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# Socioeconomic deprivation and the outcome of pulmonary rehabilitation in England and Wales

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## ABSTRACT

**Background** Pulmonary rehabilitation (PR) improves exercise capacity and health status in patients with COPD, but many patients assessed for PR do not complete therapy. It is unknown whether socioeconomic deprivation associates with rates of completion of PR or the magnitude of clinical benefits bequeathed by PR.
**Methods** PR services across England and Wales enrolled patients to the National PR audit in 2015. Deprivation was assessed using Index of Multiple Deprivation (IMD) derived from postcodes. Study outcomes were completion of therapy and change in measures of exercise performance and health status. Univariate and multivariate analyses investigated associations between IMD and these outcomes.
**Results** 210 PR programmes enrolled 7413 patients. Compared with the general population, the PR sample lived in relatively deprived neighbourhoods. There was a statistically significant association between rates of completion of PR and quintile of deprivation (70% in the least and 50% in the most deprived quintiles). After baseline adjustments, the risk ratio (95% CI) for patients in the most deprived relative to the least deprived quintile was 0.79 (0.73 to 0.85), p<0.001. After baseline adjustments, IMD was not significantly associated with improvements in exercise performance and health status.
**Conclusions** In a large national dataset, we have shown that patients living in more deprived areas are less likely to complete PR. However, deprivation was not associated with clinical outcomes in patients who complete therapy. Interventions targeted at enhancing referral, uptake and completion of PR among patients living in deprived areas could reduce morbidity and healthcare costs in such hard-to-reach populations.

## Key messages

**What is the key question?**

- Are clinical outcomes (improvement in exercise performance and health status) and completion of pulmonary rehabilitation (PR) associated with socioeconomic deprivation in patients with COPD?

**What is the bottom line?**

- Using data from the national audit of PR clinical outcomes in England and Wales, we demonstrate that patients living in more socially deprived areas are less likely to complete a programme of PR, but clinical outcomes in those who do finish treatment are similar to those referred from less deprived areas.

**Why read on?**

- Targeted interventions aimed at enhancing referral, uptake and completion of PR among patients with COPD living in deprived areas have the potential to improve health outcomes in this population.

## INTRODUCTION

COPD is an important and prevalent non-communicable long-term condition that imposes a significant burden of mortality and morbidity worldwide.[1] The prevalence and impact (eg, the risk of hospitalisation) of COPD has been shown to be associated with poor socioeconomic status in many countries including the UK.[2 3] National clinical audits of hospital care (2014) in England and Wales (E&W) have similarly demonstrated a gradient of prevalence across socioeconomic strata.[4]

Clinical trials of pulmonary rehabilitation (PR) have demonstrated unequivocal and substantial improvements in breathlessness, exercise limitation and health status in people with COPD.[5] The 2015 E&W national audit of PR comprehensively appraised services and patient outcomes in a cohort of over 7000 patients attending an assessment for PR, providing for the first time a detailed assessment of the effectiveness of PR 'in the field'.[6] The audit has confirmed that the benefits of PR observed in clinical trials are delivered at a comparable magnitude in real-life clinical practice in patients who attend and complete therapy. However, the audit also confirms that many patients do not enrol or complete their course of PR and as expected there is heterogeneity in the response to therapy. Previous studies conducted in single centres or regions have investigated factors predicting PR adherence, completion and clinical response but due to limitations of sample size and geographical scope have not identified clear-cut patient level indicators predicting these outcomes.[7–12] In particular, it is unknown whether social deprivation (across the breadth of national socioeconomic strata) is a predictor of these

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outcomes of therapy. This is an important question because PR is one of the few interventions in COPD that has been shown to reduce subsequent healthcare resource utilisation (and costs) including days spent in hospital.[13 14] Given that the risk of hospitalisation is also greater in populations with low socioeconomic status,[15 16] an understanding of the relationship between social disadvantage and other disease or demographic factors and the prediction of successful attendance and completion of PR might allow targeted interventions/resource aimed at enhancing both the uptake and completion of PR as well as clinical outcomes in particular groups of patients. This could in turn reduce morbidity and healthcare costs in hard-to-reach populations such as those at social disadvantage.

In the E&W national PR audit, individual patient postcodes were used to obtain a set of deprivation indices (Index of Multiple Deprivation (IMD)) pertaining to the area in which the patient lived at the time of their assessment for treatment. In this study, we determined whether completion of treatment and clinical outcomes recorded during the audit were associated with IMD and whether any such associations held true when adjusted for other disease and demographic variables recorded at baseline assessment for PR.

## METHODS

### Audit methodology

The National COPD Audit Programme, commissioned by the Healthcare Quality Improvement Partnership (HQIP) as part of the National Clinical Audit Programme (NCA), delivers a programme of work that aims to drive improvements in the quality of care and services provided for patients with COPD in E&W. The programme is led by the Royal College of Physicians, working in partnership with the British Thoracic Society, the British Lung Foundation, the Primary Care Respiratory Society UK, the Royal College of General Practitioners and the Health and Social Care Information Centre.

