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## Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Title page

### Title

Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Abstract

### Introduction

It is important to ascertain the cost-effectiveness of alternative services to traditional cardiac rehabilitation while the economic credentials of the Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) program among people with coronary heart disease (CHD) are unknown. This economic protocol outlines the methods for undertaking a trial-based economic evaluation of SCRAM in the real world setting in Australia.

### Methods and analysis

The within-trial economic evaluation will be undertaken alongside a randomised controlled trial (RCT) designed to determine the effectiveness of SCRAM in comparison to usual care cardiac rehabilitation (UC) alone in people with CHD. Pathway analysis will be performed to identify all the costs related to the delivery of SCRAM and UC. Both a healthcare system and a limited societal perspective will be adopted to gauge all costs associated with health resource utilisation and productivity loss. Healthcare resource use over the six-month participation period will be extracted from administrative databases (i.e. Pharmaceutical Benefits Scheme and Medical Benefits Schedule). Productivity loss will be measured by absenteeism from work (valued by human capital approach). The primary outcomes for the economic evaluation are maximal oxygen uptake ( $VO_{2max}$ ,  $ml \cdot kg^{-1} \cdot min^{-1}$ , primary RCT outcome) and Quality-adjusted life years estimated from health-related quality of life (HRQoL) as assessed by the Assessment of Quality of Life (AQoL-8D) instrument. The incremental cost-effectiveness ratio (ICER) will be calculated using the differences in costs and benefits (i.e. primary and secondary outcomes) between the two randomised groups from both perspectives with no discounting. All costs will be valued in Australian dollars for the year 2020.

### Ethics and dissemination

The study protocol has been approved under Australia's National Mutual Acceptance agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119). It is anticipated that SCRAM is a cost-effective cardiac telerehabilitation program for people

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2  
3 with CHD from both a healthcare and limited societal perspective in Australia. The evaluation  
4 will provide evidence to underpin national scale-up of the program to a wider population.  
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7 Trial registration  
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10 Australian New Zealand Clinical Trials Registry (ACTRN12618001458224)  
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## Strengths and limitations of the study

- Health economics data will be collected prospectively along with a randomised controlled trial to reliably capture the individual-level health care resource use and changes in productivity.
- National administrative data collection (i.e. Medicare and Pharmaceutical Benefits Scheme Australia) will be extracted to source the healthcare resource utilisation over the trial duration.
- The economic evaluation is based on the sample size determined by the primary outcome of the SCRAM RCT, which may be underpowered to detect a difference in costs.



## Introduction

Cardiac rehabilitation (CR) is an effective multifactorial secondary prevention intervention that is typically delivered in centre-based (i.e. face-to-face) settings. Centre-based CR reduces recurrent ischaemic events, improves health-related quality of life and long-term prognosis for coronary heart disease (CHD) patients<sup>1-3</sup>. CR programs have also been reported to reduce overall premature mortality (relative risk (RR) 0.87, 95% confidence interval (CI): 0.75-0.99) and cardiac deaths (RR 0.74 (95%CI 0.63-0.87) in comparison with no CR.<sup>4</sup> Despite effectiveness of CR, many people with CHD do not engage in such programs.<sup>5</sup> For instance, CR utilisation is low in Australia; uptake (attended  $\geq 1$  session) and completion rates have been estimated at 25% to 60% and 19% to 42%, respectively, across the country; uptake rates as low as 10% have been reported in Victoria.<sup>6-9</sup> Reasons underlying poor participation are complex, but accessibility barriers such as limited program availability, transport restrictions, conflicting domestic/occupational responsibilities, and geographic isolation are key contributors.<sup>10-13</sup>

For these reasons, clinicians and researchers have been prompted to seek novel strategies for delivering CR programs to facilitate greater uptake and adherence rates. Telerehabilitation—defined as rehabilitation services that are delivered remotely through information and communication technologies—has received increasing attention as it can overcome key accessibility barriers that limit participation in centre-based CR. The effectiveness of telerehabilitation, which commonly includes telephone, internet and videoconference communication between participants and healthcare practitioners,<sup>14</sup> has been demonstrated. Systematic reviews have consistently shown that telerehabilitation services improve CVD risk factors (i.e. total cholesterol, blood pressure, high- and low-density lipoprotein), compared to controls<sup>10 15</sup>; and comparisons of traditional centre-based CR with telerehabilitation have shown them to be equivalent in terms of mortality, exercise capacity and quality of life outcomes<sup>16</sup>. The effectiveness of CR interventions delivered via telephone, internet, and videoconference has been well established; however, few trials have capitalised on opportunities to augment intervention design and delivery by using rapidly advancing mobile communication and device technologies (i.e. mobile broadband and smartphones; mHealth).

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3 Four randomised-controlled trials (RCT) have compared mHealth CR with traditional centre-  
4 based programs. One study showed improved uptake and completion rate in comparison to  
5 the control group<sup>17</sup>, two indicated mHealth and centre-based CR had comparable effects on  
6 maximal oxygen uptake (i.e. exercise capacity),<sup>18 19</sup> while the fourth suggested mHealth CR  
7 led to improvements in maximal oxygen uptake and quality of life<sup>20</sup>. The results from existing  
8 economic evaluations of mHealth intervention are not consistent<sup>18 19 21 22</sup>.

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15 We are currently undertaking a multi-centre RCT of a smartphone-based platform to support  
16 remotely delivered CR called Smartphone Cardiac Rehabilitation, Assisted self-Management  
17 (SCRAM). Unlike its predecessor REMOTE-CR<sup>18</sup>, SCRAM extends beyond a single behaviour  
18 (exercise) to include other secondary prevention self-management behaviours (medication  
19 adherence, physical activity and sedentary behaviour, healthy eating, stress management,  
20 and smoking cessation). To establish the economic credentials of the SCRAM program in the  
21 Australian setting, an economic evaluation will be conducted to examine the balance between  
22 health effects and costs of health technologies (i.e. SCRAM program, medications, diagnostic  
23 tests, medical services, etc.) to inform efficient allocation of limited healthcare funding. In  
24 response to the transparent reporting of clinical trials, this paper outlines the methods of the  
25 prospective within-trial economic evaluation to be undertaken alongside the RCT<sup>23</sup>, to  
26 provide important evidence for policy decision-making around the provision of cardiac  
27 rehabilitation services. It will include both cost-effectiveness and cost-utility analysis with a  
28 view to informing resource allocation, practice change and investment in the SCRAM  
29 program.  
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## 46 Methods

### 47 Design

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49 The details of the study design are reported elsewhere<sup>23</sup>. Briefly, SCRAM is a multicentre  
50 investigator-, assessor-, and statistician-blinded parallel two-arm RCT comparing effects and  
51 costs of the 24-week SCRAM intervention with usual care CR. A process evaluation is also  
52 being undertaken. Participants are randomised (1:1) to receive either SCRAM (intervention)  
53 or usual care CR (control).  
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3 The study protocol was prospectively registered with the Australian New Zealand Clinical  
4 Trials Registry (ACTRN12618001458224) on 30/08/2018 and adheres to the SPIRIT 2013  
5 statement.<sup>24</sup> The intervention has been described according to recommendations in the  
6 TIDieR and CONSORT (eHealth extension) statements. Reporting of trial outcomes will adhere  
7 to the CONSORT statement and its eHealth extension.<sup>25-27</sup>  
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14 The economic evaluation will be undertaken from both an Australian healthcare system plus  
15 a limited societal perspective, incorporating all health care costs subsidised by state and  
16 Commonwealth governments in Australia. In addition, participant absenteeism from work  
17 due to CHD will be monetised and the associated cost will be included in the estimation from  
18 the limited societal perspective. The reporting of this economic evaluation will adhere to the  
19 Consolidated Health Economics Evaluation Reporting Standards (CHEERS) guidelines<sup>28</sup>.  
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#### 28 Study population

29 A total of 220 participants (N=110 per randomised group) diagnosed with CHD within the  
30 previous six months, are being recruited from hospitals, outpatient clinics, and cardiac  
31 rehabilitation services in Sunshine, Geelong, and Bendigo, Victoria, Australia. As study centres  
32 provide treatment to ~1.5 million individuals across broad catchment areas the trial cohort is  
33 anticipated to include a geographically diverse mix of metropolitan-, regional- and rural-  
34 dwelling participants.  
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42 Participants are randomised (1:1) to receive the SCRAM program (intervention) or usual care  
43 CR (control), stratified by sex and study centre. Key inclusion criteria at baseline are: aged  
44 over 18 years; diagnosed CHD within the previous six months (angina, myocardial infarction,  
45 or coronary revascularisation); outpatients who have been clinically stable for at least 6  
46 weeks; able to perform exercise; and can understand and write English. Exclusion criteria  
47 include: New York Heart Association (NYHA) Functional class III/IV heart failure; terminal  
48 disease; significant non-CHD exercise limitations; contraindications for maximal exercise  
49 testing.  
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#### 57 Patient and public involvement

58 There is not patient and public involvement.  
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### Sample size

The target sample will provide 90% power at a 5% significance level (two-sided) to detect a clinically meaningful difference of  $2.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  in  $\text{VO}_2\text{max}$  at 24 weeks (primary RCT outcome) between the control and intervention groups, assuming a standard deviation of 6.75, a correlation of 0.8 between the pre- and post-intervention measures, and 20% loss-to-follow-up. Minimum detectable differences in secondary RCT outcomes are outlined in the main trial protocol<sup>23</sup>.

### Baseline assessment

Prior to randomisation, researchers collect the following information: sociodemographic and clinical (diagnostic, smoking, alcohol history, medication) characteristics, ehealth literacy (a questionnaire),  $\text{VO}_2\text{max}$ , and secondary outcomes (detailed below).

### Randomisation

Treatment allocation follows a computer-generated schedule prepared by a biostatistician who is not involved with recruitment, treatment allocation, or outcome assessment<sup>23</sup>. Investigators, outcome assessors, and the statistician remain blinded to the group allocation over the course of the trial.

### Treatment arms

#### Usual care cardiac rehabilitation

Usual care CR typically includes face-to-face support/education to adhere to medical treatment and health-promoting lifestyle behaviours as well as supervised exercise training. Specific program components vary across Australian healthcare providers but most offer education and exercise components;<sup>29</sup> stratification of treatment allocation by trial centre will ensure variation is balanced across treatment groups.

