Predictors and population health outcomes of persistent high GP turnover in English general practices: a retrospective observational study

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Supplementary Material

We used a retrospective observational design using the GP workforce dataset; GP-by-practice data; Hospital Episodes Statistics (HES) data and General Practitioner Patient' Survey (GPPS) data between 2007-2019 and 2009-2017 in England. Practice characteristics and GPs' turnover were obtained from the GP workforce dataset linked to the GP-by-practice data *(GP membership-epracmem)* by practice code and each year. "HES and the GPPS were used to identify population health outcomes. It is noteworthy, information from these datasets was available only at aggregate level."

Text 1. Data sources

GP workforce dataset

NHS Digital regularly publishes workforce datasets which include information on individual GPs and practice level characteristics since 1995. These datasets are publicly available on the NHS Digital website.[1] This study used the annual datasets (September releases) between 2007 and 2020 and the files containing practice-level data containing all the information relative to a practice.[2]

Membership of practices

The GPs-by-general practice data *(GP membership-epracmem)*, available from the NHS Prescription Data Service (NHS RxS) and published by the NHS Organisation Data Service (ODS) contains information on dates when a GP joins and leaves a GP practice which enables the calculation of GP turnover across a specified time window. These datasets include information only on those GPs who have been allocated an individual prescribing number i.e. GP partners and salaried GPs. These data are published free of charge and capture information on GP membership to each practice from 1974 and are updated weekly on the NHS Technology Reference data Update Distribution (TRUD)[3] website. Data on GP membership of practices were extracted on the second week of November 2020. The GP workforce dataset and GPs-by-practice data were linked following the same process as in Parisi et al., (2021).

HES dataset

HES is an administrative record level dataset containing all publicly funded NHS hospital activity in England.[4] The data was primarily collected for commissioning purposes, where hospitals are reimbursed for the activity they provide. Data was extracted from the Accident and Emergency and the Admitted Patient Care (APC) data series between 2009/10 -2017/18 financial years, for HES APC data provider spells were constructed from the patient-episode level data. We obtain the number of non-elective admissions (where the HES APC variable "ADMIMETH" began with the value 2) and A&E attendances for patients registered at each GP practice in England. We had access to an already processed dataset where data were aggregated (specifically, A&E emergency attendances or admissions per 100 registered patients). During the study window 99.5% of practices were merged to HES data."

GPPS dataset

The GPPS is a biannual postal survey conducted on behalf of NHS England, which collects patients' views and experiences of the services provided by their practice.[5] We used the surveys published between 2009 and 2017.

Supplementary Figure 1: Proportion of practices with persistent high turnover by year
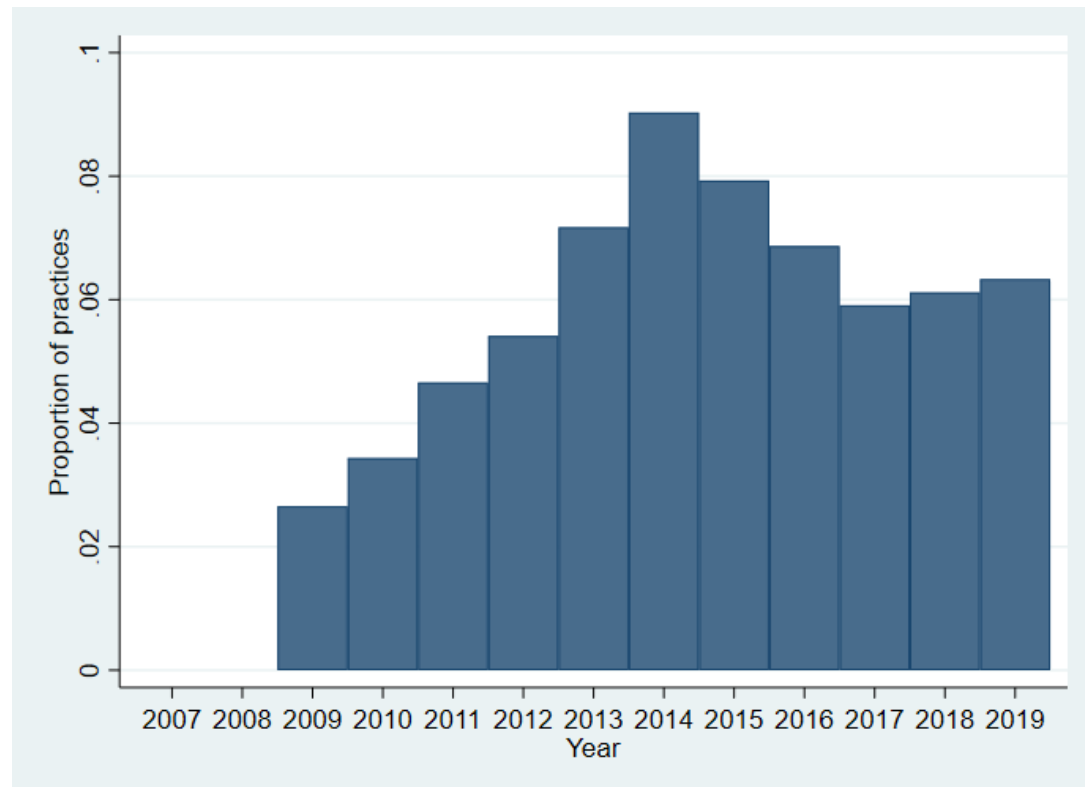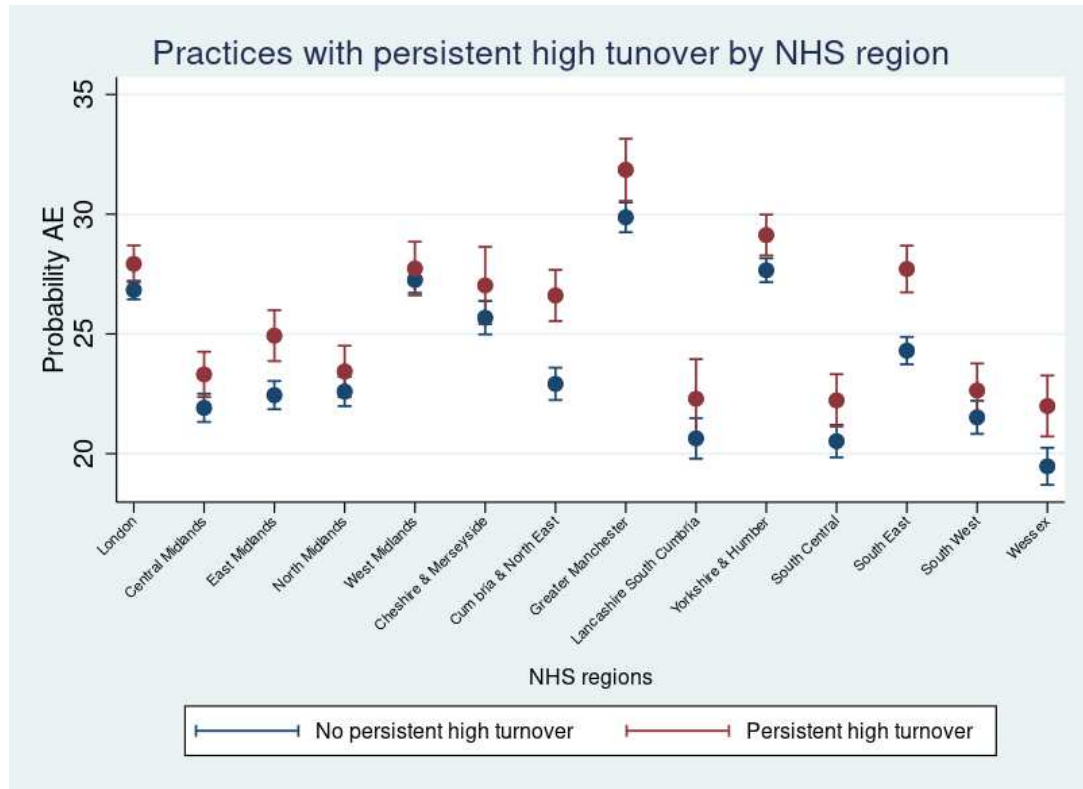
Statistical analyses

Supplementary Table 1. Unadjusted analysis of risk factors for persistent high turnover.