The first national audit of clinical outcomes of PR in E&W reported clinical outcomes in 2016.[6] A detailed account of the audit methodology is provided in the online supplementary material and reports are also publicly accessible at http://www.rcplondon.ac.uk/projects/national-copd-audit-programme-pulmonary-rehabilitation-workstream.

Prior to undertaking the audit, PR services across E&W were comprehensively surveyed and mapped (see online supplementary material for details) with 230 programmes invited to enrol patients. Programmes were requested to audit all patients with a primary respiratory diagnosis of COPD who attended an initial assessment for PR between 12 January 2015 and 10 April 2015, with a further 3-month period (to 10 July 2015) to allow the patients who had been recruited and consented to complete their PR and for data to be entered onto the online data collection tool. The clinical audit dataset was developed by the PR workstream group, in consultation with COPD experts across E&W. The dataset is provided in the online supplementary material and is also available to download via the weblink above. Section 251 approval was obtained via the National Confidentiality Advisory Group for the collection of patient identifiable data. Caldicott Guardian approval was obtained from each participating unit before access to the online audit web tool was granted and patients enrolled to the audit provided individual written consent before their data were uploaded.

### Index of multiple deprivation

Definitions and assessment of deprivation and socioeconomic position are complex.[17] Social deprivation arises from the inequity of an individual's socioeconomic position comparative to others, formed from the hierarchical distribution of wealth, welfare and opportunity within society.[18] Deprivation covers a broad range of issues and refers to unmet needs caused by a lack of resources of all kinds, not just financial.

E&W produce their own separate indices of multiple deprivation (http://www.neighbourhood.statistics.gov.uk/dissemination/MetadataDownloadPDF;

http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6222/1871538.pdf), with scores that are not directly comparable. For this audit, patient postcodes were used to obtain a set of deprivation indices data pertaining to the area in which the patient lived at the time of their enrolment to PR; these data being publicly available.

### Clinical outcomes

Three outcomes were chosen to reflect success or otherwise in various aspects of a PR programme. First, patients were considered to have completed PR if they attended a discharge assessment (irrespective of attendance rates during the programme), where other outcomes were recorded. The other two outcomes relate to improvements in health status and in exercise performance, and applied to those with relevant baseline and discharge values. The Incremental Shuttle Walk test (ISWT) and the 6 min walk test (6MWT) were amalgamated by taking the percentage change from initial to discharge assessment. Health status measures comprised the St George's Respiratory Questionnaire (SGRQ), the Chronic Respiratory Questionnaire (CRQ) and the COPD Assessment Test (CAT). Since these ordinal scales were unsuitable for computing percentage change, a combined health status outcome was obtained by amalgamating minimum clinically important differences (MCID). The MCID for the SGRQ was a reduction of 4 points in the total score, for the CRQ an increase of 0.5 points in the average of the four domain scores and for the CAT a reduction of 2 points.[19–21] The combined health status outcome measure was then the achievement of any of these MCID. Baseline scores for exercise and health status were categorised into quartiles—best quartile through to worst quartile of scores. Patients having more than one type of assessment (eg, ISWT and 6MW for exercise, or SGRQ and CAT for health status) were placed according to the assessment quartile they performed best on. These and all other baseline patient/clinical characteristics used in the analysis were as categorised in table 2.

### Statistical analysis

The $\chi^2$ test was used to test for association between deprivation quintiles and other baseline characteristics, for association between baseline characteristics and whether or not patients attended a discharge assessment and (for those with relevant data) whether an MCID was achieved in regard to health status. The Mann-Whitney U test (2 groups) or Kruskal-Wallis test (>2 groups) was used to test for association in the percentage change in exercise distance, the distribution of which was notably skewed. Preliminary visual graphical inspection of outcomes by IMD within each stratum of factors in table 1 and baseline assessment quartiles was undertaken to inspect for evidence of interaction. No such evidence was found. Binary regression (STATA binreg procedure, rr link option) was used to assess the association of deprivation quintile with whether or not patients attended a discharge assessment, and with whether or not an MCID in health status was achieved. Median regression (STATA qreg/qreg2 procedures) was used to assess the association of deprivation quintile with percentage change in

**Table 1** Prevalence of sample characteristics at baseline across IMD deprivation quintiles results where the association was statistically significant at the 5% level