Usual care CR is not delivered as part of this trial. All participants retain access to usual care CR—regardless of treatment allocation—as it is unethical to withhold evidence-based

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3 treatment. Participants randomised to the control group have access to usual care CR alone,  
4 as offered by their local CR provider, without further support.  
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#### 9 Intervention: SCRAM program

10 Participants randomised to the intervention group receive the 24-week dual-phase SCRAM  
11 intervention, which is described in detail in the main trial protocol<sup>23</sup>. Briefly, during an initial  
12 12-week intensive phase, participants receive real-time remotely prescribed, supervised and  
13 coached exercise training from accredited exercise physiologists as well as a modular  
14 multifactorial library of evidence- and theory-based behaviour change support push  
15 notifications. This phase is designed to provide intensive support for exercise and lifestyle  
16 behaviour uptake and adherence. During a subsequent 12-week maintenance phase,  
17 participants receive reduced frequency and intensity of exercise and behaviour change  
18 support. This phase is designed to provide tapered support that transitions participants  
19 towards long-term self-determined adherence to exercise and health-promoting lifestyle  
20 behaviours. Participants receive all intervention components via the bespoke SCRAM  
21 software platform, using an Android smartphone.  
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#### 36 Comparator

37 It is important for the economic evaluation to be able to ascertain whether the planned  
38 intervention is conducted in addition to existing practices, or as a replacement to them.  
39 Consistent with the RCT design<sup>23</sup>, SCRAM intervention will be compared to usual care CR (i.e.  
40 traditional centre-based CR).  
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#### 49 Measurement of clinical endpoints

##### 50 Outcome measures for the within-trial economic evaluation

51 Primary outcomes for the economic evaluation will be maximal oxygen uptake ( $\text{VO}_2\text{max}$ ,  
52  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , primary RCT outcome)—measured during an individualised treadmill  
53 cardiopulmonary exercise test—and health-related quality of life (HRQoL)—measured using  
54 the Assessment of Quality of Life-8D (AQoL-8D).  $\text{VO}_2\text{max}$  is measured at baseline and 24-week  
55 follow-up, whilst HRQoL is assessed at baseline, 12-weeks, and 24-weeks. Secondary  
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3 outcomes, including modifiable cardiovascular risk factors and adverse events, are described  
4 in the main trial protocol<sup>23</sup>.  
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## 10 Measurement of costs

### 11 Direct cost of delivering the SCRAM program

12 In identifying relevant costs, the following principles will be adhered to:

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16 • Identification of costs to be included, using 'pathway analysis' (Figure 1), where  
17 activities in all stages of the roll out of the SCRAM project are fully specified; A healthcare  
18 system perspective and steady state operation of the intervention will be assumed  
19 (intervention is up and running, and start-up costs, like development of SCRAM app will be  
20 excluded). Costs will largely relate to the time costs of the remote exercise physiologists and  
21 project staff (using opportunity cost principles). Any administrative resources used at the  
22 program management level also will be identified and included.  
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- 30 • Measurement of the resources consumed in natural units (number of hours spent by  
31 remote exercise physiologists to deliver the intervention, etc.);  
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- 34 • Valuation of these resources in monetary units (Australian dollars), using 2020 as the  
35 reference year.  
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### 41 Direct health costs of participants

42 Beside intervention cost, healthcare-related costs including inpatient and outpatient care  
43 associated with CHD are documented. The cost of inpatient care over the 24-week  
44 participation period (e.g. emergency department (ED) visits and rehospitalisations will be  
45 estimated from self-reported adverse events documented throughout the trial.  
46 Complementary approaches will be utilised to calculate the cost for each hospitalisation  
47 episode: first, the cost per hospital admission from the National Hospital Cost Data Collection  
48 (actual cost per AR-DRG) will be used; second the National Efficient Price (projected cost)  
49 according the AR-DRG code<sup>30</sup> will be used to value the per hospitalisation episode adjusted  
50 for the length of hospital stay. The cost of outpatient care (e.g. outpatient consultations,  
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3 examinations) and medication use over the 24-week participation period will be estimated  
4 from MBS and PBS data, respectively.  
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#### 10 Productivity cost (absenteeism from work)

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12 Absence from work (i.e. days of sick leave) due to CHD is self-reported by participants of  
13 working age (i.e. ≤65 years old; people post working age do not attract productivity loss from  
14 a societal perspective) using a pre-designed questionnaire at baseline and 24-week follow up.  
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16 The human capital approach will be used to value the productivity cost<sup>31</sup>.  
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#### 22 Exclusion of trial costs

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24 Research-driven activities will be separated from the activities that would be carried out  
25 should the program be adopted by the healthcare system. Costs associated with trial  
26 administration, data collection, and RCT outcome assessment will be excluded.  
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#### 32 Data analysis

##### 33 Within-trial economic evaluation

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35 The within-trial economic evaluation will be based on the intention-to-treat population as per  
36 the primary outcome of the RCT<sup>23</sup>. All evaluation results will be expressed as incremental  
37 results over and above the comparator case. In other words, the additional cost/saving of the  
38 intervention (SCRAM) compared to current practice will be expressed as a ratio by dividing by  
39 the net benefits derived. The following formula represents the calculation of the incremental  
40 cost-effectiveness ratio (ICER):  
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$$48 \text{ ICER} = C_i - C_{UC} / B_i - B_{UC}$$

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50 where C=costs, B=benefits, i=SCRAM intervention, UC=usual care CR  
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53 For the cost-effectiveness analysis (CEA), the incremental cost per unit increase in benefits  
54 for both the primary and secondary outcomes will be calculated if significant between-group  
55 differences are observed. For the cost-utility analysis (CUA), the quality-adjusted life year  
56 (QALY) will be estimated from HRQoL assessed by AQoL-8D by intervention group (Table 2).  
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3 A plot on the cost effectiveness plane will be drawn to illustrate the distribution of costs and  
4 effectiveness. A cost-effectiveness acceptability curve will also be plotted in order to assess  
5 the degree of uncertainty associated with the conclusion using a predetermined empirical  
6 willingness-to-pay (WTP) threshold for the QALY outcome (i.e. AU\$50,000/QALY)<sup>32</sup>.  
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11 Bootstrap simulation of the ICER will be used to simulate the study results over 2,000  
12 iterations. This technique is used when data are skewed (cost data are nearly always highly  
13 skewed) and the confidence interval of a ratio using skewed data is required. The within-trial  
14 economic analysis will be undertaken using STATA 15 (StataCorp. 2017. Stata Statistical  
15 Software: Release 15. College Station, TX: StataCorp LLC).  
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#### 20 21 Long-term modelling

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23 For the long-term modelling that is beyond the trial duration, benefits observed in the trial  
24 will be translated into health benefits (e.g., avoided morbidity/mortality outcomes, and  
25 calculated in terms of QALY gained). The modelled economic evaluation will simulate the  
26 impact of increased maximal oxygen uptake on the overall well-being/survival of the cohort  
27 over its lifetime compared with the control group. A Markov model consisting of health states  
28 associated with CHD (i.e. recurrent myocardial infarction, angina, revascularisation, stroke or  
29 death) will be used to accrue costs and benefits over the lifetime horizon. The long-term  
30 improved outcomes may translate into the cost savings due to avoided ED visit and  
31 rehospitalisation. Long-term modelling will be performed in TreeAge Pro 2019.  
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#### 40 Sensitivity analysis

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42 Uncertainty analyses will be conducted based on Monte Carlo simulations. The between-  
43 group differences in both costs and QALY will be bootstrapped to estimate the probability of  
44 the SCRAM program being cost-effective regardless of the significance in between-group  
45 difference<sup>33</sup>. A series of one-way sensitivity analyses will be undertaken to examine  
46 robustness of the base-case ICER, for example, alternative costing approach for  
47 rehospitalisation (unit costs derived from Independent Hospital Pricing Authority, Australia;  
48 Australian Institute of Health and Wellbeing), labours (unit costs sourced from Australia  
49 Bureau of Statistics, PayScale), and SCRAM intervention delivery (varying the quantity and  
50 unit cost of the resource utilised).  
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## Ethics approval

The study protocol has been approved under Australia's National Mutual Acceptance agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119). Ethics approval has been ratified by the Deakin University Human Research Ethics Committee (2018-251). All participants provide written informed consent prior to undertaking baseline assessments. Separate consent is sought to extract MBS/PBS data for the purpose of this study.

## Discussion

This paper details the protocol of a trial-based economic evaluation that purports to assess the cost-effectiveness of the SCRAM telerehabilitation program among people with CHD. It has a number of methodological strengths, the key one being that the economic evaluation will be undertaken alongside a prospective RCT. This has the advantage of being efficient and timely in terms of the data collected. In addition, the RCT design provides credibility through high internal validity, minimisation of bias, and tight protocol control. The SCRAM RCT aims to minimise the predictable sources of bias and confounding via allocation concealment, blinded outcome assessment and intention-to-treat analysis. The primary costing data will be sourced from administrative databases including MBS, PBS, and hospital costing system data; this allows for maximum accuracy of the data collected and enhances the capture of effects and outcomes. Furthermore, this RCT is recruiting participants from metropolitan, regional and rural areas of Victoria, Australia, allowing for broader representativeness of participants that will maximise generalisability of the results. Lastly, HRQoL will be assessed by the AQoL-8D, a 35-item questionnaire, which has been widely applied in measuring HRQoL for Australia-based studies<sup>34-37</sup>. It has increased measurement sensitivity, especially in the psychosocial dimensions, compared with existing instruments [i.e. EuroQol-5D-5L (EQ-5D-5L), Quality of Wellbeing (QWB), Health Utilities Index Mark 3 (HUI3), and 15D] that vary greatly and report inconsistent utility scores<sup>38</sup>.

The economic credentials of traditional centre-based CR versus no CR have long been established. A systematic review of 19 CEAs of such interventions concluded that the majority reported traditional CR was cost-effective versus no CR (ICER ranged from US\$1065 to

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3 US\$71755/QALY), especially with exercise as a component<sup>39 40</sup>. Specifically in relation to  
4 cardiac telerehabilitation (not involving a smartphone-based remote CR component), studies  
5 are varied in terms of their results. Whilst one within-trial economic evaluation reported that  
6 such an intervention (offering the flexibility of having the CR at hospital, healthcare centre, or  
7 call centre) was not cost-effective given its high cost (ICER €400,000 per QALY)<sup>21</sup>, others have  
8 demonstrated more positive outcomes. A trial-based economic analysis home-based CR was  
9 associated with non-significantly lower costs and a high probability of being cost-effective<sup>19</sup>.  
10 Another CUA showed that the mean cost per patient in a telemonitoring program was €564  
11 lower than in the control group, but with higher QALY gains (0.026), thereby making the  
12 intervention dominant (lower costs but higher benefits)<sup>22</sup>. Another CEA of home-based  
13 telerehabilitation, delivered through online videoconferencing for patients with heart failure,  
14 concluded that it was associated with significantly lower costs (-AU\$1590, 95%CI -\$2822 to -  
15 \$359) during the 6 month participation period<sup>41</sup>. Our previous economic evaluation alongside  
16 a non-inferiority RCT in New Zealand indicated the REMOTE-CR smartphone-based cardiac  
17 telerehabilitation program—a precursor to SCRAM—was associated with cost-saving (-  
18 NZ\$4615/participant) and comparable benefits<sup>18</sup>.

