PEER REVIEW HISTORY

BMJ Open publishes all reviews undertaken for accepted manuscripts. Reviewers are asked to complete a checklist review form (**http://bmjopen.bmj.com/site/about/resources/checklist.pdf**) and are provided with free text boxes to elaborate on their assessment. These free text comments are reproduced below.

ARTICLE DETAILS

TITLE (PROVISIONAL)	A smartphone app for sedentary behaviour change in cardiac rehabilitation and the effect on hospital admissions: the ToDo-CR randomised controlled trial study protocol
AUTHORS	Patterson, Kacie; Davey, Rachel; Keegan, Richard; Niyonsenga, Theophile; Mohanty, Itismita; van Berlo, Sander; Freene, Nicole

VERSION 1 – REVIEW

REVIEWER	Ashenafi Habte Woyessa Wollega University Ethiopia
REVIEW RETURNED	18-Jun-2020

GENERAL COMMENTS	General comments This is a randomized control trial protocol aimed to change behaviors of cardiac patients using a smartphone app and to see its effect on hospital admissions. Generally I found it one of the excellent works in reducing mortality among cardiac patients in Australia. The problem under consideration is really a problem and needs intervention. The research proposed method (The assessor-blind, multi-centre parallel RCT) is also reasonably appropriate. I firmly believe that the proposal will bear fruit with further modifications before conducting the actual study. I kindly recommend the investigators to consider the following specific comments to make the work a robust one. INTRODUCTION: i. The investigators have nicely showed the justification behind this research protocol: “studies show that participants remain largely sedentary” despite the current programs like To Do-CR. However, I believe the investigators need to tell us why the current programs are not effective. Identifying factors related to Sedentariness will help us justify that the program we are proposing would cover those gaps. Going without knowing why current programs are not effective measures will shadow uncertainty on the solutions being proposed by theses researchers. ii. What is the criterion to choose a “Vire” while many other smartphone applications could exist to serve this purpose? Make sure that this is the only application in the world? iii. We did not hear proposed solutions for patients who might not have a Smartphone that supports the application. iv. I am not sure if Vire app is free of draw backs to serve this purpose. I recommend the investigators to have a checklist and ensure that the components of the app are adequate. If not, they may consult the producers of the app. v. Let us assume that the investigators would come up with strong findings that could impact the current approach and their invention gets accredited for utilization. A big question that could come after

	this is that: Will this new technique be impartial enough for all patients (equally or nearly equally suitable for all/ majority of cardiac the patients who deserve rehabilitation)? METHODS AND ANALYSIS: i. Exclusion criteria- I believe that this criterion does not seem persuasive. - The researcher is going to exclude patients below 18 years considering that above this have adequate English language and cognitive skills. In this sense, the following participants are going to unjustifiable included in the study. - Participants who have already cognitive problems, example very aged people could be included - Foreigners who are not native English speakers and lived in Australia for short period - Furthermore, the investigators may need to justify why participants are going to be excluded by specific criteria like having primary diagnosis of Atrial Fibrillation. ii. Sample size calculation- - As the proposed sample is calculated with sufficient justification. However, the sample of 144 may not be sufficient to generalize. I doubt this could cause external invalidity to reach conclusion and utilize this new supplementary program for cardiac rehabilitation. - As this could affect the final intended outcome of the study homogeneity of the sample must be ensured. For example, the interest and regularity of using the technological products like smartphones may not be the same among different age groups may not be similar.

REVIEWER	Stephanie Prince Ware Public Health Agency of Canada, Canada
REVIEW RETURNED	09-Sep-2020

GENERAL COMMENTS	Thank you for the opportunity to review this manuscript. This paper presents the study protocol for a RCT examining the efficacy and cost-effectiveness of an app combined with a Fitbit device for reducing sedentary behaviour and hospital readmissions and emergency department visits. The paper was easy to read and follow. The study is very interesting and addresses the problem with initiating and sustaining key behaviour change within cardiac rehabilitation settings. The study appears to already be underway, therefore, I am not sure how much of the 'protocol' can actually be changed. However, I have included some points of consideration that will potentially improve the reporting and reproducibility of the trial. Comments: 1. Abstract, line 7: I believe "an" is missing after "and" and before "individualized". 2. Title, abstract and throughout: the study design is a randomised controlled trial (not control). 3. Introduction, line 72: I would add smoking cessation, medication management, sleep, and physical activity to the examples. 4. Introduction, line 74: meeting should be changed to meet 5. Introduction, line 76: should this read engaged in sedentary behaviour? 6. Introduction, lines 78, 101 and 121: please replace "objectively-measured" with "device-measured". Device measures are not

