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Exploring Exercise Intensity in Outpatient Cardiac Rehabilitation and Home Environments.

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BOND UNIVERSITY

Exploring Exercise Intensity in Outpatient Cardiac Rehabilitation and Home Environments

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Submitted in total fulfilment of the requirements of the degree of Doctor of Philosophy (PhD)

September 2020

Faculty of Health Sciences and Medicine

Professor Wayne Hing, Professor Jeff Coombes, Associate Professor Mike Climstein, Professor Rohan Jayasinghe, Assistant Professor James Furness

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ABSTRACT

BACKGROUND

Cardiovascular disease (CVD) is the leading cause of death globally and is a large contributor to the economic burden of disease. Cardiac rehabilitation (CR) is an important secondary prevention tool in the management of CVD. Research has shown CR improves cardiovascular mortality and morbidity. Exercise is a key component of CR, however, there has been minimal research investigating specific exercise parameters being used within CR programmes in Australia. There is emerging evidence to suggest high intensity interval training (HIIT) may be superior to traditional recommendations of moderate intensity continuous training (MICT) in improving cardiorespiratory fitness (CRF). However, there is minimal research investigating to what extent HIIT is being used within CR exercise programmes in Australia, nor has there been a compilation of reported adverse events occurring within the cardiac population when using HIIT.

Additionally, CRF must be maintained to provide cardio-protection long term, however there is limited research investigating the long term adherence to exercise or the amount, and intensity, of exercise currently performed by people with heart disease once they are discharged from the subacute phase (outpatient phase 2) of CR and enter the maintenance phase (Phase 3). Although wearable physical activity monitoring devices (WPAM) have grown in popularity and thought to improve exercise adherence, there is minimal research surrounding the benefits of utilising these devices for people with cardiac disease. These devices generally measure step count which does not take into account the intensity of exercise. Intensity is important to stimulate physiological adaptation to improve CRF and other cardiometabolic health outcomes.

The aims, therefore, of this thesis were firstly, to evaluate and synthesise current literature comparing improvements in physiological benefits, particularly CRF (VO_2peak) between participants diagnosed with CVD engaged in MICT

versus HIIT, analyse the effect of VO_2peak changes resulting from different durations of interventions and collate reported adverse events occurring within eligible randomised controlled trials (RCTs). Secondly, to collect data surrounding current exercise prescription parameters and clinician perceptions about implementation of HIIT, and current usage across Australia. Thirdly, to investigate the effect of WPAM within the cardiac population on CRF and finally, to evaluate the effect monitoring Personal Activity Intelligence (PAI) scores, using a WPAM, has on intensity, adherence and motivation in the maintenance phase of CR.

METHODS

Methods used to investigate these aims included two systematic reviews and meta-analyses with one including a qualitative analysis, a cross-sectional survey, and a mixed method evaluation (original research trial coupled with thematic framework analysis).

RESULTS

The main findings of this thesis were HIIT is significantly superior to MICT in improving CRF in the cardiac population and appears to a safe form of exercise. More adverse events were recorded in the MICT group (n=14) versus the HIIT group (n=9) and one cardiac adverse event was recorded in each group, however this was unrelated to the exercise sessions. No deaths or cardiac events requiring hospitalisation were reported in either group.

HIIT was found to be underutilised within Australian CR programmes. Most Australian CR programmes are located in rural settings and are hospital based. CR in Australia is mostly performed once per week for 6 - 8 weeks, are of 40 to 60 minutes duration and exercise is prescribed at a moderate intensity. Only two of 261 CR programmes in Australia utilised HIIT. Most Australian clinicians working in CR believe HIIT is unsafe or are unsure of its safety. The main barriers identified as contributing to the limited use of HIIT included lack of monitoring and staff resources, and lack of staff knowledge about HIIT.

There is a concerning lack of evaluation of CRF and strength changes resulting from attending outpatient CR. Just under half of programmes failed to

re-evaluate CRF and just over ninety percent of programmes failed to perform strength assessments before or after outpatient CR. Therefore, currently, the effectiveness of the exercise component of CR in Australia cannot be ascertained.

Long-term exercise adherence and maintenance of CRF gains is required to reduce mortality. Our results indicate that WPAM are significantly better at improving CRF compared to not utilising a device in the cardiac population. Common WPAM such as pedometers, however, do not monitor intensity of exercise and only a limited number of these devices allow people with cardiac disease to link their activity to useful information about cardiovascular risk reduction. PAI is a single metric which uses the heart rate response to exercise to provide feedback to users about whether the physical activity being performed is optimal to produce a reduction in CVD risk. PAI calculations are dependent upon accurately measuring heart rate and the higher the intensity of exercise, the greater the accumulation of PAI. The accumulation of 100 PAI/week is associated with a 25% reduced risk of mortality in healthy adults and 36% in patients with CVD ($p<0.001$)(Kieffer et al., 2018). Our research strongly supported the use of PAI as an effective strategy to increase the amount of physical activity performed by people with cardiac disease. Monitoring PAI via a WPAM was effective in significantly increasing the amount of physical activity within the cardiac population. In terms of exercise intensity, the amount of PAI accumulated whilst exercising at both medium and high intensity increased after viewing PAI, although not to statistically significant levels. However, there were statistically significant increases in the percentage of days participants achieved 25 and 50 PAI and the majority (89%) of participants increased their Total PAI after being educated about PAI and were able to view their PAI data. Our qualitative data found most participants were motivated to perform more, or higher intensity exercise when they were able to view the PAI data and would recommend PAI to others.

There were difficulties with the device itself with just under half of participants finding syncing and charging the device challenging. Some participants were confident they would continue to utilise the device for health benefits, motivation, and monitoring training. Others were unsure, however,

stated that if the WPAM improved the syncing function and aesthetics, along with offering greater functionality in line with comparative smart devices, participants would continue to use the device long term. These findings suggest PAI may be a viable strategy to assist people with cardiac disease maintain long-term exercise adherence.

CONCLUSION

This thesis has resulted in numerous insights to improve CR delivery. The results will hopefully aid in encouraging uptake of HIIT as an important tool in exercise prescription for people with cardiac disease. Particularly as the results further support the evidence to utilise HIIT as it is superior to current exercise prescription practices (MICT) in improving CRF and appears as safe as MICT.

Important considerations to improve Australian CR practices have been highlighted, particularly the lack of reassessment currently being performed within the exercise component by Australian CR programmes, thus quality of programmes cannot be adequately determined. CR is also not being offered frequently enough, nor long enough, to encourage lifetime exercise behaviour changes.

This thesis indicates that during the maintenance phase participants should utilise a WPAM as greater gains in CRF were shown. Monitoring a new exercise metric, PAI, is a promising adjunct and should be encouraged as viewing PAI significantly increased the amount of exercise performed by participants. In addition, all participants found the concept of PAI interesting and most participants stated it increased their motivation to exercise. These findings are original contributions to improve the knowledge in the area of exercise prescription and intensity in outpatient CR and home environments.

KEYWORDS

cardiac, exercise, physical activity, intensity, interval training, CR, wearables, Personal Activity Intelligence score

DECLARATION BY AUTHOR

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Doctor of Philosophy by Research.

I declare that the research presented within this thesis is a product of my own original ideas and work and contains no material which has previously been submitted for a degree at this university or any other institution, except where due acknowledgement has been made.

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Signature

Date: 14/09/2020

DECLARATION BY CO-AUTHORS

Publication co-authored	Statement of contribution
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Hannan, A., Hing, W., Climstein, M., Coombes, J.S., Furness, J., Jayasinghe, R., Byrnes. J. (2018). Australian cardiac rehabilitation exercise parameter characteristics and perceptions of high intensity interval training: a cross sectional survey*. Open Access Journal of Sports Medicine, 9, 79-89.* https://doi.org/10.2147/OAJSM.S160306 under licence CC BY-NC 3.0.	AH 85%, WH 5%, MC 2%, JC 2%, JF 2%, RJ 2%, JB 2%
Hannan, A., Harders, M., Hing, W., Climstein, M., Coombes, J.S., Furness, J. (2019). Impact of wearable physical activity monitoring devices with exercise prescription or advice in the maintenance phase of cardiac rehabilitation: systematic review and meta-analysis. *BMC Sports Science, Medicine and Rehabilitation, 11 (14), 1-21.* https://doi.org/10.1186/s13102-019-0126-8 under licence CC BY-NC 4.0.	AH 80%, MH 10%, WH 4%, MC 2%, JC 2%, JF 2%

Hannan, A., Hing, W., Coombes, J., Gough, S., Climstein, M., Adsett, G., Jayasinghe, R., Furness, J. (2020). Effect of Personal Activity Intelligence (PAI) monitoring in the maintenance phase of cardiac rehabilitation: A mixed methods evaluation. *Under review by BMC Sports Medicine and Rehabilitation. September 2020.*	AH 79%, WH 5%, JC 5%, SG, 3%, MC 2%, GA 3%, RJ 2%, JF 1%

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RESEARCH OUTPUTS

PEER-REVIEWED PUBLICATIONS

Hannan, A., Hing, W., Simas, V., Climstein, M., Coombes, J.S., Jayasinghe, R., Byrnes, J., Furness. J. (2018). High intensity interval training versus moderate intensity continuous training within cardiac rehabilitation: a systematic review and meta-analysis. *Open Access Journal of Sports Medicine, 9, 1-17. https:// doi.org/10.2147/OAJSM.S150596 under licence CC BY-NC 3.0. Impact factor 1.23.*

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Hannan, A., Harders, M., Hing, W., Climstein, M., Coombes, J.S., Furness, J. (2019). Impact of WPAM with exercise prescription or advice in the maintenance phase of cardiac rehabilitation: systematic review and meta-analysis. *BMC Sports Science, Medicine and Rehabilitation, 11 (14), 1-21. https://doi.org/10.1186/s13102-019-0126-8 under licence CC BY-NC 4.0. Impact factor 1.50.*

CONFERENCE PRESENTATIONS

Australian Cardiovascular Health and Rehabilitation Association Conference 2020:

Exercise Prize Session

Hannan, A., Hing, W., Simas, V., Climstein, M., Coombes, J.S., Jayasinghe, R., Byrnes, J., Furness. J. (2018). High intensity interval training versus moderate continuous training within cardiac rehabilitation: a systematic review and meta-analysis. *Open Access Journal of Sports Medicine, 9, 1-17.* https://doi.org/10.2147/OAJSM.S150596 under licence CC BY-NC 3.0.

ORAL PRESENTATION

Hannan, A., Hing, W., Climstein, M., Coombes, J.S., Furness, J., Jayasinghe, R., Byrnes. J. (2018). Australian cardiac rehabilitation exercise parameter characteristics and perceptions of high intensity interval training: a cross sectional survey. *Open Access Journal of Sports Medicine, 9, 79-89. https:// doi.org/10.2147/OAJSM.S160306 under licence CC BY-NC 3.0.*

POSTER

Hannan, A., Harders, M., Hing, W., Climstein, M., Coombes, J.S., Furness, J. (2019). Impact of wearable physical activity monitoring devices with exercise prescription or advice in the maintenance phase of cardiac rehabilitation: systematic review and meta-analysis. *BMC Sports Science, Medicine and Rehabilitation, 11 (14), 1-21. https://doi.org/10.1186/s13102-019-0126-8*
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ETHICS DECLARATION

The research associated with this thesis received ethics approval from the Bond University Human Research Ethics Committee:

Ethics application number:

Chapter 3: RO 1846

Chapter 5: 173657

Additional Trial: RO1916 (Trial not completed. Refer to Appendix 11-20)

Prospero registration number:

Chapter 2: CRD42017072093

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During this candidature I have experienced a myriad of emotions I never knew existed. I have learned an incredible amount about the trials and tribulations of research and the fulfillment that comes with receiving an “accepted for publication” notice. But most of all, I hope, in some small way, I will have contributed to improving service delivery, particularly the exercise component, of cardiac rehabilitation in Australia. By improving knowledge about the current landscape, educating health professionals about the value of high intensity interval training and offering an alternative way to monitor and ensure appropriate intensity of exercise is reached in the maintenance phase of cardiac rehabilitation, I hope this body of research will assist in providing long term protection for people with cardiac disease.

