) shows that the results are robust to operationalising the outcome variable in a different way and using linear regression.

DISCUSSION

This paper identifies several important findings: firstly, there is high access to community pharmacies in all areas of England, with over 90% of the population living within a 20-minute walk of a community pharmacy; secondly, the 'positive pharmacy care law' still stands ten years on as there is greatest access to community pharmacies in the most deprived and urban areas; and thirdly, even though geographical access has remained constant, the reduction in the number of community pharmacies in England means that each community pharmacy serves a higher number of people with the greatest decline in availability in the most deprived areas. The 20% most deprived areas experienced a decrease from 2.28 pharmacies per 10,000 people in 2014 to 2.01 pharmacies per 10,000 people in 2023 and were more likely to lose a pharmacy (OR 1.65 [1.38, 1.98]) when compared to the least deprived areas.

Policy Implications

The work shows that the 'positive pharmacy care law' is still in existence, although it appears to be eroding given the availability of community pharmacies has reduced – particularly in deprived areas where more people are served by community pharmacies due to a lack of other healthcare options. Commissioning healthcare and public health services through community pharmacies still has scope to reach people in the greatest need due to having more community pharmacies in deprived areas. In view of this, the development of new community pharmacy services, particularly those designed to increase access to tackle inequalities in health outcomes, are warranted. Good examples in this regard are the current services of influenza and covid-19 vaccinations or services to promote early cancer detection through screening and direct referral interventions. ^{31,32}

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There is now a greater reliance on community pharmacies per 10,000 population and this is greatest in deprived areas – this puts pressure onto services and staff. Indeed, due to the nature to the NHS Community Pharmacy Contractual Framework in England and the tiered levels of services, there is potential that there will be less capacity to provide the additional enhanced clinical services for community pharmacies located in the most deprived areas. For example, dispensing medication is considered a core 'essential' service that must be provided by all community pharmacies while other services, such as smoking cessation, vaccination and hypertension screening are additional services that can be offered by the community pharmacy, providing there is sufficient resource (staff to deliver the services and infrastructure to provide the services). Reviewing the NHS Community Pharmacy Contractual Framework in England to ensure there is not tension between delivering core essential services and enhanced clinical services appears to be warranted.

Community pharmacies have recently highlighted workforce challenges and staff shortages, which have been linked to a lack of funding.³³ This lack of funding has also seen the closure of multiple community pharmacies in England. Indeed, there has been debate about the challenges of community pharmacy funding, with the sector in England recently holding a national day of protest.³⁴ These disputes are also mirrored across Europe, with pharmacists in France recently holding a national strike day in relation to the challenges associated with funding.³⁵ If the policy directives of allowing community pharmacies to deliver more clinical services to support other primary care organisations are to reach their full potential, it is important that appropriate funding arrangements are in place to achieve this.

Strengths and weaknesses

In this study, we conceptualised access to a community pharmacy in two ways: firstly, the pharmacy availability in a person's "local area" and secondly, the distance to the closest pharmacy for most of the population. To facilitate this, there are some methodological changes from our original 2014 study

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around conceptualisation of "local area" and the distance calculation to the community pharmacy. For this work, we used Middle layer Super Output Areas (MSOAs) rather than Lower layer Super Output Areas (LSOAs) to represent a person's local area. We believe that the larger MSOAs are a better conceptual representation of a person's local area or town than an LSOA, so if a community pharmacy is no longer in their MSOA it means that access is more difficult since travelling to another MSOA may be perceived as leaving their local area.

To find the percentage of the population that can access a pharmacy, the 2014 study used a catchment area approach by creating a 1.6 km buffer around each pharmacy and calculating the percentage of the population covered by the buffer. Instead, we used a distance approach from the population weighted centroid (usually located in the largest population centre) of the MSOA to the nearest pharmacy, and if the distance was less than 1.6 km, we concluded that the people of that MSOA have access to a community pharmacy within a 20 minute-walk. This approach is conceptually very similar but less computationally difficult than a catchment area approach. As in the 2014 paper, we used a straight-line distance to conceptualise spatial access since this approach is less computationally intensive than street network distance. While this may be acknowledged as a limitation, previous work has shown that added accuracy from using street network distance has been found to be insignificant in most cases.^{36,37}

The study also has some methodological limitations around data availability. The MSOA boundaries used in the analysis are from 2011 rather than the latest from 2021; this approach was used to enable the linkage of the latest IMD 2019 and 2011 urban-rural classification data. In addition, the pharmacy per 10,000 people measure uses the mid-year population estimate from 2014-2020. For the years 2021-2023, we used the 2020 population estimate since more recent data is not available. This may lead to the overestimation of the community pharmacies per 10,000 people for years post 2020 as the real population denominator may have increased.