	completely objective, as they require subjective decision points to process data. 7. Introduction, line 79: please add a “the” in front of Unites States and Netherlands. 8. Introduction, lines 82-83: please reverse the beginning of this sentence. As it reads now it sound like mortality □television. I would suggest “…examining the association between television watching (a marker for SB) and 13-year all-cause mortality among people with CVD…” 9. The authors may be interested in this paper which examined the use of prompting device to reduce sedentary behaviour in a CR setting: Prince SA, Reed JL, Cotie LM, Harris J, Pipe AL, Reid RD. Results of the Sedentary Intervention Trial in Cardiac Rehabilitation (SIT-CR Study): A pilot randomized controlled trial. Int J Cardiol. 2018;269:317-324. 10. Introduction: please include your comparison group in your research questions. 11. Line 140: change “on” to “in”. 12. Randomization, lines 140-142: Do you mean that group status will be revealed following all baseline measures? 13. Figure 1. Please include the eligibility requirements in brief in the “excluded” box. Also, why are the three types of exclusion factors repeated in this box? 14. Intervention: does the ToDo-CR intervention begin with usual care CR or does it begin following CR completion? 15. To truly understand the efficacy of the program, comparison to a similar ‘touch’ control group would be helpful (i.e. app providing dietary advice or CR lasting as long). 16. How can the authors be certain that the changes observed are due to the app or self-monitoring via the Fitbit? Perhaps you could examine those in the control group with and without personal monitors if this is not an exclusion criteria. 17. Inclusion criteria: how is “stable CHD” and “optimal medical treatment” defined? Is there a minimum time since intervention required? The time since diagnosis, event or intervention is likely to affect behaviours. 18. Methods: please describe the usual standard of care for CR. What is the regular CR dose i.e. # of times per week and duration of the program. 19. Methods, intervention: lines 177-179: Can the authors expand on what sedentary behaviour targets they are including? i.e. is there a maximum amount or maximum duration per bout? It would be good to summarize the Australian guidelines for those not familiar. 20. Methods, intervention lines 181-182: The app requires data from a Fitbit; however, this was not included as an inclusion criteria for participation alongside a Smartphone. Can the authors expand? – I see this explained on lines 290-291. Perhaps participants must be willing to wear a Fitbit is an inclusion criteria? Why are those in the usual care arm not provided the Fitbit? Are you testing the efficacy of a wearable device or the app? Will there be an exclusion criteria for those already wearing an activity monitor? 21. Methods, intervention: Please describe the validity of the Fitbit for monitoring sedentary behaviour. 22. Methods, outcomes: Why is change in sedentary behaviour (which is the direct target of the app) not the primary outcome? Did the authors also consider using an activPAL device to examine

	time spent sitting, lying, standing and moving? Please include in your limitations that the ActiGraph may misclassify standing/stationary time as sedentary time, and may misclassify certain types of physical activity (e.g., arm-based movements) in other intensities. 23. Methods, outcomes: Please describe or reference the protocol for the height, waist and hip measures. 24. Methods, outcomes: Please describe what clinically meaningful changes you are using as benchmarks. i.e. what change in distance is required for the 6-minute walk test to be considered clinically meaningful outside of statistically significant changes. Please reference the score of 21 as an indicator of anxiety or depression. Also, please see this paper which describes clinically meaningful changes in the HADS: Lemay, Kyle R. BSc; Tulloch, Heather E. PhD; Pipe, Andrew L. MD; Reed, Jennifer L. RKin, PhD Establishing the Minimal Clinically Important Difference for the Hospital Anxiety and Depression Scale in Patients With Cardiovascular Disease, Journal of Cardiopulmonary Rehabilitation and Prevention: November 2019 - Volume 39 - Issue 6 - p E6-E11 25. Methods, sample size calculation: Does the 30% also account for missing data? 26. Methods: the details of the cost-effectiveness evaluation are largely missing. Please describe where costing data will come from. 27. Why was #27 and #29 of the SPIRIT checklist considered not applicable when it related to confidentiality and access of the collected information? 28. Why are you unable to append the informed consent form as per item #32 of the SPIRIT checklist?

VERSION 1 – AUTHOR RESPONSE

Reviewers' Comments:

Reviewer #1:

INTRODUCTION:

i. The investigators have nicely showed the justification behind this research protocol: "studies show that participants remain largely sedentary" despite the current programs like To Do-CR. However, I believe the investigators need to tell us why the current programs are not effective. Identifying factors related to Sedentariness will help us justify that the program we are proposing would cover those gaps. Going without knowing why current programs are not effective measures will shadow uncertainty on the solutions being proposed by theses researchers.

Thank you for raising this point. There may be a number of reasons accounting for why current face-to-face traditional cardiac rehabilitation programs are not having an effect on sedentary behaviour. Currently, there are no studies identifying the specific factors related to sedentary behaviour in cardiac rehabilitation participants. Nevertheless, sedentary behaviour in healthy adults is influenced by different factors to physical activity (i.e. environmental, social and individual determinants)[1 2] (page 9, line 238). There are limited studies focusing on sedentary behaviour in CR as currently sedentary behaviour recommendations are not included in national[3] or international cardiac rehabilitation guidelines.[4] Only in the last six years has sedentary behaviour been added to the physical activity guidelines in Australian (2014)[5] and even more recently in the United States (2018).[6]

To clarify this, we have added this summary to the introduction with track-changes:

> *Cardiac rehabilitation targets positive lifestyle behaviour change (e.g. diet, stress self-management, smoking cessation, medication adherence, sleep hygiene) and participants are encouraged to meet physical activity guidelines.[4] Despite this, participants continue to not meet the Australian Physical Activity and Sedentary Behaviour Guidelines.[6] Increasing physical activity and cardiorespiratory fitness are the main focus of CR.[7 8] This does not appear to be effective at changing sedentary behaviour in this group.[9-11] An Australian study found that CR participants were engaged in sedentary behaviours for on average 11 waking hours per day.[6] Additionally, there was no change in their sedentary behaviour over a 12-month follow-up period.[12] Similarly high levels of device-measured sedentary behaviour have been found in other CR and CVD studies in Canada,[10] the United States,[13] and the Netherlands.[11] The factors influencing sedentary behaviour in CR participants are unknown.* (page 4, line 71)

ii. What is the criterion to choose a "Vire" while many other smartphone applications could exist to serve this purpose? Make sure that this is the only application in the world?

