Improving Cardiac Rehabilitation Uptake: Potential health gains by socioeconomic status

Running title: Economic Evaluation of Cardiac Rehabilitation

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Conflict of Interests

The authors have no conflicts of interest pertaining to this study or paper

Abstract

Background

Globally cardiac rehabilitation (CR) is recommended as soon as possible after admission from an acute myocardial infarction (MI) or revascularisation, with evidence of its effectiveness identified by repeated robust systematic reviews. However, uptake is consistently poor internationally, ranging from 10% to 60%, which falls well short of national participation targets. The poor level of uptake is compounded by variation across different socioeconomic groups. Recent policy discussions have focussed on increasing uptake and addressing inequalities in participation rates. However, to date there is a paucity of economic evidence relating to increasing CR rates and an absence of evidence looking at differential impacts of increased uptake by socioeconomic status.

Methods

In this paper we construct a de-novo cost-effectiveness model of CR, utilising the results from the latest Cochrane review. We explore the role of socioeconomic status by incorporating key deprivation parameters and determine the population health gains, by socioeconomic status, of achieving the 65% UK uptake target.

Results

We find that the low cost of CR and the potential for reductions in subsequent MI and revascularisation rates combine to make it a highly cost-effective intervention. While CR is less cost-effectiveness for more deprived groups due to a poorer completion rates and underlying health; the lower level of uptake in these groups makes the potential health gains, from achieving the 65% target, greater. Alongside the health gains from reaching the target; we estimate the expenditure that could be justified while maintaining the cost-effectiveness of CR, £68.4 million per year.

Conclusions

We conclude that programmes to increase CR uptake should be designed to reduce the socioeconomic inequalities that exist in uptake. Through the estimation of potential population health gains and justifiable expenditure we have produced tools with which policy makers and commissioners can encourage greater utilisation of CR services.

Introduction

As the leading cause of death globally, heart disease was associated with an estimated 9.43 million deaths in 2016.[1] The links between heart disease, the obesity epidemic and physical inactivity is well established,[2-5] and are the primary reason for the risk of heart disease related death being almost three times greater in high income countries than low.[1] As a result, cardiac rehabilitation (CR), which is a multi-component complex intervention, has been at the forefront of attempts to reduce the impact of heart disease on population health in the developed world.[6, 7] Previous Cochrane[8, 9] and clinical reviews[10] have found that there are clear benefits from CR, which the National Institute for Health and Care Excellence (NICE) in England have indicated as being highly cost-effective.[11, 12] As a result, in their latest guidance issued in 2013, NICE recommended that CR is offered as soon as possible after admission for acute Myocardial Infarction (MI),[12] a decision mirrored elsewhere in the world.[6, 7, 13]

Despite the guidance by NICE and similar initiatives in Europe, Canada, and the US to improve the rate of uptake, the proportion of patients accessing CR remains stubbornly below national targets, for example 65% in England and 70% in the US,[6, 14] with uptake ranging from 10% to 60%.[10, 15] The problem of sub-optimal uptake is compounded by poorer uptake in more deprived groups, further compounding inequalities in cardiological health inequality.[16]

A number of interventions have been proposed to increase this rate of uptake, including improving the education of health professionals[17] and improving the accessibility of rehabilitation centres and home provision.[18, 19] However, little consideration has been given as to the level of expenditure that can be justified while maintaining the cost-effectiveness of the CR programme, or whether interventions should be stratified by deprivation group to reflect the role of deprivation in uptake and capacity to benefit.

To address these gaps in the evidence, in this paper we will explore three key aspects:

1) Determine if CR can be considered cost-effective given the contemporary evidence on its effectiveness.
2) Establish what economic analysis can tell us about how much can be spent on interventions to increase uptake, while maintaining cost-effectiveness.
3) Explore the role of deprivation in reducing both the potential to engage with CR and to gain from it.