Mandy Hannan

CONTENTS

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LIST OF ABBREVIATIONS

Abbreviations within text of thesis:	
Anaerobic threshold	AT
Australian Capital Territory	ACT
Australian Cardiovascular Health and Rehabilitation Association	ACRA
Acute coronary syndrome	ACS
Cardiac Rehabilitation	CR
Care Assessment Platform	CP-CR
Cardiovascular disease	CVD
Cardiorespiratory fitness	CRF
Control	c
Coronary artery bypass graft	CABG
Coronary heart disease	CHD
Coronary artery disease	CAD
C-reactive protein	CRP
Electrocardiograph	ECG
Female	f
Generalised estimating equations	GEE
Graded exercise stress test	GXT
Heart failure	HF
Heart rate peak	HRpeak
Heart rate reserve	HRR
Highest value of volume of oxygen on a specific test	VO_2peak
High intensity interval training	HIIT
Implantable cardioverter-defibrillator	ICD
Information technology	IT
Interleukin 6	IL6
Intervention	i
Male	m
Maximum heart rate	MHR
Maximum volume of oxygen attainable by an individual	VO_2max
Moderate intensity continuous training	MICT
Myocardial infarction	MI
Myocardial revascularisation	MR
New South Wales	NSW
Non-ST elevation myocardial infarction	NSTEMI
Northern Territory	NT
Percutaneous Coronary Intervention	PCI
Physical Activity	PA

Personal Activity Intelligence	PAI
Physiotherapy Evidence Database Scale	PEDro-Scale
Preferred Reporting Items for Systematic Reviews and Meta-analysis	PRISMA
Quality of Life	QOL
Queensland	QLD
Randomised controlled trials	RCTs
Six minute walk test	6MWT
ST elevation myocardial infarction	STEMI
Tasmania	TAS
Total	t
Unstable Angina	UA
Valve repair	VR
Victoria	VIC
Wearable physical activity monitoring device	WPAM
Western Australia	WA
Abbreviations for Units of Measurement	
One repetition maximum	1 RM
British Pound	£
Days per week	d/week
Euro	€
Hour	hr
Kilogram	kg
Kilometre	Km
Metabolic Equivalent	MET
Metabolic Equivalents	METS
Millilitre	ml
Minute/s	min/s
Months	m
Volume of oxygen at ventilatory threshold	VT
weeks	wks
Years of life lost	YLL
Statistical Abbreviations	
Confidence Interval	CI
Heterogeneity	I^2
Inverse variance	IV
Mean difference	MD
Probability value	*p*
Standard deviation	SD
Standardized mean differences	SMD

THESIS STRUCTURE

This thesis is divided into six chapters. Chapter 1 provides an introduction, narrative summary and rationale for the following five chapters. It incorporates background information pertaining to CVD and secondary prevention, the history of CR and its' different phases, intensity of exercise, alternative models of service delivery, and an introduction to PAI. It concludes with research questions and subsequent aims to address these research questions.

Chapter 2 investigates the effect of CRF and step count resulting from HIIT versus MICT in the cardiac population including the effect of duration of intervention. A published systematic review and meta-analysis, as well as compilation of adverse events resulting from eligible trials is also presented to compare HIIT and MICT training regimes.

Chapter 3 explores current exercise parameters being used within Australian CR programmes via a cross sectional survey and includes a published manuscript. Australian CR demographics, specific exercise programme characteristics (length, size, duration, intensity of exercise, individual exercise session characteristics, outcome measures used, re-evaluation methods, staff: participant ratios) were collated, including a breakdown of results per state. Perceptions of HIIT implementation were also explored, namely perceptions about safety, pre-screening and monitoring requirements.

Chapter 4 investigates the effect of WPAM in the maintenance phase of CR, particularly focusing on changes in CRF and step count. A systematic review and meta-analysis were undertaken, as well as a qualitative analysis. The published manuscript is presented.

Chapter 5 presents an original concurrent mixed methods research trial investigating PAI monitoring in the maintenance phase of CR and its effect on Total PAI and PAI earned/day comparing blinded and un-blinded periods over six weeks. Perceptions of the device, concept of PAI and barriers to exercise were explored using a thematic framework analysis. Finally, Chapter 6

summarises the thesis results, limitations, implications for practice, and future research recommendations. Figure 1 represents a diagrammatic representation of the thesis structure.

In addition, of note, there was a further randomised controlled trial that was planned, ethics approval granted, and recruitment started as part of this thesis titled: A Pilot Study to Investigate the Effects of High Intensity Interval Aerobic and Resistance Training in Supervised Cardiac Rehabilitation and Home Environment. Unforeseen difficulties with equipment failure, recruitment and external organisational difficulties such as infrastructure and staff resourcing prohibited this project from being completed. However, as a large amount of time, planning and organisation had been done, the details have been presented in Appendix 11-20. There may still be an opportunity to revive this trial in the future.

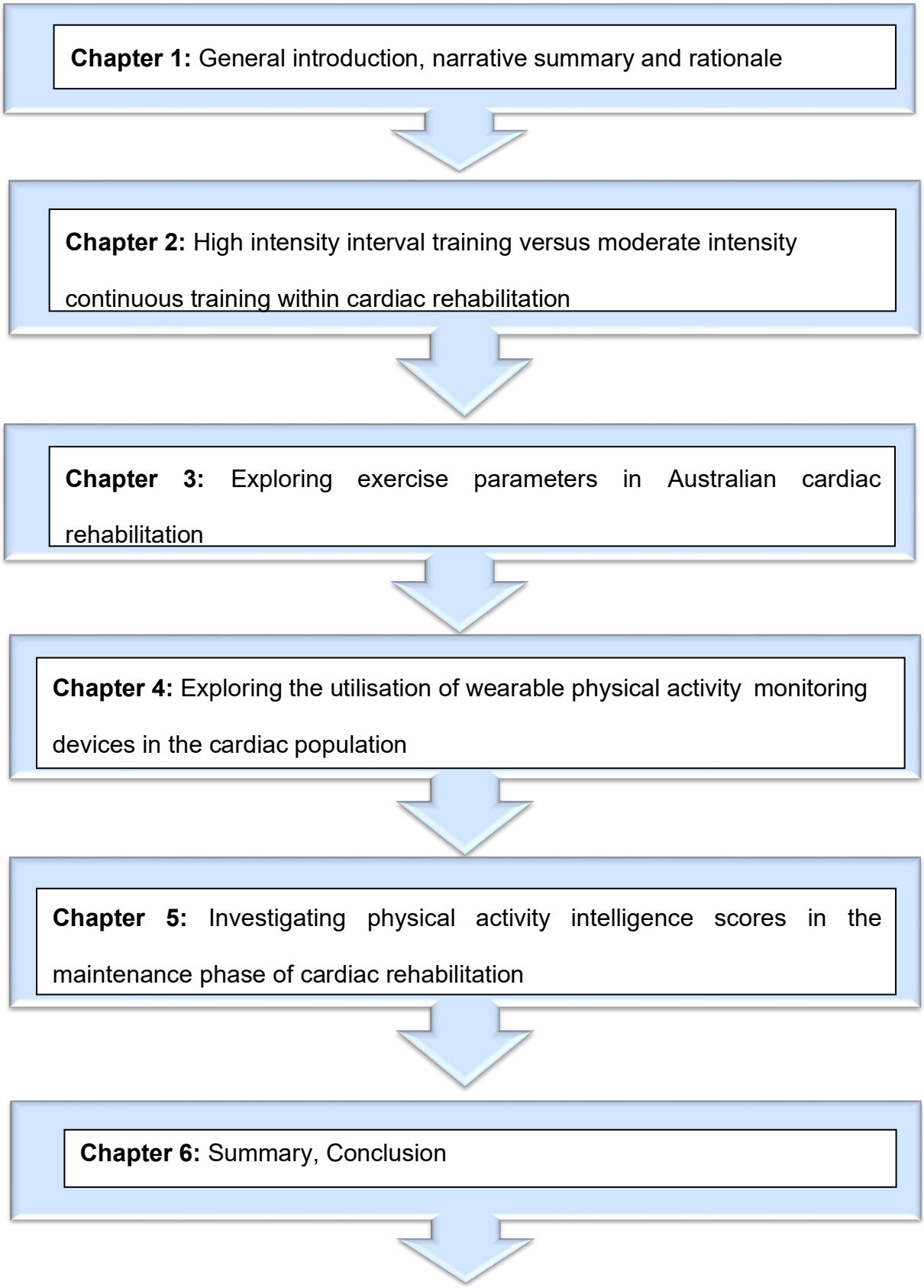

Figure 1. Diagrammatic Representation of Thesis Structure

CHAPTER 1: GENERAL INTRODUCTION

1.1 PREFACE

This chapter firstly aims to provide a narrative summary and background information on CVD, CR and intensity of exercise to highlight the need to improve physical activity outcomes for cardiac patients. Secondly, it aims to provide rationale for the ongoing chapters, outline research questions and hypotheses considered, and finally present the aims of the thesis.

1.2 General Introduction

A myocardial infarction (MI), or heart attack, is defined as an interruption of blood flow to the heart resulting in oxygen deprivation (myocardial ischaemia) and necrosis of part of the heart muscle (Thygesen et al., 2007). An MI usually occurs due to atherosclerosis, a narrowing of the arteries from a build-up of cholesterol and fatty deposits in the coronary arteries or from rupture of a plaque resulting in a blood clot. Underlying coronary heart disease (CHD) caused by atherosclerosis is the most common cause of an MI (Heart Foundation, 2019). CHD is responsible for 14.9 million deaths globally and deaths attributed to CHD have risen 19% between 2006 and 2016 (Naghavi et al., 2017).

A systematic analysis for the Global Burden of Disease Study in 2017 ranked CHD as the leading cause of years of life lost to premature death surpassing lower respiratory infections (Naghavi et al., 2017). Australia mirrors the global CHD mortality climate. The Australian Bureau of Statistics (2019) reported 18,590 deaths (12%) resulted from ischaemic heart disease, rating it Australia's leading cause of death and responsible for one death every twenty eight minutes. The Australian Institute of Health and Welfare (2018) also reported CHD as the leading cause of death in males (10,870 deaths), for people aged 45-64 years and over 75 years, regardless of geographic residence. However, in very remote areas, the age-standardised mortality rate was 1.7 times higher than those living in major cities (Australian Institute of Health and Welfare, 2018). Additionally, Indigenous Australians have higher rates of hospitalisation and death caused by CHD than non-indigenous people (Health*InfoNet*, 2019).

According to Deloitte Access Economics (2011), individuals suffering from subsequent MI cost Australian residents $8.4 billion and almost 50% of deaths occurred in those who had previous cardiac events. The National Heart Foundation of Australia (2010) estimates that by 2020 there will be an additional 5,400 admissions per year to hospital attributed solely to complications arising from previous MI and over 100,000 admissions with acute coronary syndrome (ACS). ACS is an umbrella term that refers to cardiac clinical presentations resulting in a diagnosis of non-ST elevation MI (NSTEMI), ST elevation MI (STEMI) or unstable angina (UA). More recently, National Heart Foundation of Australia (2018) estimated

the cost associated with ACS to be $1.9 billion and Schofield et al. (2019) projected the number of people out of the workforce due CHD will rise from 6700 in 2015 to 8100 in 2030. This would result in an increase in costs due to lost income from $273 million in 2015 to $443 million in 2030 (Schofield et al., 2019). Although CHD mortality appears to be decreasing in developed countries, the global aging population, growth, and longer-term survival rates from acute MI is increasing the global economic burden. Deaths from CHD have been predicted to remain high into the next decade (Jernberg et al., 2015; Johansson et al., 2017). Death rates, years of life lost and the financial burden caused from CHD are crucial global health issues, therefore the quality of secondary prevention is of paramount importance.

Secondary prevention of cardiovascular disease (CVD) entails health care measures that focus upon reducing recurrence and complications associated with CVD (National Heart Foundation of Australia, 2010). People admitted to hospital following a cardiovascular event, often receive revascularisation (angioplasty, stent or bypass) and are discharged with pharmacological intervention and medical follow-up. Only 27% of patients are discharged with comprehensive secondary prevention strategies (The George Institute for Global Health, 2014). Secondary prevention recommendations for CHD in Australia comprise targeted risk factor reduction measures (controlling blood pressure and weight, reducing lipid levels and incidence of social isolation, smoking cessation and increasing physical activity levels), influenza and pneumococcal vaccinations and referral to cardiac rehabilitation (CR) services (National Heart Foundation of Australia, 2010).

CR is an important tool in secondary prevention of CVD and facilitates participants to lead full and active lives whilst reducing the likelihood of suffering subsequent cardiac events (Anderson, Thompson, et al., 2016; Taylor et al., 2004). CR involves education, lifestyle behaviour modification, psychosocial support and supervised exercise programmes. Participation in CR programmes helps to educate clients about reducing the likelihood of suffering subsequent cardiac incidents and is particularly helpful to people who have ACS, percutaneous coronary intervention (PCI), CAD, and/or who have undergone cardiac surgery (National Heart Foundation of Australia, 2010). The National Heart Foundation of Australia, Australian Cardiovascular and Rehabilitation Association (ACRA) and Australian Commission advocate for automatic referral to CR (Australian Commission on Safety and Quality

in Health Care, 2012; National Heart Foundation of Australia, 2010; Woodruffe et al., 2015).