| | IMD | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 most deprived | Q2 | Q3 | Q4 | Q5 least deprived | Total | p Value* |
| All patients | 26% 1915 | 22% 1570 | 20% 1476 | 17% 1256 | 14% 1046 | 7263 | <0.001† |
| Gender | | | | | | | |
| Male | 25% 959 | 21% 825 | 20% 785 | 18% 709 | 15% 592 | 3870 | 0.001 |
| Female | 28% 956 | 22% 745 | 20% 691 | 16% 547 | 13% 454 | 3393 | |
| Age | | | | | | | |
| <60 | 43% 495 | 23% 266 | 18% 207 | 11% 121 | 5% 61 | 1150 | <0.001 |
| 60–64 | 32% 322 | 23% 229 | 20% 198 | 15% 150 | 10% 95 | 994 | |
| 65–69 | 25% 392 | 21% 337 | 21% 327 | 18% 290 | 14% 225 | 1571 | |
| 70–74 | 22% 322 | 21% 310 | 20% 303 | 17% 257 | 20% 290 | 1482 | |
| 75–79 | 19% 223 | 21% 246 | 20% 234 | 23% 260 | 16% 184 | 1147 | |
| ≥80 | 18% 161 | 20% 182 | 23% 207 | 19% 178 | 21% 191 | 919 | |
| Smoking status | | | | | | | |
| Current | 38% 600 | 23% 357 | 18% 291 | 13% 206 | 8% 120 | 1574 | <0.001 |
| Ex | 23% 1179 | 22% 1111 | 21% 1056 | 18% 923 | 16% 812 | 5081 | <0.001 |
| Never | 17% 77 | 18% 78 | 22% 97 | 23% 104 | 20% 88 | 444 | |
| Not known | 36% 59 | 15% 24 | 20% 32 | 14% 23 | 16% 26 | 164 | |
| Mental health disorder comorbidity | | | | | | | |
| No | 26% 1725 | 22% 1456 | 21% 1382 | 17% 1176 | 15% 991 | 6730 | <0.001 |
| Yes | 36% 190 | 21% 114 | 18% 94 | 15% 80 | 10% 55 | 533 | |
| Patient's living arrangements | | | | | | | |
| House/flat with other | 24% 1076 | 21% 961 | 21% 930 | 18% 827 | 16% 702 | 4496 | <0.001 |
| House/flat alone | 32% 651 | 22% 460 | 19% 399 | 15% 311 | 11% 235 | 2056 | <0.001 |
| Other | 33% 52 | 25% 40 | 20% 32 | 15% 23 | 6% 10 | 157 | |
| Not known | 25% 136 | 20% 109 | 21% 115 | 17% 95 | 18% 99 | 554 | |
| Patient-reported MRC dyspnoea score at assessment | | | | | | | |
| Grades 1/2 | 22% 254 | 19% 221 | 22% 262 | 18% 206 | 20% 230 | 1173 | <0.001 |
| Grade 3 | 25% 655 | 21% 556 | 21% 539 | 19% 481 | 14% 359 | 2590 | <0.001 |
| Grade 4 | 28% 644 | 24% 552 | 19% 438 | 16% 366 | 13% 288 | 2288 | |
| Grade 5 | 29% 185 | 22% 140 | 20% 123 | 16% 98 | 13% 84 | 630 | |
| Not known | 30% 177 | 17% 101 | 20% 114 | 18% 105 | 15% 85 | 582 | |

Note: Percentages for the reported variables total 100% horizontally across the IMD quintiles.
*$\chi^2$ test: first p values exclude not known, second p value includes not known.
†Goodness-of-fit test: null hypothesis—all five quintile categories have equal frequencies.
IMD, Index of Multiple Deprivation; MRC, Medical Research Council.

exercise scores; the object being to estimate the median of the dependent outcome variable, conditional on the values of the independent variables. Risk ratios (binary regression) or coefficients (median regression) were estimated, with adjustments made for possible confounder variables as independent predictors (those described in table 1, together with baseline quartiles for health status and exercise). p Values and CIs were also estimated and adjusted for programme clustering effects; SEs that are robust to intracluster correlation were obtained for both types of regression by using the option 'cluster'. Unknown data were coded to preserve the full sample size in the regression, notably affecting Medical Research Council (MRC) grade and body mass index. Due to the number of tests performed, statistical significance was regarded as p<0.001. Also, the large sample sizes sometimes resulted in small, clinically non-relevant differences being statistically significant and this is reflected in the overall interpretation.

Additional analyses were performed to consider the potential impact that categorising IMD may have had, particularly in regard to discharge assessment. These were done for England alone (96% of all cases) since the numerical scale for Wales was different. Random effects logistic regression was also used as an alternative to binary regression. Additional results are provided in online supplementary material.

### Role of the funding source

The National COPD Audit Programme is commissioned by the HQIP (http://www.HQIP.org.uk) as part of the NCA. The NCA is funded by NHS England, the Welsh Government and, with some individual audits, also funded by the Health Department of the Scottish Government, Department of Health, Social Services and Public Safety (DHSSPS) Northern Ireland and the Channel Islands. The authors are independent from HQIP and the audit funders who had no influence over the writing of the manuscript.

## RESULTS

Two hundred and ten programmes (195 in England and 15 in Wales) enrolled 7413 patients to the audit. Based on individual programme activity data provided as part of the audit of the organisation and resources of PR[22] for the same case acquisition time period as the clinical audit (12 January to 15 April 2015), the response rate was estimated as 73% of eligible patients. The reason for non-enrolment was because either the patient was

