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**FULL RESEARCH PAPER**
*Cardiac rehabilitation*

# Health inequalities in cardiac rehabilitation: a national cohort study in England

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**Aims** Participation in cardiac rehabilitation (CR) by ethnic minorities is poor, despite evidence supporting its effectiveness. This study evaluated CR participation and completion by South Asian compared with White European service users and assessed factors associated with non-completion in both groups.

**Methods and results** The National Audit of Cardiac Rehabilitation data (January 2014–February 2023) was used to identify South Asian and White European service users referred for CR following myocardial infarction, percutaneous coronary intervention, and coronary artery bypass graft. Logistic regression and backwards selection were used to examine differences in participation and completion between groups and identify associated factors.

**Discussion** From 421 281 service users eligible for CR (383 833 White European, 37 448 South Asian, 115 812 women, median age 67 years), 222 928 participated (53%), of which 171 297 (77%) completed. After adjustment for age, sex, index of multiple deprivation, and comorbidities, South Asian service users were 12% more likely to participate in CR than White Europeans [adjusted odds ratio (aOR) 1.12, 95% confidence interval (CI) 1.09–1.15], but 22% less likely to complete (aOR 0.78, 95% CI 0.75–0.82). In both groups, strongest associations with non-completion were higher deprivation, diabetes, and being single. In White European and South Asian men, stroke and depression were also key factors. Non-completion was also associated with respiratory conditions in White Europeans and with rheumatism and family cardiovascular history in South Asian men. South Asians are more likely to participate but less likely to complete CR than White Europeans. Programmes tailored to individual needs are required to reduce disparities in care.

**Lay summary** This study explores how South Asian and White European service users take part in, and complete, cardiac rehabilitation.

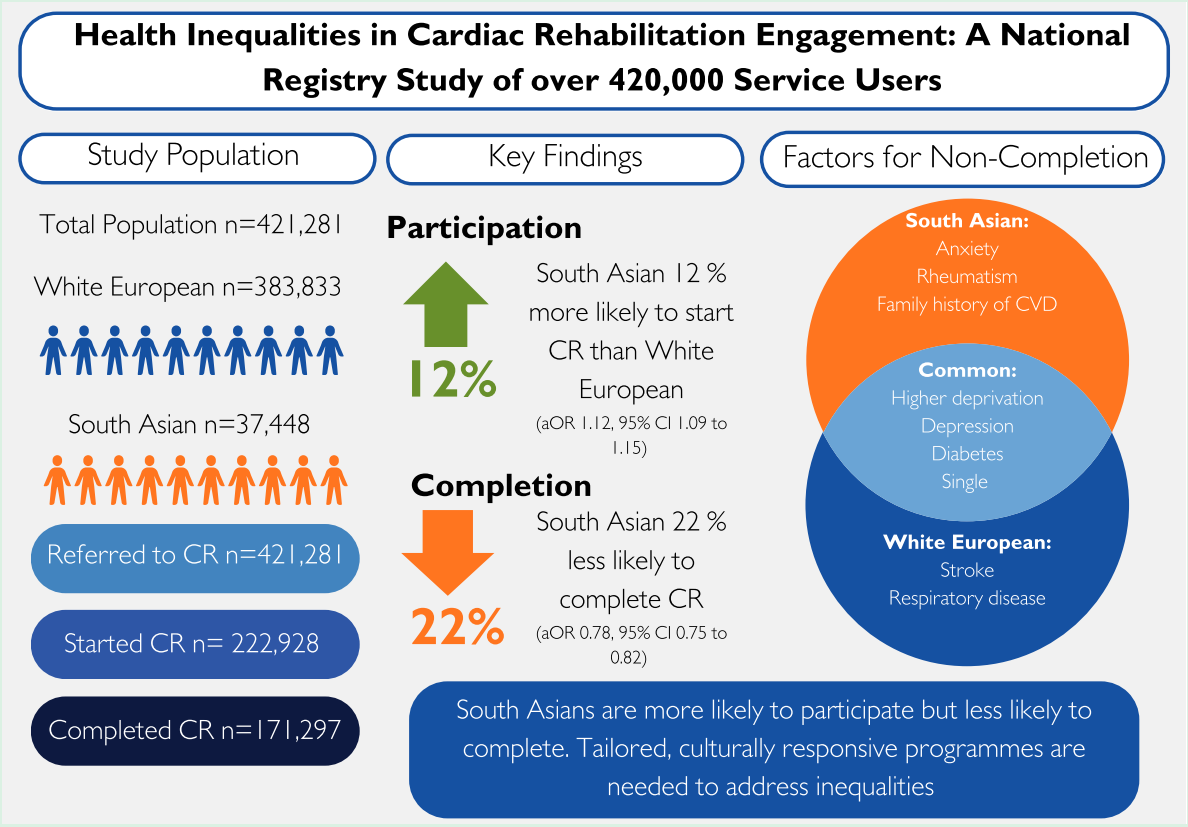
- South Asian service users were more likely to start cardiac rehabilitation than White European service users, but they were less likely to finish it.
- People from both groups were less likely to complete rehabilitation if they had conditions such as diabetes, lived in more deprived areas, were living with depression, or were single.

There is a need for culturally tailored cardiac rehabilitation (CR) interventions that challenge the assumption that ethnic minority populations are universally less likely to engage with CR. Programmes need to be tailored to individual needs to reduce inequalities and focus on equitable service provision.

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**Graphical Abstract**




**Keywords** Cardiac rehabilitation • Health inequalities • South Asian • Equitable care

## Introduction

Cardiac rehabilitation (CR) is a crucial component of recovery following acute cardiac events, offering a multifaceted approach that integrates physical activity, psychological support, and educational interventions to improve cardiovascular health and reduce the risk of recurrent events.[1,2] Strong evidence indicates that participation in a CR programme can reduce mortality by up to 20%,[3] lower the risk of rehospitalization, and decrease the likelihood of recurrent myocardial infarctions.[4] Additionally, a clear dose–response relationship underscores the importance of adherence and completion to maximize health benefits.[5] Despite its proven benefits, participation remains suboptimal. In the UK, ~50% of referred service users engage in CR programmes,[6] with global participation rates ranging from 20 to 50%.[7] Dropout rates range between 12 and 82%, with studies providing minimal or no insight of the impact of ethnicity on attrition.[2,8,9]

'Ethnic minorities' refers to groups with cultural norms differing from the majority population. Aggregating data across these groups masks crucial differences in health behaviours, limiting insights into factors affecting CR participation and outcomes. Failing to disaggregate data limits insights into participation and completion for distinct populations. South Asians, a diverse group originating from the Indian subcontinent (India, Pakistan, Bangladesh, Sri Lanka, Bhutan, Maldives, Nepal, and Afghanistan[10]) bear a disproportionately high burden of cardiovascular disease.[11] South Asians make up 25% of the global population but account for ~60% of the total cardiovascular disease (CVD) burden.[12] In Western countries, the prevalence of CVD among South Asians is three to four times higher than in majority populations, and South Asians have a 32% higher risk of CVD mortality compared with White Europeans.[13] This disparity is largely attributed to risk factors including hypertension, hyperlipidaemia, and insulin resistance, alongside sociocultural influences on dietary habits, food preparation, and physical activity levels.[14] The South Asian diaspora forms one of the largest migrant populations in the world, with global immigration increasing year on year for the last five decades.[15–17] This demographic shift underscores ethnic variety of local populations and the importance of tailored healthcare delivery to meet the specific health needs of a growing international community.