Methods

In order to estimate the cost-effectiveness of CR, a scoping review of the current evidence relating to its effectiveness and cost-effectiveness was undertaken. The 2016 Cochrane review[8] was identified as the most complete contemporary systematic review of the effectiveness evidence, exploring the impact of CR on four key aspects: the rate of repeat MI, revascularisation as either percutaneous coronary intervention (PCI) or coronary artery bypass grafts (CABG), hospitalisation, and mortality (cardiovascular and all cause). Incorporating 63 trials and 14,486 patients with heart disease, the review represents an authoritative overview of the findings of the CR literature. Details are published elsewhere[8] but in brief the review found that CR led to a statistically significant reduction in cardiovascular mortality (but not total mortality as per the previous Cochrane review[9]), and hospitalisation, but an insignificant decrease in the rate of MI and revascularisation.

A recent systematic review of cost-effectiveness studies of CR identified a limited number of relevant studies.[20] Furthermore, while an economic evaluation was conducted to inform the NICE guidelines (CG172 and CG48) following MI [11, 12] it was not appropriate to replicate the original model as it fails to reflect current thinking around the mechanism of CR.[8] Furthermore, up to date costings and evidence is now available, making the results of the NICE guidelines model inappropriate for current decision making. As a result a de-novo model, taking account of the modern era of cardiology, was constructed to fully incorporate the findings of the Cochrane review into an economic evaluation framework.

The population

We consider a patient population in keeping with the three core studies in the CR field from a UK perspective: the latest Cochrane review, the National Audit of CR (NACR), and the latest NICE guideline on CR.[8, 12, 21] This constitutes all adults who have had a recent ST evaluation or non-ST elevation MI (STEMI or non-STEMI), PCI, or CABG, consisting of an estimated 121,499 patients in England in 2015/16.[21]

In order to inform decision making in the UK and internationally, we chose to select a patient cohort indicative of the treated population characterised by the NACR rather than clinical trials, as the former more closely reflects routine clinical practice with a mean age 11 years higher than Cochrane patients, and over 50% of patients presenting with two or more comorbidities following their cardiac event. As such, the cohort has a starting age of 67 (the age at which they are eligible for CR) and a male to female ratio of 0.70.[21]

The intervention

In broad terms a CR services are defined 'comprehensive, long term programmes involving medical evaluation, prescribed exercise, cardiac risk factor modification, education, and counselling'[10], therefore constituting a range of potential modalities tailored to the patient's needs rather than a single fixed intervention. The 2017 NACR found the majority of patients underwent a group based programme (between 70% and 85%) with a spread across the other modes of delivery such as home-based. Although there is significant variation in terms of intensity, frequency, and duration of CR within the mode of delivery, [20, 21] recent observational studies of routine practice suggest that patient benefit is equivalent following group based or home-based CR.[22-24]

