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Sociodemographic Disparities in the Stage of Prostate Cancer Diagnosis in England: A Population-Based Analysis Using Linked Electronic Health Records Data

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Abstract. Early-stage cancer diagnosis improves treatment options and prognosis but is influenced by demographic and socio-economic inequalities. This study examined how sociodemographic factors relate to the stage at diagnosis among men aged ≥56 diagnosed with prostate cancer from 2010-2016, using data from the National Cancer Registration and Analysis Service (NCRAS). The differences between groups in the proportions of localised, locally advanced, or advanced cancer stages were analysed using chi-square tests and multinomial logistic regression to assess associations with age, ethnicity, deprivation, and region adjusting for comorbidity and year of diagnosis. Among 13,693 men, 45% had localised, 34% locally advanced, and 21% advanced-stage prostate cancer. Stage at diagnosis varied significantly by age ($p<0.001$), deprivation ($p=0.038$), ethnicity ($p=0.044$), and region ($p<0.001$). Men who were over 80 years old, compared to men who were 65 and below had an adjusted odds ratio (aOR) of 13.2 (95% confidence interval was 11.0 to 16.0, $p<0.001$), those from most deprived areas (aOR=1.2 (1.0 to 1.5), $p=0.014$), and whose registered primary care practice was in the East Midlands (aOR=1.6 (1.2 to 2.2), $p<0.001$) were more likely to be diagnosed at advanced stages. In contrast, Asian men had lower odds of advanced-stage diagnoses (aOR=0.6 (0.4 to 0.9), $p=0.03$) compared to White men. These findings underscore the influence of age, deprivation, ethnicity, and region on prostate cancer stage at diagnosis, highlighting the need for more in-depth research and targeted interventions for at-risk groups.

Keywords. Prostate cancer, Inequalities, Real-world data, Data linkage, Cancer stage

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1. Introduction

The stage at which cancer is diagnosed plays a crucial role in determining available treatment options and prognosis [1]. Previous studies in the United Kingdom (UK) have highlighted disparities in diagnosis stages based on ethnicity, gender, deprivation, and age [2-4]. However, these studies often focused on specific regions, earlier time periods, or limited sociodemographic factors, and many lacked adjustments for confounders like comorbidity that can influence the timing of diagnosis [5,6]. Prostate cancer (PCa), the most prevalent malignant neoplasm among men in the UK presents inequalities across the care pathway [7,8]. Recent improvements in cancer-stage data from the National Cancer Registration and Analysis Service (NCRAS) have enabled analysis of stage distribution by sociodemographic factors [9]. Addressing sociodemographic disparities could potentially reduce around 2,000 advanced-stage diagnoses and over 4,000 PCa deaths annually in England [3]. We investigated how age, ethnicity, deprivation and region impact PCa stage at diagnosis to understand potential inequalities and contribute to wider knowledge.

2. Methods

Study design and covariates: This retrospective cohort study included men aged ≥56 years diagnosed with incident PCa (ICD–10:C61) between 2010 and 2016 in England, utilising linked NCRAS, Clinical Practice Research Datalink (CPRD), and Hospital Episode Statistics (HES) data. Key variables included age at diagnosis (≤65, 66-70, 71-75, 76-80, >80), ethnicity (Asian, Black, Mixed/Other, Unknown, White), practice-level Index of Multiple Deprivation (IMD) quintiles (1=least deprived, 5=most deprived), and practice region. The cancer stage was classified as localised (Gleason score ≤ 7 and T1/T2 and N0 and M0), locally advanced (Gleason score > 7 or T3/T4 or N1 and M0), or advanced (M1) supplemented by an algorithm combining clinical assumptions and multiple imputations for missing data. Comorbidities within 5 years pre-diagnosis were assessed using the Charlson Comorbidity Index (CCI).