1.2.1 History of Cardiac Rehabilitation (Phase 2)

CR originated in 1950 in Cleveland, Ohio by an American cardiologist, Dr Herman Hellerstein. Before this time, it was common to advise people who had suffered an MI to rest in bed for six to eight weeks (Certo, 1985). This prescription progressed to chair exercises and brief three-minute walks daily. Engaging in more demanding exercise was deemed unsafe until in 1968, when Dr Hellerstein, despite facing strong opposition, engaged 200 patients in aerobic exercise after discharge from hospital and found both physiological and psychological benefits with no negative effect on morbidity or mortality (Hellerstein, 1968). In Australia, CR was first delivered in 1961 as part of a National Heart Foundation initiative (Jelinek & Bunker, 2007). CR in Australia first began by the establishment of clinics in four major cities: Melbourne, Sydney, Brisbane and Hobart. Programmes consisted of light-moderate exercise, education and group discussions. In the early 1990s, a decentralised model emerged, and hospital and community based programmes were established. Low-moderate intensity exercise was advocated as this required no special equipment or medical supervision and was much cheaper to run (Jelinek & Bunker, 2007). With advancing research surrounding the safety of aerobic exercise, CR has slowly evolved and today incorporates recommendations for thirty minutes of moderate intensity exercise on most days of the week (National Heart Foundation of Australia, 2010).

The aim of CR is to facilitate and shorten the period of recovery following an acute cardiac incident, promote strategies for achieving mutually agreed goals for ongoing prevention, develop self-management skills, engage community services and reduce the risk of subsequent events (National Heart Foundation of Australia, 2010). CR in Australia has three phases. Phase 1 occurs within the hospital setting directly following a cardiac event, Phase 2 occurs in the outpatient setting during the subacute phase and usually lasts 4-12 weeks. Phase 3 refers to the maintenance, or longer term period, after a cardiac event and usually refers to the period of recovery following Phase 2 CR (National Heart Foundation of Australia, 2010). Phase 1

usually involves basic education delivered in the acute hospital setting and simple mobility such as walking. Phase 2 CR in Australia usually involves attending a programme supervised by health professionals such as nurses, physiotherapists and exercise physiologists within a hospital or community setting, 1-2 times a week for 4-12 weeks (Abell et al., 2016). Health education, physical activity, lifestyle behaviour modification counselling, nutritional advice, self-management strategies and psychosocial support are the cornerstones of CR. Phase 3 usually involves advice given to maintain healthy behaviours for the long-term including continued participation in physical activity and exercise.

Attendance at Phase 2 CR and engaging in secondary prevention has high level evidence to show these initiatives decrease mortality and morbidity (Dalal et al., 2007; National Health and Medical Research Council, 2014). Heran et al. (2011) conducted a Cochrane review and meta- analysis which included 10,794 patients in 47 trials. The review reported a 26% reduction in cardiac associated mortality and fewer readmissions in those attending CR compared to medical care alone. Additionally, Lawler et al. (2011) analysed 34 randomised controlled trials (RCTs) and found significantly less re-infarctions occurred in CR participants. Additional Cochrane reviews conducted by Joliffe et al. (2001) and a meta-analysis by Lawler et al. (2011) have shown a 13-27% reduction in all-cause mortality for participants engaging in CR. The cost effectiveness of CR in Australia has also been investigated and was reported by Briffa et al. (2011) as equating to approximately $42,535 per quality adjusted life year saved (allowing for effect on survival).

In 2010, the National Heart Foundation published its secondary prevention of CVD action plan, advocating for an improvement in funding and accessibility to CR (Redfern et al., 2011). In 2012, an Australian National Taskforce was set up by collaboration between the National Heart Foundation and the George Institute for Global Health to develop a Blueprint for Reform. This reform outlines a Five Point Action Plan to combat the incidence of recurrent MI. The action plan involved developing and implementing a national approach to secondary prevention, bridging the gap between hospital and primary care, increasing the awareness and utilisation of existing services by patients, developing a system for monitoring and maintaining performance and implementing a communication strategy to facilitate sustainability (Chow & Redfern, 2013). In 2014, a follow up document was released highlighting

achievements and progress for the above strategic direction with further ongoing recommendations, particularly focusing on increasing attendance numbers and adherence to CR (The George Institute for Global Health, 2014). This was imperative as an audit of Australia and New Zealand secondary prevention practices in 2014 reported less than half (46%) of eligible people were referred to CR and only 27% of people with cardiac disease received comprehensive preventative care (Redfern et al., 2014).

Although attending CR is essential, there has been little focus on whether Australian CR programmes are delivering up to date evidence-based care. Despite the growing evidence of the importance of functional capacity in all-cause cardiovascular mortality and morbidity, the extent to which CR programmes in Australia improve patients' physical outcome measures is not a focus of the aforementioned action plan. Numerous studies have shown mortality benefits based on cardiorespiratory fitness (CRF). Swain and Franklin (2006) stated that every 1 metabolic equivalent (MET) improvement in CRF resulted in an 8-17% reduction in all-cause mortality (Swain & Franklin, 2006). This was further supported by Myers et al. (2002) who reported a person's MET value predicted mortality better than other risk factors for CVD, with higher MET values reducing mortality more than lower MET values. Furthermore, Keteyian et al. (2008) reported a 1ml/kg/min increase in the highest value of oxygen uptake on a specific test (VO_2peak) resulted in a 15% decrease in risk for all-cause and CVD mortality and predicted prognosis in patients with known CVD. After analysing 985 subjects, Hung et al. (2014) also concluded that CRF was a strong predictor of mortality in patients with CAD. These findings support the theory that the greater a patient's CRF, the less likely they are to experience a future cardiac event, and this should, therefore, become a primary focus in improving patient outcomes. CR programmes should be made accountable to ensure CRF is improving within individual programmes.

1.2.2 Intensity of Exercise

Wisloff et al. (2007) conducted research on 5,106 patients, and demonstrated that exercise intensity, not duration, was more important in relation to all-cause CVD and mortality. Longer periods of times spent exercising at higher levels of VO_2peak correlated with improvement in maximal CRF, which refers to the body's efficiency in delivering oxygen to working muscles. It is dependent on the pumping ability of the heart, the lungs ability to extract oxygen from the environment, delivery of oxygen rich blood to the muscles and the mitochondria's ability to extract the oxygen and produce energy for exercising muscles. The gold standard test which assesses CRF is a cardiopulmonary exercise test which measures the maximum volume of oxygen that the body can use during exercise performed to exhaustion (VO_2max) (Pescatello, 2014). CRF is improved by performing exercises that use large muscle groups in a rhythmical fashion which elevates heart rate. Attending CR reduces mortality, however further reductions in mortality result from greater CRF (Swain & Franklin, 2006). Therefore, participants attending CR should be prescribed exercise which improves CRF to the greatest extent.

Two commonly used regimes to improve CRF are moderate intensity continuous training (MICT) and high intensity interval training (HIIT). MICT involves exercising at a moderate level usually 60-75% maximal heart rate (MHR), for a prolonged period (30-60min). HIIT is defined as exercise at ≥85% VO_2peak or ≥85% heart rate reserve (HRR) or ≥ 90% MHR interspersed with lower level or no exercise (Pescatello, 2014), usually between 30 seconds and four minutes. Studies researching the effect of HIIT have shown it results in a rapid improvement in fitness with less time commitment required than MICT. HIIT allows the same volume of work to be completed in a shorter time as well as rest periods, or lower activity, allowing for participants to work at higher intensities than could be sustained with continuous training and HIIT improves CRF to a greater extent than MICT (Cardozo et al., 2015; Keteyian et al., 2014; Weston et al., 2014).

1.2.2.1 BACKGROUND: HIGH INTENSITY INTERVAL TRAINING

Elite athletes were the first group to use HIIT as a training technique. In 1936, Rudolf Harbig trained using HIIT and subsequently broke three world records. Gerschler was the pioneer behind developing HIIT as a training protocol. Under his guidance, in 1954, Roger Bannister was the first man to break the 4 minute mile using HIIT (Mosley & Bee, 2013). Currently, HIIT forms part of every top elite endurance athlete's training regime and has been shown to improve VO_2max, insulin sensitivity and mitochondrial density (allowing for improved oxygen extraction), to a greater extent than traditional continuous exercise (Mosley & Bee, 2013).

The benefits of HIIT in patients with CHD has been investigated since 1981 (Ehsani et al., 1981). This type of training regime has become of interest to clinicians working with patients diagnosed with chronic disease; particularly metabolic syndrome, CHD and heart failure (HF). A study by Ramos et al. (2015) found that HIIT reversed metabolic syndrome with all participants in the HIIT intervention showing no signs of the condition after 16 weeks of training compared with no change in the condition in the continuous exercise group. In addition, Kessler et al. (2012) published a review investigating HIIT and its potential to reduce cardio-metabolic disease risk. The review included 17 studies. Participants had risk factors of metabolic syndrome, CAD and HF. The authors found improvement in skeletal muscle sarcoplasmic reticulum calcium uptake, and stroke volume was increased only in participants engaged in interval training and concluded that HIIT was superior in improving maximal oxygen consumption to a greater degree than MICT. These positive benefits, coupled with HIIT requiring less time to implement, resulted in interest in researching the effects of HIIT implementation in the CHD population, particularly as lack of time has been reported as a major barrier to exercise participation in patients with cardiac disease (Gibala et al., 2012).

1.2.2.2 Benefits of HIIT for Clients with Coronary Artery Disease

The following section outlines research findings surrounding the beneficial physiological changes resulting from HIIT regimes used within the cardiac population.

1.2.2.2.1 Effects on Aerobic Capacity

Growing evidence is demonstrating superior patient outcomes resulting from HIIT in patients with coronary artery disease (CAD). There have been four systematic reviews reporting on the positive effects (specifically change in VO_2peak) of HIIT versus MICT in patients with CAD; all of which concluded that interval training is superior to MICT in improving CRF (Cornish et al., 2011; Elliott et al., 2015; Liou et al., 2016; Pattyn et al., 2014). The first systematic review by Cornish et al. (2011) included seven studies with a total of 213 participants. There were limitations in the studies included, with two trials being non-randomised and two failing to report exact exercise parameters used by control groups. The review found VO_2peak and VO_2 at ventilatory threshold (VT), all significantly improved by HIIT more than MICT.

A second systematic review and meta-analysis by Pattyn et al. (2014) investigating HIIT vs MICT in CAD patients identified nine RCTs and concluded that HIIT improved VO_2peak more than MICT. In addition, a meta-analysis by Elliott et al. (2015) which included six RCT studies with 229 patients up to December 2013 also found VO_2peak changes were significantly higher in the HIIT group compared with the MICT. Finally, a review by Liou et al. (2016) included ten RCTs. The researchers, after analysing 218 HIIT and 254 MICT subjects from the ten studies, concluded that HIIT improved VO_2peak significantly more than MICT. This systematic review included a study by Conraads et al. (2015) which had the largest sample size to date (n=200). The results of this larger trial found CRF improvements were similar between HIIT and MICT participants (17.6% improvement VO_2peak in HIIT group vs 15.3%VO_2peak in MICT group). In this RCT, HIIT participants were prescribed exercise at 90-95% peak heart rate (HRpeak) and MICT participants were prescribed 70-75% HRpeak. However, authors reported that the MICT group actually exercised closer to 80% HRpeak and HIIT group actually exercised

closer to 88% HRpeak (Conraads et al., 2015). The higher intensity used by the MICT group and lower intensities for the HIIIT participants may account for the non-significant results as the actual intensities used in this study were higher for MICT and lower for HIIT than previous studies used (65-75% HRpeak for MICT and 85-95% HRpeak for HIIT). The two distinct intensities were not too dissimilar, which may account for similar improvements found in VO_2peak in both groups. Although these reviews all showed greater improvements in CRF with HIIT, none investigated whether the duration of intervention mattered.

1.2.2.2.2 Effects on Heart Function

Researchers have found clinical evidence that HIIT improves heart function and can improve efficiency of the cardiovascular system. Using echocardiogram and doppler to investigate the effects of HIIT and MICT on cardiac function, Wisloff et al. (2007) demonstrated left ventricular end diastolic and end systolic volumes reduced only in HF participants engaged in HIIT. Additionally, participants' ejection fraction increased by 35% and B-type natriuretic peptide decreased 40% in HIIT participants. Improvement was also reported in brachial flow mediated dilatation, a measure of vascular function, which was greater in HIIT participants (Wisloff et al., 2007). Another study by Amundsen et al. (2008) also found left ventricular filling speed and diastolic relaxation increased only in HIIT participants. The systematic review by Cornish et al. (2011) reported left ventricular size and function, contractile function, left ventricular diastolic diameter, diastolic volume, posterior wall thickening, fractional shortening, rate pressure product, ejection fraction and endothelial function all improved more in participants engaged in HIIT, therefore, showing positive outcomes for heart function.