Previous studies examining ethnic diversity in CR have identified persistent disparities in referral, participation, and completion, with ethnic minorities often displaying lower rates in all three stages.[18–20] However, many of these studies have been conducted in North American or European contexts and often aggregate data across multiple minority groups, obscuring differences between distinct populations such as South Asians, Black, and Hispanic communities. Although ethnic disparities in CR have been recognized, much of the existing literature generalizes findings across minority groups, by aggregating data

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together for multiple ethnic groups termed 'ethnic minorities', failing to address the specific challenges faced by South Asians.[18,21,22] A Cochrane review of interventions to promote CR participation and completion found no reporting of ethnicity among included studies.[2] Separately, a study of 822 patients assessing racial disparities in CR initiation reported results only as 'White' vs. 'non-White', limiting understanding of ethnic-specific patterns.[23] Existing national audits have sporadically disaggregated ethnicity,[6,24,25] but few combine multiple years to provide a large-scale overview of participation, and have not examined factors associated with non-completion.

There is a lack of high-quality research, using disaggregated ethnicity data, to inform healthcare providers of the factors influencing participation and completion among diverse ethnic groups.[2,22] It is understood that South Asian individuals are at a higher risk of CVD,[11] and therefore be at great need of CR services; however, little is known about the factors that influence participation and completion for this individual ethnic population compared with White Europeans. Either a lack of evidence or poor-quality evidence is leaving a gap in the knowledge base, and this gap limits the development of targeted interventions that address cultural and socioeconomic barriers, ultimately hindering efforts to reduce disparities in cardiovascular outcomes.

Factors influencing CR participation and completion differ across ethnic groups, though some provider- and patient-level barriers are shared. South Asian individuals, such as Black and Hispanic populations, are reported to have lower participation and completion rates in CR compared with White individuals,[21,26] but the barriers they face show some unique patterns. Similar to other minorities, they experience lower referral rates, limited CR access, and socioeconomic constraints such as lower income, inadequate insurance, and work or caregiving responsibilities.[18,22,27,28] However, South Asians are particularly affected by cultural factors, including fatalistic health beliefs, gender norms, and traditional dietary practices that may conflict with standard CR guidance.[29,30] These challenges are less reported in Black or Hispanic populations. Across all minority groups, lack of awareness of CR programmes and mistrust of the healthcare system further reduce participation, highlighting the need for culturally tailored, accessible CR interventions to achieve equitable outcomes.[18] Audit datasets typically focus on clinical and demographic variables and rarely capture cultural or psychosocial influence. Factors such as language proficiency, health literacy, social support, religious- or gender-related beliefs, and expectations of illness and recovery are known to shape participation in CR, particularly among South Asian communities.[29] Future studies integrating audit data with qualitative or measures of cultural and social context would provide a more comprehensive understanding of these mechanisms. Despite this, large-scale audit and registry data provide valuable insights into patterns of participation and completion across diverse populations.

Most prior studies either aggregate data across multiple minority groups or lack sufficient sample sizes to examine ethnic-specific patterns, particularly for South Asians. There is limited high-quality, large-scale evidence on the sociodemographic (SD) and clinical factors influencing participation and completion in CR for this population. Addressing these gaps is essential to inform culturally sensitive, targeted interventions and improve equitable access to CR services. Given the limited availability of large-scale studies with disaggregated ethnicity data, and the elevated risk of CVD among South Asian populations, the primary aim of this study was to use data from the UK National Audit of Cardiac Rehabilitation (NACR) to evaluate CR participation and completion. The secondary aim was to assess factors associated with non-completion among South Asian and White European service users in England. The findings offer valuable insights to inform targeted interventions and enhance adherence across diverse populations.

# Methods

## Study population

In this retrospective cohort study, we used the NACR, which captures data from CR programmes across the UK on demographic, clinical, and programme-specific data. The NACR has extensive coverage with 90% of UK programmes contributing sufficient electronic data in the 2022 NACR report. The audit, hosted by the University of York, collaborates with the National Health Service England (NHSE) to ensure the anonymization of service user records prior to the use of audit data for research and reporting purposes.[31] The NACR produces annual reports, aiming to support service development, promote best practice, and target quality improvement areas such as inequitable provision.[31] Despite being established in 2005, the audit experienced significant improvements in data capture accuracy and volume following amendments; therefore, only data from 2014 onwards is included in this analysis. Dataset was released and accessed from March 2023.

Data for the NACR are collected through a combination of patient self-report questionnaires and clinician-reported information. Patients complete structured questionnaires independently at three time points: before starting rehabilitation, immediately after completion, and at 12-month follow-up. These capture demographics, clinical characteristics, and rehabilitation experiences. Programme-level information, including staffing, hours worked, and service organization, is collected annually via electronic surveys. Data are submitted to the NACR through a secure online portal, either individually or in bulk. Cardiac rehabilitation programme staff distribute questionnaires, collect responses, and submit the data, and the NACR team co-ordinates the process, collates responses, and produces annual and quarterly reports.

We included all South Asian and White European service users referred to CR between 1 January 2014 and 28 February 2023 (*Table 1*) with age, sex, and socioeconomic status recorded and any of the following initiating events: myocardial infarction (MI), percutaneous coronary intervention (PCI/PPCI) and coronary artery bypass (CABG). The MI, PCI, and/or CABG group has the most robust body of evidence supporting improvements in clinical outcomes following comprehensive CR, and all programmes across England offer CR for these core groups. Although other coronary events are eligible for CR, not all services deliver rehabilitation to these groups, and they were therefore were not considered in this study.

## Exposure groups

Sex was defined as male or female in accordance with the categorization in the NACR dataset. Socioeconomic status used the index of multiple deprivation (IMD), a comprehensive UK-based measurement that assesses the levels of deprivation across geographic areas[32] with IMD 1 representing the most deprived quintile and IMD 5 the most affluent quintile. Ethnicities were defined by categories existing in NACR database and included South Asian (Indian, Bangladeshi, Pakistani, and Asian Other) and White European (White British, White Irish, and Any Other White). Participants classified as 'Any Other White' in the dataset included individuals identifying as White who did not select a specific subcategory (e.g. British and Irish). In the UK context, this group predominantly comprises people of European descent (e.g. Eastern or