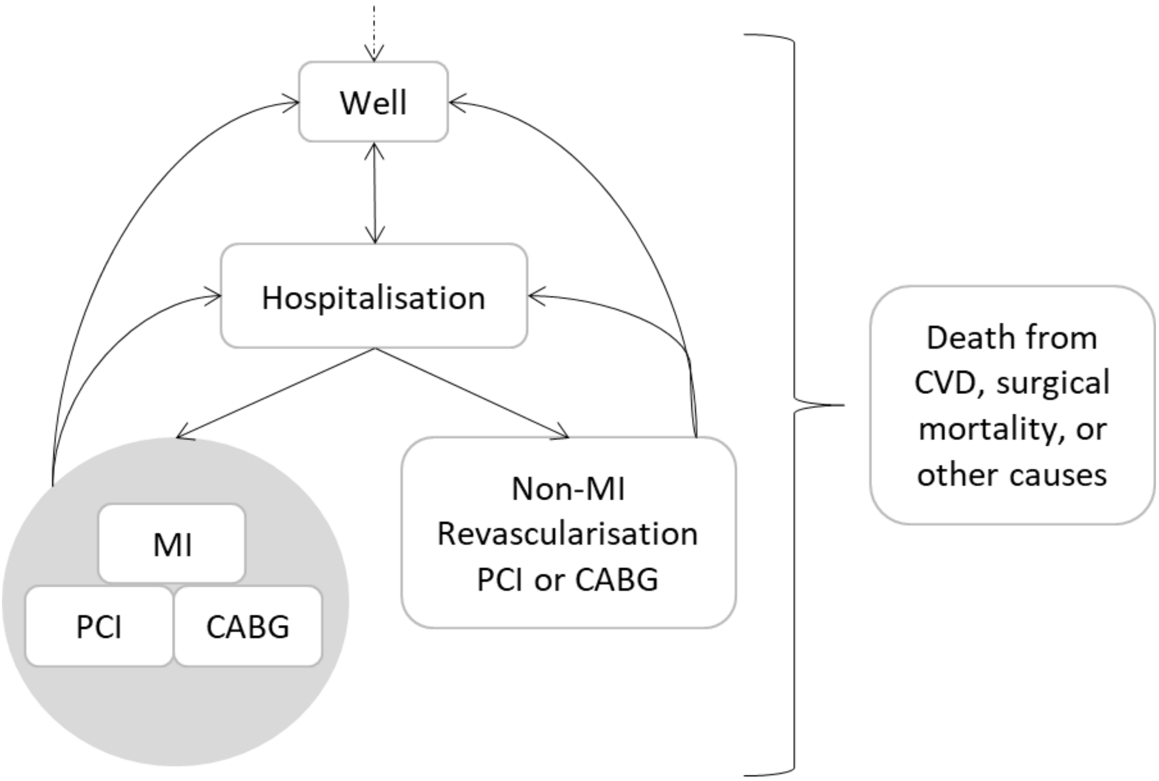
Our approach to the mode of intervention was to be inclusive as per the Anderson review[8] and the NICE guidance,[12] incorporating the full definition of CR, as is known to occur in clinical practice.[21]

The model

Decision modelling can be used as a quantitative means of combining evidence from a variety of sources to inform a particular decision problem.[25] In this case the Cochrane review alongside other sources of evidence, detailed below and in the supplementary appendix, are used within a Markov model structure to explore the impact of CR on the long term health of patients and the costs to the NHS, stratified by patient deprivation.

Figure 1 provides an overview of the model. As a starting point all patients are assumed to inhabit the 'well' state, the point at which after their first MI and/or revascularisation, they will begin CR if it is available. Due to the availability of CR at this point in the pathway only, we will not consider events prior to this point. We create two realisations of the potential patient pathway: one where CR is available and the patient undertakes it, and one where it is not available. In both realisations the patient can experience the same possible transitions, as shown in Figure 1, but the probability of them experiencing these is different in the presence of CR, as informed by the Cochrane Review[8] and national audit estimates.[21]

Figure 1: schematic of model for both CR and non-CR



The model allows patients to stay in a 'well' state, experiencing no further cardiac events, or to require admission to hospital. During a hospitalisation a patient can require no further care and return to the well state, or they can be identified as having had a MI, and can then go on to have a PCI or CABG for the MI, alternatively they can require revascularisation (PCI or CABG) for a non-MI event. From all states patients can die from cardiovascular disease (CVD) related events, other causes, or in the case of revascularisations, surgical adverse events. The structure of the model is driven by the Cochrane analysis, designed around the meta-analyses conducted.

Parameter estimation

The full list of parameters which inform the base-case analysis are given in the Supplementary Appendix. The Cochrane review[8] provided the informative evidence for many of the parameter estimates required for the model. We re-estimated the meta-analyses conducted in the Cochrane review in order to provide the most flexibility to inform the decision model, which requires transition probabilities rather than the risk ratios estimated in the review. The Cochrane report summaries were used to estimate 6 month transition probabilities for the no CR population, odds ratios (OR), also calculated from the Cochrane review, were applied to these probabilities to inform the CR model. A mean follow-up of 12 months and a random effects model was assumed consistent with the Cochrane findings. Adjustments were made using Bayes' theorem to ensure accuracy of the estimates to the model structure.[26] The estimated probabilities and OR are reported in the Supplementary Appendix.

