**1.0 Introduction**

The rising incidence of cardiovascular disease, combined with a reduced mortality rate[1,2], means an even higher proportion of people will need help to recover from cardiovascular diseases in the future. Cardiac rehabilitation (CR) aims to restore physical, mental and social impairments making patients able to return to the routines of their daily life prior to the cardiovascular disease[3]. The effects of CR are well documented and services have been implemented in most European counties[4–6]. Despite this, the number of patients who enrol in CR across Europe are under 50%[7,8].

To make CR more attractive to the range of eligible patients, clinical guidelines and experts have underlined the importance of CR being delivered in consideration with patient needs and preferences[3,9]. Hence, a vast amount of tailored CR interventions have been investigated, with increasing focus on new and innovative/virtual home-based modes[10–14]. Many more traditional settings of CR, that are centre-based modes, have also adopted or combined centre and home-based interventions (a hybrid model), which among other benefits, are believed to overcome a number of barriers related to accessibility of health services[8,15]. An increasing body of evidence supports the effectiveness of these new modes of delivery[10–14] and their inclusion provides a natural addition to the CR menu-based allowing greater scope for tailoring to the needs and preferences of patients[9].

To achieve effectiveness in routine practice, there is a need to ensure that quality of delivery and intervention content of these new modes are optimized. The ability to clearly denote completion of CR is an extremely important quality maker and one that aligns with appropriate evaluation of a goals based behavioural change approach[16]. A clear definition and endpoint of core CR are essential as they encompass many central post-CR elements including; post-assessment and providing patients with a long-term maintenance strategy[16]. A lack of clear CR completion can lead to ambiguity around the full intervention delivery and effectiveness which is unlikely to yield expected results[17].

A number of predictors for completion of CR have been identified that can be divided into the individual patient characteristics[18–20], the rehabilitation service, work or other social concerns[8,20]. In everyday CR across the UK, for both men and women, the reasons for not taking part in daily CR are most often defined as personal to the individual patient characteristics[8]. The extent to which patient characteristics and patient choice influence the preference of mode of CR delivery has not been sufficiently explored. It may be that specific patient types are presently taking up the home-based and hybrid-based models in greater number which by self-selection are a sub-population. In addition, it is important to identify if there are specific characteristics that predispose these groups to not complete CR.

The aim of this study was to compare modes of delivery and individual patient characteristics and to investigate if any difference in modes was associated with completion in everyday CR. This would not only help inform routine CR interventions, but also be relevant for other home-based lifestyle inventions across patient groups.

**2.0 Method**

This study is based on routinely collected CR data from the National Audit of Cardiac Rehabilitation (NACR) database[21] and has been reported in accordance with the STROBE checklist of observational studies[22]. Over 220 CR programs are registered in NACR covering England, Northern Ireland and Wales. In 2020, 189 (82%) use electronically registration of data.

NACR is funded by the British Heart Foundation and has a data sharing agreement with NHS Digital, which as part of their annual data governance arrangement has approval to collect patient data under 251 exemption (i.e. without requiring patient consent). After collection, data is anonymized before shared with NACR.

**2.1 Participants**

All patients (≥18 years) in the period from the 1st of January 2014 to the 31st of December 2019 were referred and took part in a pre-assessment session before entering CR after a coronary heart diagnosis (e.g. myocardial infarction (MI) or valve disease) or a treatment procedure (e.g. percutaneous coronary intervention (PCI) and coronary artery bypass (CABG) eligible for the study. Only patients with a recorded mode of delivery were included. Baseline demographics including age, gender, marital status, ethnicity and treatment type were compared between patients with and without a recorded mode of delivery to assess the possibility of reporting bias. Patients with a pre-diagnosed heart failure were excluded.