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**Table 1 Baseline characteristics of White European and South Asian service users in the referral cohort (*n* = 421 281)**

| | All *n* = 421 281 | White European *n* = 383 833 (91%) | South Asian *n* = 37 448 (9%) | Missing |
|---|---|---|---|---|
| Male | 305 469 (73%) | 276 288 (72%) | 29 181 (78%) | |
| Female | 115 812 (27%) | 107 545 (28%) | 8267 (22%) | |
| Age at initiating event (yrs) | 67.0 (58.0–76.0) | 68.0 (59.0–76.0) | 61.0 (52.0–70.0) | |
| Index of multiple deprivation quintile | | | | |
| IMD 5 (most affluent) | 85 156 (20%) | 81 353 (21%) | 3803 (10%) | |
| IMD 4 | 87 465 (21%) | 82 844 (22%) | 4621 (12%) | |
| IMD 3 | 85 524 (20%) | 79 138 (21%) | 6386 (17%) | |
| IMD 2 | 81 119 (19%) | 71 096 (19%) | 10 023 (27%) | |
| IMD 1 (most deprived) | 82 017 (19%) | 69 402 (18%) | 12 615 (34%) | |
| Marital status | | | | 109 155 |
| No partner | 82 544 (26%) | 78 585 (27%) | 3959 (15%) | |
| Partner | 229 582 (74%) | 207 777 (73%) | 21 805 (85%) | |
| Employment status | | | | 237 776 |
| Employed | 57 645 (31%) | 51 520 (31%) | 6125 (39%) | |
| Unemployed | 8463 (5%) | 6709 (4%) | 1754 (11%) | |
| Sick | 19 360 (11%) | 17 222 (10%) | 2138 (14%) | |
| Retired | 98 037 (53%) | 92 463 (55%) | 5574 (36%) | |
| Initiating event | | | | |
| MI | 97 371 (23.1%) | 90 396 (23.6%) | 6975 (18.6%) | |
| PCI/PPCI | 264 212 (62.7%) | 239 440 (62.4%) | 24 772 (66.2%) | |
| CABG | 59 698 (14.2%) | 53 997 (14.1%) | 5701 (15.2%) | |
| Family history of CVD | 83 116 (20%) | 76 749 (20%) | 6367 (17%) | |
| Comorbidities | | | | |
| Number | | | | |
| None | 126 297 (30%) | 114 537 (30%) | 11 760 (31%) | |
| One to two | 158 878 (38%) | 146 160 (38%) | 12 718 (34%) | |
| Three or more | 136 106 (32%) | 123 136 (32%) | 12 970 (35%) | |
| Angina | 50 465 (12%) | 46 535 (12%) | 3930 (10%) | |
| Hypertension | 155 085 (37%) | 139 988 (36%) | 15 097 (40%) | |
| Hyperlipidaemia | 100 653 (24%) | 88 971 (23%) | 11 682 (31%) | |
| Diabetes | 78 600 (19%) | 66 225 (17%) | 12 375 (33%) | |
| Stroke | 16 562 (4%) | 15 299 (4%) | 1263 (3%) | |
| Anxiety | 17 603 (4%) | 16 697 (4%) | 906 (2%) | |
| Depression | 19 276 (5%) | 18 136 (5%) | 1140 (3%) | |
| Bronchitis | 12 029 (3%) | 11 606 (3%) | 423 (1%) | |
| Emphysema | 10 116 (2%) | 9845 (3%) | 271 (1%) | |
| Asthma | 24 863 (6%) | 22 266 (6%) | 2597 (7%) | |
| Cancer | 23 479 (6%) | 22 846 (6%) | 633 (2%) | |
| Claudication | 6414 (2%) | 6126 (2%) | 288 (1%) | |
| Rheumatism | 6545 (2%) | 6196 (2%) | 349 (1%) | |
| Arthritis | 39 938 (9%) | 37 567 (10%) | 2371 (6%) | |
| Osteoporosis | 4896 (1%) | 4690 (1%) | 206 (1%) | |

Data are presented as median (25th and 75th percentiles) for continuous measures and *n* (%) for categorical measures.
CR, cardiac rehabilitation; COPD, chronic obstructive pulmonary disease; IMD, index of multiple deprivation; PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft; CVD, cardiovascular disease; White European, combination of White British, White Irish, and any other White background ethnicity groups present in NACR; South Asian, combination of Asian/Asian British–Indian, Pakistani, Bangladeshi, and any other Asian background ethnicity groups present in NACR.

Southern European), although a small minority may originate from other regions such as North America or Australasia. Exact proportions are not available, but national census data suggest that non-European representation within this group is minimal. Accordingly, we refer to this group as 'White European' throughout the paper.

## UK cardiac rehabilitation provision

In the UK, CR is provided free of charge, through the National Health Service (NHS), to all eligible service users who have been referred by a clinician following an acute cardiac event. It is a multidisciplinary programme combining exercise training, education, and

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psychosocial support. Referral occurs following hospital discharge, and programmes are delivered in hospital-, community-, and home-based settings, with referrals embedded in national clinical guidance.[33]

## Data cleaning procedures and outliers

Only participants with complete data on ethnicity, age, sex, and socioeconomic status were included in the analysis. The NACR routinely performs systematic data cleaning and validation, removing outliers that fall outside predefined physiological thresholds. For example, implausible weight values (<30 kg or >300 kg) are automatically excluded during validation. Upon receipt, the study team conducted additional cleaning and consistency checks to prepare the dataset for analysis (Supplementary material online, *Figure S1*). Clinical comorbidities were coded as zero in the absence of a recorded entry, reflecting the absence of a documented condition. No imputation was applied to variables with substantial missingness (e.g. employment status); these were therefore excluded from multivariable analyses to maintain methodological rigour and reduce bias.[34] Data on participation and completion outcomes were complete, as missing dates or participation flags were coded as non-participation or non-completion, respectively, with full definitions provided below.

## Characteristics

Sociodemographic characteristics included age at initiating event, sex, socioeconomic status, marital status, and employment status. Employment status was categorized as unemployed, employed, sick, and retired, and marital status included partner and no partner. Comorbidities, recorded at initial assessment prior to starting exercise or education classes, included angina, arthritis, cancer, diabetes, rheumatism, stroke, osteoporosis, hypertension, chronic bronchitis, emphysema, asthma, claudication, anxiety, depression, family history of CVD, and hyperlipidaemia. They were also classified by number: none, 1–2 comorbidities and ≥3 comorbidities.

## Service engagement

Participation was defined as having a start date for CR recorded in NACR and having participated in at least one exercise or education class. Participants were considered to have completed CR if they had a completion date or a post-CR assessment date and they did not have a recorded reason for not completing.

## Outcomes

The primary outcome was non-completion. This was defined as not having a completion assessment date or post-CR completion date or having a recorded reason for non-completion.

## Statistical analysis

Baseline characteristics are first presented for all eligible service users as mean ± standard deviation when normally distributed, median and interquartile ranges (25th–75th percentiles) for skewed distributions, and as frequencies and percentages for categorical variables. Logistic regression was used to estimate the association between ethnicity and CR participation and completion. Unadjusted odds ratios (ORs) with 95% confidence intervals (CIs) are first presented followed by a two-stage adjustment for (i) SD factors (sex, age at initiating event, IMD and marital status) and (ii) SD factors and comorbidities [number of comorbidities (0, 1–2, and >2) and type (angina, arthritis, cancer, diabetes, rheumatism, stroke, osteoporosis, hypertension, chronic bronchitis, emphysema, asthma, claudication, anxiety, depression, family history of CVD, and hyperlipidaemia)]. Variables were selected based on established evidence and data completeness. Sociodemographic characteristics and comorbidities were included as key patient-level predictors, consistent with multiple large-scale studies and Cochrane reviews identifying these factors as strong determinants of CR participation and completion. Behavioural variables were excluded due to substantial missing data (e.g. smoking 30% missing and physical activity 50% missing) and variable reporting quality, which could introduce bias and reduce model reliability. As the focus of this analysis was on patient-level determinants, provider-level data (e.g. staffing) and programme characteristics (e.g. duration and mode of delivery) were not included. This approach ensured that the analyses were based on high-quality data, providing a robust and interpretable assessment of individual-level disparities in CR participation and completion. Next, backwards stepwise logistic regression stratified by ethnicity and sex was then performed to identify group-specific factors associated with non-completion. Characteristics used in the adjusted models were included, with the addition of erectile dysfunction for males. A *P*-value of <0.2 was used to retain potentially relevant covariates, and variables retained in the final model were subsequently evaluated for statistical significance ($P < 0.05$), ensuring meaningful inclusion.[35] Collinearity among predictor variables was assessed using variance inflation factors (VIFs). All included variables had VIFs < 5, indicating that multicollinearity was not a significant concern in the model.