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33 Some methodological limitations are worth mentioning: first of all, the economic evaluation  
34 is based on the sample size determined by the primary outcome of the SCRAM RCT. It may be  
35 underpowered to detect a difference in costs. Second, whilst the gold standard is to  
36 undertake economic evaluations from a societal perspective (which captures all costs falling  
37 on patients, their carers, and families), the current study only considers a limited societal  
38 perspective (i.e. including only productivity costs); the costs borne by carers and families are  
39 excluded. However, it is believed that the health care system plus the limited societal  
40 perspectives will provide sufficient information to inform decision-making around investment  
41 in the SCRAM program in Australia and elsewhere.

## 50 51 Conclusion

52  
53 The results of this economic evaluation will fill the evidence gap for the cost-effectiveness of  
54 this mHealth CR program versus usual care CR alone, given that the current economic  
55 credentials of a pre-cursor intervention are based on a non-inferiority RCT<sup>18</sup>. Results will assist  
56 policy makers, healthcare managers and other healthcare service providers to inform  
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3 decisions regarding the ongoing use or future implementation of the SCRAM program. If the  
4 economic evaluation finds the SCRAM program to be cost-effective, then it can be  
5 recommended at the national or even international level as a complementary alternative CR  
6 delivery model that may meet the needs of many people who are unable or unwilling to  
7 participate in traditional centre-based CR services.  
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### 18 **Contributorship statement**

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20 All the authors contributed to the study design and the protocol of the economic analysis. LG  
21 drafted the initial manuscript. All the other authors reviewed, edited and approved the final  
22 manuscript.  
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### 29 **Competing interests**

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31 None declared.  
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40 grant 1144331).  
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Tables

Table 1 Identified cost items according to pathway analysis

Process to be costed	Identification of costs	Measurement of costs	Valuation of costs	Who records cost data & how is it collected
Recruitment of participants	Researcher	minutes/hours	Salary costs	Researcher records time taken
Training				
Training/induction session for participants	Project team time	hours	Salary costs	Project team records time taken
Training/induction session for accredited exercise physiologist	Project team time	hours	Salary costs	Project team records time taken
Capital				
Leasing of venue for training/induction sessions	Cost of leasing	Unit cost	Market price	Research team to record
Leasing of venues for cardiac rehabilitation professionals to deliver the SCRAM program	Cost of leasing	Unit cost	Market price	Research team to record



Wearable sensor devices	Cost of sensor device	Unit cost	Market price	Research team to record
Smartphone	Cost of smartphone	Unit cost	Market price	Research team to record
Computers (desktop or laptop)	Cost of computer	Unit cost	Market price	Research team to record
Staffing				
CR professional	CR professional time	Hours	Salary costs	CR professional records time taken
Administrative support	Project staff time	Hours	Salary costs	Project staff records time taken
Miscellaneous costs				
Mobile phone/internet access	Cost of mobile phone, internet access	Unit cost	Market price	Research team to record
Stationery	Cost of stationery	Unit cost	Market price	Research team to record
Utilities (i.e. electricity)	Cost of utility	Unit cost	Market price	Research team to record
Hosting (server)	Cost of server	Unit cost	Market price	Research team to record



Handouts (flyer, information sheet, etc.)	Cost of printing	Unit cost	Market price	Research team to record
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Abbreviation: CR, cardiac rehabilitation.

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Table 2. Expected outcomes of the economic analysis

Analysis	Incremental costs	Incremental effectiveness	Incremental cost-effectiveness
Incremental cost-effectiveness analysis	AUD	Maximal oxygen uptake (VO <sub>2</sub> max, ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	Cost of per unit improvement in VO <sub>2</sub> max
	AUD	Anthropometry (i.e. body weight, BMI, waist/hip circumference, etc.*)	Cost of per unit improvement in anthropometry outcomes
	AUD	Blood lipid and glucose concentrations, blood pressure	Cost per unit improvement in biomedical outcomes
Incremental cost-utility analysis	AUD	Quality-adjusted life year gained	Cost per additional quality-adjusted life year gained

\*complete list of secondary outcomes could be found in the trial protocol<sup>23</sup>.

AUD: Australian dollar; BMI: body mass index

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## Figures

Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery

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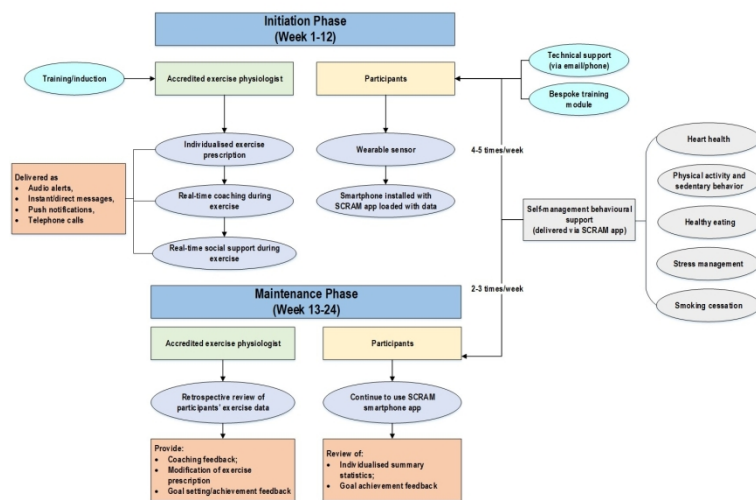


Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery

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# BMJ Open

## Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Title page

### Title

Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Abstract

### Introduction

It is important to ascertain the cost-effectiveness of alternative services to traditional cardiac rehabilitation while the economic credentials of the Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) program among people with coronary heart disease (CHD) are unknown. This economic protocol outlines the methods for undertaking a trial-based economic evaluation of SCRAM in the real world setting in Australia.

### Methods and analysis

The within-trial economic evaluation will be undertaken alongside a randomised controlled trial (RCT) designed to determine the effectiveness of SCRAM in comparison to usual care cardiac rehabilitation (UC) alone in people with CHD. Pathway analysis will be performed to identify all the costs related to the delivery of SCRAM and UC. Both a healthcare system and a limited societal perspective will be adopted to gauge all costs associated with health resource utilisation and productivity loss. Healthcare resource use over the six-month participation period will be extracted from administrative databases (i.e. Pharmaceutical Benefits Scheme and Medical Benefits Schedule). Productivity loss will be measured by absenteeism from work (valued by human capital approach). The primary outcomes for the economic evaluation are maximal oxygen uptake ( $VO_{2max}$ ,  $ml \cdot kg^{-1} \cdot min^{-1}$ , primary RCT outcome) and Quality-adjusted life years estimated from health-related quality of life (HRQoL) as assessed by the Assessment of Quality of Life (AQoL-8D) instrument. The incremental cost-effectiveness ratio (ICER) will be calculated using the differences in costs and benefits (i.e. primary and secondary outcomes) between the two randomised groups from both perspectives with no discounting. All costs will be valued in Australian dollars for the year 2020.

### Ethics and dissemination

The study protocol has been approved under Australia's National Mutual Acceptance agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119). It is anticipated that SCRAM is a cost-effective cardiac telerehabilitation program for people

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3 with CHD from both a healthcare and limited societal perspective in Australia. The evaluation  
4 will provide evidence to underpin national scale-up of the program to a wider population.  
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## Strengths and limitations of the study

- Health economics data will be collected prospectively along with a randomised controlled trial to reliably capture the individual-level health care resource use and changes in productivity.
- National administrative data collection (i.e. Medicare and Pharmaceutical Benefits Scheme Australia) will be extracted to source the healthcare resource utilisation over the trial duration.
- The economic evaluation is based on the sample size determined by the primary outcome of the SCRAM RCT, which may be underpowered to detect a difference in costs.

## Introduction

Cardiac rehabilitation (CR) is an effective multifactorial secondary prevention intervention that is typically delivered in centre-based (i.e. face-to-face) settings. Centre-based CR reduces recurrent ischaemic events, improves health-related quality of life and long-term prognosis for coronary heart disease (CHD) patients<sup>1-3</sup>. CR programs have also been reported to reduce overall premature mortality (relative risk (RR) 0.87, 95% confidence interval (CI): 0.75-0.99) and cardiac deaths (RR 0.74 (95%CI 0.63-0.87) in comparison with no CR.<sup>4</sup> Despite effectiveness of CR, many people with CHD do not engage in such programs.<sup>5</sup> For instance, CR utilisation is low in Australia; uptake (attended  $\geq 1$  session) and completion rates have been estimated at 25% to 60% and 19% to 42%, respectively, across the country; uptake rates as low as 10% have been reported in Victoria.<sup>6-9</sup> Reasons underlying poor participation are complex, but accessibility barriers such as limited program availability, transport restrictions, conflicting domestic/occupational responsibilities, and geographic isolation are key contributors.<sup>10-13</sup>

For these reasons, clinicians and researchers have been prompted to seek novel strategies for delivering CR programs to facilitate greater uptake and adherence rates. Telerehabilitation—defined as rehabilitation services that are delivered remotely through information and communication technologies—has received increasing attention as it can overcome key accessibility barriers that limit participation in centre-based CR. The effectiveness of telerehabilitation, which commonly includes telephone, internet and videoconference communication between participants and healthcare practitioners,<sup>14</sup> has been demonstrated. Systematic reviews have consistently shown that telerehabilitation services improve CVD risk factors (i.e. total cholesterol, blood pressure, high- and low-density lipoprotein), compared to controls<sup>10 15</sup>; and comparisons of traditional centre-based CR with telerehabilitation have shown them to be equivalent in terms of mortality, exercise capacity and quality of life outcomes<sup>16</sup>. The effectiveness of CR interventions delivered via telephone, internet, and videoconference has been well established; however, few trials have capitalised on opportunities to augment intervention design and delivery by using rapidly advancing mobile communication and device technologies (i.e. mobile broadband and smartphones; mHealth).

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3 Four randomised-controlled trials (RCT) have compared mHealth CR with traditional centre-  
4 based programs. One study showed improved uptake and completion rate in comparison to  
5 the control group<sup>17</sup>, two indicated mHealth and centre-based CR had comparable effects on  
6 maximal oxygen uptake (i.e. exercise capacity),<sup>18 19</sup> while the fourth suggested mHealth CR  
7 led to improvements in maximal oxygen uptake and quality of life<sup>20</sup>. The results from existing  
8 economic evaluations of mHealth intervention are not consistent<sup>18 19 21 22</sup>.

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15 We are currently undertaking a multi-centre RCT of a smartphone-based platform to support  
16 remotely delivered CR called Smartphone Cardiac Rehabilitation, Assisted self-Management  
17 (SCRAM). Unlike its predecessor REMOTE-CR<sup>18</sup>, SCRAM extends beyond a single behaviour  
18 (exercise) to include other secondary prevention self-management behaviours (medication  
19 adherence, physical activity and sedentary behaviour, healthy eating, stress management,  
20 and smoking cessation). To establish the economic credentials of the SCRAM program in the  
21 Australian setting, an economic evaluation will be conducted to examine the balance between  
22 health effects and costs of health technologies (i.e. SCRAM program, medications, diagnostic  
23 tests, medical services, etc.) to inform efficient allocation of limited healthcare funding. In  
24 response to the transparent reporting of clinical trials, this paper outlines the methods of the  
25 prospective within-trial economic evaluation to be undertaken alongside the RCT<sup>23</sup>, to  
26 provide important evidence for policy decision-making around the provision of cardiac  
27 rehabilitation services. It will include both cost-effectiveness and cost-utility analysis with a  
28 view to informing resource allocation, practice change and investment in the SCRAM  
29 program. This planned economic evaluation aims to provide the evidence around the cost-  
30 effectiveness of tele-cardiac rehabilitation, assessing its value-for-money in Australia context.