Table 2 Univariate associations for the three study outcomes by each of the study baseline variables

| | % of those assessed attending a discharge assessment | p Value* | % achieving MCID in health status† | p Value* | % change in ISWT/6MWT exercise test distance Median (IQR), N | p Value‡ |
|---|---|---|---|---|---|---|
| All patients | 59% (4353/7413) | | 61% (2240/3664) | | 25 (8–54), n=3901 | |
| (W)IMD | | | | | | |
| Q1 most deprived | 50% (951/1915) | <0.001 | 60% (458/760) | 0.20 | 27 (9, 63), n=843 | <0.001 |
| Q2 | 55% (860/1570) | <0.001 | 64% (473/736) | 0.30 | 29 (11, 59), n=782 | <0.001 |
| Q3 | 62% (919/1476) | | 62% (489/786) | | 23 (7, 50), n=823 | |
| Q4 | 63% (801/1256) | | 59% (401/685) | | 23 (7, 49), n=719 | |
| Q5 least deprived | 70% (736/1046) | | 60% (373/623) | | 22 (6, 47), n=658 | |
| Not known | 57% (86/150) | | 62% (46/74) | | 22 (7, 46), n=76 | |
| Gender | | | | | | |
| Male | 60% (2353/3948) | 0.10 | 62% (1224/1976) | 0.28 | 23 (7, 50), n=2136 | <0.001 |
| Female | 58% (2000/3465) | | 60% (1016/1688) | | 27 (10, 58), n=1765 | |
| Age | | | | | | |
| <60 | 45% (525/1180) | <0.001 | 64% (281/439) | 0.15 | 33 (15,70), n=459 | <0.001 |
| 60–64 | 56% (570/1020) | | 60% (294/491) | | 23 (7, 54), n=531 | |
| 65–69 | 61% (985/1604) | | 60% (500/839) | | 24 (9, 50), n=889 | |
| 70–74 | 63% (945/1505) | | 63% (504/802) | | 22 (7, 50), n=860 | |
| 75–79 | 63% (739/1167) | | 63% (389/616) | | 23 (7, 50), n=651 | |
| ≥80 | 63% (589/937) | | 57% (272/477) | | 26 (6, 64), n=511 | |
| Ethnicity | | | | | | |
| White: British/Irish/other | 59% (4006/6772) | 0.13 | 61% (2062/3368) | 0.17 | 25 (8, 54), n=3582 | 0.23 |
| Other | 54% (108/201) | 0.05 | 68% (65/95) | 0.12 | 31 (9, 63), n=100 | 0.30 |
| Not known | 54% (239/440) | | 56% (113/201) | | 23 (8, 46), n=219 | |
| Previous PR completion | | | | | | |
| Yes | 62% (734/1175) | 0.006 | 59% (361/611) | 0.24 | 22 (7, 47), n=648 | 0.03 |
| No | 58% (3286/5650) | 0.01 | 62% (1700/2758) | 0.50 | 25 (8, 54), n=2952 | 0.08 |
| Not known | 57% (333/588) | | 61% (179/295) | | 27 (8, 62), n=301 | |
| Smoking status | | | | | | |
| Current | 47% (753/1614) | <0.001 | 58% (359/619) | 0.15 | 25 (8, 55), n=662 | 0.44 |
| Ex | 62% (3214/5179) | <0.001 | 62% (1676/2725) | 0.27 | 24 (8, 53), n=2904 | 0.22 |
| Never | 66% (296/449) | | 64% (160/249) | | 27 (11, 52), n=258 | |
| Not known | 53% (90/171) | | 63% (45/71) | | 33 (8, 91), n=77 | |
| No. of comorbidities (0–23) | | | | | | |
| 0 | 61% (1074/1771) | 0.001 | 62% (559/902) | 0.16 | 22 (8, 50), n=958 | <0.001 |
| 1 | 60% (1446/2397) | | 59% (714/1210) | | 24 (7, 50), n=1305 | |
| 2 | 59% (978/1662) | | 61% (517/850) | | 27 (8, 52), n=891 | |
| 3 | 54% (501/931) | | 66% (276/419) | | 26 (9, 57), n=443 | |
| ≥4 | 54% (354/652) | | 61% (174/283) | | 35 (13, 68), n=304 | |
| Cardiovascular comorbidity§ | | | | | | |
| No | 58% (2259/3880) | 0.36 | 60% (1156/1915) | 0.32 | 24 (8, 53), n=2029 | 0.34 |
| Yes | 59% (2094/3533) | | 62% (1084/1749) | | 26 (8, 54), n=1872 | |
| Diabetes comorbidity | | | | | | |
| No | 59% (3794/6426) | 0.15 | 61% (1942/3184) | 0.65 | 24 (8, 53), n=3397 | 0.07 |
| Yes | 57% (559/987) | | 62% (298/480) | | 27 (10, 60), n=504 | |
| Locomotor problems comorbidity | | | | | | |
| No | 60% (3912/6557) | <0.001 | 61% (2022/3297) | 0.47 | 25 (8, 53), n=3528 | 0.20 |
| Yes | 52% (441/856) | | 59% (218/367) | | 30 (7, 61), n=373 | |
| Mental health disorder comorbidity | | | | | | |
| No | 60% (4090/6871) | <0.001 | 61% (2101/3441) | 0.71 | 24 (8, 53), n=3659 | <0.001 |
| Yes | 49% (263/542) | | 62% (139/223) | | 32 (14, 72), n=242 | |
| No. of times patient hospitalised for a COPD exacerbation in the past 12 months | | | | | | |
| 0 | 61% (2692/4382) | <0.001 | 60% (1372/2269) | 0.53 | 24 (8, 50), n=2441 | 0.001 |
| 1 | 59% (789/1330) | <0.001 | 61% (397/648) | 0.62 | 26 (8, 57), n=693 | 0.003 |
| ≥2 | 47% (286/608) | | 64% (154/240) | | 36 (12, 72), n=244 | |
| Not known | 54% (586/1093) | | 63% (317/507) | | 24 (8, 54), n=523 | |
| Oxygen therapy at home at the time of assessment | | | | | | |
| Yes | 54% (318/590) | 0.008 | 58% (153/265) | 0.24 | 26 (0, 60), n=263 | 0.72 |
| No | 59% (3971/6674) | <0.001 | 61% (2056/3347) | 0.48 | 25 (8, 53), n=3583 | 0.84 |