We conducted two sensitivity analyses. First, because the data spanned the coronavirus disease-19 (COVID-19) period, we repeated the analyses using pre-pandemic data (2014–19), excluding data from 2020 onwards to account for potential disruptions in service delivery and data collection (see Supplementary material online, *Tables S3–S5*). Second, as data across the 8-year period were aggregated to increase statistical power and produce stable estimates of overall group differences, we examined age-adjusted annual trends in participation and completion to ensure that aggregation did not mask temporal variation. These analyses showed consistent patterns of ethnic disparity throughout the study period (see Supplementary material online, *Figure S2*).

Statistical analysis was carried out in StataBE-17™. This retrospective observational study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[36] (see Supplementary material online, *Table S7*). The NACR has approval from the Health Research Authority's Confidentiality Advisory Group (under Section 251 of the NHS Act 2006) to collect service user-identifiable data without explicit consent from individual service users for the purposes of audit and research. Approval is reviewed annually. Separate ethical approval was therefore not required as part of this project. Access to the national registry for research purposes was granted by the University of York.

## Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

# Results

There were 421 281 individuals referred for CR following an eligible acute cardiac event (referral cohort), of which 383 833 (91%) were White European and 37 448 (9%) were South Asian. A total of 97 371 individuals (23%) had a medically managed MI, 264 212 (63%) had a PCI (with or without an MI), and 59 698 (14%) had a CABG (with or without an MI) (*Table 1*). South Asians were younger [median age 61.0 (interquartile range (IQR) 52.0–70.0)] and had a higher proportion of males (29 181, 78%) compared with White Europeans [median age 68.0 years (IQR 59.0–76.0); 305 469, 72%]. South Asians also exhibited greater socioeconomic deprivation (IMD Quintile 1)

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**Table 2 Baseline characteristics of White and South Asian service users, comparing participation in cardiac rehabilitation (*n* = 421 281)**

| | Participation in CR Yes (*n* = 222 928, 53%) | | Participation in CR No (*n* = 198 353, 47%) | |
|---|---|---|---|---|
| | White European *n* = 202 188 (53%) | South Asian *n* = 20 740 (55%) | White European *n* = 181 645 (47%) | South Asian *n* = 16 708 (45%) |
| Male | 150 428 (74%) | 16 613 (80%) | 125 860 (69%) | 12 568 (75%) |
| Female | 51 760 (26%) | 4127 (20%) | 55 785 (31%) | 4140 (25%) |
| Age at initiating event (yrs) | 66.0 (58.0–74.0) | 60.0 (51.0–68.0) | 70.0 (60.0–79.0) | 63.0 (54.0–73.0) |
| Index of multiple deprivation quintile | | | | |
| IMD 5 (most affluent) | 47 545 (24%) | 2525 (12%) | 33 808 (19%) | 1278 (8%) |
| IMD 4 | 45 743 (23%) | 2837 (14%) | 37 101 (20%) | 1784 (11%) |
| IMD 3 | 41 976 (21%) | 3680 (18%) | 37 162 (20%) | 2706 (16%) |
| IMD 2 | 34 922 (17%) | 5686 (27%) | 36 174 (20%) | 4337 (26%) |
| IMD 1 (most deprived) | 32 002 (16%) | 6012 (29%) | 37 400 (21%) | 6603 (40%) |
| Marital status | | | | |
| No partner | 38 576 (25%) | 2121 (14%) | 40 009 (31%) | 1838 (17%) |
| Partner | 118 559 (75%) | 13 040 (86%) | 89 218 (69%) | 8765 (83%) |
| Employment status | | | | |
| Employed | 42 307 (32%) | 5408 (40%) | 9213 (27%) | 717 (33%) |
| Unemployed | 5213 (4%) | 1486 (11%) | 1496 (4%) | 268 (12%) |
| Sick | 14 495 (11%) | 1852 (14%) | 2727 (8%) | 286 (13%) |
| Retired | 71 462 (54%) | 4640 (35%) | 21 001 (61%) | 934 (42%) |
| Initiating event | | | | |
| MI | 32 123 (16%) | 2551 (12%) | 58 273 (32%) | 4424 (27%) |
| PCI | 134 634 (67%) | 14 305 (69%) | 104 806 (58%) | 10 467 (63%) |
| CABG | 35 431 (18%) | 3884 (19%) | 18 566 (10%) | 1817 (11%) |
| Family history of CVD | 47 466 (23%) | 4538 (22%) | 29 283 (16%) | 1829 (11%) |
| Comorbidities | | | | |
| Number | | | | |
| None | 53 601 (27%) | 5101 (25%) | 60 936 (34%) | 6659 (40%) |
| One to two | 79 804 (39%) | 7586 (37%) | 66 356 (37%) | 5132 (31%) |
| Three or more | 68 783 (34%) | 8053 (39%) | 54 353 (30%) | 4917 (29%) |
| Angina | 24 910 (12%) | 2418 (12%) | 21 625 (12%) | 1512 (9%) |
| Hypertension | 75 244 (37%) | 8970 (43%) | 64 744 (36%) | 6127 (37%) |
| Hyperlipidaemia | 52 731 (26%) | 7441 (36%) | 36 240 (20%) | 4241 (25%) |
| Diabetes | 33 380 (17%) | 7319 (35%) | 32 845 (18%) | 5056 (30%) |
| Stroke | 7062 (3%) | 640 (3%) | 8237 (5%) | 623 (4%) |
| Anxiety | 11 143 (6%) | 638 (3%) | 5554 (3%) | 268 (2%) |
| Depression | 11 532 (6%) | 795 (4%) | 6604 (4%) | 345 (2%) |
| Bronchitis | 5188 (3%) | 201 (1%) | 6418 (4%) | 222 (1%) |
| Emphysema | 4278 (2%) | 123 (1%) | 5567 (3%) | 148 (1%) |
| Asthma | 12 922 (6%) | 1578 (8%) | 9344 (5%) | 1019 (6%) |
| Cancer | 12 186 (6%) | 380 (2%) | 10 660 (6%) | 253 (2%) |
| Claudication | 3061 (2%) | 192 (1%) | 3065 (2%) | 96 (1%) |
| Rheumatism | 3494 (2%) | 191 (1%) | 2702 (1%) | 158 (1%) |
| Arthritis | 22 485 (11%) | 1613 (8%) | 15 082 (8%) | 758 (5%) |
| Osteoporosis | 2557 (1%) | 144 (1%) | 2133 (1%) | 62 (0%) |

Data are presented as median (25th and 75th percentiles) for continuous measures and *n* (%) for categorical measures.
CR, cardiac rehabilitation. COPD, chronic obstructive pulmonary disease; IMD, index of multiple deprivation; PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft; CVD, cardiovascular disease; White European, combination of White British, White Irish, and any other White background ethnicity groups present in NACR; South Asian, combination of Asian/Asian British–Indian, Pakistani, Bangladeshi, and any other Asian background ethnicity groups present in NACR.