**2.2 Mode of delivery**

There are many variations of mode of delivery within the NACR data. These include 11 possible unique modes of delivery including Angina Plan[23], REACH-HF[24] and the Heart Manual[25]. For this paper these have been divided into centre-based, home-based and hybrid. Centre-based covering modes performed in a supervised and group-based method which are either education or exercise orientated. Home-based is conducted at home in a facilitated way via structured contact to CR staff. Hybrid is a combination between home and centre or can be at home with the presence of trained CR staff. Modes were self-chosen with consultation by a clinicians at the point of assessment based on identified risk factors, goals and personal preferences.

The healthcare professionals are responsible for imputing all relevant patient demographics and clinical data across the full patient journey from acute in-hospital early CR to outpatient core CR delivery to the NACR database.

**2.3 Outcome**

The dependent variable was whether the patient completed their CR program. Completion is defined in a variety of ways across Europe, which include total time enrolled, or total sessions attended. Within the UK National Audit of Cardiac rehabilitation[8], the completion status is a joint decision between clinician and patients which determines the end of the core rehabilitation program. A post assessment is made which helps to set long term goals moving to Phase 4. For this paper, patients were deemed to have completed the program if they were recorded as having completed or had a post-assessment with no other recorded reason for them not to have completed.

**2.4 Predictors**

Based on the literature on completion of CR, a wide collection of patient and service factors were included[18–20]. Patient characteristics, and additional service data, were collected at two time points. Age, gender, ethnicity and treatment procedure were collected during the hospitalization stay prior to referral. All other covariables were collected during a pre-assessment session after a patient was referred to CR. Hence, variables collected during the pre-assessment session were not available for the analysis of referral. Self-reported comorbidities from 15 disease categories were conceptualized into similar or dissimilar based on overall related pathophysiologic profile and care management as CHD. This approach has been described in details elsewhere and has been found to be associated with CR uptake but not referral[26].

**2.5 Statistical approach**

Bivariate analyses were used to explore the different populations presently taking part in CR in the UK. All patient characteristics are compared across the three modes. For categorical variables, Pearson Chi-square tests were used and mean and standard deviation (SD) for continuous variables along with independent samples t-tests to compare the means of two continuous variables. Logistic regression models were performed to investigate association between mode of delivery accounting for other predictors and completion. All statistical tests were considered significant if P-value <0.05.

**3.0 Results**

Based on the inclusion and exclusion criteria, a total of 298,569 patients had a coronary heart disease and started core cardiac rehabilitation. A total of 182,722 of these patients had mode of delivery recorded (61%) (Figure 1). The sample was compared for risk of bias and we found no significant difference in age, gender and other socio-demographic characteristics.

Table 1 shows the socio-demographic and service differences across the centre-based, home-based and hybrid modes. The split across the modes was 72.8% centre-based, 8.3% home-based and 18.9% hybrid. The average age of patients in the home-based group (mean 68 years 12 SD) was 3 years older than centre-based (mean 65 years 11 SD) and 2 years older than hybrid (mean 66 12 SD), the difference was significant (<0.001).

The gender, marital, ethnicity and employment splits were also all significant with more female, single, white and unemployed patients attending the home-based mode in comparison to hybrid and centre-based modes (<0.001).

A lower rate of patients had no comorbidity in the home-based compared to the two other modes. However, more had a similar and dissimilar comorbidity profile (27.2%). The single measure of hypertension was also significantly higher in the home-based mode than the other modes (<0.001).

In terms of risk factors, there were higher rates of less active, smoking, obese, anxious and depressed patients in the home-based mode than the centre-based modes (<0.001).

The rates of the more deprived populations in the centre-based mode were much lower than the home-based and hybrid modes. This aligns with the higher associated risk factors in these groups. The proportion in the most deprived was 13.5% in the centre-based mode, whereas it was 17.9% and 18.6% in the home-based and hybrid modes respectively.