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Due to being an area level study, we acknowledge the limitation that the findings may not be directly applicable to individuals with different ages, comorbidities and behaviours. We also acknowledge that just because a person lives within 20 minute walking distance (1 mile) of a community pharmacy does not necessarily mean they can walk the distance; there could be a number of physical, mental and cultural factors that impact on an individual's walking ability. However, the strength of area level findings is that they can be used to inform country-wide availability of pharmacies and highlight differences in geographic contexts, over and above individual capabilities.

Conclusion

There is high access to community pharmacies in England with access to a community pharmacy greatest in the most deprived areas, showing that the 'positive pharmacy care law' remains. However, the 'positive pharmacy care law' is eroding as the availability of community pharmacies has reduced over time – particularly in deprived areas, with more people reliant on each community pharmacy. Reinvestment in the community pharmacy network will help reduce inequalities in access to health care.

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Competing Interest Statement

None declared

CRediT author statement

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Data sharing statement

All of the primary data sources used to compile the database for this study are referenced within the manuscript. We are unable to share licensed data, but open data are available from the corresponding author on reasonable request.

Ethics Statement

This study did not involve human participants or personal data. Ethical review was not applicable.

Figure Legends

Figure 1: People living within a 20-minute walk of a community pharmacy by Index of Multiple Deprivation and Urban Rural Classification (top) and Community pharmacy availability per 10,000 people over time from 2014-2023 (bottom).

Legend: Map 1 (top left) shows People living within a 20-minute walk of a community pharmacy. Blue means Yes and light green means No. Map 2 (top middle) shows IMD quintile where blue is the most deprived and green is the least deprived. Map 3 (top right) shows urban/rural classification where blue is most urban, and green is most rural. The bottom maps show pharmacy provision per 10,000 people where the darker green means higher provision. From left to right is data from 2014, 2019 and 2023.

Figure 2: Community pharmacy availability per 10,000 people between 2014 and 2023 by IMD quintile

Legend: This figure shows a line graph with year on the x-axis and provision per 10,000 people on the y-axis. IMD 1 is dark grey solid line, IMD 2 is dark grey dotted line, IMD 3 is light grey solid line, IMD 4 is black solid line and IMD 5 is dark grey dashed line.

Figure 3: Community pharmacy accessibility within 20-minute walking distance between 2014 and 2023 by IMD quintile

Legend: This figure shows a line graph with year on the x-axis and percentage of people with access within 20-minute walking distance on the y-axis. IMD 1 is dark grey solid line, IMD 2 is dark grey dotted line, IMD 3 is light grey solid line, IMD 4 is black solid line and IMD 5 is dark grey dashed line.

Figure 4: Percentage of people with a pharmacy within a 20-minute walk between 2014 and 2023 by Urban/Rural classification

Legend: This figure shows a line graph with year on the x-axis and percentage of people with access within 20-minute walking distance on the y-axis. Urban Conurbations are light grey solid line, City and Town is light grey solid line, Town and Fringe is black solid line and Villages and Hamlets are light grey dashed line



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Page 22 of 34



Figure 2: Community pharmacy provision per 10,000 people between 2014 and 2023 by IMD quintile



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Figure 3: Community pharmacy accessibility within 20-minute walking distance between 2014 and 2023 by IMD quintile

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Figure 4: Percentage of people with a pharmacy within a 20-minute walk between 2014 and 2023 by Urban/Rural classification

387x220mm (130 x 130 DPI)

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Supplementary material

Relationship between Deprivation and urbanicity

Code	Number	Classification
A1	2,399	Major Urban Conurbations
B1	249	Minor Urban Conurbations
C1	2,938	City and Town
C2	13	City and Town in Sparse Setting
D1	588	Town and Fringe
D2	20	Town and Fringe in Sparse Setting
E1	539	Villages and Hamlets
E2	45	Villages and Hamlets in Sparse Setting