Neubeck et al. (2015) reviewed mobile technologies for CVD, and suggested the core components and ideal features for apps to change behaviour include: simplicity of use, provision of credible information, use of behaviour change concepts, real-time biometric data tracking, rewards, app personalisation, social elements and privacy.[7] We chose the Vire app due to it largely meeting these criteria after randomly reviewing other apps and finding that they generally did not meet this criteria. This has now been summarised and provided in the methods with track-changes:

> *The ToDo program was created by the company Onmi, in collaboration with the Do Something Different approach to behaviour change.[39 40] The Do Something Different approach encourages people to try various small tasks to break existing habits and achieve behavioural flexibility without needing sustained willpower.[41] Neubeck et al. (2015) reviewed mobile technologies for CVD, and suggested the core components and ideal features for apps to change behaviour include: simplicity of use, provision of credible information, use of behaviour change concepts, real-time biometric data tracking, rewards, app personalisation, social elements and privacy.[42] The research team chose the Vire app due to it largely meeting these criteria. The ToDo program was adapted by the research team to target sedentary behaviour based on the Australian Physical Activity and Sedentary Behaviour Guidelines[43] and CR guidelines [7] to create the 6-month ToDo-CR program. (page 7, line 182)*

Provision of credible information:

> The research team were able to work with the app developers to provide expertise on the Australian cardiac rehabilitation guidelines and Australian Physical Activity and Sedentary Behaviour Guidelines and ensure provision of credible information (page 7, line 190).

Use of behaviour change concepts:

> The Vire app's approach to behaviour change following the Do Something Different approach[8] is unique. This approach *"encourages people to try various small tasks to break existing habits and achieve behavioural flexibility without needing sustained willpower."* (page 7, line 184). The way that the Vire app operates makes it completely individualised and adapting to the needs of the participant at any given time over the delivery of the 6-month program. The Vire app and ToDo-CR program is the only program to our knowledge that is currently targeting sedentary behaviour and grounded in trying to create behavioural flexibility. This has been summarised with track changes:
>
> > *By combining innovative technology, evidence-based activity guidelines and BCTs, the ToDo-CR program aims to create sustained behaviour change in reducing*

sedentary time. The Vire app and ToDo-CR program is the only program to our knowledge targeting sedentary behaviour in CR. (page 19, line 533)

The Vire app suggests *"small positive actions designed to disrupt usual habits; encouraging the participant to step outside of their comfort zone (i.e. habitual behaviours).[44]"* (page 8, line 225). This app also uses "*16 different BCTs (as analysed using Michie's BCT taxonomy v1)[50] targeted at decreasing prolonged periods of sedentary behaviour. These are explained in detail in Table 2."* (page 10, line 269). This approach aims to appeal to a large variety of ways in eliciting behaviour change.

Real-time biometric data tracking:

This app is highly unique in the way that it uses machine learning principles to analyse participants' current activity (as measured by the Fitbit) and location variation data (as measured using phone GPS) in comparison to their baseline week of data (page 8, line 212). Any changes in the current data and the information that the participant provided in their baseline questionnaire (e.g. How often do you watch TV at night?) informs what "Do" is sent to the participant. *"This is done in real time, using specific algorithms which process and interpret the data input and generate an appropriate action. These algorithms create a comprehensive digital profile and informs the delivery of the personalised ToDo-CR program to target the participant's current behaviour."* (page 8, line 198)

iii. We did not hear proposed solutions for patients who might not have a Smartphone that supports the application.

Thank you for raising this concern. This study is conducted in a real-world environment and as such, smartphones that support the application would not be provided to participants in the healthcare system. An inclusion criterion to participate in this study is that they must have a compatible smartphone.

Participants will be eligible if they are aged 18+ years old, currently enrolled in CR at the above sites, have a smartphone compatible with downloading the Vire app, willing to wear a Fitbit for 6-months, and have adequate English language and cognitive skills. (page 6, line 159)

This is a limitation to our RCT and is listed in the Discussion.

A limitation to this study is the requirement of participants in this study to have a compatible smartphone to download the app may slow recruitment and distort the study population. (page 18, line 507)

iv. I am not sure if Vire app is free of draw backs to serve this purpose. I recommend the investigators to have a checklist and ensure that the components of the app are adequate. If not, they may consult the producers of the app.

Thank you for this comment. The producers of the app ensured the components of the app were adequate for our needs prior to commencing the study. The ToDo-CR program is designed to help the user break existing routines and become open to change. By increasing the user's cognitive flexibility, we expect they become able to break existing habits and slowly but surely create new healthy ones. In this process of becoming flexible and breaking existing routines, Vire plays an important role.

The main design requirement for Vire was to keep the app simple and intuitive. A previous version included the visualisation of a wider range of behavioural data parameters, but this became overwhelming to some participants. By keeping the list of functional requirements short, the app development team at Onmi attempted to let Vire serve a clear goal. The design itself is friendly and attractive.

The app producers used the following checklist of functional requirements when developing the app. This has also now been provided as a supplementary file and referred to as part of the Methods with track-changes.

> *A summary of the functional requirements of the Vire app is provided by the app developers; see Supplementary file 2.* (page 10, line 271)

Checklist of functional requirements for the Vire app

#	**Requirement**	**Implementation**
1	Send messages (Do's), notify user new messages have been received	Vire has a menu item devoted to this functionality, the "Do's screen" lists all the messages received so far. Every time a new message arrives, Vire sends a push notification. The home screen also shows a "Do bubble" when a new message is available.
2	Enable user to mark a Do as completed, and provide feedback on experience for analysis	After opening a Do and acting on it, the user can press the "Complete button", provide a rating and mark the Do as completed. The Do message changes colour so the user is aware which Do's in the list are completed and not completed.
3	Collect behavioural data (GPS and Activity, enable connection to third party services)	GPS tracking and activity tracking are implemented as background processes, the user consents to both during onboarding after reading the terms and conditions of using the app. This approval for tracking can be revoked at any time in the settings. A link to connect Fitbit to Vire is also included in the settings screen.
4	Give insight into progress of programme	In the Do's list the user can observe the number of Do's that have been sent and completed so far.
5	Show a dynamic behavioural score of today	The home screen shows 3 bubbles which represent abstraction of 3 important behaviours in everyday life, Activity, Variety and Social Opportunity. The bubbles increase in size when the score is higher, by clicking on a bubble the user can access more detailed parameters that are used to calculate the score.
6	Show historic data that lets you understand why certain Do's are sent	The data history screen shows behavioural scores of the past 2 weeks. Here the user gets a simple abstract overview of progress in their measured habits.
7	Manage a profile and settings	During the onboarding process the user is asked to fill in their name for a more personalised experience. The settings screen lets the user change this and manage data collection processes. This screen also includes a link to a Frequently Asked Questions page where the user can find answers to common question about Vire.