## 47 48 Methods

### 49 50 Design

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52 The details of the study design are reported elsewhere<sup>23</sup>. Briefly, SCRAM is a multicentre  
53 investigator-, assessor-, and statistician-blinded parallel two-arm RCT comparing effects and  
54 costs of the 24-week SCRAM intervention with usual care CR. A process evaluation is also  
55 being undertaken. Participants are randomised (1:1) to receive either SCRAM (intervention)  
56 or usual care CR (control).  
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5 The study protocol was prospectively registered with the Australian New Zealand Clinical  
6 Trials Registry (ACTRN12618001458224) on 30/08/2018 and adheres to the SPIRIT 2013  
7 statement.<sup>24</sup> The intervention has been described according to recommendations in the  
8 TIDieR and CONSORT (eHealth extension) statements. Reporting of trial outcomes will adhere  
9 to the CONSORT statement and its eHealth extension.<sup>25-27</sup>  
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16 The economic evaluation will be undertaken from both an Australian healthcare system plus  
17 a limited societal perspective, incorporating all health care costs subsidised by state and  
18 Commonwealth governments in Australia. In addition, participant absenteeism from work  
19 due to CHD will be monetised and the associated cost will be included in the estimation from  
20 the limited societal perspective. The reporting of this economic evaluation will adhere to the  
21 Consolidated Health Economics Evaluation Reporting Standards (CHEERS) guidelines<sup>28</sup>.  
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### 30 Study population

31 A total of 220 participants (N=110 per randomised group) diagnosed with CHD within the  
32 previous six months, are being recruited from hospitals, outpatient clinics, and cardiac  
33 rehabilitation services in Sunshine, Geelong, and Bendigo, Victoria, Australia. As study centres  
34 provide treatment to ~1.5 million individuals across broad catchment areas the trial cohort is  
35 anticipated to include a geographically diverse mix of metropolitan-, regional- and rural-  
36 dwelling participants.  
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43 Participants are randomised (1:1) to receive the SCRAM program (intervention) or usual care  
44 CR (control), stratified by sex and study centre. Key inclusion criteria at baseline are: aged  
45 over 18 years; diagnosed CHD within the previous six months (angina, myocardial infarction,  
46 or coronary revascularisation); outpatients who have been clinically stable for at least 6  
47 weeks; able to perform exercise; and can understand and write English. Exclusion criteria  
48 include: New York Heart Association (NYHA) Functional class III/IV heart failure; terminal  
49 disease; significant non-CHD exercise limitations; contraindications for maximal exercise  
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### 59 Patient and public involvement

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3 There is not patient and public involvement.  
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#### 5 6 Sample size

7 The target sample will provide 90% power at a 5% significance level (two-sided) to detect a  
8 clinically meaningful difference of  $2.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  in  $\text{VO}_2\text{max}$  at 24 weeks (primary RCT  
9 outcome) between the control and intervention groups, assuming a standard deviation of  
10 6.75, a correlation of 0.8 between the pre- and post-intervention measures, and 20% loss-to-  
11 follow-up. Minimum detectable differences in secondary RCT outcomes are outlined in the  
12 main trial protocol<sup>23</sup>.  
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#### 22 Baseline assessment

23 Prior to randomisation, researchers collect the following information: sociodemographic and  
24 clinical (diagnostic, smoking, alcohol history, medication) characteristics, ehealth literacy (a  
25 questionnaire),  $\text{VO}_2\text{max}$ , and secondary outcomes (detailed below).  
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#### 32 Randomisation

33 Treatment allocation follows a computer-generated schedule prepared by a biostatistician  
34 who is not involved with recruitment, treatment allocation, or outcome assessment<sup>23</sup>.  
35 Investigators, outcome assessors, and the statistician remain blinded to the group allocation  
36 over the course of the trial.  
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#### 45 Treatment arms

##### 46 Usual care cardiac rehabilitation

47 Usual care CR typically includes face-to-face support/education to adhere to medical  
48 treatment and health-promoting lifestyle behaviours as well as supervised exercise training.  
49 Specific program components vary across Australian healthcare providers but most offer  
50 education and exercise components;<sup>29</sup> stratification of treatment allocation by trial centre  
51 will ensure variation is balanced across treatment groups. It is unclear how many participants  
52 will opt for both SCRAM and usual care CR; nevertheless, widespread low uptake of centre-  
53 based CR suggests very few patients randomised to SCRAM program will seek to complete  
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3 both programs<sup>13</sup>. To explore impact on trial outcomes, self-reported usual care CR utilisation  
4 for patients assigned to SCRAM program will be assessed.  
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7 Usual care CR is not delivered as part of this trial. All participants retain access to usual care  
8 CR—regardless of treatment allocation—as it is unethical to withhold evidence-based  
9 treatment. Participants randomised to the control group have access to usual care CR alone,  
10 as offered by their local CR provider, without further support.  
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#### 16 Intervention: SCRAM program

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18 Participants randomised to the intervention group receive the 24-week dual-phase SCRAM  
19 intervention, which is described in detail in the main trial protocol<sup>23</sup>. Briefly, during an initial  
20 12-week intensive phase, participants receive real-time remotely prescribed, supervised and  
21 coached exercise training from accredited exercise physiologists as well as a modular  
22 multifactorial library of evidence- and theory-based behaviour change support push  
23 notifications. This phase is designed to provide intensive support for exercise and lifestyle  
24 behaviour uptake and adherence. During a subsequent 12-week maintenance phase,  
25 participants receive reduced frequency and intensity of exercise and behaviour change  
26 support. This phase is designed to provide tapered support that transitions participants  
27 towards long-term self-determined adherence to exercise and health-promoting lifestyle  
28 behaviours. Participants receive all intervention components via the bespoke SCRAM  
29 software platform, using an Android smartphone.  
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#### 44 Comparator

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46 It is important for the economic evaluation to be able to ascertain whether the planned  
47 intervention is conducted in addition to existing practices, or as a replacement to them.  
48 Consistent with the RCT design<sup>23</sup>, SCRAM intervention will be compared to usual care CR (i.e.  
49 traditional centre-based CR).  
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## Measurement of clinical endpoints

### Outcome measures for the within-trial economic evaluation

Primary outcomes for the economic evaluation will be maximal oxygen uptake ( $\text{VO}_2\text{max}$ ,  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , primary RCT outcome)—measured during an individualised treadmill cardiopulmonary exercise test—and health-related quality of life (HRQoL)—measured using the Assessment of Quality of Life-8D (AQoL-8D). The Australian tariff for AQoL-8D will be used to estimate the QALY gains for individual participant<sup>30</sup>.  $\text{VO}_2\text{max}$  is measured at baseline and 24-week follow-up, whilst HRQoL is assessed at baseline, 12-weeks, and 24-weeks. Secondary outcomes, including modifiable cardiovascular risk factors and adverse events, are described in the main trial protocol<sup>23</sup>.

## Measurement of costs

### Direct cost of delivering the SCRAM program

In identifying relevant costs, the following principles will be adhered to:

- Identification of costs to be included, using 'pathway analysis' (Figure 1), where activities in all stages of the roll out of the SCRAM project are fully specified; A healthcare system perspective and steady state operation of the intervention will be assumed (intervention is up and running, and start-up costs, like development of SCRAM app will be excluded). Costs will largely relate to the time costs of the remote exercise physiologists and project staff (using opportunity cost principles). Any administrative resources used at the program management level also will be identified and included.
- Measurement of the resources consumed in natural units (number of hours spent by remote exercise physiologists to deliver the intervention, etc.);
- Valuation of these resources in monetary units (Australian dollars), using 2020 as the reference year.

### Direct health costs of participants

Beside intervention cost, healthcare-related costs including inpatient and outpatient care associated with CHD are documented. The cost of inpatient care over the 24-week

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3 participation period (e.g. emergency department (ED) visits and rehospitalisations will be  
4 estimated from self-reported adverse events documented throughout the trial.  
5 Complementary approaches will be utilised to calculate the cost for each hospitalisation  
6 episode: first, the cost per hospital admission from the National Hospital Cost Data Collection  
7 (actual cost per AR-DRG) will be used; second the National Efficient Price (projected cost)  
8 according the AR-DRG code<sup>31</sup> will be used to value the per hospitalisation episode adjusted  
9 for the length of hospital stay. The cost of outpatient care (e.g. outpatient consultations,  
10 examinations) and medication use over the 24-week participation period will be estimated  
11 from MBS and PBS data, respectively. Cost items are summarised in Table 1.  
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### 23 Productivity cost (absenteeism from work)

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25 Absence from work (i.e. days of sick leave) due to CHD is self-reported by participants of  
26 working age (i.e. ≤65 years old; people post working age do not attract productivity loss from  
27 a societal perspective) using a pre-designed questionnaire at baseline and 24-week follow up.  
28 The human capital approach will be used to value the productivity cost<sup>32</sup>.  
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### 35 Exclusion of trial costs

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37 Research-driven activities will be separated from the activities that would be carried out  
38 should the program be adopted by the healthcare system. Costs associated with trial  
39 administration, data collection, and RCT outcome assessment will be excluded.  
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### 46 Data analysis

#### 47 Within-trial economic evaluation

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49 The within-trial economic evaluation will be based on the intention-to-treat population as per  
50 the primary outcome of the RCT<sup>23</sup>. In particular, completers data will be used for the base  
51 case analysis, whereas the imputed data analysis (using multiple missing data imputation  
52 approach, with the assumption that missingness is at random) will be undertaken to examine  
53 the robustness of base case results. All evaluation results will be expressed as incremental  
54 results over and above the comparator case. In other words, the additional cost/saving of the  
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3 intervention (SCRAM) compared to current practice will be expressed as a ratio by dividing by  
4 the net benefits derived. The following formula represents the calculation of the incremental  
5 cost-effectiveness ratio (ICER):  
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$$8 \quad ICER = C_i - C_{UC} / B_i - B_{UC}$$