	OR (95% CI)	p-value
IMD 1	Reference	
IMD 2	1.04 (0.88 to 1.23)	0.661
IMD 3	1.03 (0.87 to 1.22)	0.720
IMD 4	0.97 (0.82 to 1.16)	0.764
IMD 5	0.85 (0.71 to 1.01)	0.063
Listsize 1, (mean; sd) (2528; 592)	0.14 (0.12 to 0.18)	<0.001
Listsize 2 (4493; 565)	0.42 (0.36 to 0.49)	<0.001
Listsize 3 (6532; 649)	Reference	
Listsize 4 (9119; 866)	1.73 (1.53 to 1.96)	<0.001
Listsize 5 (14291; 4362)	2.75 (2.41 to 3.13)	<0.001
NHS London	Reference	
NHS Central Midlands	2.28 (1.79 to 2.9)	<0.001
NHS East Midlands	1.7 (1.32 to 2.18)	<0.001
NHS North Midlands	1.8 (1.4 to 2.32)	<0.001
NHS West Midlands	1.03 (0.81 to 1.32)	0.795
NHS Cheshire and Merseyside	0.72 (0.52 to 0.99)	0.043
NHS Cumbria and North East	2.57 (1.98 to 3.33)	<0.001
NHS Greater Manchester	1.06 (0.8 to 1.39)	0.699
NHS Lancashire and South Cumbria	1.21 (0.85 to 1.71)	0.286
NHS Yorkshire and Humber	1.9 (1.52 to 2.37)	<0.001
NHS South Central	2.25 (1.73 to 2.93)	<0.001
NHS South East	1.78 (1.4 to 2.27)	<0.001
NHS South West	2.3 (1.76 to 3.01)	<0.001
NHS Wessex	2.24 (1.67 to 3.01)	<0.001
QoF preval serious conditions	1.03 (1.03 to 1.04)	<0.001
Rurality	0.87 (0.74 to 1.02)	0.082

Supplementary Table 2. Distribution of emergency attendance and admissions per practice.

Year	Practices (=n)	Practices in the analysis (=n)	Practices with missing outcome, n (%)	Emergency attendances Mean (SD)	Median (IQR)	Emergency admissions Mean (SD)	Median (IQR)
2009	7749	7709	40 (0.52)	17.44 (12.97)	18.10 (3.81-26.62))	9.02 (2.65)	8.72 (7.36-10.37)
2010	7841	7732	109 (1.39)	22.98 (11.43)	22.89 (16.17-30.15)	9.10 (2.60)	8.77 (7.43-10.48)
2011	7895	7785	110 (1.39)	25.16 (10.41)	24.22 (18.58-31.05)	9.03 (2.70)	8.75 (7.35-10.37)
2012	7907	7885	22 (0.28)	25.52 (9.28)	24.80 (19.24-31.13)	9.06 (2.44)	8.83 (7.47-10.44)
2013	7795	7778	17 (0.22)	25.60 (8.90)	24.74 (19.41-30.80)	9.15 (2.46)	8.91 (7.54-10.54)
2014	7619	7612	7 (0.09)	25.75 (8.79)	24.76 (19.59-31.05)	9.33 (2.55)	9.15 (7.68-10.79)
2015	7371	7368	3 (0.04)	26.32 (9.02)	25.40 (20.08-31.72)	9.50 (2.47)	9.34 (7.88-10.97)
2016	7175	7170	5 (0.07)	26.62 (8.91)	25.69 (20.46-31.83)	9.54 (2.59)	9.37 (7.86-11.03)
2017	6925	6919	6 (0.09)	26.57 (8.95)	25.56 (20.54-31.63)	9.85 (2.67)	9.65 (8.16-11.31)
2009-2017				24.62 (10.34)	24.28 (18.45-30.80)	9.28 (2.58)	9.03 (7.61-10.71)

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Supplementary Figure 2: Predicted probabilities from the multivariable analysis of the association between persistent high turnover and emergency attendances with an interaction between persistent high turnover and NHS region.

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Supplementary Figure 3: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and emergency admissions with an interaction between persistent high turnover and social deprivation (IMD).

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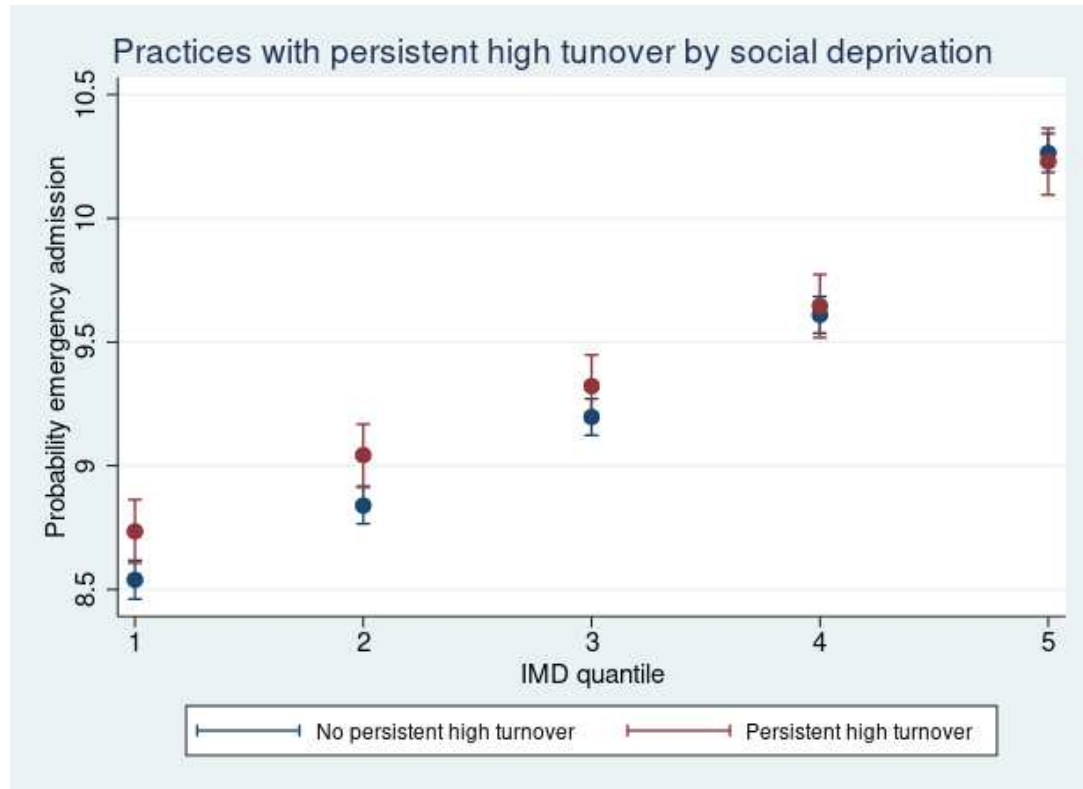
Supplementary Table 3. Distribution of the outcome "Frequency of seeing preferred GPs 'always or almost always' or 'a lot of times'".