Continued

**Table 2** Continued

| | % of those assessed attending a discharge assessment | p Value* | % achieving MCID in health status† | p Value* | % change in ISWT/6MWT exercise test distance Median (IQR), N | p Value‡ |
|---|---|---|---|---|---|---|
| Not known | 43% (64/149) | | 60% (31/52) | | 27 (8, 58), n=55 | |
| Patient's living arrangements | | | | | | |
| House/flat with other | 60% (2752/4593) | 0.003 | 62% (1450/2340) | 0.001 | 25 (8, 54), n=2470 | 0.94 |
| House/flat alone | 58% (1220/2100) | 0.001 | 59% (594/1013) | 0.001 | 25 (8, 53), n=1089 | 0.97 |
| Other | 47% (75/159) | | 83% (48/58) | | 23 (0, 63), n=62 | |
| Not known | 55% (306/561) | | 58% (148/253) | | 24 (7, 50), n=280 | |
| FEV$_1$ | | | | | | |
| ≤0.92 | 59% (662/1128) | 0.04 | 59% (340/579) | 0.13 | 25 (7, 54), n=586 | 0.25 |
| 0.93–1.27 | 64% (716/1115) | <0.001 | 60% (363/608) | 0.19 | 25 (8, 50), n=628 | 0.40 |
| 1.28–1.71 | 62% (690/1108) | | 64% (375/588) | | 23 (7, 50), n=636 | |
| 1.72+ | 60% (653/1089) | | 64% (363/566) | | 25 (9, 56), n=590 | |
| Not known | 55% (1632/2973) | | 60% (799/1323) | | 25 (8, 56), n=1461 | |
| Body mass index | | | | | | |
| <21 | 55% (376/688) | <0.001 | 53% (161/304) | 0.01 | 25 (7, 62), n=334 | 0.008 |
| 21–24 | 62% (712/1140) | <0.001 | 62% (373/601) | 0.02 | 22 (8, 48), n=638 | 0.01 |
| 25–29 | 63% (979/1544) | | 63% (520/828) | | 25 (10, 51), n=877 | |
| 30–34 | 62% (540/865) | | 65% (304/466) | | 25 (8, 54), n=487 | |
| 35 or above | 58% (381/661) | | 61% (201/332) | | 32 (12, 73), n=340 | |
| Not known | 54% (1365/2515) | | 60% (681/1133) | | 25 (7, 50), n=1225 | |
| Patient-reported MRC dyspnoea score at assessment | | | | | | |
| Grades 1/2 | 64% (760/1195) | <0.001 | 55% (360/650) | 0.003 | 18 (6, 35), n=708 | <0.001 |
| Grade 3 | 63% (1669/2656) | <0.001 | 62% (893/1435) | 0.006 | 23 (8, 48), n=1531 | <0.001 |
| Grade 4 | 56% (1302/2328) | | 62% (690/1107) | | 33 (10, 71), n=1139 | |
| Grade 5 | 49% (312/643) | | 67% (147/218) | | 46 (15, 100), n=238 | |
| Not known | 52% (310/591) | | 59% (150/254) | | 25 (10, 53), n=285 | |
| ISWT/6MWT distance quartiles at initial assessment | | | | | | |
| 1. Worst quartile | 54% (898/1676) | <0.001 | 62% (465/746) | 0.11 | 78 (33, 150), n=824 | |
| 2 | 61% (1087/1785) | <0.001 | 59% (551/931) | 0.03 | 33 (13, 59), n=1005 | |
| 3 | 68% (1040/1538) | | 64% (579/900) | | 20 (5, 36), n=983 | <0.001 |
| 4. Best quartile | 69% (1137/1640) | | 60% (595/988) | | 14 (3, 25), n=1089 | |
| No ISWT/6MWT | 25% (191/774) | | 51% (50/99) | | – | |
| SGRQ total/CRQ average/CAT score quartiles at initial assessment | | | | | | |
| 1. Worst quartile | 51% (634/1247) | <0.001 | 76% (466/617) | | 40 (15, 86), n=571 | <0.001 |
| 2 | 62% (978/1584) | <0.001 | 70% (665/952) | | 30 (11, 65), n=892 | <0.001 |
| 3 | 68% (950/1399) | | 64% (586/920) | <0.001 | 22 (7, 46), n=864 | |
| 4. Best quartile | 72% (1210/1690) | | 45% (523/1175) | | 19 (5, 38), n=1113 | |
| No SGRQ/CRQ/CAT | 39% (581/1493) | | – | | 25 (7, 66), n=461 | |