Supplement	entary Table 2: Relationship between IMD and Urban/Rural Classification groups												
	IMD 1 deprive	– most d	2		3		4		5		Total		
	Ν	%	Ν	%	N		%	Ν	%	Ν	%		
A1/B1	795	58.5	664	48.9	4	99	36.7	342	25.2	348	25.6	2648	39.0
C1/C2	539	39.7	571	42.0	5	579	42.6	571	42.0	691	50.8	2951	43.5
D1/D2	22	1.6	68	5.0	1	.15	8.5	198	14.6	205	15.1	608	9.0
E1/E2	2	0.1	55	4.1	1	.65	12.2	247	18.2	115	8.5	584	8.6
Total	1358		1358		13	58		1358		1359		6791	

Descriptive Statistics for All of England:

Supplementary	/ Table 3: All of E	ngland Pharmacy availa	ability	
Year	Total # open	MSOAs with at least 1 pharmacy	Median pharmacies per 10,000 people	Median distance to pharmacy
2014	11776	5366	1.60	0.456
2015	11617	5369	1.59	0.454
2016	11453	5379	1.57	0.454
2017	11283	5386	1.56	0.454
2018	11249	5380	1.54	0.455
2019	11214	5451	1.58	0.447
2020	10749	5431	1.54	0.448
2021	10795	5427	1.54	0.452
2022	10749	5431	1.54	0.452
2023	10494	5388	1.51	0.454
Total Change	-1,282/- 10.8%	+22/+0.40%	-0.09/5.6%	+0.02

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Supplementary Table 4: Percentage of people with a Pharmacy in 1 mile walk in all of England									
Year	[% (N)]								
	Yes	No							
2014	91.3 (6200)	8.7 (591)							
2015	91.3 (6203)	8.7 (588)							
2016	91.3 (6203)	8.7 (588)							
2017	91.3 (6203)	8.7 (588)							
2018	91.3 (6203)	8.7 (588)							
2019	91.8 (6231)	8.2 (560)							
2020	91.8 (6236)	8.2 (555)							
2021	91.7 (6227)	8.3 (564)							
2022	91.8 (6234)	8.2 (557)							
2023	91.7 (6228)	8.3 (563)							

Supplementary Table 5: percentage of population with a pharmacy in 20 minute walk by urban/rural classification

classification								
Year	Major a Urban Conurba	Major and Minor Urban Conurbations		d Towns	Town and	l Fringe	Villages Hamlets	and
	Yes	No	Yes	No	Yes	No	Yes	No
2014	99.6	0.4	98.2	1.8	81.7	18.3	28.6	71.4
2015	99.6	0.4	98.3	1.7	82.4	17.6	28.1	71.9
2016	99.6	0.4	98.3	1.7	82.4	17.6	28.1	71.9
2017	99.6	0.4	98.2	1.8	82.7	17.3	28.3	71.7
2018	99.6	0.4	98.1	1.9	82.9	17.1	28.4	71.6
2019	99.7	0.3	98.6	1.4	85.4	14.6	27.9	72.1
2020	99.7	0.3	98.6	1.4	85.4	14.6	28.6	71.4
2021	99.7	0.3	98.6	1.4	84.5	15.5	28.3	71.7
2022	99.7	0.3	98.6	1.4	85.0	15.0	28.3	71.7
2023	99.6	0.4	98.5	1.5	85.2	14.8	28.3	71.7