Table 2 shows the socio-demographics of the non-completers in each mode of delivery. The overall rate of non-completion was highest in the home-based mode (26%) whereas hybrid and centre-based modes were similar with one fifth not completing. The trend where consistent for most of the socio-demographic and patient factors as non-completion rates across the different sociodemographic and patient factors were from 1% to 9% higher in home-based mode compared to centre-based and hybrid modes. The factor which did not follow the trend was smoking, which showed a >10% higher likelihood of non-completion in the centre-based than the home-based and hybrid modes (Table 2).

The results from the regression models are shown in Table 3. There were three sequential models built, the first included mode of delivery, gender and age, the second included patient demographics and baseline assessments and the third also included service indicators. The models were a good fit and met all assumptions and the third model correctly predicted 83.6%.

The regression models show that in all three models there was a negative association between patients attending a home-based program in the time period and completion of core CR compared to centre-based mode. The odds ratio in the final model was 0.66 (p 0.01, 95% CI 0.48-0.91) and indicates a 34% reduced likelihood of completing CR once the population was accounted for. The attendance of a hybrid program compared to a centre-based program, in any statistical model, did not yield a statistical significant difference in terms of completion (p >0.05).

**4.0 Discussion**

In this study, we found that the population receiving CR in the home-based mode was significantly different from the populations in the centre-based and hybrid modes. The population receiving the home-based mode included more females, single, white and unemployed patients that, in addition, had more baseline risk factors such as not adhering to physical activity recommendations, smoking and obesity. The rate of non-completion in the home-based mode was higher than the other modes and had different subgroups of patients not-completing. The main regression analysis found that, after accounting for the population receiving each mode of delivery, there was a consistent, significant negative association in completion in home-based modes compared to traditional centre-based CR – even when taking common predictors into consideration. Patient-selected delivery models is a natural step towards tailored intervention, which requires clinical teams to strive to achieve a clear point of completion of CR in all modes, preferably based around post-assessment.

In the research domain, and to some extent in routine practice, alternative delivery modes in CR (e.g. home-based) are known to demonstrate effectiveness comparable with that of traditional centre-based CR[10–14,27]. The inclusion of home-based modes into routine practice is also viewed as a solution to overcome low attendance rates in CR services[7,8] and provide a better alignment with patients’ needs and preferences[9,28]. In a randomized trial with preference arms, Dalal et al.[29] showed that clinical outcomes were not worse in patients choosing the preferred mode. Similar findings have been showed in routine NACR data across various outcomes when comparing patients from patient-selected modes to each other[11–13]. Pooling data across the intervention arms of two parallel randomized controlled trials using two self-preferred CR modes Tang et al[30] reach similar findings as the routine NACR data. These studies all support the effectiveness of patient-selected modes in CR. However, it is important to acknowledge that to achieve the expected outcome from CR, high adherence and completion of the CR program is necessary[17]. A fundamental part of successful CR completion includes post-assessment and provision of a long-term maintenance strategy[16]. So far, knowledge on alternative delivery modes has mainly been assessed in randomized trials[10,14,27] restricting the knowledge on patient characteristics and completion rates in patient-selected delivery modes using routine data. Our findings of low completion rates in the home-based mode illustrate why it is important to ensure that effective alternative CR delivery modes in randomized trials are correctly adopted in routine practice and meet the clinical standards[31]. Comparing patient characteristics in randomized trials to routine practice data display substantial differences in e.g. age of the patients[17,32].

Our results demonstrate a skewed distribution of patients’ characteristics across the three groups of delivery modes. Home-based programs were originally made to accommodate those patients who were unable to attend CR sessions due to problems accessing the rehabilitation centre, e.g., elderly[10,33]. This somewhat aligns with our findings across the three modes, as the population in home-based mode were predominantly made up by higher risk profile patients, that are correlated with reduced outcomes and benefit from CR[34]. From previous studies, a patient’s employment status, income and ethnic background have been reported as factors that could affect a patient’s choice of mode[35]. Nonetheless, research is needed to help enhance our understanding of the mechanisms that influences why some programme better appeals to certain patients types. This, together with more clinical knowledge could support strategies on how to improve completion for especially home-based modes when used in routine CR.