| Year	Practices, n	Missing outcome (%)	Practices included, n	Mean (SD)	Median (IQR)
2009	7749	268 (3.46)	7481	72.51 (14.81)	73.8 (62.92 to 83.54)
2010	7841	148 (1.89)	7693	72.81 (14.39)	74.08 (63.38 to 83.48)
2011	7895	151 (1.91)	7744	71.36 (15.2)	72.83 (61.25 to 82.67)
2012	7907	361 (4.57)	7546	65.99 (15.85)	67.09 (55.44 to 77.9)
2013	7795	346 (4.44)	7449	63.63 (16.63)	64.64 (52.03 to 76.25)
2014	7619	342 (4.49)	7277	61.64 (17.12)	62.14 (49.75 to 74.52)
2015	7371	344 (4.67)	7027	60.36 (16.94)	61.23 (48.61 to 72.94)
2016	7175	323 (4.5)	6852	58.93 (17.1)	59.49 (46.94 to 71.39)
2017	6925	315 (4.55)	6610	56.09 (18.03)	56.21 (43.14 to 69.39)
				65.08 (17.24)	66.41 (53.28 to 78.07)

Supplementary Table 4. Distribution of the outcome "proportion of patients able to obtain an appointment on the same day".

Year	Practices, n	Missing outcome (%)	Practices included, n	Mean (SD)	Median (IQR)
2009	7749	9 (11.61)	7740	80.33 (11.55)	81.93 (73.33 to 89.02)
2010	7841	12 (15.3)	7829	80.26 (11.38)	81.4 (73.04 to 88.8)
2011	7895	3 (3.8)	7892	35.56 (14.26)	33.35 (24.78 to 44.92)
2012	7907	5 (6.32)	7902	35.6 (14.17)	33.49 (24.94 to 44.93)
2013	7795	4 (5.13)	7791	35.88 (14.38)	33.77 (25.09 to 45.27)
2014	7619	4 (5.25)	7615	36.38 (14.67)	34.24 (25.54 to 45.82)
2015	7371	1 (1.36)	7370	36.7 (14.54)	34.98 (25.75 to 45.77)
2016	7175	4 (5.58)	7171	37.35 (14.48)	35.54 (26.54 to 46.94)
2017	6925	4 (5.78)	6921	32.3 (13.92)	30.15 (21.95 to 41.53)
				45.88 (23.25)	39.74 (27.51 to 62.13)

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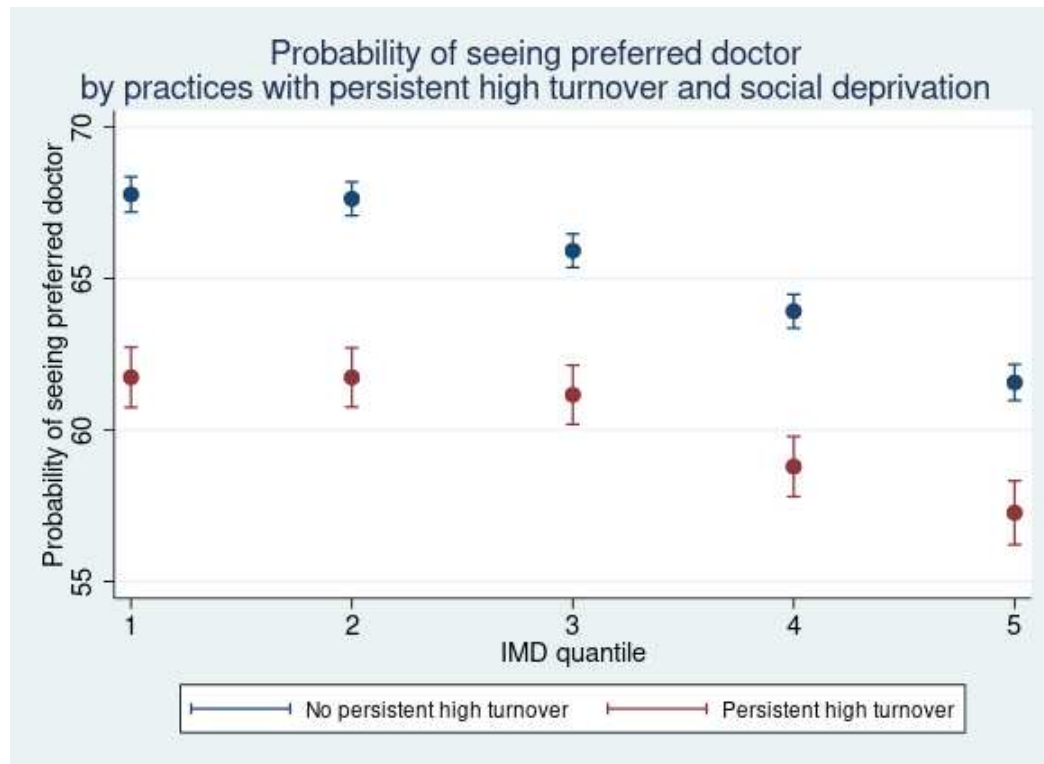
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Supplementary Table 5. Distribution of the outcome "proportion of patients' overall satisfaction with the practice".

Year	Practices, n	Missing outcome (%)	Practices included, n	Mean (SD)	Median (IQR)
2009	7749	28 (0.36)	7721	89.31 (7.38)	91.01 (85.85 to 94.56)
2010	7841	94 (1.2)	7747	82.68 (11.07)	85.16 (76.69 to 90.86)
2011	7895	45 (0.57)	7850	88.67 (6.92)	90.14 (85.21 to 93.64)
2012	7907	12 (0.15)	7895	88.08 (7.66)	89.59 (84.15 to 93.65)
2013	7795	14 (0.18)	7781	86.64 (8.43)	88.26 (82.08 to 92.93)
2014	7619	6 (0.08)	7613	85.82 (8.81)	87.48 (80.92 to 92.34)
2015	7371	0 (0)	7371	84.96 (9.54)	86.69 (79.81 to 91.97)
2016	7175	2 (0.03)	7173	85.33 (9.18)	87.12 (80.42 to 92.17)
2017	6925	2 (0.03)	6923	85.13 (9.55)	86.91 (79.74 to 92.4)
				86.33 (9.01)	88.26 (81.66 to 92.91)