Statistical analysis: We performed descriptive analyses and chi-square tests to explore stage-related disparities, followed by multinomial logistic regression to estimate the odds of locally advanced or advanced stages (vs. localised). Models were built sequentially: Model 1 (age and IMD), Model 2 (age, IMD, ethnicity), and Model 3 (age, IMD, ethnicity, region, diagnosis year, CCI). Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. All analyses used R software (version 4.3.2) with significance set at $p < 0.05$.

Approvals: This study was approved by the Medicines and Healthcare Products Regulatory Agency (MHRA) Independent Scientific Advisory Committee (protocol number 19_050R).

3. Results

There were 13,693 men diagnosed with PCa during 2010-2016 after excluding 388 (2.8%) due to missing ethnicity or region data; 95% were classified as White, and 61%

were >70 years old (mean: 73 years, standard deviation: 7.7). Most men had localised cancer (45%), followed by locally advanced (34%) and advanced disease (21%).

Descriptive analysis: Cancer stage distribution varied significantly by year ($p<0.001$), age ($p<0.001$), IMD ($p=0.038$), ethnicity ($p=0.044$), and region ($p<0.001$). Localised diagnoses decreased over time by 18%, while locally advanced and advanced cases rose by 17% and 18%, respectively. Men with localised cancer were younger on average (71.0 years) compared to locally advanced (73.6 years) and advanced (78.3 years). The proportion of localised cancer decreased from 47% in the least deprived areas to 43% in the most deprived areas, whereas advanced cancer increased from 19% to 23%. Asian patients had the highest proportion of locally advanced cancer (38%) and the lowest of advanced cancer (13%). Regionally, the East Midlands had the lowest proportion of localised cancer patients (41%) and the highest of advanced cancer (29%). Patients with higher comorbidities (CCI ≥2) were more likely to have advanced cancer (34%).

Table 1. Cohort characteristics stratified by prostate cancer stage at diagnosis by N (%)

Patient characteristics	All patients N (%)	Localised N (%)	Locally advanced N (%)	Advanced N (%)
Total number of patients	13693 (100)	6206 (45)	4642 (34)	2845 (21)
Year of diagnosis				
2010	2079 (15)	1024 (49)	653 (31)	402 (19)
2011	1945 (14)	934 (48)	626 (32)	385 (20)
2012	2066 (15)	952 (46)	675 (33)	439 (21)
2013	2096 (15)	945 (45)	727 (35)	424 (20)
2014	2027 (15)	904 (45)	693 (34)	430 (21)
2015	1836 (13)	780 (43)	666 (36)	390 (21)
2016	1644 (12)	667 (41)	602 (37)	375 (23)
Age at diagnosis				
Mean (standard deviation)	73.0 (7.7)	71.0 (6.5)	73.6 (7.4)	78.3 (8.3)
Median (IQR)	73 (68-79)	71 (66-76)	73 (68-79)	79 (72-85)
≤65	2147 (16)	1318 (61)	642 (30)	188 (9)
66-70	3194 (23)	1750 (55)	1065 (33)	381 (12)
71-75	3207 (23)	1566 (49)	1149 (36)	492 (15)
76-80	2561 (19)	1068 (42)	926 (36)	573 (22)
>80	2575 (19)	504 (20)	860 (33)	1211 (47)
IMD				
1 - least deprived	2402 (18)	1125 (47)	826 (34)	451 (19)
2	2616 (19)	1200 (46)	894 (34)	522 (20)
3	2729 (20)	1253 (46)	918 (34)	558 (20)
4	3037 (22)	1368 (45)	1015 (33)	654 (22)
5 - most deprived	2909 (21)	1260 (43)	989 (34)	660 (23)
Ethnicity				
Asian	190 (1)	93 (49)	73 (38)	24 (13)
Black	326 (2)	162 (50)	103 (32)	61 (19)
Mixed	44 (0)	22 (50)	14 (32)	8 (18)
Other	85 (1)	43 (51)	29 (34)	13 (15)
White	13048 (95)	5886 (45)	4423 (34)	2739 (21)
Practice Region				
1-North East	493 (4)	224 (45)	148 (30)	121 (25)
2-North West	1735 (13)	796 (46)	615 (35)	324 (19)
3-Yorkshire & The Humber	629 (5)	266 (42)	217 (35)	146 (23)
4-East Midlands	385 (3)	158 (41)	114 (30)	113 (29)
5-West Midlands	1920 (14)	841 (44)	677 (35)	402 (21)
6-East of England	1376 (10)	640 (47)	434 (32)	302 (22)
7-South West	2331 (17)	1006 (43)	804 (35)	521 (22)
8-South Central	1793 (13)	882 (49)	579 (32)	332 (19)
9-London	1333 (10)	624 (47)	470 (35)	239 (18)