Additional benefits of HIIT on heart function have also been reported. HIIT was shown to reduce myocardial ischaemia at the same or higher rate pressure product in patients with CHD by Ehsani et al. (1981). Resting heart rate has been reported to decrease with HIIT training and in theory, it has been postulated that HIIT could be safer than continuous training when going above the ischaemic threshold as HIIT results in intermittent ischaemia rather than prolonged ischaemia, and improved collateral circulation (Guirand et al., 2010). Finally, Jaureguizar et al. (2016) found

heart rate recovery improved only in HIIT participants, however blood pressure and resting heart rate were not found to be significantly different between groups.

1.2.2.2.3 Effects on Inflammation

Inflammation can have detrimental effects on patients with cardiac disease. The effects of inflammation on tissue function was investigated by Munk et al. (2009). These researchers demonstrated HIIT reduced stent restenosis, improved endothelial function, decreased vascular systemic inflammation and attenuated the interleukin 6 C-reactive protein (IL6-CRP) pathway, reducing the risk of future cardiac events (Munk et al., 2011).

1.2.2.2.4 Effects on Skeletal Muscle Physiology

Wisloff et al. (2007) investigated the effect HIIT versus MICT had on skeletal muscle physiology. These researchers found mitochondrial function in vastus lateralis muscle only increased with HIIT and maximal rate of calcium reuptake in sarcoplasmic reticulum increased 60% only for HIIT participants. This evidence that HIIT improves skeletal muscle physiology may therefore be partly responsible for the greater efficiency of the cardiovascular system resulting with HIIT compared to MICT.

1.2.2.2.5 Effects of HIIT on Common Outcome Measures in Cardiac Rehabilitation

Common outcome measures used in CR are six minute walk tests, treadmill speed, time to exhaustion, body fat, cholesterol, blood pressure and glucose regulation. There is limited research investigating the effect of HIIT on six-minute walking distance or treadmill speed. Jaureguizar et al. (2016) found a significant improvement in six-minute walking distance in both HIIT and MICT groups, however the HIIT participants increased their walking distance significantly more than MICT participants (49.6+/-6.3m vs 29.6+/-12m respectively). Rognmo et al. (2004) found a

statistically significant increase in treadmill test speed for HIIT participants compared with MICT participants when comparing pre and post measures (5.3+/-1.7 km/hr to 6.8+/-1.8 km/hr vs 5.7+/-1.7 km/hr to 6.8+/-1.8 km/hr; $p<0.02$ respectively). Additionally, Warburton et al. (2005) reported HIIT participants improved time to exhaustion whereas MICT group participants did not.

With respect to body fat, a systematic review by Pattyn et al. (2014) reported MICT was superior to HIIT in reducing body weight. However, more recently, a systematic review by Keating et al. (2017) reported no meaningful difference in the reduction of body fat in either HIIT or MICT groups. With respect to cholesterol, Kessler et al. (2012) found HDL cholesterol and blood pressure improved more with HIIT. Finally, studies have shown HIIT to improve mitochondrial biogenesis, insulin sensitivity (Kessler et al., 2012) and glucose regulation (Gibala et al., 2012), all of which are important for patients with CHD.

1.2.2.6 Effects on Adherence, Enjoyment and Quality of Life

There is some evidence that HIIT is a preferred mode of exercise as reported by patients. HIIT has been perceived as more enjoyable than MICT in a small group of runners and is more time efficient, both which may have positive implications for adherence (Bartlett et al., 2011). Within the cardiac population, Guirand et al. (2010) reported that HIIT is better tolerated by patients than MICT and found patients reported less dyspnoea during this type of training. Similarly, Munk et al. (2011) reported patients were more motivated in the HIIT sessions versus MICT and described MICT as being boring. Additionally, a trial by Vella et al. (2017) reported HIIT and MICT groups were similarly enjoyable and both groups had high adherence rates in overweight and obese adults.

More recently, a systematic review by Oliveira et al. (2018) which analysed trials comparing effects of acute bouts of HIIT and MICT on affective and enjoyment responses in healthy and overweight individuals, concluded that less strenuous bouts of HIIT, using adequate rest between intervals, had a positive effect on affective/enjoyment responses. However, HIIT performed at strenuous levels with less recovery time was perceived as less enjoyable (Oliveira et al., 2018). Another

systematic review and meta-analysis by Niven et al. (2020) including healthy and clinical populations, reported HIIT was perceived less positively (affect), but more enjoyable afterwards than MICT. The review highlighted the need to further define affect and enjoyment.

Furthermore, a randomised crossover trial by Sagelv et al. (2019) which investigated healthy participants engaging in a 4 x 4 min HIIT interval prescription (commonly used in research investigating HIIT in the cardiac population) found reported exercise enjoyment was similar for both types of exercise regimes and thus concluded adherence would be similar across groups.

There is conflicting evidence in the literature with respect to the effect of HIIT versus MICT on Quality of Life (QOL) scores. Munk et al. (2011) reported higher QOL scores in HIIT participants. Similarly, Benetti et al. (2010) found HIIT participants improved quality of life scores in the physical domain significantly more than MICT participants. Conversely, several authors showed no significance difference in quality of life scores between HIIT and MICT participants (Conraads et al., 2015; Jaureguizar et al., 2016; Moholdt et al., 2012). In addition, a systematic review and meta-analysis by Gomes-Neto et al. (2017) reported no significant differences in the physical and mental components of SF 12 and SF 36, nor the physical, emotional, social domains of quality of life in the MacNew questionnaire between participants with CAD training using HIIT versus MICT.

1.2.3 Challenges of Prescribing HIIT

Despite the above evidence, there is active debate among researchers and clinicians regarding the usefulness of prescribing HIIT within CR settings and as a public health strategy. According to Biddle and Batterham (2015) both camps (those for and against HIIT) agree that HIIT results in better CRF for participants. The differing perspectives surround motivation, exercise adherence (both short and long term) and, reach, with the anti-HIIT group suggesting that HIIT is perceived negatively, causes unpleasant feelings which could deter further exercise, reducing motivation and adherence and would not be the mode of choice for most people diminishing its reach. In the paper written by Biddle and Batterham (2015) Biddle

believes the focus should be more on increasing the number of active adults rather than specifically advocate HIIT. Conversely, in the same paper, Batterham supports the use of HIIT and highlights that the research showing HIIT is perceived as unpleasant was based on a protocol known as sprint interval training (20-30 seconds of all out sprints) which is not used in clinical populations and referenced the study by Jung et al. (2014) who reported participants engaged in HIIT had more positive affect than MICT. This was further supported by Martinez et al. (2015) who found similar positive effect in overweight, sedentary adults.

Another controversial area surrounding HIIT prescription is the perception that there is a lack of reliability of exercise intensity prescription of HIIT for patients on beta blockade. However, Chaloupka et al. (2005) reported percentage VO_2peak, percentage HRpeak and percentage HRR were all an accurate estimation of the exercise training intensity in patients treated with beta blockers after MI.

1.2.4 Safety of HIIT

There is anecdotal concern among clinicians surrounding the safety of an acute bout of exercise and HIIT. Research has shown that the risk of an adverse CVD event may increase during or after an acute bout of exercise and could lead to platelet activation and possible arterial thrombosis (Linden et al., 2007; Whittaker et al., 2013). However, a study by Haynes et al. (2018) reported an acute bout of exercise resulted in vasodilation for up to one hour post exercise and no evidence of platelet activation. It was reported that this may be due to a compensatory shear-mediated activation of the epithelium which may offset the impact of platelet activation. However, this was based on a small number of middle aged participants without cardiac disease.

Research investigating the safety of HIIT in the cardiac population is limited. However, a retrospective analysis of 4,846 patients with CVD by Rognmo et al. (2012) analysed 175,820 hours of exercise training for rates of adverse events. With regard to safety, they found 1 fatal event was reported per 129,456 hours of MICT and 2 non-fatal events per 23,182 hours of HIIT and concluded that the risk of adverse events were low in both modes of exercise and the authors recommended

the use of HIIT for people with CAD due to the significant cardiovascular adaptations gained from its use.

More recently, a systematic review by Wewege et al. (2018) investigating the safety of HIIT analysed 23 studies (1117 participants) who had CAD and HF. The authors reported one major cardiovascular event per 17,083 training sessions (11,333 hours) and concluded HIIT has a low rate of major cardiovascular events during CR.

1.2.5 Australian Exercise Guidelines and HIIT

In Australia, two studies from Melbourne conducted by Goble et al. (1991) and Worcester et al. (1993) concluded that light to moderate exercise showed similar results to HIIT despite, at eight weeks, results by Worcester et al. (1993) showing a significant difference in MET levels, with HIIT increasing by 1 MET more than MICT (p=0.005) and results by Goble et al. (1991) reporting HIIT significantly increased MET levels by 0.9 METs more than MICT at 11 weeks. Both studies showed no significant difference between groups at 12 months. In addition, a further study by Blumenthal et al. (1988) also showed no significant difference in VO_2max between HIIT and MICT training regimes after 12 weeks of exercise. These studies were used to influence exercise prescription guidelines in Australia (Jelinek & Bunker, 2007). However, the participants in the high intensity groups in all three studies did not exercise above 75% MHR, therefore participants were actually training at a moderate intensity. The reliance of these papers to justify low to moderate intensity exercise over HIIT is therefore flawed and was a barrier to changing guidelines within Australia. Currently, the Australian guidelines still recommend low to moderate intensity activity, however does state that HIIT may be offered to participants with high levels of fitness who aim to return to high intensity physical activity as long as they receive consent from their treating doctor (Woodruffe et al., 2015).

The literature thus far, appears to support HIIT being superior to MICT in improving CRF, endothelial, heart and mitochondrial function; and decreasing inflammation. These physiological adaptions are favourable in reducing the risk of CVD, therefore would be beneficial for people living with cardiac issues.

However, there are no studies, which have investigated the effect of training for different durations, nor has there been a collation of adverse events across RCTs comparing HIIT and MICT in the cardiac population. Additionally, there is no literature examining the prevalence of HIIT usage in Australian CR settings, nor clinicians' perceptions about HIIT in Australia.

1.2.6 MAINTENANCE (PHASE 3)

In reducing mortality and morbidity from CVD, higher levels of CRF need to be maintained long-term. Once participants complete supervised outpatient CR, they need to ensure they maintain their fitness to benefit from the cardioprotective effects of physical activity. However, little research has investigated the amount of exercise or intensity of exercise participants perform after Phase 2 CR.

A systematic review and meta-analysis published by Claes et al. (2017) investigated the longer term effects of home based exercise and physical activity in CAD patients compared with usual care or centre based rehabilitation. Non-randomised and randomised trials with a follow up period of greater than 12 months were included. Seven studies were included in the meta-analysis on exercise capacity. Included trials could have reported exercise capacity as METs, Watts or peak oxygen consumption (Aamot et al., 2016; Arrigo et al., 2008; Brubaker et al., 2000; Karjalainen et al., 2015; Lear et al., 2003; Madssen et al.; Smith et al., 2004) and two were included in the meta-analysis on physical activity (Lear et al., 2003; Smith et al., 2004). They found no significant differences in exercise capacity between home-based and usual care and a small significant difference in exercise capacity between home and centre-based, in favour of home-based exercise. However, upon closer inspection of the data, the authors found that all but one study by Madssen et al. (2014) reported higher exercise capacity (VO_2peak) in the home-based group. Sample sizes of trials investigating home-based exercise ranged from

48-302 participants. There was a large variation of exercise delivery, particularly frequency (2-6 times; median 4), intensity (50-65% HRR, 70-80% of HRR or 75-95% MHR and/or Borg rating scale of 11-13/20), type (endurance) and duration (30-70mins) with a median follow up time of 12 months. Monitoring was also varied from the use of logbooks, diaries, telephone calls, group gatherings and home visits.

A study by Smith et al. (2011) examined longer term maintenance of CRF following CR both in the home and hospital environments. Participants in this study underwent coronary artery bypass graft surgery (CABG) and subsequently performed Phase 2 in either the home environment or the hospital setting. Both groups then continued to exercise at home for six years after CR. The authors found that participants who performed Phase 2 in the home environment compared with Phase 2 in the supervised, hospital-based setting had less decline in exercise capacity (VO_2peak) after six years. They also found greater compliance to regular physical activity and fewer hospital admissions for those who performed Phase 2 in the home. Over the six years, both groups fitness levels declined from immediate post CR levels attained, however exercise capacity (VO_2peak) remained above levels measured before attending CR. This suggests that performing CR in the home rather than attending a hospital-based programme, may develop better lifestyle behaviour change as patients viewed the intervention as a lifestyle change rather than a treatment with a finite timeframe.

Furthermore, there are varying views in the literature regarding the current amounts of physical activity and intensity being performed in the maintenance phase of CR. An American study by Bock et al. (2003) reported that participants who participated in a phase 3 CR programme were significantly more likely to continue regular activity and a larger percentage of participants engaged in vigorous activity. Conversely, Khushhal et al. (2019) reported exercise training intensity in the UK during Phase 3 CR was below the minimum recommended intensity guidelines and may be contributing to poor CRF improvements. Currently, there is no literature which investigates the longer-term exercise practices of cardiac patients in Australia, nor the intensity of exercise currently being performed.