Supplementary Figure 4: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and proportion of patients seeing their preferred doctor with an interaction between persistent high turnover and NHS region.
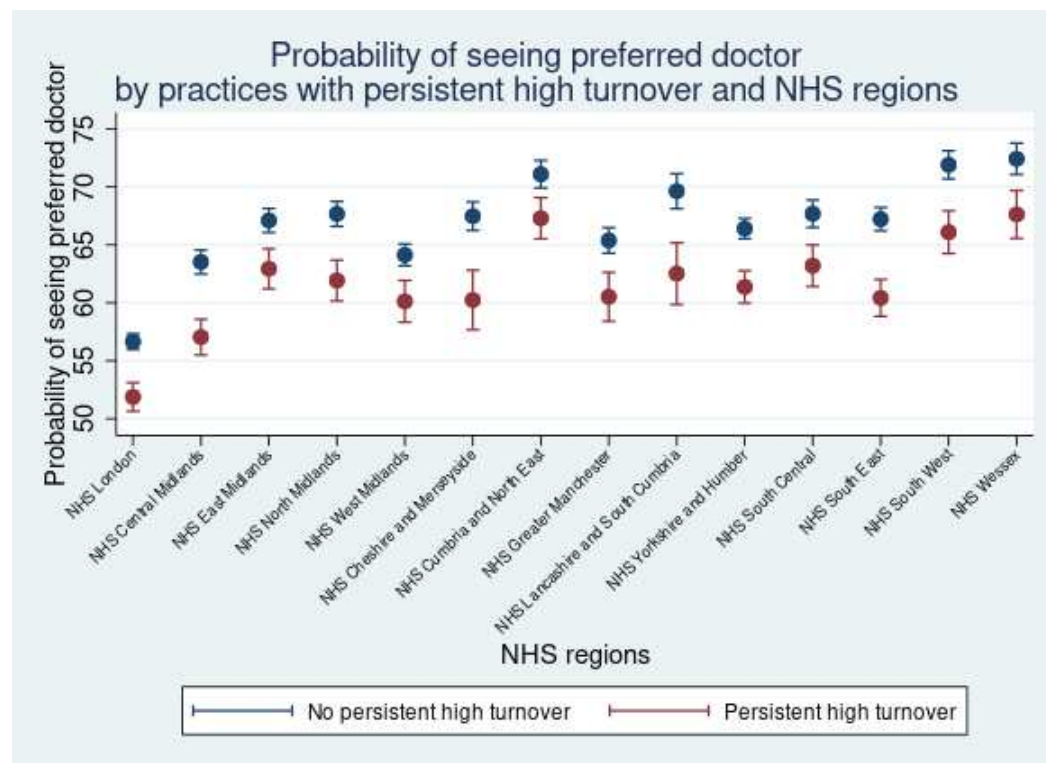
Supplementary Figure 5: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and proportion of patients seeing their preferred doctor with an interaction between persistent high turnover and social deprivation (IMD).

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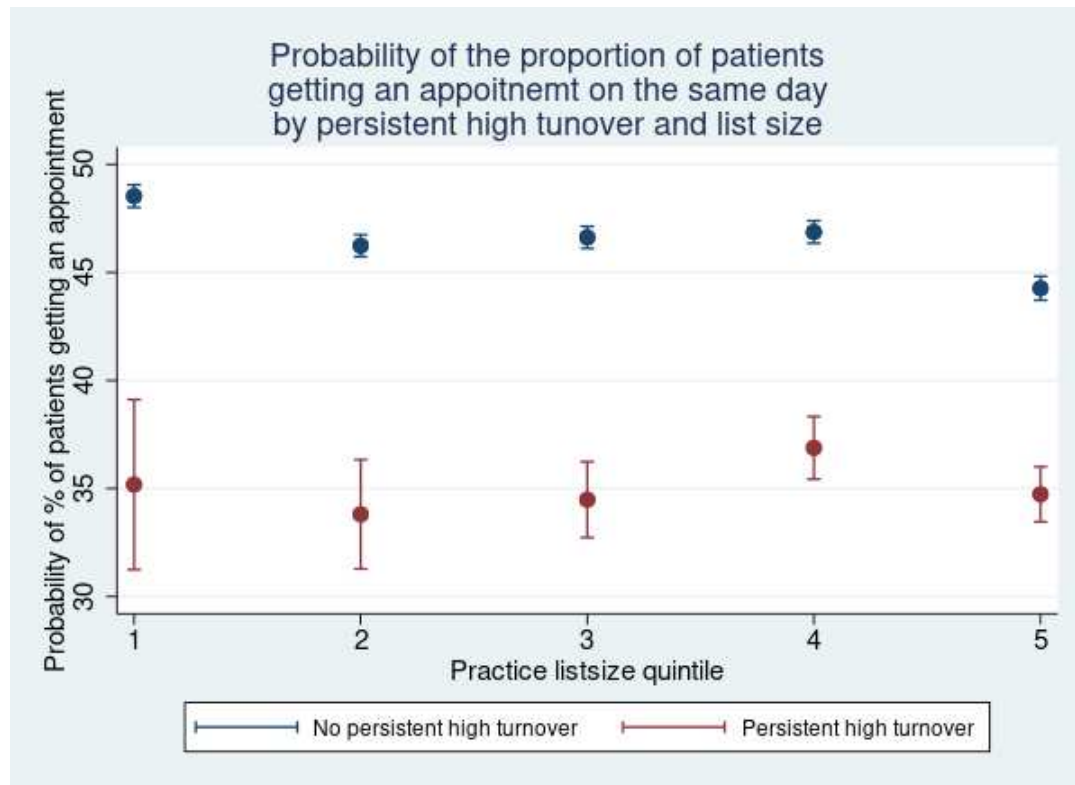
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Supplementary Figure 6: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and proportion of patients getting an appointment on the same day with an interaction between persistent high turnover and listsize.

Probability of the proportion of patients getting an appoitnemt on the same day by persistent high tunover and list size

Supplementary Figure 7: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and proportion of patients getting an appointment on the same day with an interaction between persistent high turnover and social deprivation (IMD).