Other model parameters including the rate of MI patients requiring revascularisation,[27] the current ratio of PCI to CABG,[21] surgical mortality rates,[28, 29] and non-CVD mortality rates,[30] were estimated from other published sources and data requests made to the NACR.

The NHS Reference Costs were used as the main source of unit cost evidence, supplemented with estimates from published literature. This included estimates of the cost of a typical CR programme[31] and MI.[32]

Patient quality of life was modelled using the utilities generated in the Lewis et al.[33] analysis applied as decrements to an age adjusted profile of 'normal' population quality of life scores.[34]

The model is constructed in keeping with best practice as reported in the NICE Methods Guide[35] including the use of a discount rate of 3.5% for both costs and outcomes, a lifetime analytical horizon, and the use of a NHS and personal social services perspective combined with patient health outcomes measured in terms of quality adjusted life years (QALYs).

To estimate the justifiable expenditure to increase the rate of uptake while remaining cost-effective we use an estimate of the marginal productivity of the NHS of £12,936/QALY as reported by Claxton et al.[36] This was used to estimate the point at which increases in population health from an increase in CR uptake would no longer be worth the opportunity cost to the NHS of funding them in place of other activities.

The role of completion

In addition to issues of low level of uptake of CR, a number of patients who commence the programme do not finish it, estimated as 75.4% using the latest NACR data request. The variation in CR programmes means that the impact of a patient failing to complete can have different impacts. For example, under a cohort programme, where a group conducts the programme as a single class, it is not possible to replace someone who drops out during the course, therefore the place is lost. In contrast under a rolling programme, where patients join and complete the programme on a continuous basis, the drop-out can be replaced by another patient with only the loss of a few sessions.

To ensure a conservative approach to estimating the cost-effectiveness of CR, our base-case analysis assumes that all patients who fail to complete a CR programme entail the full cost of the programme to the NHS but receive none of the health benefits.

Incorporating uncertainty

Intrinsic to any economic evaluation model is the role of uncertainty. To explore the role of uncertainty on our model we conducted probabilistic sensitivity analysis (PSA),[25] whereby distributions are fitted to all relevant model parameters to reflect the range of possible mean values for the cohort. The informative distributions used are detailed in the Supplementary Appendix. Such an approach explicitly incorporates the uncertainty reported in the Cochrane review regarding the effectiveness of CR. By repeatedly sampling from the informative distributions, the accumulated impact of the combined uncertainty can be reported. The result of this resampling is reported in terms of both the probability of CR being cost-effective as well as the impact of the uncertainty on the justifiable expenditure to increase CR uptake.

Incorporating the impact of deprivation

The role of social inequality and deprivation on cardiovascular health[37-39] and CR engagement[40-42] is well documented. To consider the role of deprivation both on the cardiovascular health of patients as well as their propensity to engage with CR we modelled the correlation between a number of key parameters and an index of multiple deprivation (IMD). The parameters included were selected through a pragmatic search of the literature based on the identification of areas where deprivation was expected to have an impact a-priori. The values incorporated in the model are given in Table 1, with all odds ratios indexed against IMD 3 for modelling purposes. As expected a-priori the identified evidence suggests that the level of uptake and completion are worse in more deprived groups (IMD levels 1&2), who also experience poorer health outcomes, both for CVD and all other health concerns.

Table 1: Impact of deprivation on model parameters and CR engagement

IMD	CVD mortality	Non-CVD mortality	QoL decrement	Rate of recurrence	CR uptake	CR completion (probability)
1	1.04	1.17	0.06	1.23	0.81	0.67
2	1.00	1.06	0.02	1.10	0.91	0.72
3	1.00	1.00	0.00	1.00	1.00	0.75
4	0.93	0.96	-0.03	0.95	1.04	0.78
5	0.81	0.92	-0.05	0.83	1.12	0.80
Source	ONS [43]	ONS [30]	Love-Koh [44]	Smolina [27]	NACR data request	NACR data request

Results

Cost-effectiveness of the CR programme

The cost-effectiveness results generated by the model are given in

Table 2, reporting: the total discounted costs and benefits for both CR and no CR strategies, the incremental cost-effectiveness ratio (ICER), and the probability of CR being cost-effective at a threshold value of £12,936/QALY, all stratified by IMD status.