*$\chi^2$ test: first p values exclude not known, 2nd p value includes not known.
†Combined outcome with a MCID achieved in any of the following: for the SGRQ the MCID was a reduction of 4 points in the total score, for the CRQ the MCID was an increase of 0.5 points in the average of the four domain scores and for the CAT the MCID was a reduction of 2 points.
‡Mann-Whitney U test (2 groups) or Kruskal-Wallis test (>2 groups): first p values exclude not known, second p value includes not known.
§Any of atrial fibrillation, hypertension, heart failure, ischaemic heart disease, stroke, other cardiovascular.
6MWT, 6 min walk test; CAT, COPD Assessment Test; CRQ, Chronic Respiratory Questionnaire; IMD, Index of Multiple Deprivation; ISWT, Incremental Shuttle Walk test; MCID, minimum clinically important differences; MRC, Medical Research Council; PR, pulmonary rehabilitation; SGRQ, St George's Respiratory Questionnaire.

not approached or declined to provide consent for their data to be used. (W)IMD deprivation data was available for 7263 patients, but unknown for 150 (2%) (across 75 programmes). If the COPD PR audit sample living in E&W was comparable to E&W as a whole, then 20% of the sample would live within each national quintile of postcode areas. This was not so (goodness-of-fit test, p<0.001, table 1). The sample was relatively deprived with 48% living in the two most deprived quintiles and only 31% in the two 'least deprived' quintiles. Table 1 shows statistically significant associations between deprivation quintile and other baseline variables. Analysis of associations between undertaking of baseline exercise and health status assessments and IMD quintiles is provided in the online supplementary material. Of the initial sample, 6772 (91%) were 'white British or Irish or from any other white background', 201 (3%) were 'other ethnic groups' and 440 (6%) were 'not stated'. The number of cases from other ethnicities was too small to allow a meaningful analysis of PR completion or outcome by ethnic group.

Baseline characteristics of the sample and the univariate association with the three audit outcomes are shown in table 2. Many baseline factors were associated with attendance at a discharge assessment, which was achieved for 4456 (59%) overall. Of these, data for health status and exercise measures was available for 3664 and 3901, respectively. There was a gradient in attendance at a discharge assessment by IMD quintile, with

**Table 3** Binary regression risk ratio (with 95% CI and p value) of reaching a discharge assessment for IMD deprivation quintile relative to the reference group of least deprived IMD quintile, for 7413 patients

| IMD quintile | Unadjusted risk ratio (95% CI) | After adjusting for table 1 variables* and programme clustering effects |
|---|---|---|
| Q1 most deprived | 0.71 (0.66 to 0.75), p<0.001 | 0.79 (0.73 to 0.85), p<0.001 |
| Q2 | 0.78 (0.73 to 0.83), p<0.001 | 0.84 (0.77 to 0.90), p<0.001 |
| Q3 | 0.88 (0.84 to 0.94), p<0.001 | 0.92 (0.86 to 0.98), p=0.02 |
| Q4 | 0.91 (0.86 to 0.96), p=0.001 | 0.94 (0.88 to 1.00), p=0.05 |
| Q5 least deprived | Reference risk ratio=1.00 | Reference risk ratio=1.00 |
| Not known | 0.81 (0.71 to 0.94), p=0.005 | 0.88 (0.75 to 1.04), p=0.14 |

*Gender, age group, smoking status, mental health disorder comorbidity, patients living arrangements and patient-reported MRC dyspnoea score at initial assessment.
IMD, Index of Multiple Deprivation; MRC, Medical Research Council.

discharge assessment achieved by 70% in the least deprived quintile and by 50% in the most deprived quintile. A number of baseline sample characteristics were associated with rate of attendance at a discharge assessment and changes in walking performance and health status recorded at the assessment (see table 2 and more detailed description in the online supplementary material).

Regression analyses to assess the association of IMD deprivation quintile with each outcome both before and after adjusting for other baseline variables that were associated with both IMD and outcome are presented in tables 3–5. Adjustments were made for the variables from table 1, together with baseline exercise and health status as appropriate, and for PR programme clustering effects (for more detail see online supplementary material). In respect of patients having a discharge assessment, adjustments in the binary regression did diminish the IMD quintile gradient (table 3), but a statistically significant association remained; the risk ratio (95% CI) for patients in the most deprived quintile relative to patients in the least deprived quintile was 0.79 (0.73 to 0.85), that is a 21% (15%–27%) less chance of having a discharge assessment. Furthermore, an IMD gradient was observed at each categorisation level of all others variables listed in table 2 (results not shown). In regard to achieving MCIDs for health status, the binary regression adjustment for all table 1 variables was not achieved because of model convergence issues. However, adjustment was possible for the two most predictive variables, namely baseline score quartile and MRC dyspnoea score. After adjustment no statistically significant ($p<0.001$) risk ratios were seen (table 4). Regarding percentage change in ISWT/6MWT exercise test distance, the better results for patients living in more deprived areas suggested by unadjusted univariate analyses were largely extinguished after adjustment for baseline exercise score quartile and other variables (table 5).