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11 where C=costs, B=benefits, i=SCRAM intervention, UC=usual care CR  
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14 For the cost-effectiveness analysis (CEA), the incremental cost per unit increase in benefits  
15 for both the primary and secondary outcomes will be calculated if significant between-group  
16 differences are observed. For the cost-utility analysis (CUA), the quality-adjusted life year  
17 (QALY) will be estimated from HRQoL assessed by AqoL-8D by intervention group (Table 2).  
18 A plot on the cost effectiveness plane will be drawn to illustrate the distribution of costs and  
19 effectiveness. A cost-effectiveness acceptability curve will also be plotted in order to assess  
20 the degree of uncertainty associated with the conclusion using a predetermined empirical  
21 willingness-to-pay (WTP) threshold for the QALY outcome (i.e. AU\$50,000/QALY)<sup>33</sup>.  
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29 Bootstrap simulation of the costs and ICER will be used to simulate the study results over  
30 2,000 iterations. This technique is used when data are skewed (cost data are nearly always  
31 highly skewed) and the confidence interval of a ratio using skewed data is required. The  
32 within-trial economic analysis will be undertaken using STATA 15 (StataCorp. 2017. Stata  
33 Statistical Software: Release 15. College Station, TX: StataCorp LLC).  
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### 39 Long-term modelling

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41 Model-based long-term cost-effectiveness analysis of SCRAM versus usual care CR will be  
42 undertaken if the primary outcome (VO2 max) from the RCT is proven to significantly increase.  
43 The VO2 max will be converted to the reduction in overall mortality (i.e. odds ratio in mortality  
44 for 1 Metabolic Equivalents increase). The difference (if any, observed from the RCT) in the  
45 incidence of recurrent CVD post the index MI will also be used to model the long-term health  
46 and cost outcomes associated with the application of the two modes of CR. Benefits observed  
47 in the trial will be translated into health benefits (e.g., avoided morbidity/mortality outcomes,  
48 and calculated in terms of QALY gained). The modelled economic evaluation will simulate the  
49 impact of increased maximal oxygen uptake on the overall well-being/survival of the cohort  
50 over its lifetime compared with the control group. A Markov model consisting of health states  
51 associated with CHD (i.e. recurrent myocardial infarction, angina, revascularisation, stroke or  
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3 death) will be used to accrue costs and benefits over the lifetime horizon. The long-term  
4 improved outcomes may translate into the cost savings due to avoided ED visit and  
5 rehospitalisation. Long-term modelling will be performed in TreeAge Pro 2019.  
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### 8 9 Sensitivity analysis

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11 Uncertainty analyses will be conducted based on Monte Carlo simulations. The between-  
12 group differences in both costs and QALY will be bootstrapped to estimate the probability of  
13 the SCRAM program being cost-effective regardless of the significance in between-group  
14 difference<sup>34</sup>. A series of one-way sensitivity analyses will be undertaken to examine  
15 robustness of the base-case ICER, for example, alternative costing approach for  
16 rehospitalisation (unit costs derived from Independent Hospital Pricing Authority, Australia;  
17 Australian Institute of Health and Wellbeing), labours (unit costs sourced from Australia  
18 Bureau of Statistics, PayScale), and SCRAM intervention delivery (varying the quantity and  
19 unit cost of the resource utilised).  
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### 31 Ethics approval

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33 The study protocol has been approved under Australia's National Mutual Acceptance  
34 agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119).  
35 Ethics approval has been ratified by the Deakin University Human Research Ethics Committee  
36 (2018-251). All participants provide written informed consent prior to undertaking baseline  
37 assessments. Separate consent is sought to extract MBS/PBS data for the purpose of this  
38 study.  
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## 49 Discussion

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51 This paper details the protocol of a trial-based economic evaluation that purports to assess  
52 the cost-effectiveness of the SCRAM telerehabilitation program among people with CHD. It  
53 has a number of methodological strengths, the key one being that the economic evaluation  
54 will be undertaken alongside a prospective RCT. This has the advantage of being efficient and  
55 timely in terms of the data collected. In addition, the RCT design provides credibility through  
56 high internal validity, minimisation of bias, and tight protocol control. The SCRAM RCT aims  
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3 to minimise the predictable sources of bias and confounding via allocation concealment,  
4 blinded outcome assessment and intention-to-treat analysis. The primary costing data will be  
5 sourced from administrative databases including MBS, PBS, and hospital costing system data;  
6 this allows for maximum accuracy of the data collected and enhances the capture of effects  
7 and outcomes. Furthermore, this RCT is recruiting participants from metropolitan, regional  
8 and rural areas of Victoria, Australia, allowing for broader representativeness of participants  
9 that will maximise generalisability of the results. Lastly, HRQoL will be assessed by the AQoL-  
10 8D, a 35-item questionnaire, which has been widely applied in measuring HRQoL for Australia-  
11 based studies<sup>35-38</sup>. It has increased measurement sensitivity, especially in the psychosocial  
12 dimensions, compared with existing instruments [i.e. EuroQol-5D-5L (EQ-5D-5L), Quality of  
13 Wellbeing (QWB), Health Utilities Index Mark 3 (HUI3), and 15D] that vary greatly and report  
14 inconsistent utility scores<sup>39</sup>. Further, undertaking both completers and imputed data analyses  
15 for the trial-based economic evaluation will increase the validity of the results given the  
16 potential significant proportion of missingness in follow up cost and QALY data. The trial-  
17 based economic evaluation only has a short 24 week timeframe and was based on the trial  
18 under strictly controlled research conditions. It cannot answer the long term cost-  
19 effectiveness of SCRAM program which is pivotal for the reimbursement decision-making. The  
20 model-based economic evaluation that extrapolates the short-term trial outcome to the  
21 lifetime horizon and a real-world setting will inform the cost-effectiveness of the proposed  
22 program in the Australian context.

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The economic credentials of traditional centre-based CR versus no CR have long been  
established. A systematic review of 19 CEAs of such interventions concluded that the majority  
reported traditional CR was cost-effective versus no CR (ICER ranged from US\$1065 to  
US\$71755/QALY), especially with exercise as a component<sup>40 41</sup>. Specifically in relation to  
cardiac telerehabilitation (not involving a smartphone-based remote CR component), studies  
are varied in terms of their results. Whilst one within-trial economic evaluation reported that  
such an intervention (offering the flexibility of having the CR at hospital, healthcare centre, or  
call centre) was not cost-effective given its high cost (ICER €400,000 per QALY)<sup>21</sup>, others have  
demonstrated more positive outcomes. A trial-based economic analysis home-based CR was  
associated with non-significantly lower costs and a high probability of being cost-effective<sup>19</sup>.  
Another CUA showed that the mean cost per patient in a telemonitoring program was €564

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3 lower than in the control group, but with higher QALY gains (0.026), thereby making the  
4 intervention dominant (lower costs but higher benefits)<sup>22</sup>. Another CEA of home-based  
5 telerehabilitation, delivered through online videoconferencing for patients with heart failure,  
6 concluded that it was associated with significantly lower costs (-AU\$1590, 95%CI -\$2822 to -  
7 \$359) during the 6 month participation period<sup>42</sup>. Our previous economic evaluation alongside  
8 a non-inferiority RCT in New Zealand indicated the REMOTE-CR smartphone-based cardiac  
9 telerehabilitation program—a precursor to SCRAM—was associated with cost-saving (-  
10 NZ\$4615/participant) and comparable benefits<sup>18</sup>.

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19 Some methodological limitations are worth mentioning: first of all, the economic evaluation  
20 is based on the sample size determined by the primary outcome of the SCRAM RCT. It may be  
21 underpowered to detect a difference in costs. Second, whilst the gold standard is to  
22 undertake economic evaluations from a societal perspective (which captures all costs falling  
23 on patients, their carers, and families), the current study only considers a limited societal  
24 perspective (i.e. including only productivity costs); the costs borne by carers and families are  
25 excluded. However, it is believed that the health care system plus the limited societal  
26 perspectives will provide sufficient information to inform decision-making around investment  
27 in the SCRAM program in Australia and elsewhere.

## 36 Conclusion

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The results of this economic evaluation will fill the evidence gap for the cost-effectiveness of  
this mHealth CR program versus usual care CR alone, given that the current economic  
credentials of a pre-cursor intervention are based on a non-inferiority RCT<sup>18</sup>. Results will assist  
policy makers, healthcare managers and other healthcare service providers to inform  
decisions regarding the ongoing use or future implementation of the SCRAM program. If the  
economic evaluation finds the SCRAM program to be cost-effective, then it can be  
recommended at the national or even international level as a complementary alternative CR  
delivery model that may meet the needs of many people who are unable or unwilling to  
participate in traditional centre-based CR services.

### **Contributorship statement**

All the authors (LG, RM, JR, KB, BO, CC, SAM, KL, JA, VN, CN, SC, and MM) contributed to the study design and the protocol of the economic analysis. LG drafted the initial manuscript. All the other authors (RM, JR, KB, BO, CC, SAM, KL, JA, VN, CN, SC, and MM) reviewed, edited and approved the final manuscript.

### **Competing interests**

None declared.

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## Tables

Table 1 Identified cost items according to pathway analysis

Process to be costed	Identification of costs	Measurement of costs	Valuation of costs	Who records cost data & how is it collected
Recruitment of participants	Researcher	minutes/hours	Salary costs	Researcher records time taken
Training				
Training/induction session for participants	Project team time	hours	Salary costs	Project team records time taken
Training/induction session for accredited exercise physiologist	Project team time	hours	Salary costs	Project team records time taken
Capital				
Leasing of venue for training/induction sessions	Cost of leasing	Unit cost	Market price	Research team to record
Leasing of venues for cardiac rehabilitation professionals to deliver the SCRAM program	Cost of leasing	Unit cost	Market price	Research team to record

Wearable sensor devices	Cost of sensor device	Unit cost	Market price	Research team to record
Smartphone	Cost of smartphone	Unit cost	Market price	Research team to record
Computers (desktop or laptop)	Cost of computer	Unit cost	Market price	Research team to record
Staffing				
CR professional	CR professional time	Hours	Salary costs	CR professional records time taken
Administrative support	Project staff time	Hours	Salary costs	Project staff records time taken
Miscellaneous costs				
Mobile phone/internet access	Cost of mobile phone, internet access	Unit cost	Market price	Research team to record
Stationery	Cost of stationery	Unit cost	Market price	Research team to record
Utilities (i.e. electricity)	Cost of utility	Unit cost	Market price	Research team to record
Hosting (server)	Cost of server	Unit cost	Market price	Research team to record

Handouts (flyer, information sheet, etc.)	Cost of printing	Unit cost	Market price	Research team to record
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Abbreviation: CR, cardiac rehabilitation.

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Table 2. Expected outcomes of the economic analysis

Analysis	Incremental costs	Incremental effectiveness	Incremental cost-effectiveness
Incremental cost-effectiveness analysis	AUD	Maximal oxygen uptake (VO <sub>2</sub> max, ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	Cost of per unit improvement in VO <sub>2</sub> max
	AUD	Anthropometry (i.e. body weight, BMI, waist/hip circumference, etc.*)	Cost of per unit improvement in anthropometry outcomes
	AUD	Blood lipid and glucose concentrations, blood pressure	Cost per unit improvement in biomedical outcomes
Incremental cost-utility analysis	AUD	Quality-adjusted life year gained	Cost per additional quality-adjusted life year gained

\*complete list of secondary outcomes could be found in the trial protocol<sup>23</sup>.