10-South East Coast	1698 (12)	769 (45)	584 (34)	345 (20)
CCI				
0	6332 (46)	3211 (51)	2183 (35)	938 (15)
1	3694 (27)	1726 (47)	1309 (36)	659 (18)
≥2	3667 (27)	1269 (35)	1150 (31)	1248 (34)

Multivariate analysis: Men aged >80 years had significantly higher odds of locally advanced (OR=3.5 (3.0 to 4.1, p<0.001) and advanced-stage (OR=16.9 (14.0 to 20.3), p<0.001) compared to those ≤65 years (Table 2 - crude models).

Table 2. Impact of sociodemographic factors on stage at diagnosis using multinomial logistic regression models

Characteristic	LOCALLY ADVANCED								ADVANCED PROSTATE CANCER							
	Crude Models				Adjusted Model 3				Crude Models				Adjusted Model 3			
	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value
Age at diagnosis (years)																
≤65	*Reference*				*Reference*				*Reference*				*Reference*			
66-70	1.2	1.1	1.4	**0.000**	1.2	1.1	1.4	**0.003**	1.5	1.3	1.8	**0.000**	1.4	1.2	1.7	**0.000**
71-75	1.5	1.3	1.7	**0.000**	1.5	1.3	1.6	**0.000**	2.2	1.8	2.6	**0.000**	2.0	1.6	2.4	**0.000**
76-80	1.8	1.6	2.0	**0.000**	1.7	1.5	2.0	**0.000**	3.8	3.1	4.5	**0.000**	3.2	2.6	3.8	**0.000**
>80	3.5	3.0	4.0	**0.000**	3.4	2.9	3.9	**0.000**	16.8	14.0	20.3	**0.000**	13.2	11.0	16.0	**0.000**
IMD																
1 - least deprived	*Reference*				*Reference*				*Reference*				*Reference*			
2	1.0	0.9	1.1	0.819	1.0	0.9	1.2	0.787	1.1	0.9	1.3	0.286	1.1	1.0	1.3	0.140
3	1.0	0.9	1.1	0.973	1.0	0.9	1.1	0.597	1.1	1.0	1.3	0.164	1.0	0.9	1.2	0.597
4	1.0	0.9	1.1	0.865	1.0	0.9	1.1	0.894	1.2	1.0	1.4	**0.016**	1.1	1.0	1.3	0.095
5 - most deprived	1.1	0.9	1.2	0.285	1.0	0.9	1.2	0.607	1.3	1.1	1.5	**0.000**	1.2	1.0	1.5	**0.014**
Ethnicity																
White	*Reference*				*Reference*				*Reference*				*Reference*			
Asian	1.0	0.8	1.4	0.782	1.0	0.7	1.4	0.900	0.6	0.4	0.9	**0.010**	0.6	0.4	0.9	**0.029**
Black	0.8	0.7	1.1	0.190	0.8	0.7	1.1	0.224	0.8	0.6	1.1	0.164	0.9	0.7	1.3	0.631
Mixed/Other	0.9	0.6	1.3	0.519	0.9	0.6	1.3	0.508	0.7	0.4	1.1	0.148	0.7	0.4	1.3	0.259
Practice Region																
9-London	*Reference*				*Reference*				*Reference*				*Reference*			
1-North East	0.9	0.7	1.1	0.284	0.8	0.6	1.1	0.137	1.4	1.1	1.8	**0.012**	1.2	0.9	1.6	0.250
2-North West	1.0	0.9	1.2	0.754	1.0	0.8	1.2	0.784	1.1	0.9	1.3	0.546	0.9	0.7	1.2	0.531
3-Yorkshire & The Humber	1.1	0.9	1.3	0.468	1.0	0.8	1.3	0.703	1.4	1.1	1.8	**0.005**	1.3	1.0	1.7	0.055
4-East Midlands	1.0	0.7	1.3	0.754	0.9	0.7	1.2	0.405	1.9	1.4	2.5	**0.000**	1.6	1.2	2.2	**0.003**
5-West Midlands	1.1	0.9	1.3	0.406	1.0	0.9	1.2	0.842	1.2	1.0	1.5	**0.023**	1.1	0.9	1.4	0.405
6-East of England	0.9	0.8	1.1	0.228	0.9	0.7	1.0	0.079	1.2	1.0	1.5	**0.043**	1.1	0.9	1.4	0.297
7-South West	1.1	0.9	1.2	0.443	1.0	0.9	1.2	0.863	1.4	1.1	1.6	**0.001**	1.2	1.0	1.5	0.060
8-South Central	0.9	0.7	1.0	0.090	0.8	0.7	1.0	0.060	1.0	0.8	1.2	0.862	0.9	0.7	1.1	0.312
10-South East Coast	1.0	0.9	1.2	0.920	1.0	0.8	1.2	0.805	1.2	1.0	1.4	0.114	1.2	0.9	1.4	0.181