v. Let us assume that the investigators would come up with strong findings that could impact the current approach and their invention gets accredited for utilization. A big question that could come after this is that: Will this new technique be impartial enough for all patients (equally or nearly equally suitable for all/ majority of cardiac the patients who deserve rehabilitation)?

Thank you for this comment. This new technique will not be impartial enough for all patients, although *"approximately 65% of Australian CR participants report having a smartphone.[84]"* (page 18, line 516). There is a limiting factor to the equality of access to such an app as it relies on the patient to have a smartphone of recent enough software compatibility. We have acknowledged this as an inclusion criterion for participating in this study and as a limitation in the discussion.

Methods:

> *Participants will be eligible if they are aged 18+ years old, currently enrolled in CR at the above sites, have a smartphone compatible with downloading the Vire app, willing to wear a Fitbit for 6-months, and have adequate English language and cognitive skills.* (page 6, line 159)

Discussion:

> *A limitation to this study is the requirement of participants to have a compatible smartphone to download the app which may slow recruitment and distort the study population.* (page 18, line 507)

We also acknowledge that the use of apps may not be a preference for all patients. However, one of the strengths for this app is that it could be offered to those who choose not to attend cardiac rehabilitation to still provide them with some support. Of those who are referred for cardiac rehabilitation in Australian, only 28% attend.[9] Alternate technology-based methods may offer more opportunity to reach those not attending traditional CR.

METHODS AND ANALYSIS:

i. Exclusion criteria- I believe that this criterion does not seem persuasive.

- The researcher is going to exclude patients below 18 years considering that above this have adequate English language and cognitive skills. In this sense, the following participants are going to unjustifiable included in the study.

> **1) Participants who have already cognitive problems, example very aged people could be included**
>
> **2) Foreigners who are not native English speakers and lived in Australia for short period**
>
> **3) Furthermore, the investigators may need to justify why participants are going to be excluded by specific criteria like having primary diagnosis of Atrial Fibrillation.**

Thank you for your comment. In clinical practice, cardiac rehabilitation programs are usually delivered as a group-based intervention and programs may exclude individuals who require higher levels of supervision to exercise. This may include those with significant cognitive deficit (e.g. severe dementia) or uncontrolled medical conditions (e.g. uncontrolled diabetes, hypertension).[3] We are recruiting participants from a real-world environment and therefore have used real-world inclusion and exclusion criteria except for diagnosis. Please see below for a direct response to each of your points above.

> 1) Those with cognitive impairment would unlikely have the ability to engage adequately in the use of potentially unfamiliar technology. Age is not an exclusion criterion provided they are 18+ years old.

2) Those without adequate English proficiency will also be excluded as the app will only be delivered in English. In future, if this app proves to be effective, it could also be trialled in other languages and cultures.

3) People with a primary diagnosis of atrial fibrillation will be excluded on the basis that they have not received a diagnosis of established coronary heart disease or having had a myocardial infarction. This is to ensure a homogeneity of the sample. Atrial fibrillation, high risk coronary artery disease and familial hypercholesterolaemia are not routinely included or targeted in cardiac rehabilitation, however, are likely to benefit from participation in such programs.[3] If the Vire app is effective in a homogenous group of coronary heart disease, then it could also be trialled in these other patient groups.

ii. Sample size calculation-
- As the proposed sample is calculated with sufficient justification. However, the sample of 144 may not be sufficient to generalize. I doubt this could cause external invalidity to reach conclusion and utilize this new supplementary program for cardiac rehabilitation.
- As this could affect the final intended outcome of the study homogeneity of the sample must be ensured. For example, the interest and regularity of using the technological products like smartphones may not be the same among different age groups may not be similar.

Thank you for your comment. We understand that this sample of 144 may not be sufficient to generalize. If effective, the intervention may be trialled in larger populations/samples.

We agree that smartphone use and preference may be different across age groups. The average age of cardiac rehabilitation participants internationally is 65 years old. A study investigating the mobile technology use across age groups (N = 282; mean age 66.5years ± SD 10.6 years) in patients eligible for cardiac rehabilitation found the middle-aged group (56-69 years) were two times more likely to use mobile technology compare to the oldest age group (>69 years).[10] However, 56.5% (65/115) of the oldest group did still report using mobile technology.[10] Given this large proportion of individuals from this study in the oldest age group having and using mobile technology, we did not wish to limit their participation in the study by including upper range age limits. We have acknowledged the potential limitations associated with age in the Discussion section with specific reference to smartphone use in Australian cardiac rehabilitation programs:

> *The use of new and innovative smartphone technology is likely to skew the participant population to a younger cohort as seen in other CVD smartphone-based interventions, with mean age: 46yrs-58yrs.[25 79-81] Despite this, studies have found that Australian CR participants are interested in support via the internet and mobile phones [82 83] and approximately 65% of CR participants reported having a smartphone.[84] This may not be an issue in the future with further proliferation of mobile technology use across generations and in healthcare.[85]* (page 18, line 512).