## DISCUSSION

Using data from the first national audit of PR clinical outcomes in E&W, we have demonstrated for the first time at a national level that patients living in more socially deprived areas are less likely to complete therapy. Patients from more deprived IMD quintiles who completed PR were less likely to achieve a gain in health status above accepted thresholds for clinically important change but this association disappeared after adjustment for other baseline variables apart from those from the lowest IMD quintile. After adjustment for baseline variables, IMD was not associated with gains in exercise performance in those completing PR.

The E&W national audit of PR has provided the largest audit dataset (>7000 patients) of PR outcomes in COPD to date worldwide and has offered an opportunity to investigate, in a large nationwide sample, clinical and sociodemographic associations with rates of PR completion and gains in health status and exercise performance. In addition to IMD quintile, we identified a number of other variables recorded at baseline assessment for PR (presented in table 2) that were associated with PR completion. These included factors that in themselves were associated with IMD and may therefore have confounded the relationship between IMD and completion such as smoking status and living circumstances (shown in table 1). However, in the multivariate regression analysis, the gradient of completion rates across IMD quintiles remained significant after adjusting for these variables. The relationship between IMD quintile and the clinical outcome of treatment (assessed using health status instruments and field walking tests) was less clear cut. This analysis may have also been influenced by differences at baseline in health status and exercise measures across IMD quintiles (although adjustment for baseline values was included in the multivariate analysis) and also by methods used to assess improvement across these groups. For health status, improvement above accepted MCIDs

**Table 4** Binary regression risk ratio (with 95% CI and p value) of achieving a minimum clinically important improvement in health status for IMD deprivation quintile relative to the reference group of least deprived IMD quintile for 3664 patients

| IMD quintile | Unadjusted risk ratio (95% CI) | After adjusting for baseline health status score quartile and PR programme clustering effects | After adjusting for baseline health status score quartile, patient-reported MRC dyspnoea score at initial assessment and PR programme clustering effects |
|---|---|---|---|
| Q1 most deprived | 1.01 (0.92 to 1.10), p=0.88 | 0.91 (0.84 to 0.99), p=0.03 | 0.91 (0.84 to 0.99), p=0.03 |
| Q2 | 1.07 (0.99 to 1.17), p=0.10 | 0.99 (0.93 to 1.06), p=0.83 | 0.99 (0.92 to 1.06), p=0.79 |
| Q3 | 1.04 (0.96 to 1.13), p=0.37 | 0.98 (0.91 to 1.06), p=0.58 | 0.98 (0.91 to 1.05), p=0.56 |
| Q4 | 0.98 (0.89 to 1.07), p=0.62 | 0.93 (0.86 to 1.01), p=0.08 | 0.93 (0.87 to 1.01), p=0.08 |
| Q5 least deprived | Reference risk ratio=1.00 | Reference risk ratio=1.00 | Reference risk ratio=1.00 |
| Not known | 1.04 (0.86 to 1.25), p=0.70 | 0.98 (0.81 to 1.19), p=0.84 | 0.97 (0.80 to 1.18), p=0.75 |

IMD, Indices of Multiple Deprivation; MRC, Medical Research Council; PR, Pulmonary Rehabilitation.

**Table 5** Median regression coefficients (with 95% CI and p value) for IMD quintile relative to the reference group of least deprived quintile, in the percentage change of ISWT/6MWT exercise test distances for 3901 patients

| IMD quintile | Unadjusted coefficient (95% CI) | After adjusting for baseline ISWT/6MWT exercise score quartile and PR programme clustering effects | After adjusting for table 1 variables*, baseline ISWT/6MWT exercise score quartile and PR programme clustering effects |
|---|---|---|---|
| Q1 most deprived | 5.43 (1.56 to 9.30), p=0.006 | 2.17 (−1.48 to 5.83), p=0.24 | −0.03 (−4.10 to 4.04), p=0.99 |
| Q2 | 6.70 (2.76 to 10.6), p=0.001 | 4.55 (1.03 to 8.07), p=0.01 | 3.43 (−0.71 to 7.58), p=0.10 |
| Q3 | 1.20 (-2.69 to 5.09), p=0.55 | 0.07 (−3.72 to 3.86), p=0.97 | −1.00 (−5.31 to 3.32), p=0.65 |
| Q4 | 1.20 (-2.81 to 5.21), p=0.56 | 0.07 (−3.70 to 3.83), p=0.97 | −0.26 (−4.20 to 3.67), p=0.90 |
| Q5 least deprived | Reference coefficient=0.00 | Reference coefficient=0.00 | Reference coefficient=0.00 |
| Not known | 0.35 (−8.66 to 9.36), p=0.94 | 2.17 (−3.54 to 7.88), p=0.46 | 2.62 (−3.89 to 9.13), p=0.43 |