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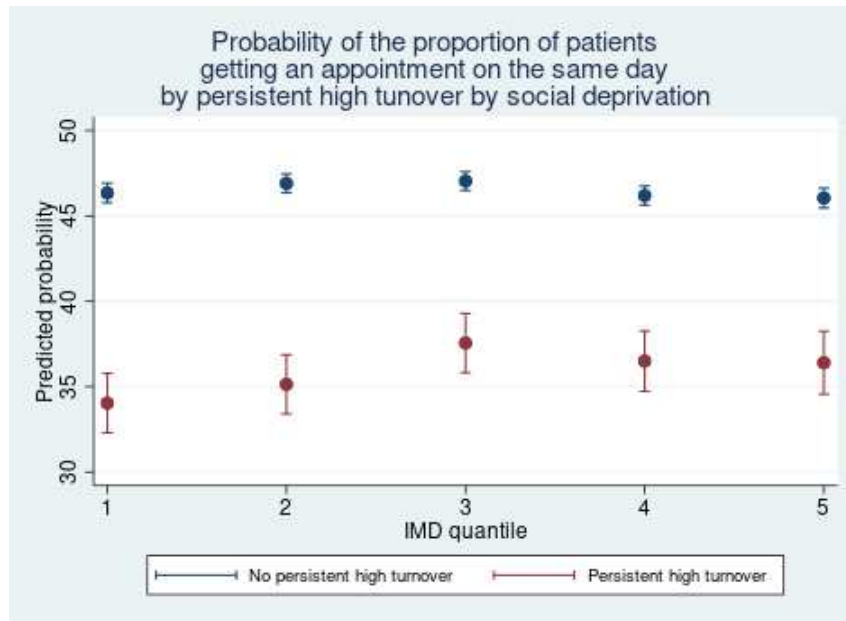
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Supplementary Figure 8: Predicted probabilities from the multivariable analysis of the association of persistent high turnover and proportion of patients overall satisfied with the practice with an interaction between persistent high turnover and social deprivation.
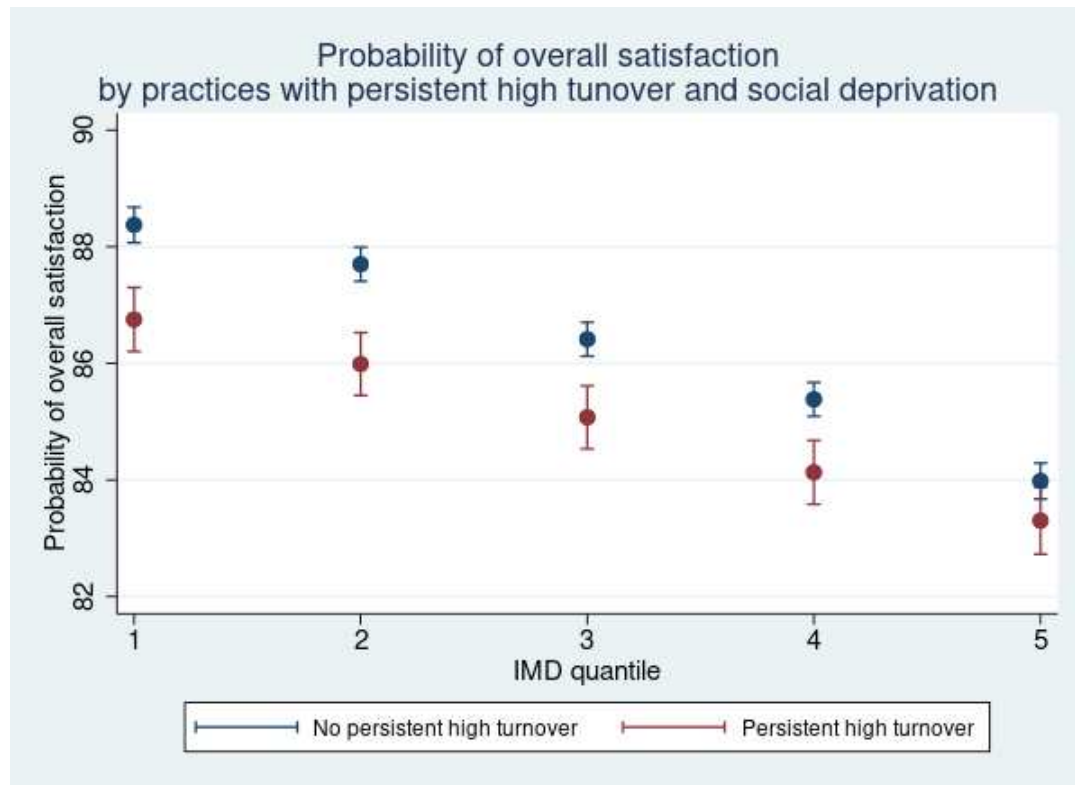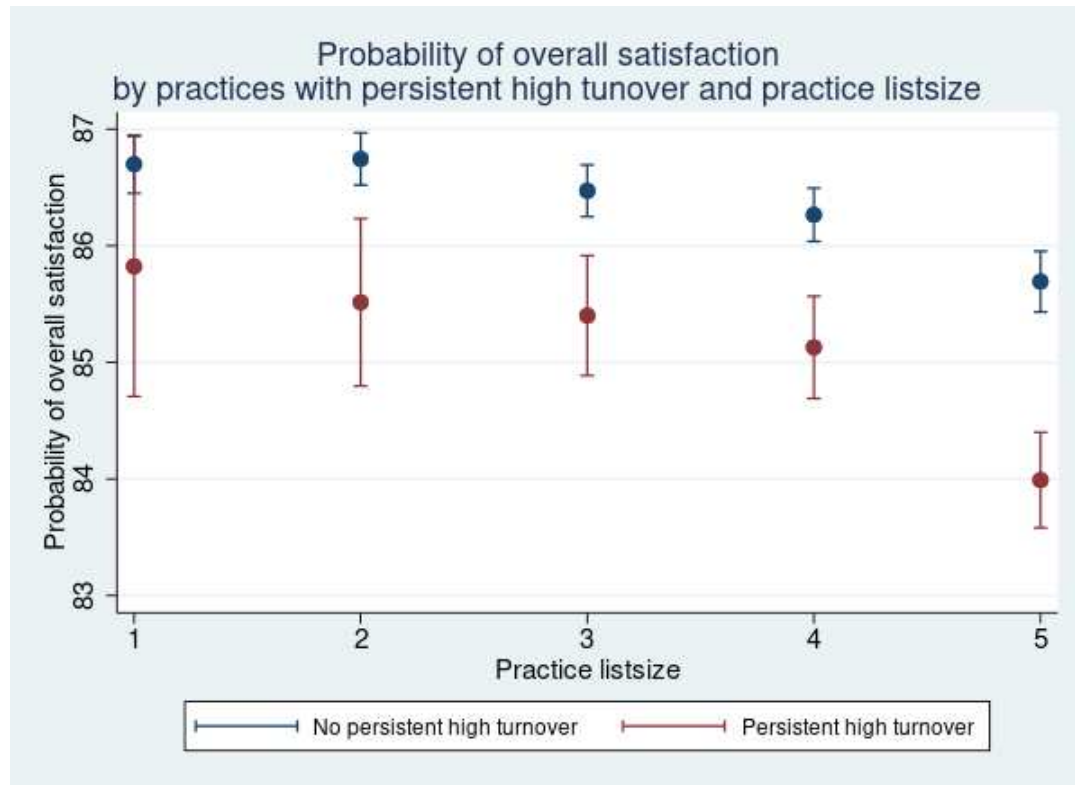
Supplementary Figure 9: Predicted probabilies from the multivariable analysis of the association of persistent high turnover and proportion of patients overall satisfied with the practice with an interaction between persistent high turnover and listsize.

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Supplementary Table 6. Sensitivity analysis of the multivariable analysis of risk factors associated with persistent high turnover, restricting the analysis to 2015-2019 and including FTE per patients ratio in the model.

	OR (95% CIs)	p-value
FTE per pts ratio/1000	0.43 (0.31 to 0.61)	<0.001
IMD 1	Reference	
IMD 2	1.21 (0.93 to 1.56)	0.153
IMD 3	1.13 (0.87 to 1.47)	0.368
IMD 4	1.24 (0.95 to 1.63)	0.117
IMD 5	1.09 (0.81 to 1.45)	0.578
Listsize 1 (2528; 592)	0.07 (0.05 to 0.12)	<0.001
Listsize 2 (4493; 565)	0.32 (0.24 to 0.42)	<0.001
Listsize 3 (6532; 649)	Reference	
Listsize 4 (9119; 866)	1.72 (1.39 to 2.13)	<0.001
Listsize 5 (14291; 4362)	2.21 (1.78 to 2.75)	<0.001
NHS London	Reference	
NHS Central Midlands	2.03 (1.4 to 2.94)	<0.001
NHS East Midlands	1.27 (0.85 to 1.9)	0.243
NHS North Midlands	1.65 (1.1 to 2.49)	0.016
NHS West Midlands	1.4 (0.95 to 2.08)	0.091
NHS Cheshire and Merseyside	1.34 (0.83 to 2.16)	0.228
NHS Cumbria and North East	2.86 (1.87 to 4.38)	<0.001
NHS Greater Manchester	1.76 (1.16 to 2.68)	0.008
NHS Lancashire and South Cumbria	1.91 (1.12 to 3.25)	0.017
NHS Yorkshire and Humber	2.02 (1.41 to 2.88)	<0.001
NHS South Central	2.52 (1.69 to 3.75)	<0.001
NHS South East	1.75 (1.2 to 2.55)	0.004
NHS South West	2.97 (1.95 to 4.5)	<0.001
NHS Wessex	2.56 (1.65 to 3.97)	<0.001
QoF preval serious conditions	1 (0.99 to 1.01)	0.818
Rurality	0.89 (0.68 to 1.15)	0.369

Supplementary Table 7. Sensitivity analysis of the association between persistent high turnover and emergency attendances. Multivariable analysis including GP turnover modelled as continuous variable.