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and higher prevalence of CVD risk factors such as diabetes, hypertension, and hypercholesterolaemia compared with White Europeans.

In the White European group, 202 188 (53%) participated in CR (participation cohort), of which 156 520 (77%) completed (completion cohort). In the South Asian group, 21 550 (55%) participated, of which 14 777 (69%) completed. In the participation cohort (*Table 2*), South Asian compared with White British participants were younger (60 vs. 66 years) and more likely to reside in the most deprived socioeconomic areas (29% vs. 16%) and be employed (40% vs. 30%). Within the completion cohort (*Table 3*), South Asians were again younger (60 vs. 66 years), less likely to be female (20% vs. 26%), and more likely to have ≥3 comorbidities (39% vs. 34%), with higher prevalence of diabetes, hypertension, and hyperlipidaemia than White European service users. Characteristics were similar once the COVID-19 years were removed (see Supplementary material online, *Tables S3* and *S4*).

## Associations between ethnicity and participation and completion

In the unadjusted associations, South Asians were 4% more likely to participate in CR than White Europeans (OR with 95% confidence intervals CIs, OR 1.04 (1.02–1.06)]. This association strengthened following adjustment for SD factors and comorbidities (*Table 4*), with South Asians 12% more likely to participate in CR compared with White Europeans (adjusted odds ratio (aOR) 1.12; 1.09–1.15). Despite higher initial participation rates, South Asians were 22% less likely than White Europeans to complete their CR programme after adjustment (aOR 0.78; 0.75–0). Removing the COVID-19 years (2020–22) did not alter the participation findings and resulted in a slight improvement in completion rates. South Asians remained 12% more likely to participate (aOR 1.12: 1.08–1.16) and 17% less likely to complete (aOR 0.83: 0.79–0.87) compared with White Europeans (see Supplementary material online, *Table S6*).

## Factors associated with non-completion of cardiac rehabilitation

In men and women across both groups, factors with the strongest associations with non-completion were living with higher levels of deprivation (increasing risk of non-completion by 63% in White Europeans and 41% in South Asians) and diabetes (increasing risk by ~25% in both groups) (*Table 5*). Having one to two comorbidities was independently associated with a lower risk of CR non-completion, whereas higher levels of multiple long-term conditions (>3 comorbidities) were not independently associated with completion after multivariable adjustment. In White Europeans and South Asian men, stroke and depression were also key factors (increasing risk by ~25% in White Europeans and 37% in South Asian men). Non-completion was associated with respiratory conditions in White Europeans, increasing the risk by more than 20%. It was also linked to rheumatism (increasing the risk by 62%) and a family history of cardiovascular conditions in South Asian men, not observed in other groups. Anxiety was a significant factor for South Asians (increasing risk by 24%), but lost significant in the smaller sex-stratified models.

## Patient and public involvement

Multiple public engagements and informal discussions with South Asian health service users, cardiac rehabilitation healthcare professionals, and members of the public informed the question development and interpretation of findings.

# Discussion

In this large sample of more than 420 000 eligible South Asian and White European service users referred to CR in England, 53% started, and of these, 77% completed. This is the largest dataset to be interrogated describing health inequalities in participation and completion for CR that has been reported to date, using a national dataset. The particular focus was on the influence of South Asian ethnicity compared with white European. Incidence of CVD in the South Asian population is disproportionality high,[11] and their access to CR is critical. Our data showed that whilst South Asian service users were more likely to participate in CR, they were significantly less likely to complete. Key drivers of non-completion for both groups were living with higher levels of deprivation and mental health and cardiometabolic conditions, with anxiety and family history unique to the South Asian group. This study highlights important factors in the participation and completion of CR in South Asian and White European service users, emphasizing the necessity for tailored interventions to improve adherence and ensure equitable healthcare delivery.

The higher participation but lower completion of South Asian service users compared with White British service users indicates that there is an appetite to participate in CR, but programmes across the UK are not sufficiently meeting the needs of the South Asian community. This is contrary to current evidence, which suggests that ethnic minority populations are less likely to start CR[18,37–40]; however, these prior studies have aggregated ethnic groups, so data on individual discrepancies are lacking. We cannot definitively explain this increased participation within the constraints of our epidemiological design; however, previous research suggests that South Asian service users may place strong trust in the publicly funded health service model (in the UK, the NHS) and may respond to clinician recommendations in a context of hierarchical respect for medical authority.[18,29,30] Furthermore, referrals originating from a doctor may carry particular weight in some communities, thus increasing initial participation.[29] Referral pathways to CR in the UK are not fully standardized; however, referrals are often included in a discharge letter, which is typically written by a doctor and copied to the patient's general practitioner. This process may serve to reinforce the recommendation and encourage attendance, particularly in South Asian communities where trust in healthcare professionals and respect for medical authority are high. Contrastingly, the same literature highlights barriers for South Asian service users, such as negative previous healthcare experiences, limited cultural sensitivity of programmes, language difficulties, and transport or scheduling constraints,[18,29,30] which may help explain why higher initial uptake does not always translate into higher completion. In our cohort, it is possible that these enabling and motivational factors facilitated attendance, but the persisting structural or cultural barriers may underlie the attrition we observed. This finding raises important questions about whether current CR programmes adequately address the specific needs and expectations of South Asian service users.

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**Table 3 Baseline characteristics of White European and South Asian service users, comparing completion of cardiac rehabilitation (*n* = 222 928)**