Table 2: Cost-effectiveness of CR by IMD

IMD	no CR		CR		incremental		ICER /QLAY	Probability CE
	disc. cost	disc. QALY	disc. cost	disc. QALY	disc. cost	disc. QALY		
1	£7,696	3.80	£8,420	4.03	£724	0.22	£3,240	0.996
2	£7,328	4.22	£8,046	4.49	£718	0.27	£2,630	0.997
3	£6,863	4.42	£7,577	4.72	£714	0.30	£2,395	0.998
4	£6,760	4.75	£7,443	5.07	£683	0.32	£2,133	0.996
5	£6,340	5.12	£6,983	5.44	£643	0.32	£1,991	1.000

disc. - discounted

Across all IMD categories CR is associated with greater total discounted costs and QALYs than no CR, resulting in an ICER that would conventionally be considered highly cost-effective with high certainty, as the mean ICERs are below £3,500/QALY for all IMD groups and the probability of cost-effective 99.6%. The results also demonstrate the impact of socioeconomic inequality on the cost-effectiveness of CR. The poorer quality of life, life expectancy, and recurrence rates of the more deprived results in the deprived cohort's baseline expected QALYs much lower, 3.80 QALYs in IMD1 compared to 5.12 in IMD5, while their poorer completion rates make their propensity to gain under the current CR system less, incremental QALYs 0.22 compared to 0.32.

Scatter plots presenting the probabilistic simulations for each of the IMD groups, and a table of results under the assumption that completion rates are 100%, are provided in the Supplementary Appendix.

The benefit and justifiable cost of reaching 65% uptake

Table 3 provides estimates of the annual total health gains (in terms of QALYs) from achieving the 65% uptake target (assuming current rates of completion), alongside the justifiable expenditure to achieve the target, stratified by IMD. The total population health gain was calculated by combining the increased uptake required to achieve the target, the estimated size of the eligible population per year, and the QALY gain per person starting CR as reported in

Table 2. The total justifiable expenditure represents an estimate of the additional cost that could be spent on a CR programme while maintaining its cost-effectiveness.

Table 3: Annual benefits and justifiable cost of reaching 65% target, by IMD

IMD	current uptake (NACR data request)*	Increment to 65% target	eligible population (NACR data request, 2015/16 data)	QALY gain per person of CR	Total QALY gain for reaching target	justifiable expenditure to reach target while cost effective	
						per person	whole pop
1	37.61%	27.39%	22,194	0.22	1,358	£2,166	£13,167,695
2	41.97%	23.03%	22,952	0.27	1,442	£2,812	£14,863,740
3	46.21%	18.79%	23,470	0.30	1,314	£3,141	£13,849,816
4	48.14%	16.86%	27,086	0.32	1,464	£3,462	£15,812,812
5	51.75%	13.25%	22,842	0.32	978	£3,537	£10,701,547
				Total	6,556	N/A	£68,395,610

*the numerator for this estimate of uptake is calculated using only those programmes which upload their data to NACR, averaged across 2015 to 2018, we assume the same rate of uptake in these programmes as those who do not, this assumption is consistent with current NACR reporting.[21]

The table shows that while the potential health gains per person, and therefore the justifiable expenditure to achieve them, is less in the more deprived groups, as they have the greatest required increase in uptake to achieve the 65% target, the total justifiable expenditure to achieve it is similar to the less deprived. The exception is the IMD 5 group who, in spite of their large potential to gain from CR, have a relatively low total justifiable expenditure (£10.7 million) due to their significantly higher current uptake greatly reducing the total gain from achieve the target. The total justifiable expenditure of £68.4 million across all groups provides an estimate of the maximum annual expenditure that could be justified if intervention was able to increase uptake to 65% in all IMD groups.