Reviewer #2:

1. Abstract, line 7: I believe "an" is missing after "and" and before "individualized".

Thank you for picking this up. We have now amended this; see tracked changes.

> *This study will explore the effectiveness and costs of a smartphone application (Vire) and an individualised online behaviour change program (ToDo-CR) in reducing sedentary behaviour* (page 2, line 7)

2. Title, abstract and throughout: the study design is a randomised controlled trial (not control).

This has now been corrected throughout the paper, thank you. See tracked changes.

3. Introduction, line 72: I would add smoking cessation, medication management, sleep, and physical activity to the examples.

Thank you for this suggestion, we have added these topics to the Introduction. See tracked changes.

> *Cardiac rehabilitation targets positive lifestyle behaviour change (e.g. diet, stress self-management, smoking cessation, medication adherence, sleep hygiene) and participants are encouraged to meet physical activity guidelines.*[4] (page 4, line 71)

4. Introduction, line 74: meeting should be changed to meet

Thank you for this correction, please see tracked changes (page 4, line 77).

5. Introduction, line 76: should this read engaged in sedentary behaviour?

Thank you for this suggestion. We have reworded this sentence. Please see tracked changes.

> *An Australian study found that CR participants were engaged in sedentary behaviours for on average 11 waking hours per day.*[6] (page 4, line 76)

6. Introduction, lines 78, 101 and 121: please replace "objectively-measured" with "device-measured". Device measures are not completely objective, as they require subjective decision points to process data.

Thank you for drawing this to our attention. We have changed this terminology as suggested throughout the paper. See tracked changes.

7. Introduction, line 79: please add a "the" in front of Unites States and Netherlands.

This has been amended, thank you.

> *Similarly high levels of device-measured sedentary behaviour have been found in other CR and CVD studies in Canada,*[10] *the United States,*[13] *and the Netherlands.*[11] (page 4, line 79)

8. Introduction, lines 82-83: please reverse the beginning of this sentence. As it reads now it sound like mortality ◊television. I would suggest "…examining the association between television watching (a marker for SB) and 13-year all-cause mortality among people with CVD…"

Thank you for this recommendation. We have modified this sentence, see tracked changes.

> *A study examining the relationship between television watching (a marker of sedentary behaviour) and 13-year all-cause mortality among people with CVD (n = 609), found a 52% increased risk of mortality in those who watched >4 hours per day compared to those who watched <2 hours per day.*[17] (page 4, line 84)

9. The authors may be interested in this paper which examined the use of prompting device to reduce sedentary behaviour in a CR setting:
Prince SA, Reed JL, Cotie LM, Harris J, Pipe AL, Reid RD. Results of the Sedentary Intervention Trial in Cardiac Rehabilitation (SIT-CR Study): A pilot randomized controlled trial. Int J Cardiol. 2018;269:317-324.

Thank you for drawing our attention to this paper. The use of cues and prompts from wearables and other technology may offer new approaches to cardiac rehabilitation in order to specifically target sedentary behaviour change. We have included this reference in support for the potential that such technologies may have in behaviour change for cardiac rehabilitation participants in the Introduction with track-changes.

> *Cues and prompts from mobile technologies such as smartphone applications (apps) and wearables may offer new approaches for changing health behaviours such as sedentary time for CR participants.*[20] (page 4, line 95)

Of interest was the reference to some of your work noting features of promising sedentary behaviour interventions among people with pre-existing disease, including targeting both physical activity and sedentary behaviour, the use of wearables and being based on behavioural theories.[11] We have included this as part of our Methods in justification for the use of both sedentary behaviour and physical activity messaging with track-changes.

> *Though the targeted behaviour in this intervention is sedentary behaviour, when sedentary behaviour is reduced, the behaviour is substituted by physical activity, albeit often light intensity physical activity.*[18] *Further, incorporating a combination of sedentary behaviour and physical activity focused elements has been identified as a feature of promising sedentary behaviour interventions in those with pre-existing disease.*[48] *This justifies the relevance of some Do's promoting physical activity.* (page 9, line 240)

10. Introduction: please include your comparison group in your research questions.

We have now added the comparison group of usual care cardiac rehabilitation to the research questions, thank you. See tracked changes.

> *The research questions are:*
> *(1) is the behavioural smartphone app (Vire) and 6-month online behaviour change program (ToDo-CR) effective in reducing the risk of unplanned cardiac-related hospital admissions and emergency department visits during the 12-months following commencement of a traditional CR program compared to usual care CR?*
> *(2) is the ToDo-CR program effective in decreasing objectively measured sedentary time in CR participants at the end of the intervention (6-months) and at follow-up (12-months) compared to usual care CR?*
> *(3) is the ToDo-CR program cost-effective in delivering the desired outcome?* (page 5, line 119)

11. Line 140: change "on" to "in".

Thank you, this has been correct (page 6, line 141), please see tracked changes.

> *Block randomisation will be computerised by an external biostatistician, with participants allocated in a 1:1 ratio to CR plus the ToDo-CR program or usual care CR.*

12. Randomization, lines 140-142: Do you mean that group status will be revealed following all baseline measures?

Thank you for this clarification, we will be revealing group status to the participant following completion of all of their baseline measures. This has now been better explained with tracked changes.

Randomised group status will be revealed to the baseline assessor and participant following completion of all baseline measures via a phone call from a research member. (page 6, line 144)

13. Figure 1. Please include the eligibility requirements in brief in the "excluded" box. Also, why are the three types of exclusion factors repeated in this box?

Thank you for this suggestion. The eligibility requirements have now been included in Figure 1. The added items are highlighted in yellow. The exclusion factors are no longer repeated.