AUD: Australian dollar; BMI: body mass index

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## Figures

Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery

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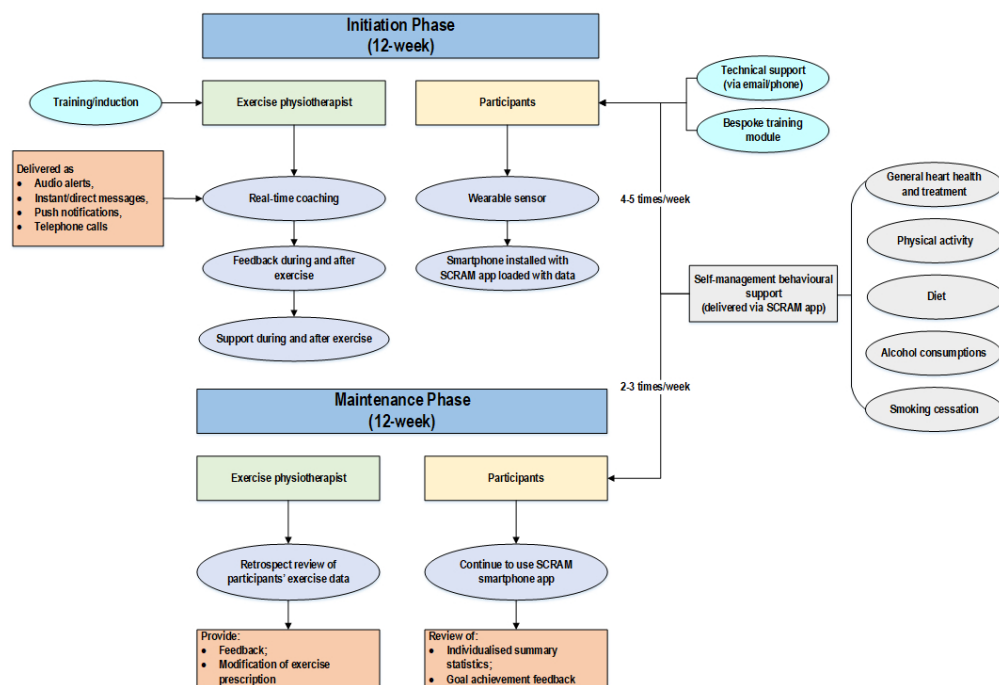


Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery

# BMJ Open

## Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Title page

### Title

Economic evaluation protocol for a multicentre randomised controlled trial to compare Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) versus usual care cardiac rehabilitation among people with coronary heart disease

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## Abstract

### Introduction

It is important to ascertain the cost-effectiveness of alternative services to traditional cardiac rehabilitation while the economic credentials of the Smartphone Cardiac Rehabilitation, Assisted self-Management (SCRAM) program among people with coronary heart disease (CHD) are unknown. This economic protocol outlines the methods for undertaking a trial-based economic evaluation of SCRAM in the real world setting in Australia.

### Methods and analysis

The within-trial economic evaluation will be undertaken alongside a randomised controlled trial (RCT) designed to determine the effectiveness of SCRAM in comparison to usual care cardiac rehabilitation (UC) alone in people with CHD. Pathway analysis will be performed to identify all the costs related to the delivery of SCRAM and UC. Both a healthcare system and a limited societal perspective will be adopted to gauge all costs associated with health resource utilisation and productivity loss. Healthcare resource use over the six-month participation period will be extracted from administrative databases (i.e. Pharmaceutical Benefits Scheme and Medical Benefits Schedule). Productivity loss will be measured by absenteeism from work (valued by human capital approach). The primary outcomes for the economic evaluation are maximal oxygen uptake ( $VO_{2max}$ ,  $ml \cdot kg^{-1} \cdot min^{-1}$ , primary RCT outcome) and Quality-adjusted life years estimated from health-related quality of life (HRQoL) as assessed by the Assessment of Quality of Life (AQoL-8D) instrument. The incremental cost-effectiveness ratio (ICER) will be calculated using the differences in costs and benefits (i.e. primary and secondary outcomes) between the two randomised groups from both perspectives with no discounting. All costs will be valued in Australian dollars for the year 2020.

### Ethics and dissemination

The study protocol has been approved under Australia's National Mutual Acceptance agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119). It is anticipated that SCRAM is a cost-effective cardiac telerehabilitation program for people with CHD from both a healthcare and limited societal perspective in Australia. The evaluation

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3 will provide evidence to underpin national scale-up of the program to a wider population.  
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5 Results of the economic analysis will be submitted for publication in a peer-reviewed journal.  
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8 Trial registration

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## Strengths and limitations of the study

- Health economics data will be collected prospectively along with a randomised controlled trial to reliably capture the individual-level health care resource use and changes in productivity.
- National administrative data collection (i.e. Medicare and Pharmaceutical Benefits Scheme Australia) will be extracted to source the healthcare resource utilisation over the trial duration.
- The economic evaluation is based on the sample size determined by the primary outcome of the SCRAM RCT, which may be underpowered to detect a difference in costs.

## Introduction

Cardiac rehabilitation (CR) is an effective multifactorial secondary prevention intervention that is typically delivered in centre-based (i.e. face-to-face) settings. Centre-based CR reduces recurrent ischaemic events, improves health-related quality of life and long-term prognosis for coronary heart disease (CHD) patients<sup>1-3</sup>. CR programs have also been reported to reduce overall premature mortality (relative risk (RR) 0.87, 95% confidence interval (CI): 0.75-0.99) and cardiac deaths (RR 0.74 (95%CI 0.63-0.87) in comparison with no CR.<sup>4</sup> Despite effectiveness of CR, many people with CHD do not engage in such programs.<sup>5</sup> For instance, CR utilisation is low in Australia; uptake (attended  $\geq 1$  session) and completion rates have been estimated at 25% to 60% and 19% to 42%, respectively, across the country; uptake rates as low as 10% have been reported in Victoria.<sup>6-9</sup> Reasons underlying poor participation are complex, but accessibility barriers such as limited program availability, transport restrictions, conflicting domestic/occupational responsibilities, and geographic isolation are key contributors.<sup>10-13</sup>

For these reasons, clinicians and researchers have been prompted to seek novel strategies for delivering CR programs to facilitate greater uptake and adherence rates. Telerehabilitation—defined as rehabilitation services that are delivered remotely through information and communication technologies—has received increasing attention as it can overcome key accessibility barriers that limit participation in centre-based CR. The effectiveness of telerehabilitation, which commonly includes telephone, internet and videoconference communication between participants and healthcare practitioners,<sup>14</sup> has been demonstrated. Systematic reviews have consistently shown that telerehabilitation services improve CVD risk factors (i.e. total cholesterol, blood pressure, high- and low-density lipoprotein), compared to controls<sup>10 15</sup>; and comparisons of traditional centre-based CR with telerehabilitation have shown them to be equivalent in terms of mortality, exercise capacity and quality of life outcomes<sup>16</sup>. The effectiveness of CR interventions delivered via telephone, internet, and videoconference has been well established; however, few trials have capitalised on opportunities to augment intervention design and delivery by using rapidly advancing mobile communication and device technologies (i.e. mobile broadband and smartphones; mHealth).

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3 Four randomised-controlled trials (RCT) have compared mHealth CR with traditional centre-  
4 based programs. One study showed improved uptake and completion rate in comparison to  
5 the control group<sup>17</sup>, two indicated mHealth and centre-based CR had comparable effects on  
6 maximal oxygen uptake (i.e. exercise capacity),<sup>18 19</sup> while the fourth suggested mHealth CR  
7 led to improvements in maximal oxygen uptake and quality of life<sup>20</sup>. The results from existing  
8 economic evaluations of mHealth intervention are not consistent<sup>18 19 21 22</sup>.

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15 We are currently undertaking a multi-centre RCT of a smartphone-based platform to support  
16 remotely delivered CR called Smartphone Cardiac Rehabilitation, Assisted self-Management  
17 (SCRAM). Unlike its predecessor REMOTE-CR<sup>18</sup>, SCRAM extends beyond a single behaviour  
18 (exercise) to include other secondary prevention self-management behaviours (medication  
19 adherence, physical activity and sedentary behaviour, healthy eating, stress management,  
20 and smoking cessation). To establish the economic credentials of the SCRAM program in the  
21 Australian setting, an economic evaluation will be conducted to examine the balance between  
22 health effects and costs of health technologies (i.e. SCRAM program, medications, diagnostic  
23 tests, medical services, etc.) to inform efficient allocation of limited healthcare funding. In  
24 response to the transparent reporting of clinical trials, this paper outlines the methods of the  
25 prospective within-trial economic evaluation to be undertaken alongside the RCT<sup>23</sup>, to  
26 provide important evidence for policy decision-making around the provision of cardiac  
27 rehabilitation services. It will include both cost-effectiveness and cost-utility analysis with a  
28 view to informing resource allocation, practice change and investment in the SCRAM  
29 program. This planned economic evaluation aims to provide the evidence around the cost-  
30 effectiveness of tele-cardiac rehabilitation, assessing its value-for-money in Australia context.

## 47 48 Methods

### 49 50 Design

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52 The details of the study design are reported elsewhere<sup>23</sup>. Briefly, SCRAM is a multicentre  
53 investigator-, assessor-, and statistician-blinded parallel two-arm RCT comparing effects and  
54 costs of the 24-week SCRAM intervention with usual care CR. A process evaluation is also  
55 being undertaken. Participants are randomised (1:1) to receive either SCRAM (intervention)  
56 or usual care CR (control).  
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5 The study protocol was prospectively registered with the Australian New Zealand Clinical  
6 Trials Registry (ACTRN12618001458224) on 30/08/2018 and adheres to the SPIRIT 2013  
7 statement.<sup>24</sup> The intervention has been described according to recommendations in the  
8 TIDieR and CONSORT (eHealth extension) statements. Reporting of trial outcomes will adhere  
9 to the CONSORT statement and its eHealth extension.<sup>25-27</sup>  
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16 The economic evaluation will be undertaken from both an Australian healthcare system plus  
17 a limited societal perspective, incorporating all health care costs subsidised by state and  
18 Commonwealth governments in Australia. In addition, participant absenteeism from work  
19 due to CHD will be monetised and the associated cost will be included in the estimation from  
20 the limited societal perspective. The reporting of this economic evaluation will adhere to the  
21 Consolidated Health Economics Evaluation Reporting Standards (CHEERS) guidelines<sup>28</sup>.  
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### 30 Study population