1.2.7 ALTERNATE METHODS FOR PROVIDING CARDIAC REHABILITATION

In Australia, alternate methods of delivering CR to improve geographic reach, has been of interest in recent years. A systematic review by Clark et al. (2015) identified 83 studies describing alternate ways of providing CR. However, these studies were based primarily in Phase 2. These included multifactorial individualised telehealth, internet-based delivery, telehealth interventions focused on exercise, telehealth interventions focused on recovery, community or home-based CR, rural and remote programmes and multiple models of care and alternative, complimentary models. The authors concluded that community or home-based CR produce similar reductions in cardiovascular risk factors compared with hospital-based programmes. Most of the studies to date investigating CR in the home have been conducted during Phase 2 (subacute CR). However, continuation of exercise during Phase 3 (maintenance) and beyond is required to maintain the gains made during Phase 2 and to provide cardio-protective benefits long term.

Wearable technology is thought to improve the amount of physical activity people engage in and is also an alternative CR delivery method (Ehn et al., 2018; Finkelstein et al., 2016; Gualtieri et al., 2016; Jang et al., 2018). Exercise interventions and devices studied in the home environment in people with CAD have utilised:

- accelerometers and self-reported physical activity logs (Pinto et al., 2011)
- pedometers (Butler et al., 2009; Cheng et al., 2016; Furber et al., 2010; Sangster et al., 2017)
- electrocardiograph monitoring, video conferencing, DVDs, one lead ECG and BP trans-telephonic and electronic data transmission (Scalvini et al., 2013)
- tele-medicine delivered exercise (Dalleck et al., 2011)
- Heart Manual with telephone support (Dalal et al., 2007)
- smartphone, ECG and GPS (Worringham et al., 2011)
- Veteran Affairs Fitheart mobile web application (Beatty et al., 2018)

There is conflicting evidence in the literature surrounding the benefits of using pedometers to promote physical activity. A study by Butler and Dwyer (2004) found no difference in the amount of walking completed by healthy participants wearing a pedometer displaying the step counts compared to the step counts being obscured from patients. However, a systematic review by Bravata et al. (2007) found the use of a pedometer in healthy populations significantly increased physical activity. This was further supported by Butler et al. (2009) who reported pedometers increased adherence and physical activity in cardiac patients.

The previously listed exercise monitoring devices were successfully implemented in the home environment and have their own inherent advantages and disadvantages. Using ECG or tele-cardiology monitoring is expensive and staff intensive, whereas pedometers and accelerometers are cheaper. Pedometers do monitor steps, however, do not capture intensity of exercise. Accelerometers only capture locomotion and are not as accurate when performing stationery cycling or elliptical equipment and cannot usually be worn swimming (Physical Activity Resource Center For Public Health, 2020). The current physical activity advice of 10,000 steps, which could be performed slowly or briskly, also does not take intensity and heart rate into account (National Heart Foundation of Australia, 2010).

1.2.8 Personalised Activity Intelligence

Combining duration and intensity of physical activity which is also easily understood by the lay-person and can feedback information regarding CVD risk would potentially counter the issues with exercise monitoring devices described above. Providing one number for participants to monitor may reduce confusion and be a suitable solution. Nes et al. (2016) therefore developed and validated an algorithm which they described as Personalised Activity Intelligence (PAI) which addresses problems with other physical activity tracking devices. PAI is a personal activity score which monitors your heart rate and thereby exercise intensity and converts each exercise session into a PAI score (Zisko et al., 2017). PAI will therefore be accrued differently for each individual and the higher the intensity of exercise, the more PAI will accumulate. A PAI score of 100 or more over a week has been shown to reduce the risk of CVD mortality by 17-23% compared with more

sedentary subjects (Nes et al., 2016). PAI can be tracked using a wearable physical activity monitoring device (WPAM). There are no studies to date, which have investigated whether PAI could benefit people in the maintenance phase of CR by improving adherence to exercise regimes and increasing the amount and intensity of exercise and subsequently reduce their cardiovascular risk. Additionally, previous research has found lack of motivation and time were the most common barriers to engaging in physical exercise in participants with CAD (Alharbi et al., 2017). This was further supported by Bravata et al. (2007) who concluded lack of motivation negatively influenced self-efficacy for exercise. Furthermore, Ruano-Ravina et al. (2016) reported low adherence for people who lacked transportation or who live further from CR facilities. These barriers may potentially be overcome with the assistance of a WPAM which monitors PAI and encourages long-term activity.

1.3 Summary and Rationale

CR is a key component in secondary prevention of CVD, the leading cause of death worldwide. CRF has been shown to be inversely proportionate to mortality and morbidity. Therefore, to reduce the risk of further cardiac events, patients should aim to improve their CRF levels as much as possible after experiencing a cardiac issue and these increased levels need to be maintained long-term for ongoing cardio-protection. CR aims to improve participant's health and wellbeing and exercise is a core component in achieving this. Yet, currently there is minimal research, particularly in Australia, that investigates exercise practices within outpatient and maintenance phases of CR. HIIT is superior to current recommended intensity (MICT) guidelines in improving CR, however, the effect of duration of HIIT on CRF improvements had not been investigated nor had a collation of adverse events been undertaken. Intensity prescription and actual intensity undertaken by patients within Phase 2 and 3 had not been investigated in Australia. WPAM are a promising tool to improve adherence to physical activity long term. However, there had been no research in Australia to investigate the value of using WPAM that calculate PAI score, which is based on heart rate and intensity, to encourage adherence to lifelong exercise at an intensity to improve heart health. Given the above rationale several questions, hypotheses and aims were established as seen on the following page.

1.4 RESEARCH QUESTIONS AND HYPOTHESES

1. QUESTIONS: Will adding up to date RCT results investigating the effect of HIIT versus MICT in the cardiac population continue to support HIIT as being superior to MICT in improving CRF and does the duration of exercise training impact the degree of changes in CRF due to HIIT versus MICT in people with CHD?
   HYPOTHESES: HIIT will be superior to MICT and the longer duration of intervention will be proportionate to CRF changes.

2. QUESTION: Does HIIT result in more reported adverse events than MICT in people with CHD?
   HYPOTHESIS: HIIT will produce more adverse events than MICT due to the higher physiological stress placed on the heart during high intensity exercise.

3. QUESTIONS: What exercise intensity is being prescribed in Australian CR programmes and is HIIT being used and if so, to what extent?
   HYPOTHESES: CR programmes are under-utilising HIIT, particularly as current guidelines recommend MICT for most patients.

4. QUESTIONS: Are WPAM being used significantly in the cardiac population and are they superior to no device in improving CRF and step counts in the maintenance phase of CR?
   HYPOTHESES: Pedometers are being used significantly within the cardiac population, which do not monitor intensity; therefore, these devices may improve step counts, but not CRF.

5. QUESTIONS: Does monitoring PAI in the maintenance phase of CR, improve intensity, motivation and adherence to exercise?
   HYPOTHESES: Knowledge of PAI will assist cardiac patients to gain a better understanding of exercise required to improve their heart health and monitoring PAI will improve motivation to exercise and may increase the intensity of exercise performed.

1.5 Overall Research Aims of Thesis

Therefore, to answer the research questions, the aims of this PhD were:

1. To evaluate and synthesise current literature comparing improvements in physiological benefits, particularly CRF (VO_2peak) between participants diagnosed with CHD engaged in MICT versus HIIT, analyse the effect of VO_2peak changes resulting from different durations of interventions and collate and compare reported adverse events occurring within eligible RCTs (Chapter 2).
2. To collect data surrounding current exercise prescription parameters, current usage and clinician perceptions about implementation of HIIT across Australia (Chapter 3).
3. Investigate the effect of WPAM devices within the cardiac population on CRF (Chapter 4).
4. Investigate the effect of monitoring PAI scores, using a WPAM, on intensity, adherence and motivation in cardiac populations, during the maintenance phase of CR and in the home environment (Chapter 5).

CHAPTER 2: HIGH INTENSITY INTERVAL TRAINING VERSUS MODERATE INTENSITY CONTINUOUS TRAINING WITHIN CARDIAC REHABILITATION

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2.1 PREFACE

This chapter aligns to the first thesis aim:

> *"To evaluate and synthesise current literature comparing improvements in physiological benefits, particularly CRF (VO_2peak) between participants diagnosed with CHD engaged in MICT versus HIIT, analyse the effect of VO_2peak changes resulting from different durations of interventions and collate and compare reported adverse events occurring within eligible RCTs."*

Recent systematic reviews have supported the view that exercise intensity is important in improving CRF and has suggested HIIT is more effective than MICT in improving CRF. Therefore, the aim of this chapter, was to review and update current literature which has compared HIIT with MICT within the cardiac population. A systematic review and meta-analysis were conducted. The review, specifically, investigated CRF changes resulting from HIIT versus MICT, the effect of duration of interventions on CRF changes and presented a collation and comparison of adverse events reported in both training groups. The published manuscript is in the final format, as presented in the journal, at Appendix 1.

High intensity interval training versus moderate intensity continuous training within cardiac rehabilitation: a systematic review and meta-analysis (Published manuscript, see Appendix 1).

2.2 ABSTRACT

2.2.1 BACKGROUND

Aerobic capacity has been shown to be inversely proportionate to cardiovascular mortality and morbidity and there is growing evidence that HIIT appears to be more effective than MICT in improving CRF within the cardiac population. Previously published systematic reviews in CVD have not investigated the effect the number of weeks of the intervention has on CRF changes, nor have adverse events been collated.

2.2.2 OBJECTIVE

We aimed to undertake a systematic review and meta-analysis of RCTs within the cardiac population that investigated CRF changes resulting from HIIT versus MICT and to collate adverse events.

2.2.3 METHODS

A critical narrative synthesis and meta-analysis was conducted after systematically searching relevant databases up to July 2017. We searched for RCTs which compared CRF changes resulting from HIIT versus MICT interventions within the cardiac population.

2.2.4 RESULTS

Seventeen studies, involving 953 participants (465 for HIIT and 488 for MICT) were included in the analysis. HIIT was significantly superior to MICT in improving CRF overall (SMD 0.34 ml/kg/min; 95% CI (0.2-0.48); $p<0.00001$; I^2 =28%). There were no deaths or cardiac events requiring hospitalisation reported in any study during training. Overall, there were more adverse events reported as a result of the MICT (n=14) intervention than HIIT intervention (n=9). However, some adverse events (n=5) had not been classified by intervention group.

2.2.5 CONCLUSION

HIIT is superior to MICT in improving CRF in CR participants. The improvements in CRF are significant for CR programmes of greater than six weeks' duration. Programmes of 7-12 weeks' duration resulted in the largest improvements in CRF for patients with CAD. HIIT appears to be as safe as MICT for CR participants.

2.3 INTRODUCTION

Coronary heart disease (CHD) results in one in four deaths globally; an increase from one in five deaths twenty years ago (Lozano et al., 2012). A systematic analysis for the Global Burden of Disease Study in 2012 ranked CHD as the leading cause of years of life lost (YLL) to premature death surpassing lower respiratory infections. In the last twenty years, YLL attributed to CHD has increased by 28% (Lozano et al., 2012).

Cardiac rehabilitation (CR) is an important tool in secondary prevention of cardiovascular disease. It aims to assist participants to lead full, healthy lives, whilst reducing the likelihood of suffering subsequent cardiac incidents (Heran et al., 2011; Taylor et al., 2004). CR involves education, lifestyle behaviour modification, psychosocial support and supervised exercise programmes (Anderson, Thompson, et al., 2016; National Heart Foundation of Australia, 2010). These exercise programmes aim to increase the CRF and muscular strength of CR participants; however international CR guidelines are inconsistent in their recommendations concerning exercise intensity. The American Heart Association, American College of Sports Medicine, European Association for Cardiovascular Prevention and Rehabilitation, Canadian Association of Cardiac Rehabilitation, and American Association of Cardiovascular and Pulmonary Rehabilitation Guidelines, and Scottish Intercollegiate guidelines endorse moderate to vigorous intensity exercise, whilst Australia, New Zealand, Japan and the UK favour lower intensity exercise (Mezzani et al., 2013; Pescatello, 2014; Price et al., 2016; Scottish Intercollegiate Guidelines Network (SIGN), 2002; Woodruffe et al., 2015). Current Australian guidelines recommend 30 minutes or more of low to moderate intensity physical activity for most people with CHD. For participants with high levels of fitness who

aim to return to high intensity physical activity the Australian guidelines state that high intensity training may be offered with their treating doctor's consent (Woodruffe et al., 2015).