	Coefficient (95% CIs)	p-value
GP turnover %	0.01 (0 to 0.01)	<0.001
IMD 1	Reference	
IMD 2	0.93 (0.49 to 1.37)	<0.001
IMD 3	2.36 (1.91 to 2.82)	<0.001
IMD 4	4.86 (4.39 to 5.33)	<0.001
IMD 5	7.96 (7.47 to 8.45)	<0.001
Listsize 1 (2528; 592)	0.12 (-0.23 to 0.46)	0.504
Listsize 2 (4493; 565)	0.24 (-0.05 to 0.53)	0.105
Listsize 3 (6532; 649)	Reference	
Listsize 4 (9119; 866)	-0.31 (-0.6 to -0.02)	0.038
Listsize 5 (14291; 4362)	0.46 (0.11 to 0.81)	0.010
NHS London	Reference	
NHS Central Midlands	-4.92 (-5.62 to -4.22)	<0.001
NHS East Midlands	-4.35 (-5.06 to -3.64)	<0.001
NHS North Midlands	-4.28 (-5.01 to -3.55)	<0.001
NHS West Midlands	0.36 (-0.29 to 1.02)	0.278
NHS Cheshire and Merseyside	-1.21 (-2.01 to -0.4)	0.003
NHS Cumbria and North East	-3.75 (-4.54 to -2.96)	<0.001
NHS Greater Manchester	3.04 (2.31 to 3.77)	<0.001
NHS Lancashire and South Cumbria	-6.21 (-7.14 to -5.28)	<0.001
NHS Yorkshire and Humber	0.82 (0.18 to 1.45)	0.012
NHS South Central	-6.27 (-7.05 to -5.5)	<0.001
NHS South East	-2.41 (-3.1 to -1.72)	<0.001
NHS South West	-5.33 (-6.13 to -4.53)	<0.001
NHS Wessex	-7.29 (-8.15 to -6.43)	<0.001
QoF preval serious conditions %	0.17 (0.15 to 0.18)	<0.001
Rurality	-3.8 (-4.28 to -3.32)	<0.001

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Supplementary Table 8. Sensitivity analysis of the association between persistent high turnover and emergency attendances restricting the analysis to 2015-2017 and including FTE per patients ratio.

	Coefficient (95% CIs)	p-value
Persistent high turnover	0.2 (-0.04 to 0.44)	0.106
FTE per pts ratio	-0.68 (-1.07 to -0.29)	0.001
IMD 1	Reference	
IMD 2	1.2 (0.72 to 1.68)	<0.001
IMD 3	3.11 (2.61 to 3.6)	<0.001
IMD 4	5.47 (4.96 to 5.98)	<0.001
IMD 5	8.59 (8.05 to 9.12)	<0.001
Listsize 1, mean; sd (2528; 592)	0.16 (-0.25 to 0.58)	0.447
Listsize 2 (4493; 565)	0.52 (0.19 to 0.84)	0.002
Listsize 3 (6532; 649)	Reference	
Listsize 4 (9119; 866)	-0.25 (-0.56 to 0.06)	0.113
Listsize 5 (14291; 4362)	-0.44 (-0.8 to -0.07)	0.02
NHS London	Reference	
NHS Central Midlands	-1.88 (-2.6 to -1.16)	<0.001
NHS East Midlands	-0.26 (-0.99 to 0.48)	0.490
NHS North Midlands	-2.69 (-3.45 to -1.93)	<0.001
NHS West Midlands	1.52 (0.83 to 2.2)	<0.001
NHS Cheshire and Merseyside	1.17 (0.34 to 2)	0.006
NHS Cumbria and North East	1.38 (0.56 to 2.2)	0.001
NHS Greater Manchester	5.19 (4.44 to 5.94)	<0.001
NHS Lancashire and South Cumbria	-2.71 (-3.69 to -1.73)	<0.001
NHS Yorkshire and Humber	2.53 (1.87 to 3.2)	<0.001
NHS South Central	-4.4 (-5.2 to -3.6)	<0.001
NHS South East	1.43 (0.72 to 2.15)	<0.001
NHS South West	-3.37 (-4.21 to -2.54)	<0.001
NHS Wessex	-3.29 (-4.19 to -2.4)	<0.001
QOF prevalence serious conditions %	-0.02 (-0.04 to 0)	0.045
Rurality	-3.39 (-3.88 to -2.89)	<0.001

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Supplementary Table 9. Sensitivity analysis of the association between persistent high turnover and emergency admissions. Multivariable analysis including GP turnover modelled as continuous variable.

	Coef (95% CIs)	p-value
GP turnov %	0.001 (0 to 0.001)	0.004
IMD 1	Reference	
IMD 2	0.302 (0.203 to 0.402)	<0.001
IMD 3	0.654 (0.55 to 0.758)	<0.001
IMD 4	1.062 (0.955 to 1.169)	<0.001
IMD 5	1.715 (1.602 to 1.829)	<0.001
Listsize 1 mean; sd (2528; 592)	0.154 (0.08 to 0.227)	<0.001
Listsize 2 (4493; 565)	0.062 (0.003 to 0.122)	0.039
Listsize 3 (6532; 649)	Reference	
Listsize 4 (9119; 866)	-0.046 (-0.106 to 0.014)	0.132
Listsize 5 (14291; 4362)	0.115 (0.041 to 0.189)	0.002
NHS London	Reference	
NHS Central Midlands	0.961 (0.794 to 1.129)	<0.001
NHS East Midlands	0.64 (0.471 to 0.81)	<0.001
NHS North Midlands	1.492 (1.318 to 1.665)	<0.001
NHS West Midlands	1.3 (1.143 to 1.457)	<0.001
NHS Cheshire and Merseyside	3.19 (2.999 to 3.381)	<0.001
NHS Cumbria and North East	2.56 (2.373 to 2.748)	<0.001
NHS Greater Manchester	2.331 (2.157 to 2.504)	<0.001
NHS Lancashire and South Cumbria	2.171 (1.948 to 2.393)	<0.001
NHS Yorkshire and Humber	1.729 (1.578 to 1.88)	<0.001
NHS South Central	0.482 (0.297 to 0.667)	<0.001
NHS South East	1.091 (0.927 to 1.255)	<0.001
NHS South West	1.046 (0.856 to 1.237)	<0.001
NHS Wessex	1.513 (1.307 to 1.719)	<0.001
QoF preval serious conditions %	0.094 (0.091 to 0.098)	<0.001
Rurality	-0.724 (-0.836 to -0.612)	<0.001

Supplementary Table 10. Sensitivity analysis of the association between persistent high turnover and emergency admissions restricting the analysis to 2015-2017 and including FTE per patients ratio.

	Coefficient (95% CIs)	p-value
Persistent high turnov	0.12 (0.04 to 0.2)	0.004
FTE per pts ratio	0.05 (-0.07 to 0.17)	0.416
IMD 1	Reference	
IMD 2	0.36 (0.23 to 0.48)	<0.001
IMD 3	0.71 (0.58 to 0.84)	<0.001
IMD 4	1.13 (1 to 1.26)	<0.001
IMD 5	1.86 (1.73 to 2)	<0.001
Listsize 1	-0.2 (-0.31 to -0.08)	0.001
Listsize 2	-0.04 (-0.13 to 0.06)	0.447
Listsize 3	Reference	
Listsize 4	0.05 (-0.04 to 0.15)	0.259
Listsize 5	0.07 (-0.03 to 0.17)	0.187
NHS London	Reference	
NHS Central Midlands	1.15 (0.97 to 1.34)	<0.001
NHS East Midlands	0.81 (0.62 to 0.99)	<0.001
NHS North Midlands	1.33 (1.14 to 1.52)	<0.001
NHS West Midlands	1.41 (1.23 to 1.58)	<0.001
NHS Cheshire and Merseyside	3.04 (2.83 to 3.25)	<0.001
NHS Cumbria and North East	2.12 (1.91 to 2.33)	<0.001
NHS Greater Manchester	1.75 (1.56 to 1.94)	<0.001
NHS Lancashire and South Cumbria	1.69 (1.44 to 1.94)	<0.001
NHS Yorkshire and Humber	1.38 (1.22 to 1.55)	<0.001
NHS South Central	0.93 (0.73 to 1.14)	<0.001
NHS South East	1.19 (1.01 to 1.37)	<0.001
NHS South West	1.28 (1.07 to 1.49)	<0.001
NHS Wessex	1.51 (1.29 to 1.74)	<0.001
QoF preval serious conditions %	0.13 (0.12 to 0.13)	<0.001
Rurality	-0.85 (-0.98 to -0.72)	<0.001

Supplementary Table 11. Sensitivity analysis of the association between persistent high turnover and GPPS outcomes. Multivariable analysis including GP turnover modelled as continuous variable.