31 A total of 220 participants (N=110 per randomised group) diagnosed with CHD within the  
32 previous six months, are being recruited from hospitals, outpatient clinics, and cardiac  
33 rehabilitation services in Sunshine, Geelong, and Bendigo, Victoria, Australia. As study centres  
34 provide treatment to ~1.5 million individuals across broad catchment areas the trial cohort is  
35 anticipated to include a geographically diverse mix of metropolitan-, regional- and rural-  
36 dwelling participants.  
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43 Participants are randomised (1:1) to receive the SCRAM program (intervention) or usual care  
44 CR (control), stratified by sex and study centre. Key inclusion criteria at baseline are: aged  
45 over 18 years; diagnosed CHD within the previous six months (angina, myocardial infarction,  
46 or coronary revascularisation); outpatients who have been clinically stable for at least 6  
47 weeks; able to perform exercise; and can understand and write English. Exclusion criteria  
48 include: New York Heart Association (NYHA) Functional class III/IV heart failure; terminal  
49 disease; significant non-CHD exercise limitations; contraindications for maximal exercise  
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### 59 Patient and public involvement

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#### 5 Sample size

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7 The target sample will provide 90% power at a 5% significance level (two-sided) to detect a  
8 clinically meaningful difference of  $2.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  in  $\text{VO}_2\text{max}$  at 24 weeks (primary RCT  
9 outcome) between the control and intervention groups, assuming a standard deviation of  
10 6.75, a correlation of 0.8 between the pre- and post-intervention measures, and 20% loss-to-  
11 follow-up. Minimum detectable differences in secondary RCT outcomes are outlined in the  
12 main trial protocol<sup>23</sup>.  
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#### 22 Baseline assessment

23 Prior to randomisation, researchers collect the following information: sociodemographic and  
24 clinical (diagnostic, smoking, alcohol history, medication) characteristics, ehealth literacy (a  
25 questionnaire),  $\text{VO}_2\text{max}$ , and secondary outcomes (detailed below).  
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#### 32 Randomisation

33 Treatment allocation follows a computer-generated schedule prepared by a biostatistician  
34 who is not involved with recruitment, treatment allocation, or outcome assessment<sup>23</sup>.  
35 Investigators, outcome assessors, and the statistician remain blinded to the group allocation  
36 over the course of the trial.  
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#### 45 Treatment arms

##### 46 Usual care cardiac rehabilitation

47 Usual care CR typically includes face-to-face support/education to adhere to medical  
48 treatment and health-promoting lifestyle behaviours as well as supervised exercise training.  
49 Specific program components vary across Australian healthcare providers but most offer  
50 education and exercise components;<sup>29</sup> stratification of treatment allocation by trial centre  
51 will ensure variation is balanced across treatment groups. It is unclear how many participants  
52 will opt for both SCRAM and usual care CR; nevertheless, widespread low uptake of centre-  
53 based CR suggests very few patients randomised to SCRAM program will seek to complete  
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3 both programs<sup>13</sup>. To explore impact on trial outcomes, self-reported usual care CR utilisation  
4 for patients assigned to SCRAM program will be assessed.  
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7 Usual care CR is not delivered as part of this trial. All participants retain access to usual care  
8 CR—regardless of treatment allocation—as it is unethical to withhold evidence-based  
9 treatment. Participants randomised to the control group have access to usual care CR alone,  
10 as offered by their local CR provider, without further support.  
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#### 16 Intervention: SCRAM program

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18 Participants randomised to the intervention group receive the 24-week dual-phase SCRAM  
19 intervention, which is described in detail in the main trial protocol<sup>23</sup>. Briefly, during an initial  
20 12-week intensive phase, participants receive real-time remotely prescribed, supervised and  
21 coached exercise training from accredited exercise physiologists as well as a modular  
22 multifactorial library of evidence- and theory-based behaviour change support push  
23 notifications. This phase is designed to provide intensive support for exercise and lifestyle  
24 behaviour uptake and adherence. During a subsequent 12-week maintenance phase,  
25 participants receive reduced frequency and intensity of exercise and behaviour change  
26 support. This phase is designed to provide tapered support that transitions participants  
27 towards long-term self-determined adherence to exercise and health-promoting lifestyle  
28 behaviours. Participants receive all intervention components via the bespoke SCRAM  
29 software platform, using an Android smartphone.  
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#### 44 Comparator

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46 It is important for the economic evaluation to be able to ascertain whether the planned  
47 intervention is conducted in addition to existing practices, or as a replacement to them.  
48 Consistent with the RCT design<sup>23</sup>, SCRAM intervention will be compared to usual care CR (i.e.  
49 traditional centre-based CR).  
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## Measurement of clinical endpoints

### Outcome measures for the within-trial economic evaluation

Primary outcomes for the economic evaluation will be maximal oxygen uptake ( $VO_2\text{max}$ ,  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , primary RCT outcome)—measured during an individualised treadmill cardiopulmonary exercise test—and health-related quality of life (HRQoL)—measured using the Assessment of Quality of Life-8D (AQoL-8D). The Australian tariff for AQoL-8D will be used to estimate the QALY gains for individual participant<sup>30</sup>.  $VO_2\text{max}$  is measured at baseline and 24-week follow-up, whilst HRQoL is assessed at baseline, 12-weeks, and 24-weeks. Secondary outcomes, including modifiable cardiovascular risk factors and adverse events, are described in the main trial protocol<sup>23</sup>.

## Measurement of costs

### Direct cost of delivering the SCRAM program

In identifying relevant costs, the following principles will be adhered to:

- Identification of costs to be included, using 'pathway analysis' (Figure 1), where activities in all stages of the roll out of the SCRAM project are fully specified; A healthcare system perspective and steady state operation of the intervention will be assumed (intervention is up and running, and start-up costs, like development of SCRAM app will be excluded). Costs will largely relate to the time costs of the remote exercise physiologists and project staff (using opportunity cost principles). Any administrative resources used at the program management level also will be identified and included. Cost items identified from pathway analysis are summarised in Table 1.
- Measurement of the resources consumed in natural units (number of hours spent by remote exercise physiologists to deliver the intervention, etc.);
- Valuation of these resources in monetary units (Australian dollars), using 2020 as the reference year.

### Direct health costs of participants

Beside intervention cost, healthcare-related costs including inpatient and outpatient care associated with CHD are documented. The cost of inpatient care over the 24-week participation period (e.g. emergency department (ED) visits and rehospitalisations) will be estimated from self-reported adverse events documented throughout the trial. Complementary approaches will be utilised to calculate the cost for each hospitalisation episode: first, the cost per hospital admission from the National Hospital Cost Data Collection (actual cost per AR-DRG) will be used; second the National Efficient Price (projected cost) according the AR-DRG code<sup>31</sup> will be used to value the per hospitalisation episode adjusted for the length of hospital stay. The cost of outpatient care (e.g. outpatient consultations, examinations) and medication use over the 24-week participation period will be estimated from MBS and PBS data, respectively.

### Productivity cost (absenteeism from work)

Absence from work (i.e. days of sick leave) due to CHD is self-reported by participants of working age (i.e.  $\leq 65$  years old; people post working age do not attract productivity loss from a societal perspective) using a pre-designed questionnaire at baseline and 24-week follow up. The human capital approach will be used to value the productivity cost<sup>32</sup>.

### Exclusion of trial costs

Research-driven activities will be separated from the activities that would be carried out should the program be adopted by the healthcare system. Costs associated with trial administration, data collection, and RCT outcome assessment will be excluded.

### Data analysis

#### Within-trial economic evaluation

The within-trial economic evaluation will be based on the intention-to-treat population as per the primary outcome of the RCT<sup>23</sup>. In particular, completers data will be used for the base case analysis, whereas the imputed data analysis (using multiple missing data imputation



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3 approach, with the assumption that missingness is at random) will be undertaken to examine  
4 the robustness of base case results. All evaluation results will be expressed as incremental  
5 results over and above the comparator case. In other words, the additional cost/saving of the  
6 intervention (SCRAM) compared to current practice will be expressed as a ratio by dividing by  
7 the net benefits derived. The following formula represents the calculation of the incremental  
8 cost-effectiveness ratio (ICER):  
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$$14 \quad ICER = C_i - C_{UC} / B_i - B_{UC}$$

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17 where C=costs, B=benefits, i=SCRAM intervention, UC=usual care CR  
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20 For the cost-effectiveness analysis (CEA), the incremental cost per unit increase in benefits  
21 for both the primary and secondary outcomes will be calculated if significant between-group  
22 differences are observed. For the cost-utility analysis (CUA), the quality-adjusted life year  
23 (QALY) will be estimated from HRQoL assessed by AQoL-8D by intervention group (Table 2).  
24 A plot on the cost effectiveness plane will be drawn to illustrate the distribution of costs and  
25 effectiveness. A cost-effectiveness acceptability curve will also be plotted in order to assess  
26 the degree of uncertainty associated with the conclusion using a predetermined empirical  
27 willingness-to-pay (WTP) threshold for the QALY outcome (i.e. AU\$50,000/QALY)<sup>33</sup>.  
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35 Bootstrap simulation of the costs and ICER will be used to simulate the study results over  
36 2,000 iterations. This technique is used when data are skewed (cost data are nearly always  
37 highly skewed) and the confidence interval of a ratio using skewed data is required. The  
38 within-trial economic analysis will be undertaken using STATA 15 (StataCorp. 2017. Stata  
39 Statistical Software: Release 15. College Station, TX: StataCorp LLC).  
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#### 45 Long-term modelling

46 Model-based long-term cost-effectiveness analysis of SCRAM versus usual care CR will be  
47 undertaken if the primary outcome (VO2 max) from the RCT is proven to significantly increase.  
48 The VO2 max will be converted to the reduction in overall mortality (i.e. odds ratio in mortality  
49 for 1 Metabolic Equivalent increase). The difference (if any, observed from the RCT) in the  
50 incidence of recurrent CVD post the index MI will also be used to model the long-term health  
51 and cost outcomes associated with the application of the two modes of CR. Benefits observed  
52 in the trial will be translated into health benefits (e.g., avoided morbidity/mortality outcomes,  
53 and calculated in terms of QALY gained). The modelled economic evaluation will simulate the  
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3 impact of increased maximal oxygen uptake on the overall well-being/survival of the cohort  
4 over its lifetime compared with the control group. A Markov model consisting of health states  
5 associated with CHD (i.e. recurrent myocardial infarction, angina, revascularisation, stroke or  
6 death) will be used to accrue costs and benefits over the lifetime horizon. The long-term  
7 improved outcomes may translate into the cost savings due to avoided ED visit and  
8 rehospitalisation. Long-term modelling will be performed in TreeAge Pro 2019.  
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### 14 Sensitivity analysis

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16 Uncertainty analyses will be conducted based on Monte Carlo simulations. The between-  
17 group differences in both costs and QALY will be bootstrapped to estimate the probability of  
18 the SCRAM program being cost-effective regardless of the significance in between-group  
19 difference<sup>34</sup>. A series of one-way sensitivity analyses will be undertaken to examine  
20 robustness of the base-case ICER, for example, alternative costing approach for  
21 rehospitalisation (unit costs derived from Independent Hospital Pricing Authority, Australia;  
22 Australian Institute of Health and Wellbeing), labours (unit costs sourced from Australia  
23 Bureau of Statistics, PayScale), and SCRAM intervention delivery (varying the quantity and  
24 unit cost of the resource utilised).  
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### 36 Ethics approval