An interesting aspect is that randomized trials do not normally demonstrate low completion rate in home-based modes[14]. In all our three regression models, we found lower completion rates in home-based modes compared to centre-based-modes – also in the fully patient characteristics adjusting model. This could indicate a potential influence at other professional and organizational factors known to influence participation[36–38]. Such factors will typically be controlled or similarly distributed in randomized trials whereas modes in routine care may not meet the standard of that found in randomized trials. Unfortunately, the current data within the audit cannot be used to ascertain how much of the association seen between the modes and completion was down to the type of mode and any possible practitioner impact not offering a clear point of completion for patients. It might be that, on the home-based mode, patients are not presented with as clear a completion date in comparison to the centre-based program, as patients simply can continue their long-term management at home. However, home-based programs should highlight the importance of discharging and performing a post-assessment after core CR since it helps providing patients with new goals for long-term management[16]. Identifying more detailed reasons why there was higher non-completion in the home-based CR is required, not only to inform routine CR interventions, but also other home-based lifestyle interventions in pulmonary, stroke and diabetes populations.

Hybrid models are gaining more ground in CR, and similar to our findings, studies are reporting promising results equal to the centre-based modes[39,40]. A future strategy may be to encourage and enrol a higher proportion of patients into individualized tailored hybrid programs instead of home-based modes - especially for the subpopulations of patients with higher drop-out rates, e.g. patients with a partner or with clinical depression. Yet, our findings reflect CR before the COVID-19 pandemic which has resulted in a widespread adoption of home-based CR. In UK, during the time of COVID-19, the population in home-based modes have increase by 36 % whereas centre-based modes and hybrids modes have dropped by 27% and 8%, respectively[32]. Whether this is maintained in the COVID-19 era and beyond is uncertain. Due to the widespread adoption, it is however unlikely that services will go back to where they were before the pandemic.

**5.0 Limitations**

One of the main limitations of this study is that it was utilizing routine data which may be limited in terms of data completion and specific data points that could improve the analysis. For example, 39% of all those who started CR did not have a mode of CR delivery recorded in the time period. Through the inclusion of audit and evaluation in the BACPR core components and the prioritization of completion of data via the National Certification Program, the recording of key fields such as the mode of delivery is likely to increase which will reduce this limitation in future work[31].

Another potential limitation is that the mode of delivery between 2014-mid 2019 was limited to nine choices, however, development in May 2019 increased the granularity of recording to include more choices such as splitting home-based options into named interventions e.g. Heart Manual[25], Angina Plan[23] and REACH-HF[24]. Unfortunately, the small time period meant that this could not be utilized for this study. In general, we divided all modes into three groups; centre-based, hybrid and home-based. Future research should study patients that receive more specific modes within each delivery group.

Finally, lack of randomization to delivery modes do not allows us to conclusion if the mode itself or the skewed distribution of patients’ characteristics across the delivery modes that explain the difference in terms of completion. By adjusting our analysis, we did tried to take account for the skewed distribution but some variance is likely still to occur due patient-preferred delivery modes as used in routine CR.

**6.0 Conclusion**

This study is the first utilizing routinely collected data to compare the different populations attending various modes of CR delivery and identify predictors of completion. Moreover, it is unique in that in contrast to the literature supporting equivalency in outcomes across modes of CR delivery, this study suggests that, in its routine form, the home-based mode has significantly lower completion recorded on the national registry even after accounting for differences in the populations. Given the positive and widespread adoption of various delivery modes in CR, especially since the COVID-19 pandemic, clinical programs offering home-based and hybrid modes should strive to achieve a clear point of CR completion defined by end of post-assessment as part of routine practice.

**Author Contributions:**

Authors Dr. Tang and Dr. Harrison’s contributions to the paper are equal and would like to be acknowledged as equal and both first author.

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