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Supplementary Table 6: % Access (within 1 mile walk) in 2023											
IMD Quintile	All England	Major and Minor Urban Conurbations	Cities and Towns	Town and Fringe	Villages and Hamlets						
1 – most deprived	99.9	100.0	99.8	100.0	50.0						
2	96.3	99.8	99.8	85.3	30.9						
3	89.2	99.4	99.5	92.2	20.6						
4	83.7	99.1	97.2	84.3	30.8						
5 – least deprived	89.4	99.1	96.7	80.5	32.2						
Median pharmacies per 10,000 in 2023											
Niculari priarri	lacies per 10,	000 111 2023									
IMD Quintile	All England	Major and Minor Urban Conurbations	Cities and Towns	Town and Fringe	Villages and Hamlets						
IMD Quintile	All England 2.01	Major and Minor Urban Conurbations 2.00	Cities and Towns 2.08	Town and Fringe 1.64	Villages and Hamlets 2.08						
IMD Quintile 1 – most deprived 2	All England 2.01 1.59	Major and Minor Urban Conurbations 2.00 1.61	Cities and Towns 2.08	Town and Fringe 1.64 1.88	Villages and Hamlets 2.08 1.00						
IMD Quintile 1 – most deprived 2 3	All England 2.01 1.59 1.51	Major and Minor Urban Conurbations 2.00 1.61 1.61	Cities and Towns 2.08 1.66 1.63	Town and Fringe 1.64 1.88 1.92	Villages and Hamlets 2.08 1.00 0						
IMD Quintile 1 – most deprived 2 3 4	All England 2.01 1.59 1.51 1.41	Major and Minor Urban Conurbations 2.00 1.61 1.61 1.60	Cities and Towns - 2.08 - 1.66 - 1.63 - 1.43 -	Town and Fringe 1.64 1.88 1.92 1.53	Villages and Hamlets 2.08 1.00 0 0						

Pharmacies Data Cleaning Supplement

The aim of this section is to outline the data investigation and cleaning procedure for the Ordnance Survey Points of Interest dataset¹ to harmonise it with the list of registered pharmacies by the General Pharmaceutical Service.²

The Ordnance Survey Dataset

This dataset covers the entire United Kingdom, so the first step was to filter the points of interest to those in England only. There were approximately 3 million points of interest per year in England. The points of interest are organised by a general category, for example, "Health and Education" then a further class name – in our case "Chemists and Pharmacies". Each point of interest also has its name, spatial co-ordinates, address and data source registered in the dataset. We used the data from September of each year 2014-2023.

General Pharmaceutical Services

The General Pharmaceutical Services in England collects information about community pharmacy contractors and dispensing of prescription items. Pharmacy premises must be registered and reviewed every year, so the number of pharmacies in the dataset is the definitive number in England in each financial year. We excluded distance selling pharmacies since they are not necessarily physically accessible like a community pharmacy. The data is available for the financial year (April to April) from 2015/16 to 2022/23.

Supplementary Table 7: Comparison between the Ordnance Survey Dataset and General										
Pharmaceutical Services Dataset										
	Number of reg	gistered	Number of	pharmacies in	Difference					
	pharmacies in	GPS excluding	the OS Data	aset using	between OS					
	distance sellin	g	"Chemists a	and	and GPS					
			Pharmacies	" Class Name						
Year		Year on year		Year on year	N	%				
		change		change						
2014			10750		-	-				
2015			10868		-	-				
2016	11822		10858		-964	-8.2				
2017	11586	-236	10843	-15	-743	-6.4				
2018	11616	+30	10715	-128	-901	-7.8				
2019	11511	-105	11238	+523	-273	-2.4				
2020	11436	-75	11508	+270	72	0.6				
2021	11264	-172	11205	-303	-59	-0.5				
2022	11147	-117	11085	-120	-62	-0.6				
2023	11016	-131	10804	-281	-212	-1.9				

Table 7 illustrates the number of registered community pharmacies, and the number of pharmacies present in the OS dataset when using the "chemists and pharmacies" class name. We expected that there would be differences in the numbers in both datasets due to the difference in the data collection period (rolling financial year vs one snapshot in September). We also expected missing data in the OS dataset as they state that the dataset is not a complete record of all points of interest. While there is no absolute cut off, it is generally posited that around 5% missingness can be ignored in spatial datasets with minimal risk of bias.^{3,4}

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However, the issue here is not the overall percentage of missing data, rather the *pattern* of missingness and how it relates to the registered pharmacies in the GPS dataset. For the community pharmacies, there has been a steady decline since 2016 (barring a slight increase in 2018). In the Ordnance Survey dataset, there are an additional 523 and 270 pharmacies added in 2019 and 2020 respectively. There is also a significant undercount between 2016 and 2019 – the missing data percentage is inconsistent across years. More importantly, this does not reflect the year-on-year change as shown in the GPS dataset – there was no big increase of pharmacies between 2019 and 2022, rather the opposite.