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38 The study protocol has been approved under Australia's National Mutual Acceptance  
39 agreement by the Melbourne Health Human Research Ethics Committee (HREC/18/MH/119).  
40 Ethics approval has been ratified by the Deakin University Human Research Ethics Committee  
41 (2018-251). All participants provide written informed consent prior to undertaking baseline  
42 assessments. Separate consent is sought to extract MBS/PBS data for the purpose of this  
43 study.  
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### 53 Discussion

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55 This paper details the protocol of a trial-based economic evaluation that purports to assess  
56 the cost-effectiveness of the SCRAM telerehabilitation program among people with CHD. It  
57 has a number of methodological strengths, the key one being that the economic evaluation  
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3 will be undertaken alongside a prospective RCT. This has the advantage of being efficient and  
4 timely in terms of the data collected. In addition, the RCT design provides credibility through  
5 high internal validity, minimisation of bias, and tight protocol control. The SCRAM RCT aims  
6 to minimise the predictable sources of bias and confounding via allocation concealment,  
7 blinded outcome assessment and intention-to-treat analysis. The primary costing data will be  
8 sourced from administrative databases including MBS, PBS, and hospital costing system data;  
9 this allows for maximum accuracy of the data collected and enhances the capture of effects  
10 and outcomes. Furthermore, this RCT is recruiting participants from metropolitan, regional  
11 and rural areas of Victoria, Australia, allowing for broader representativeness of participants  
12 that will maximise generalisability of the results. Lastly, HRQoL will be assessed by the AQoL-  
13 8D, a 35-item questionnaire, which has been widely applied in measuring HRQoL for Australia-  
14 based studies<sup>35-38</sup>. It has increased measurement sensitivity, especially in the psychosocial  
15 dimensions, compared with existing instruments [i.e. EuroQoL-5D-5L (EQ-5D-5L), Quality of  
16 Wellbeing (QWB), Health Utilities Index Mark 3 (HUI3), and 15D] that vary greatly and report  
17 inconsistent utility scores<sup>39</sup>. Further, undertaking both completers and imputed data analyses  
18 for the trial-based economic evaluation will increase the validity of the results given the  
19 potential significant proportion of missingness in follow up cost and QALY data. The trial-  
20 based economic evaluation only has a short 24 week timeframe and was based on the trial  
21 under strictly controlled research conditions. It cannot answer the long term cost-  
22 effectiveness of SCRAM program which is pivotal for the reimbursement decision-making. The  
23 model-based economic evaluation that extrapolates the short-term trial outcome to the  
24 lifetime horizon and a real-world setting will inform the cost-effectiveness of the proposed  
25 program in the Australian context.

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46 The economic credentials of traditional centre-based CR versus no CR have long been  
47 established. A systematic review of 19 CEAs of such interventions concluded that the majority  
48 reported traditional CR was cost-effective versus no CR (ICER ranged from US\$1065 to  
49 US\$71755/QALY), especially with exercise as a component<sup>40 41</sup>. Specifically in relation to  
50 cardiac telerehabilitation (not involving a smartphone-based remote CR component), studies  
51 are varied in terms of their results. Whilst one within-trial economic evaluation reported that  
52 such an intervention (offering the flexibility of having the CR at hospital, healthcare centre, or  
53 call centre) was not cost-effective given its high cost (ICER €400,000 per QALY)<sup>21</sup>, others have  
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3 demonstrated more positive outcomes. A trial-based economic analysis home-based CR was  
4 associated with non-significantly lower costs and a high probability of being cost-effective<sup>19</sup>.  
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6 Another CUA showed that the mean cost per patient in a telemonitoring program was €564  
7 lower than in the control group, but with higher QALY gains (0.026), thereby making the  
8 intervention dominant (lower costs but higher benefits)<sup>22</sup>. Another CEA of home-based  
9 telerehabilitation, delivered through online videoconferencing for patients with heart failure,  
10 concluded that it was associated with significantly lower costs (-AU\$1590, 95%CI -\$2822 to -  
11 \$359) during the 6 month participation period<sup>42</sup>. Our previous economic evaluation alongside  
12 a non-inferiority RCT in New Zealand indicated the REMOTE-CR smartphone-based cardiac  
13 telerehabilitation program—a precursor to SCRAM—was associated with cost-saving (-  
14 NZ\$4615/participant) and comparable benefits<sup>18</sup>.  
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24 Some methodological limitations are worth mentioning: first of all, the economic evaluation  
25 is based on the sample size determined by the primary outcome of the SCRAM RCT. It may be  
26 underpowered to detect a difference in costs. Second, whilst the gold standard is to  
27 undertake economic evaluations from a societal perspective (which captures all costs falling  
28 on patients, their carers, and families), the current study only considers a limited societal  
29 perspective (i.e. including only productivity costs); the costs borne by carers and families are  
30 excluded. However, it is believed that the health care system plus the limited societal  
31 perspectives will provide sufficient information to inform decision-making around investment  
32 in the SCRAM program in Australia and elsewhere.  
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41 The results of this economic evaluation will fill the evidence gap for the cost-effectiveness of  
42 this mHealth CR program versus usual care CR alone, given that the current economic  
43 credentials of a pre-cursor intervention are based on a non-inferiority RCT<sup>18</sup>. Results will assist  
44 policy makers, healthcare managers and other healthcare service providers to inform  
45 decisions regarding the ongoing use or future implementation of the SCRAM program. If the  
46 economic evaluation finds the SCRAM program to be cost-effective, then it can be  
47 recommended at the national or even international level as a complementary alternative CR  
48 delivery model that may meet the needs of many people who are unable or unwilling to  
49 participate in traditional centre-based CR services.  
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**Contributorship statement**

All the authors (LG, RM, JR, KB, BO, CC, SAM, KL, JA, VN, CN, SC, and MM) contributed to the study design and the protocol of the economic analysis. LG drafted the initial manuscript. All the other authors (RM, JR, KB, BO, CC, SAM, KL, JA, VN, CN, SC, and MM) reviewed, edited and approved the final manuscript.

**Competing interests**

None declared.

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Tables

Table 1 Identified cost items according to pathway analysis

Process to be costed	Identification of costs	Measurement of costs	Valuation of costs	Who records cost data & how is it collected
Recruitment of participants	Researcher	minutes/hours	Salary costs	Researcher records time taken
Training				
Training/induction session for participants	Project team time	hours	Salary costs	Project team records time taken
Training/induction session for accredited exercise physiologist	Project team time	hours	Salary costs	Project team records time taken
Capital				
Leasing of venue for training/induction sessions	Cost of leasing	Unit cost	Market price	Research team to record
Leasing of venues for cardiac rehabilitation professionals to deliver the SCRAM program	Cost of leasing	Unit cost	Market price	Research team to record

Wearable sensor devices	Cost of sensor device	Unit cost	Market price	Research team to record
Smartphone	Cost of smartphone	Unit cost	Market price	Research team to record
Computers (desktop or laptop)	Cost of computer	Unit cost	Market price	Research team to record
Staffing				
CR professional	CR professional time	Hours	Salary costs	CR professional records time taken
Administrative support	Project staff time	Hours	Salary costs	Project staff records time taken
Miscellaneous costs				
Mobile phone/internet access	Cost of mobile phone, internet access	Unit cost	Market price	Research team to record
Stationery	Cost of stationery	Unit cost	Market price	Research team to record
Utilities (i.e. electricity)	Cost of utility	Unit cost	Market price	Research team to record
Hosting (server)	Cost of server	Unit cost	Market price	Research team to record

Handouts (flyer, information sheet, etc.)	Cost of printing	Unit cost	Market price	Research team to record
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Abbreviation: CR, cardiac rehabilitation.

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Table 2. Expected outcomes of the economic analysis

Analysis	Incremental costs	Incremental effectiveness	Incremental cost-effectiveness
Incremental cost-effectiveness analysis	AUD	Maximal oxygen uptake (VO <sub>2</sub> max, ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	Cost of per unit improvement in VO <sub>2</sub> max
	AUD	Anthropometry (i.e. body weight, BMI, waist/hip circumference, etc.*)	Cost of per unit improvement in anthropometry outcomes
	AUD	Blood lipid and glucose concentrations, blood pressure	Cost per unit improvement in biomedical outcomes
Incremental cost-utility analysis	AUD	Quality-adjusted life year gained	Cost per additional quality-adjusted life year gained

\*complete list of secondary outcomes could be found in the trial protocol<sup>23</sup>.

AUD: Australian dollar; BMI: body mass index

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## Figures

Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery

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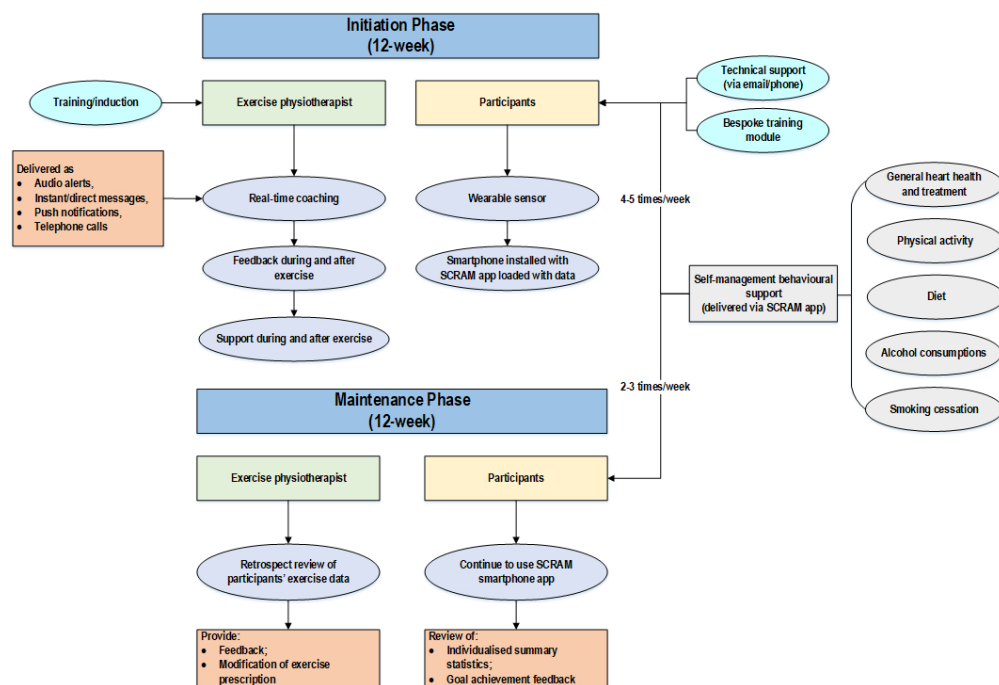


Figure 1 Pathway analysis for identifying the cost associated with SCRAM program delivery