14. Intervention: does the ToDo-CR intervention begin with usual care CR or does it begin following CR completion?

The ToDo-CR intervention will begin with usual care CR. This has been clarified with tracked changes.

The ToDo program was adapted by the research team to target sedentary behaviour based on the Australian Physical Activity and Sedentary Behaviour Guidelines [43] and CR guidelines [7] to create the 6-month ToDo-CR program. These guidelines encourage people to minimise prolonged sitting and to breakup periods of sitting frequently. The ToDo-CR program will commence within one week of starting CR. (page 7, line 190)

15. To truly understand the efficacy of the program, comparison to a similar 'touch' control group would be helpful (i.e. app providing dietary advice or CR lasting as long).

Thank you for this suggestion, although this RCT has now begun and we are unable to majorly deviate from the outlined protocol.

16. How can the authors be certain that the changes observed are due to the app or self-monitoring via the Fitbit? Perhaps you could examine those in the control group with and without personal monitors if this is not an exclusion criteria.

Thank you for this question. This is true, and a limitation for our study to disclose. Please see track-changes.

The use of a Fitbit in combination with the Vire app may make it difficult to determine if changes in behaviour occurred due to self-monitoring using the Fitbit or from self-monitoring and prompting from the Vire app. Sub-group analysis may be completed for those identified in the control group who do use activity trackers such as smartphone apps and watches in comparison to those using the Vire app and ToDo-CR program. (page 19, line 525)

We may be able to compare those who do use activity trackers in the control group to those in the intervention group to determine if there was a benefit of the Vire app and ToDo-CR program beyond self-monitoring using the provided Fitbit. This information will be collected as part of the generalised demographic and clinical information questionnaire. This information has now been added in the Methods section.

Demographic and other relevant clinical information will be collected using a questionnaire. This includes questions on socio-demographic variables (e.g. gender, age, education level) as well as clinical predictor variables (e.g. cardiac-related medication, other medical conditions, smoking status), and whether they use an activity tracker such as a smartphone app or watch. (page 15, line 409)

17. Inclusion criteria: how is "stable CHD" and "optimal medical treatment" defined? Is there a minimum time since intervention required? The time since diagnosis, event or intervention is likely to affect behaviours.

For cardiac patients to be eligible to attend traditional phase-II cardiac rehabilitation programs, they must have stable CHD and be receiving optimal medical treatment.[3] Optimal medical treatment includes best practise pharmacological therapies and surgical interventions in order to aid in stabilising the participants cardiac condition and any other comorbidities (e.g. diabetes, hypertension).[12] We have now included this definition in the Methods with track-changes.

> *Participants will be eligible if they are aged 18+ years old, currently enrolled in CR at the above sites, have a smartphone compatible with downloading the Vire app, willing to wear a Fitbit for 6-months, and have adequate English language and cognitive skills. Participants must have stable coronary heart disease and be receiving optimal medical treatment +/- revascularisation (e.g. coronary artery bypass graft surgery, percutaneous coronary intervention), or have had a myocardial infarction. Optimal medical treatment includes best practise pharmacological therapies and surgical interventions in order to aid in stabilising the participants cardiac condition and any other comorbidities (e.g. diabetes, hypertension).*[38] (page 6, line 159)

This is largely due to safety to participate in exercise. Conditions where exercise is contra-indicated include: progressive worsening of exercise tolerance or dyspnoea at rest or on exertion over previous 3-5 days; significant ischemia at low exercise intensities (<2 METS, or ~50W); uncontrolled diabetes; acute systemic illness or fever; recent embolism (<4 weeks); thrombophlebitis; active pericarditis or myocarditis; severe aortic stenosis; regurgitant valvular heart disease requiring surgery; myocardial infarction (MI) within previous 3 weeks; new onset atrial fibrillation (AF); resting HR >120 bpm.[13] Phase-II cardiac rehabilitation is delivered most often as an outpatient service in Australia[14] and all potential cardiac rehabilitation participants are screened for suitability by specialty cardiac rehabilitation staff. If a participant were to have any of these conditions, they would be considered to not be “stable” and hence excluded in line with what the exclusion criteria for this study is. This study is conducted in a real-world environment and hence follows best practice clinical guidelines.

We agree that the time since diagnosis, event or intervention may affect behaviours. The average time from intervention to admission to cardiac rehabilitation in Australia is 16 days (SD 16-23.3 days).[15] We will be recording time since diagnosis, event and intervention as part of the clinical information completed by cardiac rehabilitation staff. This has now been clarified with track-changes.

> *Demographic and other relevant clinical information will be collected using a questionnaire. This includes questions on socio-demographic variables (e.g. gender, age, education level) as well as clinical predictor variables (e.g. cardiac-related medication, other medical conditions, smoking status), and whether they use an activity tracker such as a smartphone app or watch. The CR clinicians will also record participant admission diagnosis and date of event or intervention details.* (page 15, line 409)

18. Methods: please describe the usual standard of care for CR. What is the regular CR dose i.e. # of times per week and duration of the program.

In the three sites in Canberra, Australia that are recruiting for this RCT, two sites run for 6-weeks and one site runs for 5-weeks. Each site holds 1-2 hours of education and 1-2 hours of exercise per week. This has been clarified in the Methods with tracked changes.