Alongside estimating the probability of CR being cost-effective the PSA simulations can be used to show the impact of parametric uncertainty on the estimate of total justifiable annual cost to reach the 65% uptake target, this is shown in Figure 2. The figure shows the cumulative distribution functions of total justifiable cost to achieve the target, stratified by IMD group.

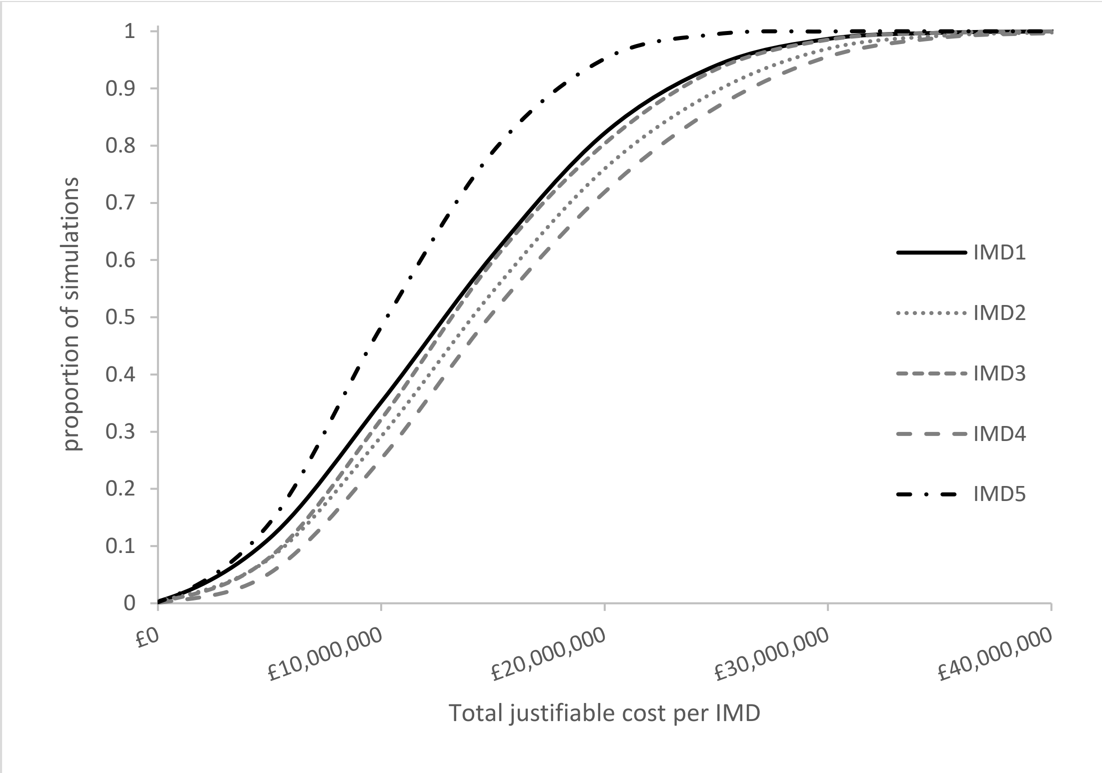


Figure 2: Cumulative distribution function for total justifiable cost, by IMD

Consistent with the results shown in Table 3 the figure shows that the mean estimated total cost is £13.2 to £15.8 million for IMD1-4 and lower for IMD5 (£10.7 million). For IMD1-4 roughly 90% of the simulated values occur under £26.0 million, highlighting the large variation in the estimate, for IMD5 this is under £18.0 million. The distribution of IMD5 lies apart from the others due to the lower required increase in uptake to reach the 65% target, despite the relatively greater justifiable expenditure per person.

Overall Table 3 and Figure 2 demonstrates that, while on average between £10.7 million and £15.8 million could be justified to increase uptake up to 65% per IMD group, there is significant uncertainty in this estimate. Summing across all IMD groups gives a total justifiable expenditure of £68.4 million if all groups achieve the target, with a 95% confidence interval of £44.1 to £94.6 million. If the 65% target was achieved our analysis suggests this would result is a reduction of roughly 21,000 hospital admissions and 8,500 deaths averted over 10 years.