We think there are two issues in the dataset:

- There is an undercount between 2016 2018 the pharmacies may be in the dataset but not under the "Chemists and Pharmacies" class name
- 2. Pharmacies were either added to the dataset or reclassified in 2019 this does not reflect an actual increase in pharmacies in reality.

Data cleaning approach

The data cleaning and validation process has two main aims – firstly, to determine if there are pharmacies present in the dataset that are not counted, and to find the reason for the additional pharmacies from 2019 onwards. Once determined, the data cleaning process should be applied to each year's dataset for consistency, even if the missing data percentage is below 5%.

1. Finding the missing pharmacies in the dataset

Firstly, we investigated whether some pharmacies are present in the data but are misclassified (not under the "chemists and pharmacies" class name) using SQL filtering in QGIS.

"classname"='Chemists and Pharmacies' OR "name" ILIKE '%pharmacy%' OR "name" ILIKE

'%chemist%'

This code selects everything that is within the class name 'Chemists and Pharmacies' or which has

pharmacy or chemist in the name of the point of interest. In 2016 this returned 12055 records, almost

Asda Instore Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Burrows & Close Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Phakeys Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Radford Road Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
The Co Operative Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services
Total Health Pharmacy	05280809	Education and	Health Practitio	Parenting and Childcare Services

2000 additional records. On closer inspection, we find that some pharmacies are misclassified – for

example here as 'Parenting and Childcare Services'

We also find that some points of interest are clearly not community pharmacies, despite having pharmacy or chemist in the name:

Some of the points are duplicated in address or co-ordinates – or one premises has two functions (e.g., a pharmacy onsite and a cosmetics store) so has two entries

5 Superdrug Pharmacy	05280364	Education and Health	Health Practitioners and Establishments	Chemists and Pharmacies	430328.70000000001	433539.29999999998
8 Superdrug Pharmacy	09480677	Retail	Household, Office, Leisure and Garden	Cosmetics, Toiletries, Perfumes and Hairdressing Supplies	430324.00000000000	433530.00000000000

Data Cleaning

After selecting everything that might be a pharmacy, we manually filtered the results to remove

Mid Sussex Maths & Chemistry Tutoring	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Chemistry	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Chemistry Lessons London	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
Professional Maths & Chemistry Tuition	05320403	Education and Health	Recreational and Vocational Education	Training Providers and Centres
norganic Chemistry Laboratory, John B. Gooden	03200269	Attractions	Tourism	Unspecified and Other Attractions
Royal Society of Chemistrys Publishing Operation Blue Plaque	03200269	Attractions	Tourism	Unspecified and Other Attractions
John Beckwith, the Oldest Chemists Shop, Edmund Lawrence, and W. P. Lawrence Blue Plaque	03200269	Attractions	Tourism	Unspecified and Other Attractions
Vet Pharmacy	05260323	Education and Health	Animal Welfare	Veterinary Pharmacies
Vet-medic Pharmacy	05260323	Education and Health	Animal Welfare	Veterinary Pharmacies

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> entries that were likely not a pharmacy, for example, bus stops, cafes, or schools. We also removed duplicate geometries and exact addresses. We kept pharmacies classified under "Ambulance and Medical Transportation Services", "Medical Equipment, Supplies and Pharmaceuticals" and "Cosmetics, Toiletries, Perfumes and Hairdressing Supplies" if there was Chemist/Pharmacy in the name.

Reasons for additional pharmacies from 2019 onwards 2.

As outlined in table 7, there was a large increase of pharmacies in 2019 and 2020 which was not reflected in the GPS registered pharmacies dataset. To address this, we reached out to the Ordnance Survey Points of Interest team about the discrepancy. They informed us that after a data respecification in 2019 onwards "additional NHS-run pharmacies which were found in hospitals and surgeries were added. This increased the number of chemist and pharmacies by around 600 records." Additionally, after the 2019 respecification, there was more attention paid to misclassification and duplicates. We took this feedback into account and found that there were indeed pharmacies in hospitals included in the dataset which were not present before 2020, which we removed for years 2020-2023. We also found very few duplicates and misclassifications in the data from 2020 onwards, compared to 2014.