	Frequency seeing preferred doctor		Same day appointment		Overall satisfaction	
	Coefficient (95% CIs)	p-value	Coefficient (95% CIs)	p-value	Coefficient (95% CIs)	p-value
Turnov %	-0.003 (-0.007 to 0.002)	0.251	-0.037 (-0.046 to -0.029)	<0.001	-0.0003 (-0.0027 to 0.0021)	0.831
IMD 1	Reference		Reference			
IMD 2	-0.181 (-0.933 to 0.571)	0.636	0.541 (-0.225 to 1.307)	0.166	-0.6958 (-1.0897 to -0.3018)	0.001
IMD 3	-1.819 (-2.603 to -1.035)	<0.001	0.818 (0.038 to 1.598)	0.040	-1.9635 (-2.3717 to -1.5553)	<0.001
IMD 4	-3.832 (-4.639 to -3.026)	<0.001	-0.041 (-0.844 to 0.761)	0.919	-2.9873 (-3.4071 to -2.5675)	<0.001
IMD 5	-6.189 (-7.041 to -5.338)	<0.001	-0.213 (-1.047 to 0.621)	0.617	-4.3807 (-4.822 to -3.9395)	<0.001
Listsize 1	10.898 (10.322 to 11.473)	<0.001	2.303 (1.584 to 3.021)	<0.001	0.257 (-0.0486 to 0.5625)	0.099
Listsize 2	4.848 (4.384 to 5.313)	<0.001	-0.111 (-0.795 to 0.572)	0.750	0.2857 (0.0311 to 0.5403)	0.028
Listsize 3	Reference		Reference			
Listsize 4	-4.37 (-4.836 to -3.904)	<0.001	0.126 (-0.561 to 0.813)	0.720	-0.2322 (-0.4887 to 0.0243)	0.076
Listsize 5	-9.454 (-10.027 to -8.881)	<0.001	-2.699 (-3.431 to -1.967)	<0.001	-0.9035 (-1.2143 to -0.5928)	<0.001
NHS London	Reference		Reference			
NHS Central Midlands	6.709 (5.479 to 7.938)	<0.001	10.6 (9.486 to 11.714)	<0.001	3.6058 (2.9747 to 4.2368)	<0.001
NHS East Midlands	10.54 (9.29 to 11.789)	<0.001	10.941 (9.807 to 12.075)	<0.001	4.9656 (4.326 to 5.6052)	<0.001
NHS North Midlands	10.999 (9.721 to 12.278)	<0.001	10.145 (8.981 to 11.31)	<0.001	6.2033 (5.5491 to 6.8575)	<0.001
NHS West Midlands	7.595 (6.437 to 8.753)	<0.001	7.555 (6.499 to 8.611)	<0.001	3.8035 (3.2111 to 4.3959)	<0.001
NHS Cheshire and Merseyside	10.917 (9.511 to 12.323)	<0.001	12.749 (11.465 to 14.034)	<0.001	8.0122 (7.2904 to 8.7339)	<0.001
NHS Cumbria and North East	14.494 (13.108 to 15.88)	<0.001	7.343 (6.072 to 8.614)	<0.001	8.8155 (8.1061 to 9.5248)	<0.001
NHS Greater Manchester	8.786 (7.503 to 10.07)	<0.001	3.369 (2.211 to 4.528)	<0.001	5.8396 (5.1848 to 6.4945)	<0.001

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NHS Lancashire and South Cumbria	12.955 (11.297 to 14.613)	<0.001	8.531 (7.04 to 10.023)	<0.001	6.5394 (5.6996 to 7.3792)	<0.001
NHS Yorkshire and Humber	9.755 (8.637 to 10.872)	<0.001	9.185 (8.164 to 10.207)	<0.001	6.0773 (5.5062 to 6.6485)	<0.001
NHS South Central	11.003 (9.644 to 12.362)	<0.001	6.319 (5.086 to 7.552)	<0.001	5.8909 (5.1929 to 6.5888)	<0.001
NHS South East	10.44 (9.231 to 11.648)	<0.001	10.349 (9.251 to 11.447)	<0.001	4.4022 (3.7823 to 5.022)	<0.001
NHS South West	15.171 (13.771 to 16.572)	<0.001	14.165 (12.885 to 15.444)	<0.001	8.4707 (7.7513 to 9.19)	<0.001
NHS Wessex	15.777 (14.265 to 17.289)	<0.001	8.705 (7.326 to 10.083)	<0.001	7.6787 (6.9009 to 8.4565)	<0.001
QoF preval serious conditions %	-0.417 (-0.443 to -0.39)	<0.001	-0.407 (-0.439 to -0.374)	<0.001	-0.0339 (-0.048 to -0.0198)	<0.001
Rurality	4.881 (4.049 to 5.712)	<0.001	1.715 (0.943 to 2.487)	<0.001	2.9275 (2.4998 to 3.3551)	<0.001

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Supplementary Table 12. Sensitivity analysis of the association between persistent high turnover and GPPS outcomes. Multivariable analysis restricting the analysis to 2011-2017.