> *Participants will be recruited from traditional phase-II (outpatient), hospital-based CR programs from three sites: Canberra Hospital, Calvary Public Hospital Bruce and National Capital Private Hospital. These hospitals follow the Australian guidelines for CR.*[7] *They are multidisciplinary, group-based, and time limited. The Canberra Hospital and Calvary Public Hospital deliver one-hour of exercise and one-hour of education, two times per week for 6-weeks. National Capital Private hospital delivers one-hour of exercise and one-hour of education, once per week for 5-weeks.* (page 6, line 150)

19. Methods, intervention: lines 177-179: Can the authors expand on what sedentary behaviour targets they are including? i.e. is there a maximum amount or maximum duration per bout? It would be good to summarize the Australian guidelines for those not familiar.

The Australian Physical and Sedentary Guidelines encourage Australians to "Minimise the amount of time spent in prolonged sitting. Break up long periods of sitting as often as possible".[5] The Australian guidelines do not specify numerical targets and therefore a target was not set. A summary of this description has been added to the Methods with tracked changes.

> *The ToDo program was adapted by the research team to target sedentary behaviour based on the Australian Physical Activity and Sedentary Behaviour Guidelines [43] and CR guidelines [7] to create the 6-month ToDo-CR program. These guidelines encourage people to minimise prolonged sitting and to breakup periods of sitting frequently.* (page 7, line 190)

The ToDo-CR program does not specify set sedentary behaviour targets for participants to try and meet. The Do's are aimed at encouraging participants to make micro behavioural changes that may indirectly influence sedentary time in such a way that they don't feel the burden of making a significant lifestyle change. This summary has been included in the Methods with tracked change:

> *The Do's either directly or indirectly target sedentary behaviour change by suggesting micro behavioural alternatives to their usual habits that may influence sedentary time in such a way that they don't feel the burden of making a significant lifestyle change.* (page 9, line 233)

20. Methods, intervention lines 181-182: The app requires data from a Fitbit; however, this was not included as an inclusion criteria for participation alongside a Smartphone. Can the authors expand? – I see this explained on lines 290-291. Perhaps participants must be willing to wear a Fitbit is an inclusion criteria? Why are those in the usual care arm not provided the Fitbit? Are you testing the efficacy of a wearable device or the app? Will there be an exclusion criteria for those already wearing an activity monitor?

Thank you for raising this concern. We have now included willingness to wear a Fitbit as part of the inclusion criteria as prior to recruitment, all potential participants were informed that they will receive a Fitbit. Please see tracked changes.

> *Participants will be eligible if they are aged 18+ years old, currently enrolled in CR at the above sites, have a smartphone compatible with downloading the Vire app, willing to wear a Fitbit for 6-months, and have adequate English language and cognitive skills.* (page 6, line 159)

However, it is not an absolute requirement for the participant to wear the Fitbit throughout the full 6-month study. As described on page 12, line 317: "*If a participant stops wearing their Fitbit, it will not impact the delivery of the intervention as the Vire app can also use the native smartphone step tracking software."* Wearing a Fitbit increases the accuracy of the data being collected to inform the ToDo-CR program and hence why we decided to include Fitbits in this study.

The Vire app, ToDo-CR program and Fitbit (informing the ToDo-CR program along with phone GPS data) are considered to be the intervention. We have clarified this in the Methods with track-changes.

> *The Vire app, ToDo-CR program and Fitbit are considered one intervention. The Vire app is the front-end application used to deliver the online ToDo-CR program (Figure 2). The Vire app also uses data input from the wearable fitness tracker Fitbit.* (page 7, 179)

As such, those in the usual care cardiac rehabilitation arm will not be provided with a Fitbit until they have completed their entire 12-month participation in the study. This is a means to also help increase control group retention rates over a 12-month study period. As we are testing the efficacy of the app

as the key behaviour change component, we will not be controlling for if a participant uses an activity monitor, although this may be possible as we are collecting this data (see below). Already having an activity tracker is not an exclusion criteria as many participants are likely to already have and use wearable devices or have had experience with using them in the past.

> *Demographic and other relevant clinical information will be collected using a questionnaire completed by the participant and CR staff. This includes questions on socio-demographic variables (e.g. gender, age, education level), clinical information and predictor variables (e.g. diagnosis, medical intervention, time from event to starting CR, cardiac-related medication, other medical conditions, smoking status), and whether they have used an activity tracker such as a smartphone app or watch.* (page 15, line 409)

21. Methods, intervention: Please describe the validity of the Fitbit for monitoring sedentary behaviour.

Thank you for your comment. We will not be using the Fitbit for monitoring sedentary behaviour or as an outcome measure. As outlined in Methods under secondary outcomes, we will be monitoring sedentary behaviour at baseline, 6-months and 12-months using an Actigrapgh wGT3X-BT:

> *Sedentary and physical activity levels will be objectively measured using a triaxial commercial accelerometer (Actigraph wGT3X-BT, Fort Walton Beach, FL) worn by participants on the right hip for seven consecutive days during waking hours.* (page 13, line 350)

The Fitbit is used to provide activity data in the form of step counts which are then analysed and integrated by the Vire app. This is explained further on page 8, line 197:

> *The Vire app integrates and analyses data from a Fitbit and the phone global positioning system (GPS) location. This is done in real time, using specific algorithms which process and interpret the data input and generate an appropriate action. These algorithms create a comprehensive digital profile and informs the delivery of the personalised ToDo-CR program to target the participant's current behaviour.*

22. Methods, outcomes: Why is change in sedentary behaviour (which is the direct target of the app) not the primary outcome? Did the authors also consider using an activPAL device to examine time spent sitting, lying, standing and moving? Please include in your limitations that the ActiGraph may misclassify standing/stationary time as sedentary time, and may misclassify certain types of physical activity (e.g., arm-based movements) in other intensities.