Final Result

Supplementary Table 8 : Comparison between the Ordnance Survey Dataset and General Pharmaceutical Services Dataset after data cleaning							
	Number of registered pharmacies in GPS excluding distance selling		Number of pharmacies in the OS Dataset after cleaning and validation		Difference between OS and GPS		
Year		Year on year		Year on year	N	%	
		change		change			
2014			11776		-	-	
2015			11617		-	-	
2016	11822		11453				
2017	11586	-236	11283	-170	-303	2.6%	
2018	11616	+30	11249	-34	-367	3.1%	
2019	11511	-105	11214	-35	-297	2.6%	
2020	11436	-75	10749	-465	-687	6.0%	
2021	11264	-172	10795	+46	-469	4.2%	

2022	11147	-117	10749	-46	-398	3.6%
2023	11016	-131	10494	-255	-522	4.7%
Total Change since						
2016	-806		-789			

The final count after cleaning shown in table 8 has addressed both issues of the undercount/missing data before 2019 and the overcount after 2019. The missing data is now between 2.6-6% which is a more acceptable percentage and trend than +0.6 to -8.2% missingness. We believe this approach is robust as we dealt with the missing data in a systematic way year on year and we consulted with the Ordnance Survey on their treatment of the data. The year on year change and total change is now closer to the trend shown by the registered pharmacies in the GPS dataset.

References

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 (2023).
- Butler, A. B., Kevin A. Best Practices for Dealing with Missing Data. *Esri* https://www.esri.com/about/newsroom/arcuser/dealing-with-missing-data/ (2019).
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Sensitivity Analysis

In these models, the outcome measure of availability per 10,000 people was operationalised as continuous for two time points instead of change over time - the difference between the two time points. Two linear models were estimated for 2014 and 2023 respectively. The models were adjusted for urban/rural classification, region, age structure and ethnicity structure.

Unadjusted:

Supplementary Table 9: Unadjusted Linear Models						
		014	2023			
IMD Quintile	Co-efficient	95% CI	Co-efficient	95% CI		
4	0.1	8 [0.03, 0.33]	0.11	[0.00, 0.23]		
3	0.4	4 [0.29, 0.59]	0.33	[0.22, 0.45]		
2	0.6	9 [0.54, 0.84]	0.49	[0.38, 0.61]		
1 (most deprived)	1.2	3 [1.08, 1.38]	0.94	[0.83, 1.06]		

Adjusted:										
Supplementary Table 10: Unadjusted Linear Models										
	201	L4	2023							
IMD Quintile	Co-efficient	95% CI	Co-efficient	95% CI						
4	0.30	[0.15, 0.45]	0.21	[0.10, 0.33]						
3	0.46	[0.31, 0.61]	0.36	[0.25, 0.48]						
2	0.56	[0.40, 0.71]	0.41	[0.29, 0.53]						
1 (most deprived)	1.00	[0.82, 1.17]	0.78	[0.65, 0.91]						
Urban/Rural										
City and Town	0.17	[0.05, 0.29]	0.05	[-0.04, 0.14]						
Town and Fringe	-0.05	[-0.24, 0.14]	0.03	[-0.11, 0.14]						
Villages	-1.19	[-1.39, -0.99]	-1.06	[-1.21, 0.14]						
Region										
Midlands	-0.17	[-0.31, -0.03]	-0.19	[-0.29, -0.08]						
South	-0.18	[-0.30, -0.06]	-0.24	[-0.33, -0.15]						
Median Age	0.00	[-0.01, 0.01]	0.01	[0.00, 0.02]						
Proportion of white										
people	-0.42	[-0.80, -0.04]	-0.56	[-0.85, -0.27]						

The adjusted model in Table 10 shows that in 2014, the 20% most deprived areas had the strongest relationship with number of pharmacies per 10,000 people (1.00 [0.82, 1.17]) when compared with the 20% least deprived areas. However, this relationship is weaker in 2023 (0.78 [0.65, 0.91]). The differences in coefficients in 2014 is 0.7 [0.67, 0.72], while in 2023 it is 0.57 [0.55, 0.59], indicating that the strong relationship between deprivation and number of pharmacies per 10,000 is eroding.

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