| | Completed CR Yes (*n* = 171 297, 77%) | | Completed CR No (*n* = 51 631, 23%) | |
|---|---|---|---|---|
| | White European *n* = 156 520 (77%) | South Asian *n* = 14 777 (71%) | White European *n* = 45 668 (23%) | South Asian *n* = 5963 (29%) |
| Male | 117 401 (75%) | 11 858 (80%) | 33 027 (72%) | 4755 (80%) |
| Female | 39 119 (25%) | 2919 (20%) | 12 641 (28%) | 1208 (20%) |
| Age at initiating event (yrs) | 67.0 (58.0–74.0) | 60.0 (51.0–68.0) | 65.0 (56.0–74.0) | 60.0 (51.0–68.0) |
| Index of multiple deprivation quintile | | | | |
| IMD 5 (most affluent) | 38 678 (25%) | 1908 (13%) | 8867 (19%) | 617 (10%) |
| IMD 4 | 36 418 (23%) | 2099 (14%) | 9325 (20%) | 738 (12%) |
| IMD 3 | 32 631 (21%) | 2581 (17%) | 9345 (20%) | 1099 (18%) |
| IMD 2 | 25 995 (17%) | 4055 (27%) | 8927 (20%) | 1631 (27%) |
| IMD 1 (most deprived) | 22 798 (15%) | 4134 (28%) | 9204 (20%) | 1878 (31%) |
| Marital status | | | | |
| No partner | 28 114 (23%) | 1419 (13%) | 10 462 (30%) | 702 (16%) |
| Partner | 93 757 (77%) | 9377 (87%) | 24 802 (70%) | 3663 (84%) |
| Employment status | | | | |
| Employed | 33 716 (32%) | 4009 (40%) | 8591 (32%) | 1399 (41%) |
| Unemployed | 3737 (3%) | 1057 (11%) | 1476 (6%) | 429 (12%) |
| Sick | 11 049 (10%) | 1386 (14%) | 3446 (13%) | 466 (13%) |
| Retired | 58 298 (55%) | 3482 (35%) | 13 164 (49%) | 1158 (34%) |
| Initiating event | | | | |
| MI | 41 792 (27%) | 3586 (24%) | 8148 (17.8%) | 790 (13.2%) |
| PCI | 62 955 (40%) | 5484 (37%) | 30 648 (67.1%) | 4253 (71.3%) |
| CABG | 51 773 (33%) | 5707 (39%) | 6872 (15.0%) | 920 (15.4%) |
| Family history of CVD | 36 484 (23%) | 3184 (22%) | 10 982 (24%) | 1354 (23%) |
| Comorbidities | | | | |
| Number | | | | |
| None | 41 792 (27%) | 3586 (24%) | 11 809 (26%) | 1515 (25%) |
| One to two | 62 955 (40%) | 5484 (37%) | 16 849 (37%) | 2102 (35%) |
| Three or more | 51 773 (33%) | 5707 (39%) | 17 010 (37%) | 2346 (39%) |
| Angina | 18 962 (12%) | 1713 (12%) | 5948 (13%) | 705 (12%) |
| Hypertension | 58 029 (37%) | 6430 (44%) | 17 215 (38%) | 2540 (43%) |
| Hyperlipidaemia | 40 669 (26%) | 5283 (36%) | 12 062 (26%) | 2158 (36%) |
| Diabetes | 24 549 (16%) | 5081 (34%) | 8831 (19%) | 2238 (38%) |
| Stroke | 5134 (3%) | 419 (3%) | 1928 (4%) | 221 (4%) |
| Anxiety | 8030 (5%) | 420 (3%) | 3113 (7%) | 218 (4%) |
| Depression | 8054 (5%) | 531 (4%) | 3478 (8%) | 264 (4%) |
| Bronchitis | 3731 (2%) | 140 (1%) | 1457 (3%) | 61 (1%) |
| Emphysema | 3067 (2%) | 85 (1%) | 1211 (3%) | 38 (1%) |
| Asthma | 9827 (6%) | 1155 (8%) | 3095 (7%) | 423 (7%) |
| Cancer | 9325 (6%) | 272 (2%) | 2861 (6%) | 108 (2%) |
| Claudication | 2253 (1%) | 135 (1%) | 808 (2%) | 57 (1%) |
| Rheumatism | 2607 (2%) | 127 (1%) | 887 (2%) | 64 (1%) |
| Arthritis | 17 294 (11%) | 1170 (8%) | 5191 (11%) | 443 (7%) |
| Osteoporosis | 1912 (1%) | 104 (1%) | 645 (1%) | 40 (1%) |

Data are presented as median (25th and 75th percentiles) for continuous measures and *n* (%) for categorical measures.
CR, cardiac rehabilitation. COPD, chronic obstructive pulmonary disease; IMD, index of multiple deprivation; PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft; CVD, cardiovascular disease; White European, combination of White British, White Irish, and any other White background ethnicity groups present in NACR; South Asian, combination of Asian/Asian British–Indian, Pakistani, Bangladeshi, and any other Asian background ethnicity groups present in NACR.

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**Table 4 Association between ethnic groups and cardiac rehabilitation participation and completion**

| | Unadjusted OR (95% CI) | Adjusted (Model 1)[a] OR (95% CI) | Fully adjusted (Model 2)[b] OR (95% CI) |
|---|---|---|---|
| Participation (*n* = 421 281) | | | |
| White European | 1.0 | 1.0 | 1.0 |
| South Asian | 1.04 (1.02–1.06) | 1.08 (1.05–1.11) | 1.12 (1.09–1.15) |
| Completion (*n* = 222 928) | | | |
| White European | 1.0 | 1.0 | 1.0 |
| South Asian | 0.74 (0.72–0.76) | 0.77 (0.74–0.80) | 0.78 (0.75–0.82) |

Data presented as odds ratio (OR) with 95% confidence intervals (CIs).
[a]Model 1 is adjusted for sociodemographic (SD) factors including sex, age at initiating event, marital status, and index of multiple deprivation (IMD).
[b]Model 2 is adjusted for SD factors and comorbidities, including number (0, 1–2, and >2) and type (angina, arthritis, cancer, diabetes, rheumatism, stroke, osteoporosis, hypertension, chronic bronchitis, emphysema, asthma, claudication, chronic back pain, anxiety, depression family history, and hyperlipidaemia).
White European, combination of White British, White Irish, and any other White background ethnicity groups present in NACR; South Asian, combination of Asian/Asian British, Indian, Pakistani, Bangladeshi and any other Asian background ethnicity groups present in NACR.

There is a lack of high-quality research, accurately recording disaggregated ethnicity data, to inform healthcare providers of the factors influencing participation and completion among diverse ethnic groups.[2,22] A recent systematic review categorized factors associated with non-participation in and dropout from CR programmes into six groups: intrapersonal and interpersonal factors, clinical, logistical, health system, and programme factors.[9] Out of the 43 studies included in the review, containing 63 424 service users from 10 different countries, none explored ethnicity-related factors associated with dropout, and only three evaluated factors relating to sex. The review acknowledges that there is a lack of evidence regarding dropout rates related to individual ethnic groups. Additionally, a Cochrane review[2] assessed interventions that aimed to increase participation, adherence, and completion. Seventeen out of the 26 studies focused on adherence and completion, with only four reporting ethnicity, none of them disaggregating data into individual ethnic groups, and were deemed low quality. Ibsen *et al.*[41] demonstrated the importance and value of identifying individuals at high risk of attrition. Researchers implemented a co-produced programme, which identified service users at high risk of dropout (termed priority patients) followed by implementation of an add-on intervention consisting of an assigned personal contact, regular communication, and follow-up. Initial reports suggest that the programme is easily implemented and well received by service users; however, its effectiveness is yet to be established. This example of tailored CR delivery demonstrates the importance of initially identifying who is least likely to complete CR, so that tailored approaches can be taken to aid retention. To implement interventions that target those at high risk of non-completion and tailor programmes towards individual needs, it is essential to be able to identify the 'at need' group first.[42] By understanding the likelihood of participation and completion, as well as the prominent factors associated with non-completion, services can identify individuals at potential risk of dropout.