Thank you for this question. You are correct, change in sedentary behaviour is not the primary outcome however is a key outcome of interest. The primary outcome is all-cause hospital admissions and ED presentations in the 12-month period following starting cardiac rehabilitation and this is what the sample size is based on. As outlined in the Introduction (page 4, line 83), sedentary behaviour is an independent risk factor for all-cause mortality and those with cardiovascular disease who are sedentary are at even great risk of mortality. Since one in three cardiac events are repeat events[16], we believe that targeting sedentary behaviour is an appropriate approach to having an effect on our primary outcome of hospital admissions.

Thank you for this suggestion for the use of activPAL over the Actigraph. The activPAL has been shown to have a high sensitivity for distinguishing between lying, sitting and standing and is considered the gold standard for measuring sedentary behaviour.[17-19] We have now added these limitations to paper.

> *The use of the Actigraph triaxial accelerometers may also misclassify standing stationary time or arm-based exercise as sedentary behaviour due to the worn location on the hips. However,*

this means of measuring quantity and intensity of movement is still considered to be valid when using appropriate cut points for sedentary behaviour.[10 61] (page 19, line 521)

Among the commercially available brands, the ActiGraph (Pensacola, FL, USA) accelerometers are the most frequently used by researchers.[20] When using the Actigraph, we will use 150 counts per minute as the most appropriate cut point to define sedentary behaviour.[18] This demonstrated the lowest bias (-0.9min, SE=7.7min, 95% CI=-15.9 to 14.1min) and when comparing the percent bias of the activPAL to using the Actigraph at 150 counts, the difference between the two was small (2.8% and 1.8% respectively).[18]

For sedentary behaviour, the vector magnitude cut-point will be <150 cpm.[10 11 59 61] (page 14, line 358)

23. Methods, outcomes: Please describe or reference the protocol for the height, waist and hip measures.

We have now described and provided a reference for the waist and hip measure protocol. Please see tracked changes.

A calibrated set of scales and stadiometer will be used to measure height (m) and weight (kg) and body mass index (kg/m^2) will be calculated. Waist and hip measures (cm) will be completed using a stretch-resistant tape measure. The waist circumference will be recorded as the midpoint between the lower margin of the lowest palpable rib and the top of the iliac crest. The hip circumference will be recorded as the widest portion of the buttocks when viewing from the side and keeping the tape measure parallel to the floor. Each measure will be repeated twice; if the measurements are within one centimetre of each other, the average will be calculated. If the difference exceeds one centimetre, the two measures will be repeated.[62] (page 14, line 366)

24. Methods, outcomes: Please describe what clinically meaningful changes you are using as benchmarks. i.e. what change in distance is required for the 6-minute walk test to be considered clinically meaningful outside of statistically significant changes. Please reference the score of 21 as an indicator of anxiety or depression. Also, please see this paper which describes clinically meaningful changes in the HADS: Lemay, Kyle R. BSc; Tulloch, Heather E. PhD; Pipe, Andrew L. MD; Reed, Jennifer L. RKin, PhD Establishing the Minimal Clinically Important Difference for the Hospital Anxiety and Depression Scale in Patients With Cardiovascular Disease, Journal of Cardiopulmonary Rehabilitation and Prevention: November 2019 - Volume 39 - Issue 6 - p E6-E11

Thank you for this, we have now added these clinically meaningful changes for 6-minute walk test and HADS and have referenced the score of 21 as an indicator of anxiety and depression. Thank you for this suggested paper of reference. Please see tracked changes.

6-minute walk test: *A change in distance of 25m is considered a clinically meaningful change in CHD participants in CR.[64]* (page 14, line 381)

HADS: *A score of zero represents the best outcome and a score of 21 is an indicator of anxiety or depression.[69] The minimally clinically important difference for patients with CVD is 1.7.[72]* (page 15, line 394)

25. Methods, sample size calculation: Does the 30% also account for missing data?

Thank you for this question, the 30% drop out rate does not account for missing data. We have now clarified this in the protocol with tracked changes.

Based on a previous observational study in the same population group, we will allow for a 30% drop out.[12] This does not account for missing data. (page 17, line 458)

26. Methods: the details of the cost-effectiveness evaluation are largely missing. Please describe where costing data will come from.

Thank you for raising this. These details have now been added with track-changes:

Information relating to the costs of implementing and delivering the intervention will be collected including payment for the use of the Vire app and ToDo-CR program, time and phone call support from a researcher for issues relating to the app download and general function, and Fitbit Inspire purchases … Hospital cost information will be obtained from Independent Hospital Pricing Authority (IHPA) Australia and/or Australian Institute of Health and Welfare (AIHW). Information on secondary measures such as health behaviour change (sedentary behaviour and moderate-to-vigorous physical activity), BMI, waist circumference, quality of life (AQoL-6D), clinical and demographic information and the costs associated with the use and delivery of the Vire app and ToDo-CR program will be used. (page 16, line 433)

27. Why was #27 and #29 of the SPIRIT checklist considered not applicable when it related to confidentiality and access of the collected information?

Thank you for this question. Item #27 has now been amended with inclusion of the consent form and participant information sheet as a supplementary file.

A statement regarding the availability of data has also been added to the paper to meet the requirements of item #29.

Availability of data

Following completion of trial and publication, requests for access to the final deidentified trial dataset will be considered where the proposed use complies with trial ethical approval, as well as where the requestor is willing to sign a data access agreement. (page 18, line 488)

28. Why are you unable to append the informed consent form as per item #32 of the SPIRIT checklist?

This item has now been addressed through the inclusion of a model informed consent form.

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VERSION 2 – REVIEW

REVIEWER	Ashenafi Habte Woyessa Wollega University, Ethiopia
REVIEW RETURNED	07-Nov-2020

GENERAL COMMENTS	The authors have addressed the given comments to my satisfaction and I highly recommend the protocol to the taken to the next stage of publication process