	Frequency seeing preferred doctor		Same day appointment		Overall satisfaction	
	Coefficient (95% CIs)	p-value	Coefficient (95% CIs)	p-value	Coefficient (95% CIs)	p-value
Persistent high turnover	-2.03 (-2.43 to -1.62)	<0.001	0.55 (0.25 to 0.86)	<0.001	-2.03 (-2.43 to -1.62)	<0.001
IMD 1	Reference		Reference		Reference	
IMD 2	-0.59 (-1.4 to 0.23)	0.159	0.69 (-0.05 to 1.43)	0.067	-0.59 (-1.4 to 0.23)	0.159
IMD 3	-2.22 (-3.07 to -1.37)	<0.001	1.41 (0.64 to 2.19)	<0.001	-2.22 (-3.07 to -1.37)	<0.001
IMD 4	-4.49 (-5.36 to -3.62)	<0.001	0.67 (-0.12 to 1.47)	0.098	-4.49 (-5.36 to -3.62)	<0.001
IMD 5	-6.95 (-7.86 to -6.03)	<0.001	1.71 (0.87 to 2.55)	<0.001	-6.95 (-7.86 to -6.03)	<0.001
Listsize 1	10.73 (10.08 to 11.37)	<0.001	-0.67 (-1.2 to -0.14)	0.013	10.73 (10.08 to 11.37)	<0.001
Listsize 2	4.75 (4.22 to 5.28)	<0.001	-0.65 (-1.08 to -0.22)	0.003	4.75 (4.22 to 5.28)	<0.001
Listsize 3	Reference		Reference		Reference	
Listsize 4	-4.11 (-4.63 to -3.59)	<0.001	0.01 (-0.42 to 0.44)	0.961	-4.11 (-4.63 to -3.59)	<0.001
Listsize 5	-8.24 (-8.87 to -7.61)	<0.001	-0.06 (-0.59 to 0.48)	0.833	-8.24 (-8.87 to -7.61)	<0.001
NHS London	Reference		Reference		Reference	
NHS Central Midlands	5.33 (4.04 to 6.61)	<0.001	9.23 (8.01 to 10.46)	<0.001	5.33 (4.04 to 6.61)	<0.001
NHS East Midlands	9.11 (7.81 to 10.42)	<0.001	8.17 (6.93 to 9.42)	<0.001	9.11 (7.81 to 10.42)	<0.001
NHS North Midlands	9.43 (8.09 to 10.77)	<0.001	6.58 (5.31 to 7.85)	<0.001	9.43 (8.09 to 10.77)	<0.001
NHS West Midlands	6.52 (5.31 to 7.74)	<0.001	4.6 (3.45 to 5.75)	<0.001	6.52 (5.31 to 7.74)	<0.001
NHS Cheshire and Merseyside	9.18 (7.7 to 10.65)	<0.001	9.69 (8.29 to 11.1)	<0.001	9.18 (7.7 to 10.65)	<0.001
NHS Cumbria and North East	12.61 (11.15 to 14.07)	<0.001	1.73 (0.35 to 3.12)	0.014	12.61 (11.15 to 14.07)	<0.001
NHS Greater Manchester	8.03 (6.68 to 9.37)	<0.001	1.32 (0.04 to 2.59)	0.043	8.03 (6.68 to 9.37)	<0.001
NHS Lancashire and South Cumbria	11.25 (9.52 to 12.99)	<0.001	4.57 (2.94 to 6.21)	<0.001	11.25 (9.52 to 12.99)	<0.001
NHS Yorkshire and Humber	8.39 (7.22 to 9.57)	<0.001	6.22 (5.11 to 7.33)	<0.001	8.39 (7.22 to 9.57)	<0.001
NHS South Central	10.23 (8.81 to 11.64)	<0.001	4.11 (2.75 to 5.47)	<0.001	10.23 (8.81 to 11.64)	<0.001
NHS South East	9.33 (8.06 to 10.59)	<0.001	8.22 (7.01 to 9.43)	<0.001	9.33 (8.06 to 10.59)	<0.001
NHS South West	13.74 (12.28 to 15.2)	<0.001	10.51 (9.11 to 11.91)	<0.001	13.74 (12.28 to 15.2)	<0.001
NHS Wessex	14.52 (12.94 to 16.1)	<0.001	4.52 (3.01 to 6.03)	<0.001	14.52 (12.94 to 16.1)	<0.001

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QoF preval serious conditions %	-0.26 (-0.3 to -0.23)	<0.001	-0.06 (-0.08 to -0.03)	<0.001	-0.26 (-0.3 to -0.23)	<0.001
Rurality	4.62 (3.75 to 5.5)	<0.001	0.29 (-0.53 to 1.12)	0.483	4.62 (3.75 to 5.5)	<0.001

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Supplementary Table 13. Sensitivity analysis of the association between persistent high turnover and GPPS outcomes. Multivariable analysis restricting the analysis to 2015-2017 and including FTE per patients ratio in the model.

	Frequency seeing preferred doctor		Same day appointment		Overall satisfaction	
	Coefficient (95% CIs)	p-value	Coefficient (95% CIs)	p-value	Coefficient (95% Cis)	p-value
Persistent high turnov	-1.58 (-2.28 to -0.87)	<0.001	0.96 (0.37 to 1.55)	0.001	-0.5 (-0.89 to -0.11)	0.012
FTE per pts ratio	2.43 (1.35 to 3.5)	<0.001	1.96 (1.06 to 2.86)	<0.001	3.75 (3.18 to 4.32)	<0.001
IMD 1	Reference		Reference		Reference	
IMD 2	-1.48 (-2.49 to -0.48)	0.004	0.74 (-0.17 to 1.65)	0.113	-1.04 (-1.59 to -0.5)	<0.001
IMD 3	-3.37 (-4.4 to -2.34)	<0.001	1.89 (0.96 to 2.83)	<0.001	-2.8 (-3.36 to -2.24)	<0.001
IMD 4	-5.73 (-6.79 to -4.67)	<0.001	1.39 (0.43 to 2.35)	0.005	-3.81 (-4.38 to -3.24)	<0.001
IMD 5	-8.06 (-9.17 to -6.95)	<0.001	2.34 (1.34 to 3.34)	<0.001	-5.87 (-6.46 to -5.27)	<0.001
Listsize 1	10.52 (9.5 to 11.55)	<0.001	-2.13 (-2.99 to -1.27)	<0.001	0.88 (0.36 to 1.41)	0.001
Listsize 2	5.14 (4.33 to 5.95)	<0.001	-0.93 (-1.64 to -0.22)	0.010	0.56 (0.12 to 1)	0.013
Listsize 3	Reference		Reference		Reference	
Listsize 4	-4.55 (-5.33 to -3.77)	<0.001	0.51 (-0.18 to 1.19)	0.146	-0.3 (-0.73 to 0.13)	0.172
Listsize 5	-6.86 (-7.71 to -6)	<0.001	0.03 (-0.73 to 0.79)	0.944	-0.53 (-1 to -0.06)	0.027
NHS London	Reference		Reference		Reference	
NHS Central Midlands	2.16 (0.69 to 3.63)	0.004	9.84 (8.51 to 11.18)	<0.001	2.42 (1.63 to 3.21)	<0.001
NHS East Midlands	5.83 (4.32 to 7.34)	<0.001	8.74 (7.37 to 10.1)	<0.001	3.31 (2.5 to 4.12)	<0.001
NHS North Midlands	5.95 (4.4 to 7.5)	<0.001	6.99 (5.58 to 8.39)	<0.001	5.38 (4.54 to 6.21)	<0.001
NHS West Midlands	3.42 (1.99 to 4.84)	<0.001	5.28 (4 to 6.55)	<0.001	2.95 (2.19 to 3.71)	<0.001
NHS Cheshire and Merseyside	5.36 (3.65 to 7.07)	<0.001	10.42 (8.88 to 11.97)	<0.001	6.46 (5.55 to 7.38)	<0.001
NHS Cumbria and North East	8.02 (6.32 to 9.72)	<0.001	2.08 (0.55 to 3.6)	0.008	7.09 (6.18 to 7.99)	<0.001
NHS Greater Manchester	5.66 (4.1 to 7.22)	<0.001	1.8 (0.41 to 3.19)	0.011	5.44 (4.61 to 6.27)	<0.001
NHS Lancashire and South Cumbria	6.41 (4.35 to 8.46)	<0.001	4.54 (2.73 to 6.35)	<0.001	5.44 (4.36 to 6.52)	<0.001
NHS Yorkshire and Humber	4.79 (3.41 to 6.18)	<0.001	6.86 (5.62 to 8.1)	<0.001	4.88 (4.15 to 5.62)	<0.001
NHS South Central	8.68 (7.05 to 10.3)	<0.001	4.05 (2.56 to 5.54)	<0.001	4.9 (4.02 to 5.79)	<0.001
NHS South East	6.91 (5.44 to 8.38)	<0.001	8.19 (6.86 to 9.52)	<0.001	3.39 (2.6 to 4.18)	<0.001
NHS South West	10.64 (8.93 to 12.34)	<0.001	10.06 (8.51 to 11.61)	<0.001	7.42 (6.5 to 8.34)	<0.001

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NHS Wessex	10.84 (9.02 to 12.66)	<0.001	3.91 (2.25 to 5.58)	<0.001	5.63 (4.64 to 6.62)	<0.001
QoF preval serious conditions %	-0.03 (-0.07 to 0.02)	0.252	-0.01 (-0.05 to 0.02)	0.464	0.04 (0.01 to 0.06)	0.002
Rurality	4.61 (3.59 to 5.63)	<0.001	-0.22 -1.14 0.7	0.644	2.64 2.09 3.19	<0.001

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