After adjusting for IMD, the most deprived quintile had higher odds of advanced-stage cancer (aOR=1.3 (1.1 to 1.5), p<0.001) but showed no impact for locally advanced cancer. Including ethnicity showed lower odds of advanced cancer for Asian men (OR=0.6 (0.4 to 0.9), p=0.027) compared to White men. Age remained the strongest predictor in the fully adjusted model with the practice region, diagnosis year, and CCI (Table 2). Regional differences were seen with higher odds of advanced-stage cancer in the East Midlands (aOR=1.6 (1.2 to 2.2), p<0.001) compared to London. The impact of IMD and ethnicity on the advanced stage persisted, highlighting that age, along with socioeconomic, ethnic, and regional factors, contributed to variations in the cancer stage.

4. Discussion and Conclusions

Using large-scale linked English national data, we identified stage-related disparities in PCa diagnosis by age, deprivation, region, and ethnicity aligning with previous research [2-4]. Evidence suggests that a national targeted screening programme is essential to address these disparities in PCa, particularly among high-risk groups, to improve early detection, enhance survival rates, and reduce the healthcare burden of late-stage diagnoses [10]. Studies leveraging real-world data provide insights into population-level

trends and disparities, offering an evidence base to inform policy changes and targeted interventions. While our study benefits from a large, population-based cohort and enhances its importance by considering comorbidity as a confounder, we acknowledge several limitations. Patient-level factors such as health literacy, symptom awareness, and familiarity with the healthcare system were not captured. Deprivation and regional data were assigned at the GP practice level, which may not always reflect individual circumstances. The study relied on routinely collected data, which, while invaluable for population-level research, comes with inherent challenges as the data were not collected primarily for research purposes.

Older age, high deprivation, and being from primary care practices in the East Midlands were associated with a higher likelihood of advanced-stage diagnosis. This research contributes to the broader understanding of PCa inequalities, providing insights that could motivate targeted interventions to reduce advanced-stage diagnoses. Ultimately, these efforts could enhance outcomes for men with PCa in England and reduce healthcare disparities.

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