Our analysis identified key factors associated with non-completion of CR across both ethnicities, with residing in the most deprived areas being a driving factor. In geographical areas of higher wealth, there is greater provision of health services, facilitating adherence to programmes due to ease of access.[43] Conversely, individuals residing in areas of high deprivation face both limited access to healthcare services and financial constraints, which may restrict their ability to afford transportation for healthcare. These barriers contribute to higher attrition rates and exacerbate health inequalities associated with socioeconomic status.[43] Anxiety and depression were also significant factors associated with non-completion. Studies worldwide have shown a higher prevalence of poor mental health in deprived communities,[44,45] with people living in most deprived areas twice as likely to have depression and elevated rates of anxiety.[46] The intersection of mental health conditions and low socioeconomic status, as factors associated with CR non-completion, compounds difficulties for this population. Middleton (2024)[46] found that individuals with low socioeconomic status and anxiety or depression show less improvement in cardiorespiratory fitness following CR completion compared with others. System-level and environmental barriers also interact with service user barriers to influence CR engagement. Practical challenges such as transport and programme location can disproportionately affect individuals from socioeconomically deprived communities. Given that higher deprivation was a major factor associated with non-completion in both ethnic groups, improving accessibility remains essential. Although CR is free within the NHS, indirect costs, work commitments, and caregiving responsibilities may further restrict attendance.[22,29] Ensuring programmes are culturally safe by providing welcoming and inclusive environments could help address these intersecting barriers and improve completion rates across diverse populations. Additionally, cultural stereotyping by healthcare professionals may also influence participation and completion. Implicit biases or assumptions made by CR staff about the attitudes, motivation, or preferences of different ethnic groups may influence the overall inclusiveness of the programme environment. Although such factors could not be measured within the current dataset, previous evidence highlights that promoting cultural competence among healthcare professionals is essential to ensure equitable support for all service users.[22,29,30]

We also observed ethnicity and sex-specific determinants. For South Asian men, rheumatism and a family history of cardiovascular conditions were associated with lower completion rates. Rheumatism has higher prevalence in South Asian populations

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**Table 5** Independent factors associated with of non-completion of cardiac rehabilitation for White European and South Asian service users (*n* = 222 928)

| | White European | | | South Asian | | |
|---|---|---|---|---|---|---|
| | All (*n* = 202 188) OR [95% CI] | Males (*n* = 150 428) OR [95% CI] | Females (*n* = 51 760) OR [95% CI] | All (*n* = 20 740) OR [95% CI] | Males (*n* = 16 613) OR [95% CI] | Females (*n* = 4125) OR [95% CI] |
| Age | 0.99 [0.99, 0.99] | 0.99 [0.99, 0.99] | 1.0 [0.99, 1.01] | 1.00 [0.99, 1.01] | 1.00 [0.99, 1.00] | - |
| Sex (female) | 1.14 [1.11, 1.16] | N/A | N/A | - | N/A | N/A |
| Socioeconomic status | | | | | | |
| IMD 5 (most affluent) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| IMD 4 | 1.10 [1.07, 1.14] | 1.10 [1.06, 1.14] | 1.10 [1.03, 1.18] | 1.08 [0.75, 1.22] | 1.10 [0.95, 1.26] | 1.05 [0.79, 1.39] |
| IMD 3 | 1.22 [1.18, 1.26] | 1.22 [1.18, 1.27] | 1.20 [1.12, 1.27] | 1.30 [1.16, 1.46] | 1.30 [1.14, 1.48] | 1.34 [1.03, 1.73] |
| IMD 2 | 1.43 [1.38, 1.48] | 1.45 [1.39, 1.51] | 1.36 [1.27, 1.45] | 1.24 [1.11, 1.38] | 1.24 [1.10, 1.40] | 1.20 [0.94, 1.54] |
| IMD 1 (most deprived) | 1.63 [1.57, 1.68] | 1.64 [1.58, 1.71] | 1.58 [1.48, 1.69] | 1.41 [1.27, 1.57] | 1.38 [1.23, 1.56] | 1.51 [1.19, 1.91] |
| Family history of CVD | | - | 0.95 [0.90, 1.00] | 1.16 [1.07, 1.26] | 1.16 [1.06, 1.27] | - |
| Marital status | | | | | | |
| Partner | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| No partner | 1.28 [1.25, 1.32] | 1.29 [1.24, 1.33] | 1.26 [1.20, 1.32] | 1.24 [1.12, 1.37] | 1.27 [1.13, 1.44] | 1.17 [0.98, 1.40] |
| Comorbidities | | | | | | |
| Number | | | | | | |
| No comorbidities | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1–2 comorbidities | 0.92 [0.90, 0.94] | 0.93 [0.90, 0.95] | 0.93 [0.88, 0.99] | 0.81 [0.75, 0.89] | 0.86 [0.78, 0.95] | — |
| ≥3 comorbidities | - | - | 1.09 [1.01, 1.17] | 0.72 [0.64, 0.82] | 0.81 [0.71, 0.91] | - |
| Erectile dysfunction | N/A | 0.87 [0.81, 0.94] | N/A | N/A | 0.64 [0.51, 0.81] | N/A |
| Angina | - | 1.04 [1.00, 1.08] | - | - | 1.10 [0.98, 1.24] | - |
| Hypertension | - | - | - | - | - | 0.82 [0.71, 0.95] |
| Hyperlipidaemia | 0.98 [0.95, 1.00] | - | 0.93 [0.88, 0.98] | 1.08 [1.00, 1.17] | - | - |
| Diabetes | 1.24 [1.18, 1.37] | 1.24 [1.20, 1.28] | 1.24 [1.17, 1.31] | 1.27 [1.18, 1.37] | 1.24 [1.14, 1.35] | 1.29 [1.11, 1.49] |
| Stroke | 1.24 [1.18, 1.31] | 1.26 [1.18, 1.34] | 1.20 [1.08, 1.33] | - | 1.37 [1.13, 1.67] | - |
| Anxiety | 1.07 [1.02, 1.13] | 1.09 [1.02, 1.16] | - | 1.24 [1.03, 1.49] | - | - |
| Depression | 1.27 [1.22, 1.34] | 1.26 [1.19, 1.34] | 1.34 [1.24, 1.44] | 1.17 [0.99, 1.39] | 1.37 [1.14, 1.64] | - |
| Bronchitis | 1.21 [1.14, 1.29] | 1.26 [1.17, 1.36] | 1.11 [1.00, 1.24] | - | - | - |
| Emphysema | 1.24 [1.16, 1.33] | 1.28 [1.18, 1.40] | 1.16 [1.03, 1.31] | - | - | - |
| Cancer | 1.10 [1.05, 1.15] | 1.12 [1.06, 1.18] | - | - | - | - |
| Claudication | 1.10 [1.01, 1.19] | - | 1.16 [0.98, 1.36] | - | - | 0.53 [0.25, 1.10] |
| Rheumatism | 1.09 [1.01, 1.18] | 1.11 [1.00, 1.23] | - | - | 1.62 [1.11, 2.35] | - |
| Arthritis | - | - | - | - | - | 0.83 [0.68, 1.00] |
| Osteoporosis | - | 1.22 [1.04, 1.43] | - | - | - | - |

Data presented as odds ratio (OR) with 95% confidence intervals (CIs) or median with interquartile ranges (25th to 75th percentiles).
CR, cardiac rehabilitation; COPD, chronic obstructive pulmonary disease; IMD, index of multiple deprivation; PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft; CVD, cardiovascular disease; White European, combination of White British, White Irish, and any other White background ethnicity groups present in NACR; South Asian, combination of Asian/Asian British, Indian, Pakistani, Bangladeshi, and any other Asian background ethnicity groups present in NACR; '-', the variable was removed in the backwards stepwise regression approach, which indicates factors not influential to CR completion; N/A, erectile dysfunction was not entered into the models that included females.