The exercise component of CR programmes should ensure the prescription of exercise results in significant improvements in CRF and adequately evaluate changes resulting from participation. This is because for every one metabolic equivalent (MET) improvement in cardiorespiratory fitness (CRF), there is an 8-17% reduction in all-cause mortality, and CRF levels can predict prognosis in patients with known CHD (Keteyian et al., 2008; Meyer et al., 2002; Swain & Franklin, 2006). Prescribing rehabilitative exercise, which increases CRF to the greatest extent, could have superior influence in reducing all-cause and cardiovascular mortality.

Benefits of HIIT in patients with CAD has been investigated since 1981 (Ehsani et al., 1981). Growing evidence is demonstrating superior patient outcomes resulting from HIIT compared to MICT in patients with CAD. There have been four systematic reviews reporting on the positive effects (specifically change in VO_2peak) of HIIT versus MICT in patients with CAD (Cornish et al., 2011; Elliott et al., 2015; Liou et al., 2016; Pattyn et al., 2014). All these concluded that HIIT is superior to MICT in improving aerobic fitness.

In patients with CHD, HIIT has been shown to significantly improve VO_2 at VT, left ventricular size and function, contractile function, left ventricular diastolic diameter, diastolic volume, posterior wall thickening, fractional shortening and rate pressure product, CRF, ejection fraction and endothelial function to a greater extent than MICT. Therefore, this shows positive outcomes for heart function. In addition, studies have shown HIIT to improve mitochondrial biogenesis, insulin sensitivity (Kessler et al., 2012) and glucose regulation (Gibala et al., 2012), HDL cholesterol, blood pressure (Kessler et al., 2012), and deep abdominal adiposity (Boutcher, 2011), more than MICT, all of which are important for patients with CHD.

The previously published systematic reviews included between seven and ten studies with participant numbers ranging from 206 to 472 participants. These systematic reviews, however, had methodological limitations including high heterogeneity ((I^2=83-93%) (Liou et al., 2016; Pattyn et al., 2014) and lacked sufficient reporting of methods implemented to calculate standard deviations,

particularly when no *p* value was published in individual publications (Cornish et al., 2011; Liou et al., 2016). Additionally, a fixed effect analysis used by Elliott et al. (2015) was chosen for statistical analysis, despite variances across trials in methods used (cycle ergometer versus treadmill) to determine peak aerobic capacity (Elliott et al., 2015). One of the reviews included non-RCTs (Cornish et al., 2011) and three reviews included trials with CR participants as well as those diagnosed with HF (Cornish et al., 2011; Liou et al., 2016; Pattyn et al., 2014).

Despite the significant research conducted to date, there has been no systematic review and meta-analysis investigating HIIT versus MICT that has analysed the effect of duration, in weeks, of programmes on CRF changes. Furthermore, other than adverse events resulting from HIIT and MICT being recorded by Rognmo et al. (2012) across three Norwegian clinics, there has not been an attempt to collate adverse events recorded as a result of HIIT or MICT across all studies.

The aim of this review, therefore, was to undertake a meta-analysis of RCTs within the cardiac population which investigated the overall effect of CRF changes resulting from HIIT versus MICT over different durations of interventions and to collate adverse events recorded as a result of both interventions. Our hypothesis was that HIIT would result in greater changes to CRF and this change would be greater, with a longer duration of the intervention.

2.4 METHODS

A narrative synthesis and meta-analysis was undertaken as detailed in the protocol registered with PROSPERO, an international database of prospectively registered systematic reviews in health and social care (Registration Number CRD42017072093).(A. Booth et al., 2012) A systematic search of all RCTs was performed by two authors (AH;VS) at the end of July 2017, in accordance with PRISMA guidelines (Moher et al., 2009).

2.4.1 STUDY SELECTION

2.4.1.1 INCLUSION CRITERIA

The inclusion criteria for the systematic review were full length research articles published in peer-reviewed academic journals with no limits set on language, date of publication or gender. Only RCTs up to July 2017 were eligible. Studies comprised participants who were diagnosed with CAD (MI, PCI, CABG surgery) who engaged in HIIT (e.g. ≥85% VO_2peak or ≥85% HRR or ≥ 90% heart rate max (HRM) interspersed with lower level exercise) versus MICT (50-75%VO_2peak or 50-75% HRR or 50-80% HRM) interventions, in an outpatient setting for at least four weeks.

The primary outcome used in the meta-analysis was CRF [VO_2peak or VO_2 at anaerobic threshold (AT)] and the assessment must have been performed before and after the CR intervention. The secondary outcome was adverse events including minor and major cardiovascular events and additional adverse events occurring within the intervention period.

2.4.1.2 EXCLUSION CRITERIA

Abstracts, conference presentations or posters, letters to the editor or book chapters, unpublished papers or retrospective designs were excluded. In addition, studies were excluded whose participants were diagnosed with congestive HF (ejection fraction less than 40%) and if HIIT intervention participants did not exercise at ≥ 85% VO_2peak or equivalent, if the baseline data were not published, or if outcomes other than VO_2peak or AT (such as peak work capacity) were used as primary outcomes.

2.4.1.3 LITERATURE SEARCH

The following databases - Embase, Medline, CINAHL, SPORTDiscus, and Web of Science - along with reference lists of eligible studies, were systematically searched. Key terms and searches were formulated in consultation with a university librarian. These terms were adapted for each unique database. The search strategy for Embase is available in supplementary material.

2.4.2 DATA EXTRACTION

All data were extracted by the principal investigator and checked for accuracy by a second author. Search results were entered into Endnote, a reference management tool, and duplicates were removed (Moher et al., 2009),(*EndNote*, 2016). Abstracts were screened for eligibility and full-length manuscripts of potential studies were retrieved for further assessment of eligibility. Disagreements regarding eligibility were resolved by consensus and selection process was entered into a PRISMA diagram (Figure 2).

For each RCT, author, year of publication, participant characteristics (age, gender, diagnosis) and exercise parameters (number of HIIT and MICT participants, length of exercise programme, intensity of HIIT and MICT exercise, mode, pre and post VO_2peak values and change in VO_2peak/VO_2 at AT) were extracted, if published.

2.4.3 STUDY QUALITY

The Physiotherapy Evidence Database Scale (PEDro-Scale) rating was modified to assess and rate the quality of the trials to be included (Verhagen et al., 1998). This tool comprises an 11 item criteria list, which allows rapid identification of studies that are internally valid and is based on the Delphi list developed by Verhagen et al. (1998). The PEDro-scale assesses how the studies are reported and includes whether subjects were randomly allocated, allotment was concealed, comparable baseline measures of patients were present, if subjects, therapists and assessors were blinded, whether outcome measures were taken from >85% of starting participants, patients received the allocated treatment and included intention to treat and whether there was statistical comparison. Eligibility criteria, for external validity only was included, but not used in final rating scores. The nature of HIIT and MICT interventions does not allow for blinding of subjects or of therapists, thus this was removed in the analysis of quality. Therefore, with these modifications, the maximum total score rating was 8. Two of the authors independently rated the studies (AH; VS). The studies were rated as poor, fair and good based on the percentage of maximum scores received as described by Kennelly and Handler (2011) and Lyons et al. (2017). Studies of good quality received >61% of available

scores, fair quality studies received 45.4-61% of available scores and poor studies received <45.4% of available scores (Kennelly & Handler, 2011; Lyons et al., 2017).

2.4.4 Statistical Analysis

A meta-analysis using Review Manager Version 5.3 (The Nordic Cochrane Centre, 2014) to investigate the comparison of VO_2peak changes or VO_2 at AT using HIIT versus MICT for those diagnosed with CAD was carried out. Studies were collated according to the duration of the intervention (up to 6 weeks, 7-12 weeks and > 12 weeks).

Effect sizes for continuous variables were calculated as either mean difference or standardised mean differences (SMD) in case different methods were used to assess the primary outcome (treadmill versus cycle ergometer), each with a 95% confidence interval (CI). The effect of treatment was calculated as the difference between intervention (HIIT or MICT) from baseline to end of follow up. For each outcome, variance was estimated based on standard deviation of the mean difference. When standard deviation was not available, we used the *p* value between groups, then within groups, or the highest calculated standard deviation if no *p* values were available, as recommended by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011). If the *p* value was reported as < 0.05, a conservative approach was used and 0.05 was used in the calculations. A random effects model and standardised means model was used to account for differences in methodology of included studies (both in assessment of CRF and variations in intervention equipment and protocols) as well as durations of intervention, to ensure a conservative estimate was calculated.

An overall forest plot was constructed which included all studies. Heterogeneity was assessed using I^2 and was considered significant at $p<0.1$. Heterogeneity was considered minimal if I^2fell between 0-30%, moderate if 30-50%, substantial if 50-90%, and considerable if > 90% (Simas et al., 2017). Publication bias was analysed using a funnel plot derived in Review Manager version 5.3 (Higgins et al., 2011; The Nordic Cochrane Centre, 2014). A sensitivity analysis was performed to investigate possible effects of certain studies on heterogeneity and overall effect.

2.5 RESULTS

The initial search resulted in 1,581 references. After duplicates were removed, the titles of 935 studies and abstracts were reviewed. Following a screening of potential records, 79 articles were reviewed for eligibility and reference lists screened. Seventeen RCTs were identified that met eligibility criteria for the systematic review and meta-analysis (Figure 2).

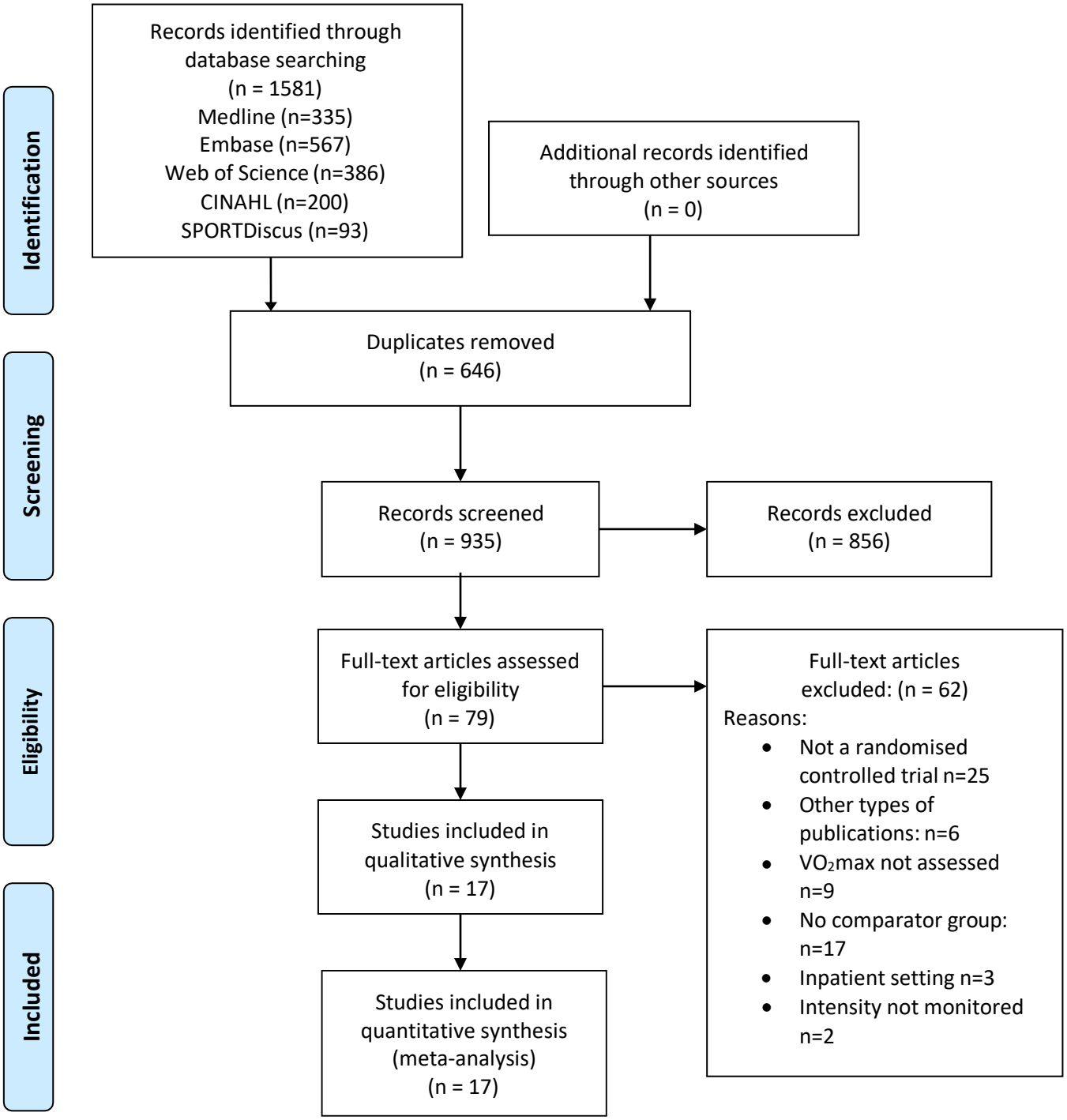


Figure 2. PRISMA Diagram of Literature Search Strategies CC BY 4.0

Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analysis

2.5.1 STUDY CHARACTERISTICS

Seventeen studies were included in the narrative analysis and all were published in English (Amundsen et al., 2008; Benetti et al., 2010; Cardozo et al., 2015; Conraads et al., 2015; Currie et al., 2015; Currie et al., 2013; Jaureguizar et al., 2016; Jensen et al., 1996; Keteyian et al., 2014; Kim et al., 2015; Mobius-Winkler et al., 2016; Moholdt et al., 2012; Moholdt et al., 2009; Prado et al., 2016; Rocco et al., 2012; Rognmo et al., 2004; Warburton et al., 2005). The RCTs were conducted in the United States of America (n=2), Belgium (n=1), Brazil (n=4), Canada (n=3), Germany (n=1), Norway (n=4), South Korea (n=1) and Spain (n=1). The total number of participants analysed across all studies was 953 participants (465 for HIIT and 488 for MICT). Not all studies reported the breakdown of gender, however for those which did, there were 5.5 times more males (661) reported than females (119). There were 123 patients reported as having CAD, 633 MI, 477 PCI and 361 CABG/myocardial revascularisations. The age range of participants was 52-76 years with 10 studies reporting mean ages < 60 years and 7 studies reporting mean ages > 60 years. Individual patient characteristics for each study can be seen in Table 1.