Note about coefficients: these estimate the difference in the median (percentage change) in the regression equation with respect to IMD quintile. In the last two columns this is after other variables have been fixed (adjusted for) in the regression equation.
*Gender, age group, smoking status, mental health disorder comorbidity, patients living arrangements and patient-reported MRC dyspnoea score at initial assessment.
6MWT, 6 min walk test; IMD, Index of Multiple Deprivation; IPR, pulmonary rehabilitation; MRC, Medical Research Council; SWT, Incremental Shuttle Walk test.

for the three instruments recorded in the audit (the SGRQ, CRQ and CAT) was calculated because the ordinal nature of health status data precludes meaningful calculation of proportionate change. For exercise measures (ISWT and 6MWD), composite proportionate improvements were calculated partly to maximise the information provided from a continuous variable and also because the most recently cited MCIDs for these tests are markedly different (27 m for the 6MWD and 48 m for the ISWT).[23] This proportionate change may have been affected by the absolute baseline value which was different across IMD quintiles, potentially explaining why unadjusted gains in exercise performance were greater in more deprived IMD quintiles. However, overall when adjusted for these differences, IMD did not predict change in exercise performance resulting from PR. Taken together, the results suggest that socioeconomic deprivation is a key factor determining the likelihood of completion of PR but for those that do complete treatment, other factors are more important in determining treatment response.

Our finding of a greater prevalence of patients referred to PR in lower IMD quintiles is in keeping with previous reports linking socioeconomic deprivation to COPD prevalence, outcomes and health resource utilisation.[2 3 16 24] Similarly, using an identical methodology to assess deprivation, the national clinical audit of acute hospital care in COPD conducted in 2014 observed a significant gradient of prevalence across IMD quintiles.[4] Indeed, the disparity of prevalence across these quintiles was greater in the national hospital audit than seen in the PR audit. We speculate that this is due to differences in rates of the offer and uptake of PR referral in more deprived populations. Although the PR audit did not assess referral practice, it may be therefore that patients from more deprived areas are less likely to complete treatment and are less likely to be referred to PR in the first place.

Previous reports have attempted to identify factors that predict the successful outcome of PR in COPD.[9] Some have identified baseline variables such as current smoking, presence of comorbidities, psychological morbidity and access to transport that predict PR completion and outcome.[25 26] However, most reports are restricted to studies in single centres or discrete geographical areas with comparatively small sample sizes and variance in outcome explained by these indices was insufficient to allow discrimination in referral criteria for PR.[8 10] It is also recognised that the benefit of PR extends beyond measurable outcome variables such as health status and exercise performance. This was highlighted by a recent large-scale single-centre study in the Netherlands where differential responses to PR were characterised using multidimensional modelling of a number of outcomes that included 'activity of daily living' scales, depression and anxiety.[27] However, this focused on clinical and physiological variables recorded at baseline PR assessment and did not include social or deprivation indices. Factors such as lack of access to transport to PR services or active smoking may be markers of social deprivation, but to our knowledge, none has reported the association of indices of social deprivation with PR outcome at a national scale.

We recognise limitations to the interpretation of our data. IMD quintiles are derived from individual postcodes and therefore provide a relative measure of deprivation at small area level. As such, IMD relates to areas and not individuals—within each area there will be both individuals who are deprived and individuals who are not. As with any regression analysis, the variance in the independent variable that is explained depends on the breadth and character of the dependent variables recorded. In this case, this was determined by the audit dataset which was in turn governed by the quality standards against which the outcome of the audit was assessed and the need to assess casemix as a means to interpret these outcomes. The assessment of the outcome of treatment was restricted to those completing a discharge assessment and was measured variably among programmes (ISWT or 6MWT for exercise performance and CRQ, SGRQ or CAT for health status). We recognise that combining these outcomes in our analysis may fail to distinguish subtle differences in how these instruments perform in the field and risk artefact due to differences relative responsiveness and thresholds for change between them. However, we believe the benefit of providing a unified analysis at a national level that can be generalised to programmes across E&W outweighs these caveats. Finally, while we believe this to be a comprehensive picture of services in E&W, we cannot rule out the possibility that PR services exist that were not identified and contacted, and therefore did not participate in the audit.

Our findings have implications for the planning and provision of PR services. The PR audit has highlighted the clinical value of exercise therapies for people with COPD but also suggests that too few patients are being referred for PR, take up the offer of referral or complete therapy.[6] Given that the available evidence suggests that completion of PR reduces subsequent health resource utilisation (such as days spent in hospital),[13 14] increasing patient referral and service provision of PR is a key health policy objective. Given the greater risk of hospital admission and poor health outcomes in patients living in deprived areas, enhancing access to PR among people living in such areas should be a priority. This may require a number of measures some of which may be straightforward such as making transport to PR services available and some more difficult such as raising awareness of the benefits of PR to patients from deprived areas and changing referral practice among healthcare workers who provide care in these areas.

In summary, using data from the national audit of PR in COPD across E&W, we have shown that rates of successful completion of therapy are lower in patients from more socioeconomically deprived areas, but that in those that complete therapy patients from all strata of deprivation gain similar benefit from PR. Given that PR is the most effective therapy available for people with COPD, targeted interventions aimed at enhancing referral, uptake and completion of PR among patients living in deprived areas could reduce morbidity and healthcare costs in such hard-to-reach populations.

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