and is strongly associated with an increased risk of cardiovascular events[47,48]; however, its resultant pain and limitations on physical movement can prevent adherence to exercise programmes, alongside beliefs that exercise could exacerbate the condition.[49,50] A multi-centred randomized control trial[51] demonstrated that supervised high-intensity interval training and strength training, both recommended forms of exercise in CR,[52,53] improved cardiovascular health and physical fitness without a deterioration in pain or movement for service users with rheumatism; however, additional motivational support may be required. South Asians, particularly those from India, Pakistan, Bangladesh, and Sri Lanka, have a higher prevalence of family history of CVD compared with White Europeans.[54] This increased risk is further compounded by a greater susceptibility to premature CVD, often attributed to genetic factors.[55] Although individuals with a family history of CVD often recognize their elevated risk, this awareness alone is not a sufficient predictor of behaviour change, including increased physical activity.[56] Additionally, previous negative healthcare experiences and mistrust of healthcare professionals have been identified as barriers leading to reduced CR participation and adherence.[29,30] Respiratory conditions were strongly associated with lower completion rates among White Europeans. White Europeans in Western countries

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have higher smoking rates compared with South Asian,[57] contributing to an increased risk of smoking-related illnesses such as heart disease, emphysema, and chronic bronchitis. Although insights into the lower completion rates among South Asian females are limited due to the small cohort size, it remains crucial to consider both ethnicity and sex when examining factors associated with non-completion. Cultural gender roles within South Asian communities significantly influence participation in cardiac rehabilitation.[22,29,30] Sociocultural norms often position men as financial providers, rather than being burdened with illness,[58] which may either facilitate or hinder their engagement in rehabilitation programmes. In contrast, women frequently assume caregiving responsibilities within the household, prioritizing the needs of family members over their own health.[22,30] Identifying factors linked to lower completion rates, stratified by both sex and ethnicity, can enable services to implement targeted interventions and support individuals at higher risk of dropout.

As CVD remains the world's leading cause of mortality, and South Asians have disproportionate prevalence of cardiac-related mortality and morbidity, understanding factors associated with individuals who are less likely to complete CR and tailoring culturally informed programmes to enhance adherence is vital.[59] The well-documented benefits of CR are only realized when the programme is consistently adhered to. Maximizing adherence is key to yielding significant physical and psychological benefits for service users whilst also providing economic advantages for healthcare systems.[4,60]

The observed higher initial participation among South Asians challenges conventional assumptions that this population is less likely to attend CR and suggests that access to CR may not be the primary issue. Instead, barriers to completion, such as culturally mediated beliefs about exercise, socioeconomic constraints, and competing health priorities, warrant further investigation. The strong association of psychological conditions with non-completion across both ethnicities and sexes provides insights on mental health disparities and their impact of CR adherence. Although cultural and psychosocial variables were not available within this dataset, these factors likely underpin some of the observed differences in completion between ethnic groups. Existing qualitative research highlights how health beliefs, family expectations, language barriers, and attitudes towards exercise can influence engagement with CR among South Asian service users.[22,29,30] By identifying specific risk factors for non-completion, this study identified an urgent need for tailored, culturally congruent interventions. Healthcare providers must adopt an intersectional approach, integrating ethnicity, sex, and comorbidity-specific factors into CR programme design to improve retention and optimize health outcomes. Future research should explore qualitative aspects of CR experiences in individual ethnic groups to further clarify barriers and enablers, ensuring that rehabilitation services are truly inclusive and effective in reducing CVD disparities. Additionally, future iterations of NACR or linked studies could include measure of psychosocial and cultural influences, which would enable more comprehensive modelling of CR participation and completion.

This study uses a large national registry of CR services across the UK, enabling robust analyses of participation rates. A recent registry-based analysis demonstrated the value of large clinical registries for understanding real-world patterns of cardiac rehabilitation engagement.[61] Given the relatively high prevalence of cardiac rehabilitation participation and completion, the ORs reported in this study may overestimate the corresponding relative risks. These estimates should therefore be interpreted as measures of association rather than direct approximations of risk.[62] The dataset is nationally representative, containing 9% South Asian participants, which is equivalent to the current South Asian population in the UK.[63] The data have been disaggregated into individual ethnic groups, allowing differentiation between different ethnic populations; however, this method falls short of capturing the intricate intra-ethnic differences within these smaller categories. The definitions of participation and completion may differ from other studies or other national databases, and there is potential misclassification of ethnicity by healthcare providers recorded in NACR. Similarly, missing comorbidities were coded as zero, and absence of disease was assumed. Whilst a standard approach in epidemiology studies,[64] it may introduce potential misclassification bias. There was a large proportion of missing ethnicity data in the audit and unmeasured confounders such as language proficiency, cultural beliefs, and behavioural or programme-level factors may influence participation and completion. Whilst these limitations restrict the ability to draw causal conclusions at the individual level, this large, population-level epidemiological study still provides valuable insights into patterns of cardiac rehabilitation engagement. There may have been a lag in data collection during the COVID-19 period (2020–22) due to healthcare disruptions and reduced reporting, which may affect the completeness and accuracy of analysis for this period. Therefore, sensitivity analysis was conducted to assess the robustness of findings using pre-pandemic data (2014–19). Whilst disaggregating data into smaller groups, such as 'South Asian', offers a more nuanced understanding, it still falls short of capturing the intricate intra-ethnic differences within these smaller categories. Although there is considerable heterogeneity within South Asian populations, subgroup analyses (e.g. Indian, Pakistani, and Bangladeshi) were not feasible due to smaller numbers and limitations in ethnicity coding. Grouping South Asian ethnicities together represents a pragmatic approach consistent with large-scale epidemiological research and allows comparability with existing studies examining ethnic differences in CR. This approach also represents an improvement over treating all ethnic minorities as a single, homogeneous group. However, future research should prioritize disaggregating data wherever possible, as this is essential to understanding intra-ethnic differences, and addressing unique needs of distinct South Asian subgroups.

This study identifies that South Asian service users referred to CR after an acute cardiac event are more likely to participate but less likely to complete compared with White European service users. Key factors influencing CR completion in South Asian and White European populations have been identified, highlighting both shared and distinct influences related to sex and ethnicity. These findings emphasize the importance of targeted strategies to address disparities and enhance CR engagement. By applying these insights to local populations, healthcare providers can optimize CR delivery and target those at risk of attrition, so that greater completion of programmes is achieved, ultimately reducing ethnic inequities in CR.

## Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

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## Author contributions

Joanne McAllister (Conceptualization [lead], Data curation [lead], Formal analysis [equal], Methodology [lead], Software [equal], Visualization [lead], Writing—original draft [lead], Writing—review & editing [lead]), Alex Harrison (Data curation [supporting], Writing—review & editing [supporting]), Patrick Doherty [Data curation (supporting)], Sally J. Singh (Conceptualization [supporting], Data curation [equal], Formal analysis [supporting], Software [equal], Writing—review & editing [supporting]), and Claire A. Lawson (Data curation [equal], Formal analysis [equal], Methodology [equal], Software [equal], Supervision [lead], Writing—review & editing [equal])

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**Conflict of interest:** C.A.L. has acted as a speaker for Boehringer Ingelheim. All other authors declare no competing interests.

## Data availability

The data that support the findings of this study are available from the National Audit of Cardiac Rehabilitation, but restrictions apply for the availability of these data, which were used under licence for the current study, as the data being link anonymized with NHS Digital under Section 251 approval cannot be shared publicly. J.M. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. A detailed protocol and statistical code can be provided on request to jsm53@leicester.ac.uk.

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