Discussion

We find that the low cost of CR and the potential for reductions in subsequent MI and revascularisation rates combine to make it a highly cost-effective intervention across all IMD groups. While the per patient lifetime costs to the NHS of providing CR to more deprived groups is greater than less deprived, and the expected QALY gains less, the lower level of current uptake in the more deprived groups makes the potential health gains from achieving the 65% target greater, and thus the total justifiable expenditure.

The main strength of this analysis is that this is the first economic evaluation of CR to incorporate the findings of the Cochrane review, alongside the incorporation of the role of deprivation on both cardio-vascular health and engagement with CR. This framework provides estimates of justifiable expenditure which can facilitate decision makers to invest in policies to increase CR uptake.

However, the analysis also has a number of weaknesses, primarily the failure to reflect different CR programmes and the potentially restrictive structure of the model. Ideally the economic evaluation would incorporate the range of different CR programme types to explore the relative cost-effectiveness of different approaches. However, the nature of the Cochrane review, which did not stratify by CR type, in addition to the recommendation that CR is flexible to patient preferences, made the incorporation of multiple programme types into the analysis both infeasible and potentially uninformative to decision makers. Furthermore, recent analyses suggests that outcomes and completion rates do not vary substantially between different modes of delivery.[22-24]

Similarly, the structure of the model is potentially an over-simplification of the post-event patient pathway, failing to explicitly reflect the full range of events, e.g. stroke, and long term non-fatal disability. However, the use of the Cochrane review to inform the parameter estimates limited the potential to incorporate a wider set of explicit patient events.

The most valuable element of this analysis is its ability to be used as a framework to demonstrate the business case for investment in interventions which increase the uptake of CR, particularly those which address the issue of inequality of uptake. Furthermore, by demonstrating the impact of uncertainty around the patient pathway we allow decision makers to understand how the estimate of justifiable expenditure to reach the 65% target can be tailored to their aversion to risk.

This analysis has highlighted a number of areas which require further research. The analysis presented here only considers the role of CR in improving outcomes related to cardio-vascular health, however, recent NACR analyses highlight the role of CR in facilitating smoking cessation, increasing physical activity rates, reducing obesity rates, anxiety and depression, and improving general quality of life.[22-24]

Furthermore, the probabilistic analysis demonstrates that while CR is highly likely to be cost-effective, with a probability of being cost-effective of almost 100% for all IMD categories, the uncertainty in the parameter estimates results in a wide distribution in terms of the justifiable expenditure to increase CR uptake. Therefore, while there is little value in further research in terms of demonstrating the cost-effectiveness of CR, such research would be informative to the business case of interventions seeking to increasing uptake to ensure efficient spending. This is potentially amplified by the failure of our analysis to incorporate the uncertainty that would be unavoidable in the ability of interventions to increase uptake to the 65% target.

Finally, the conclusions of this analysis focus on increasing CR uptake, however, there is the potential for the expenditure on CR programmes to be wasted if patients do not complete the programme. As a result, further discussion and research should be conducted to explore the role of non-completion on impacting the effectiveness and cost-effectiveness of CR, and the propensity of interventions to increase completion rates.

Conclusion

We conclude that CR, as it is currently delivered, is highly cost-effective across all IMD groups due to its low cost and high effectiveness in improving cardiovascular outcomes, as demonstrated by the Cochrane review. Furthermore, we show that there is a clear business case for spending money on incentives which increase CR uptake to the 65% target, stratified by IMD, with a justifiable expenditure of £68.4 million per year. Our analysis does, however, demonstrate that there is significant uncertainty around this justifiable expenditure, which originates from the uncertainty in the Cochrane reviews estimates of the effectiveness of CR. However, the lowest 95% confidence interval of the total justifiable expenditure is still £44.1 million, demonstrating the large potential benefit of increasing CR uptake regardless of the significant uncertainty.

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