Interventions duration ranged from 4 weeks to 12 months with four studies reporting data for 0-6 weeks (Conraads et al., 2015; Kim et al., 2015; Mobius-Winkler et al., 2016; Moholdt et al., 2009), eleven studies reporting data for 7-12 weeks (Amundsen et al., 2008; Benetti et al., 2010; Conraads et al., 2015; Currie et al., 2015; Currie et al., 2013; Jaureguizar et al., 2016; Keteyian et al., 2014; Moholdt et al., 2012; Prado et al., 2016; Rocco et al., 2012; Rognmo et al., 2004) and five studies reporting data for > 12 weeks (Cardozo et al., 2015; Currie et al., 2015; Jensen et al., 1996; Moholdt et al., 2009; Warburton et al., 2005). Four studies had data which fit across subgroups and results recorded separately for each different duration (Conraads et al., 2015; Currie et al., 2015; Jensen et al., 1996; Moholdt et al., 2009) (Table 2).

Sixteen studies reported on the frequency of training (days/week) used during the intervention. Of these, nine studies performed the intervention 3 days/week (Cardozo et al., 2015; Conraads et al., 2015; Jaureguizar et al., 2016; Jensen et al., 1996; Keteyian et al., 2014; Kim et al., 2015; Prado et al., 2016; Rocco et al., 2012;

Rognmo et al., 2004), four studies for 2 days/week(Currie et al., 2015; Currie et al., 2013; Moholdt et al., 2012; Warburton et al., 2005) and two studies for 5 days/week (Benetti et al., 2010; Moholdt et al., 2009). One study ran sessions four times a day (Mobius-Winkler et al., 2016) and another did not report frequency (Amundsen et al., 2008) (Table 2).

Of the studies that reported the mode of exercise used during training sessions, nine studies primarily utilised a treadmill (Amundsen et al., 2008; Cardozo et al., 2015; Keteyian et al., 2014; Kim et al., 2015; Moholdt et al., 2012; Moholdt et al., 2009; Prado et al., 2016; Rocco et al., 2012; Rognmo et al., 2004), four primarily used cycle ergometers (Conraads et al., 2015; Currie et al., 2015; Currie et al., 2013; Jaureguizar et al., 2016), one described the intervention as aerobic exercise (Benetti et al., 2010), another used a combination of a stair climber, treadmill and arm/leg cycle ergometer (Warburton et al., 2005), one described the intervention as multimodal exercise (Mobius-Winkler et al., 2016), and another used a combination of walk/jog or cycling (Jensen et al., 1996) (Table 2).

All studies conducted exercise within the intensity guidelines (HIIT ≥85% VO_2peak or ≥85% HRR or ≥ 90% HRM interspersed with lower level exercise and MICT (50-75%VO_2peak or 50-75% HRR or 50-80% HRM).

Table 1: *Study Characteristics*

Study	**Age (years)**	**Gender**	**Diagnosis**	
		Male/female	**MI, CAD, PCI, CABG**	
Jensen et al. (1996)	53±0.6 (total) 53.1±0.9 HIIT 54.6±0.9 MICT	199	MI	117
Rognmo et al. (2004)	62.9±11.2 HIIT 61.2±7.3 MCT	6/2 HIIT 8/1 MICT	CAD MI PCI CABG	1 8 3 5
Warburton et al. (2005)	56±7 (total) HIIT 55±7 MICT 57±8	14/0	MI PCI CABG	5 6 6
Amundsen et al. (2008)	63±11 HIIT 61±7 MICT	6/2 HIIT 8/1 MICT	MI PCI CABG	8 3 6
Moholdt et al. (2009)	60.2±-6.9 HIIT 62±7.6 MICT	24/4 HIIT 24/7 MICT	MI 56	56 (4 wks) 48 (6 mths)
Benetti et al. (2010)	57.7±6.1(total)	87/0	MI PTCA CABG	25 37 34
Moholdt et al. (2011)	57.4±9.5 (total) 56.7±10.4 HIIT 57.7±9.3 MICT	74/15	MI PCI	89 70
Rocco et al. (2012)	59.7±1.7 (total) 56.5±3 HIIT 62.5±2 MICT	28/9	CAD MI	20 17

Study	Age (years)	Gender	Diagnosis	
		Male/female	MI, CAD, PCI, CABG	
Currie et al. (2013)	68±8 MICT	23/3; 3 excluded	MI	13
	62±11 HIT		PCI	14
			CABG	7
Keteyian et al. (2014)	60±HIT	23/5	MI	17
	58±9 MICT		PCI	19
			CABG	7
Cardozo et al. (2015)	56±12 HIIT	14/9 HIIT	CAD	102
	62±12 MICT	16/8MICT	MI	105
			PCI	175
			MR	132
Conraads et al. (2015)	58.4±9.1(total)	180/20	MI	115
	57±8.8HIIT	91/9 HIIT	PCI	25
	59.9±9.2 MICT	89/11 MICT	CABG	60
Currie et al. (2015)	63±8 HIIT	18/1	MI	12
	66±8 MICT	9 HIIT	PCI	11
		10/1 MICT	CABG	7
Kim et al. (2015)	57±11.58 HIIT	22/6	MI with PCI	28
	60.2±13.64	12/2 HIIT		
		10/4 MICT		
Jaureguizar et al. (2016)	58±11 HIIT	28/8 HIIT	MI	46
	58±11 MICT	33/3 MICT	PCI	47
			CABG	13
Mobius-Winkler et al. (2016)	64.4±7.7 (total)	14/6 HIIT	MI	13
	HIIT 61.4±8.7	16/2 MICT	PCI	30
	MICT 66±5.9		CABG	2
Prado et al. (2016)	59.3±1.8 (total)	28/7	MI	15
	HIIT 56.5±2.7	14/3 HIIT	PCI	9
	MICT 61.3±2.7	14/4 MICT	CABG	26

Abbreviations: MI, myocardial infarct, CAD, coronary artery disease, PCI, percutaneous coronary intervention, CABG, coronary artery bypass graft surgery, MR, myocardial revascularisation, HIIT, high intensity interval training, MICT, moderate intensity continuous training.

Table 2: *Exercise Parameters*

Study	No. HIIT participants	No. MICT participants	Duration	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT $V0_{2peak}$ Pre ml/kg/min	HIIT $V0_{2peak}$ Post ml/kg/min	MICT $V0_{2peak}$ Pre ml/kg/min	MICT $V0_{2peak}$ Post ml/kg/min	Change in $V0_{2peak}$ ml/kg/min
Jensen et al. (1996)	108	91	6 -12 months 3d/wk	Progressed from 50% to 85% VO_2peak	Not recorded	Walking /jogging and/or cycle ergometer	Walking/ jogging and/or cycle ergometer	25.3±4.9	6 months: 27.2±5.6 12 months: 28.5±5.9	24.3±4.8	6 months: 26.1±4.4 12 months: 26.6±5.7	HIIT: 1.9 ± 12.355 at 6 months 3.2±1.893 at 12 mths: MICT: 1.8 ± 12.355 at 6 months 2.3±1.893 at 12 months
Rognmo et al. (2004)	8	9	10 weeks 3d/wk	5min warm up 50-60%VO_2peak (65-75%HRpeak) 4x4min: 4 min @ 80-90%VO_2peak (85-95% HR peak):3 min @ 50-60%VO_2peak 3min cool down 50-60%VO_2peak Total:33 mins	41 min Continuous VO_2peak @ 50-60% VO_2peak (65-75%HRpeak)	Uphill Treadmill Walking	Uphill Treadmill Walking	31.8±9.3	37.8±12.4	32.1±5.3	34.8±5.7	HIIT 6±2.342 MICT 2.7±2.342

Study	No. HIIT participants	No. MICT participants	Duration	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT $V0_{2peak}$ Pre	HIIT $V0_{2peak}$ Post	MICT $V0_{2peak}$ Pre	MICT $V0_{2peak}$ Post	Change in $V0_{2peak}$ ml/kg/min
								ml/kg/min		ml/kg/min		
Amundsen et al. (2008)	8	9	10 weeks	80-90% peak O_2 uptake	50-60% peak O_2 uptake	Uphill treadmill 4x4min interval 80-90%VO_2peak 3 min 50-60%$V0_2$peak	Uphill treadmill 50-60% VO_2peak 41 mins	32±19	37±27	31±9	35±11	HIIT 5±0.698 MICT 4±0.698
Warburton et al. (2005)	7	7	16 weeks 2d/week 30 mins	2 min 85-95% HRR interspersed with 2 min recovery for 30 mins	10 min warm up 30 mins continuous aerobic exercise at 60% HRR	10 min each of Treadmill, stairclimber, Arm/leg cycle 3 additional training days @ 60-70 HRR	10 min each of Treadmill, stairclimber, Arm/leg cycle 3 additional training days @ 60-70 HRR	VO_2peak at AT 22±4	VO_2peak at AT 29±8	VO_2peak at AT 21±3	VO_2peak at AT 23±2	HIIT 7±7.565 MICT 2±2.1625
Moholdt et al. (2009)	23	25	4 weeks 5d/week	HIIT 90% MHR	MICT 70% max heart rate	HIIT 8 min warm up 4 minx4 intervals and 3min @ 70% 5 min cool down Treadmill	MICT continuous for 46 min Treadmill	27.1±4.5	4 weeks 30.4±5.5 6 months 32.2±7	26.2±5.2	4 weeks 28.5±5.6 6 months 29.5±5.7	HIIT 4 weeks 3.3±4.7328 6 months 5.1±2.9475 MICT 4 weeks 2.3±3.5123 6 months 3.3±2.9475

Study	No. HIIT	No MICT	Length	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT		MICT		Change in VO_2peak
								$V0_{2peak}$ Pre	$V0_{2peak}$ Post	$V0_{2peak}$ Pre	$V0_{2peak}$ Post	
								ml/kg/min		ml/kg/min		
Benetti et al. (2010)	29	29	12 weeks 5d/week	85% MHR	75% MHR	45mins aerobic exercise +15min stretching	45mins aerobic exercise +15min stretching	29.2±2.2	41.6±3.9	32±5.3	37.1±3.9	HIIT 12.4 ±12.355 MICT 5.1 ±12.355
Moholdt et al. (2011)	30	59	12 weeks 2d/week plus 1d/week home	Total 38 min 4x485-95%MHR 3min 70%MHR 8min warm up 5min cool down	Periodically encouraged to do vigorous exercises	Treadmill	Total 60 mins 10 min warm up Walk/jog/squat/lunge 35 mins 5 min cool down Stretching/relax	31.6±5.8	36.2±8.6	32.2±6.7	34.7±7.9	HIIT 4.6±4.2 MICT 2.4±3.2
Rocco et al. (2012)	17	20	12 weeks 3d/week		VT Total:50mins	5 min warm up and cool down 7x3min RCP and 7x3mins VT Treadmill 42 mins	Treadmill at 5 min warm up and cool down 50 min duration	17.9±1	22.3±1.1	18±1.2	22.2±1.3	HIIT 4.4±8.5578 MICT 4.2±8.9741

Study	No. HIIT	No MICT	Length	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT		MICT		Change in VO_2peak
								$V0_{2peak}$ Pre	$V0_{2peak}$ Post	$V0_{2peak}$ Pre	$V0_{2peak}$ Post	
								ml/kg/min		ml/kg/min		
Currie et al. (2013)	11	10	12 weeks 2d/week	89% Peak Power	58% Peak Power	10x 1 min intervals at 89% peak power output interspersed with 1 min at 10 % peak power output	30-50min continuous cycling	19.8±3.7	24.5±4.5	18.7± 5.7	22.3±6.1	HIIT 4.7 ±3.398 MICT 3.6 ±2.6
Keteyian et al. (2014)	15	13	1-2 weeks MICT then 10 weeks trial 3d/week	80-90% HRR	60-80%HRR	5 min warm up 3 min 60-70 %HRR 4x4 min 80-90% HRR:3min 60-70% 4 min cool down Treadmill	5 min warm up 30 min aerobic Treadmill	22.4±4.2	26±5.9	21.8± 4	23.5±4.6	HIIT 3.6±3.1 MICT 1.7±1.7
Cardozo et al. (2015)	23	24 24 non exercise control	16 weeks 3d/week	60%MHR 90%MHR	70-75%MHR	30 mins 2min:2min Treadmill	30 min continuous aerobic exercise Treadmill	20.6±5	24.4±5	21.8±6	21.9±6	HIIT 3.8±12.35 MICT 0.1 ± 12.355

Study	No. HIIT	No MICT	Length	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT		MICT		Change in VO_2peak
								$V0_{2peak}$ Pre	$V0_{2peak}$ Post	$V0_{2peak}$ Pre	$V0_{2peak}$ Post	
								ml/kg/min		ml/kg/min		
Conraads et al. (2015)	85	89	12weeks 3d/week	90-95%peak HR 85-90%peak HR	70-75%HRpeak 60-70% HRpeak	Bicycle	Bicycle	23.5±5.7	6 weeks 26.7±6.7 12 weeks 28.6 ±6.9	22.4±5.6	6 weeks 25.2±6.2 12 weeks 26.6±6.7	HIIT 3.4± 4.7 (6 weeks) 5.1±4.0 (12 weeks) MICT 2.8±2.7 (6 weeks) 4.4±3.3 (12 weeks)
Currie et al. (2015)	9	10	12 weeks 2d/week	75-95 peak power output 1 min	51-65% peak power output	10 min warm up and cool down cycle	10 min warm up and cool down cycle	21.1±3.3	12 weeks 26.4±5.2 6 months 27.2±6	19.8±7.3	12 weeks 23.2+/-7.4 6 months 24.2±7.8	HIIT 12 weeks 5.275±2.954 6 months 5.908±3.587 MICT 12 weeks 3.762±3.168 6 months 5.148±5.742

Study	No. HIIT	No MICT	Length	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT		MICT		Change in VO_2peak
								$V0_{2peak}$ Pre	$V0_{2peak}$ Post	$V0_{2peak}$ Pre	$V0_{2peak}$ Post	
								ml/kg/min		ml/kg/min		
Kim et al. (2015)	14	14	6 weeks 3d/week	85%-95%HRR And 50-70%HRR	70-85%HRR	Total: 45mins first 3 sessions MICT 10min warm up 4x4min Treadmill 10 min cool down	Total: 45mins 10 min warm up 25 min walk 10 min cool down Treadmill	29.15 ±5.46	35.61±7.71	27.12±8.19	29.59±8.65	HIIT 12 weeks 6.46±4.296 MICT 2.47±4.296
Jaureguizar et al. (2016)	36	36	8 weeks 3d/week	104.5%+/-22.2 VO_2peak month1 134.5+/29.7% VO_2peak Month 2	64.2±8.5 VO_2peak month1 69.5+/-8.7 VO_2peak Month 2	Steep ramp test on cycle 25w increment Then 20 sec @50%srt:40s recovery at 10%	Bicycle	19.4±4.7	24±4.8	20.3±5	22.8±6.5	HIIT 4.5±4.7 MICT 2.5±3.6

Study	No. HIIT	No MICT	Length	Intensity HIIT	Intensity MICT	Protocol HIIT	Protocol MICT	HIIT $V0_{2peak}$ Pre	HIIT $V0_{2peak}$ Post	MICT $V0_{2peak}$ Pre	MICT $V0_{2peak}$ Post	Change in VO_2peak
								ml/kg/min		ml/kg/min		
Mobius-Winkler et al. (2016)	20	20 20 (Control Group)	4 weeks 4times/day	95% angina free threshold Interspersed with 70 % angina free threshold And 1 hr recovery between sessions 30 min/session	20 mins 6-8 times /day 60% angina free threshold	Not stated	Multimodal intervention	23.1±5.2	26.1±5.7	22.8±4.8	27±5.9	HIIT 3.1±2.34 MICT 3.88±3.01
Prado et al. (2016)	17	18	12 weeks 3d/week	7x 3min Respiratory compensation point And 3 min Vent anaerobic threshold	Vent anaerobic threshold	5 min warm up and cool down 42 mins Treadmill	5 min warm up and cool down 50 min Treadmill	17.9±-1	22.3±1.1	18.8±1.2	23±-1.3	HIIT 4.4±8.5578 MICT 4.2 ±8.4458

Abbreviations: HIIT, High intensity interval training, MICT, moderate intensity continuous training, HRpeak, heart rate peak, MHR, maximal heart rate, HRR, heart rate reserve, AT, anaerobic threshold, VT, ventilatory threshold

2.5.2 STUDY QUALITY

The PEDro-scale was used to analyse study quality. Seventeen studies were scored by two authors (AH; VS) independently, and discrepancies discussed and resolved. Of the seventeen studies, 13 (76%) were of good quality, 3 (18%) were of poor quality and one (6%) was of poor quality (Table 3).

Table 3: *Quality Analysis using The Physiotherapy Evidence Based Database*

RCT	Random Allocation	Concealed Allocation	Baseline Similarities Between groups	Blinding of Assessors	Outcome measure from >85% subjects	Intention to treat	Between group Statistical Comparison	Point measures and measures of variability	Total Score /8
Jensen et al. (1996)	✓	×	✓	×	✓	✓	✓	✓	6
Rognmo et al. (2004)	✓	✓	✓	×	×	✓	✓	✓	5
Warburton et al. (2005)	✓	×	✓	×	✓	✓	✓	✓	6
Amundsen et al. (2008)	✓	×	✓	×	×	×	✓	✓	4
Moholdt et al. (2009)	✓	×	✓	✓	×	×	✓	✓	5
Benetti et al. (2010)	✓	×	✓	×	✓	×	✓	✓	5
Moholdt et al. (2011)	✓	✓	✓	×	×	×	✓	✓	5
Rocco et al. (2012)	✓	×	✓	×	×	×	✓	✓	3
Currie et al. (2013)	✓	×	✓	×	×	×	✓	✓	4
Keteyian et al. (2014)	✓	✓	✓	✓	×	×	✓	✓	6
Cardozo et al. (2015)	✓	×	✓	×	✓	✓	✓	✓	6
Conraads et al. (2015)	✓	×	×	×	✓	✓	✓	✓	5
Currie et al. (2015)	✓	×	✓	×	×	×	✓	✓	4
Kim et al. (2015)	✓	×	✓	×	✓	×	✓	✓	5
Jaureguizar et al. (2016)	✓	×	✓	✓	✓	×	✓	✓	6
Mobius-Winkler et al. (2016)	✓	×	✓	×	✓	×	✓	✓	5
Prado et al. (2016)	✓	×	✓	×	✓	✓	✓	✓	6

2.5.3 Study Duration

Studies were separated into three groups depending upon duration (0-6 weeks, 7-12 weeks, and >12 weeks), and a meta-analysis was calculated to analyse VO_2peak changes or VO_2 at AT. In addition, studies that reported results across two different time frames were separated in to 'a' and 'b' subgroups (Conraads et al., 2015; Currie et al., 2015; Jensen et al., 1996; Moholdt et al., 2009). The forest plots for changes in VO_2peak or VO_2 at AT between HIIT and MICT interventions with subgroups based upon duration are seen in Figure 3.

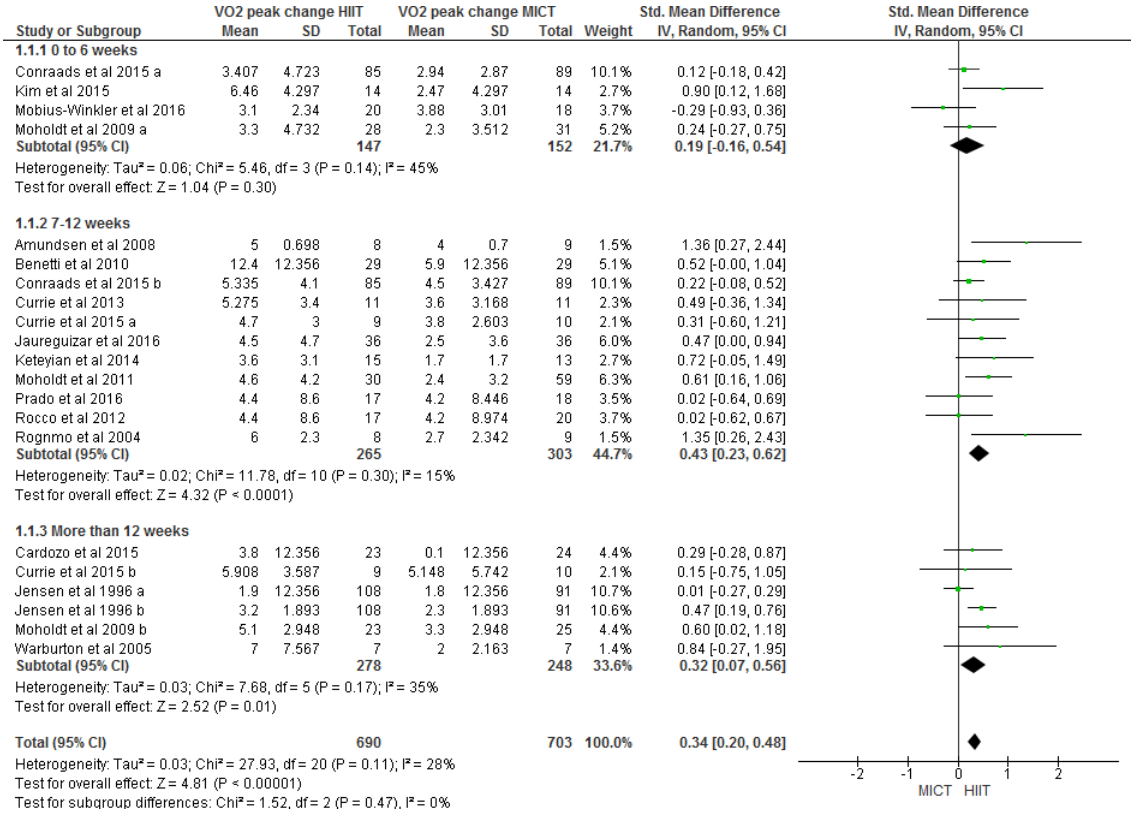


Figure 3. Forest Plots depicting aerobic capacity changes as a result of HIIT versus MICT (Standard mean difference in ml/kg/min).

Abbreviations: HIIT, high intensity interval training, MICT, moderate intensity continuous training, IV, inverse variance, CI, confidence interval, SD, standard deviation.

The meta-analysis identified that of the seventeen studies, sixteen significantly ($p<0.05$) favoured HIIT (Amundsen et al., 2008; Benetti et al., 2010; Cardozo et al., 2015; Conraads et al., 2015; Currie et al., 2015; Currie et al., 2013; Jaureguizar et al., 2016; Jensen et al., 1996; Keteyian et al., 2014; Kim et al., 2015; Moher et al., 2009; Moholdt et al., 2012; Moholdt et al., 2009; Prado et al., 2016; Rocco et al., 2012; Rognmo et al., 2004; Warburton et al., 2005). One favoured MICT (Mobius-Winkler et al., 2016); however, the results were not significant in our meta-analysis ($p =0.3758$). HIIT was significantly superior to MICT in improving VO_2peak (SMD 0.34 ml/kg/min; 95% CI (0.2-0.48); $p<0.00001$; $I^2 =28\%$). For studies of up to 6 weeks' duration, HIIT was shown to improve VO_2peak more than MICT (SMD 0.19 ml/kg/min; 95% CI (-0.16-0.54); $p= 0.3$; $I^2 = 45\%$); however, this was not significant. For interventions of 7-12 weeks, HIIT was found to be significantly superior to MICT in improving VO_2peak (SMD 0.43 ml/kg/min; 95% CI (0.23-0.62), $p<0.0001$; $I^2 =15\%$). For studies greater than 12 weeks' duration, HIIT was significantly superior to MICT in improving VO_2peak (SMD 0.32 ml/kg/min; 95% CI (0.07-0.56); $p=0.01$; $I^2 = 35\%$). Figure 4 depicts a funnel plot for publication bias which suggests this to be unlikely.

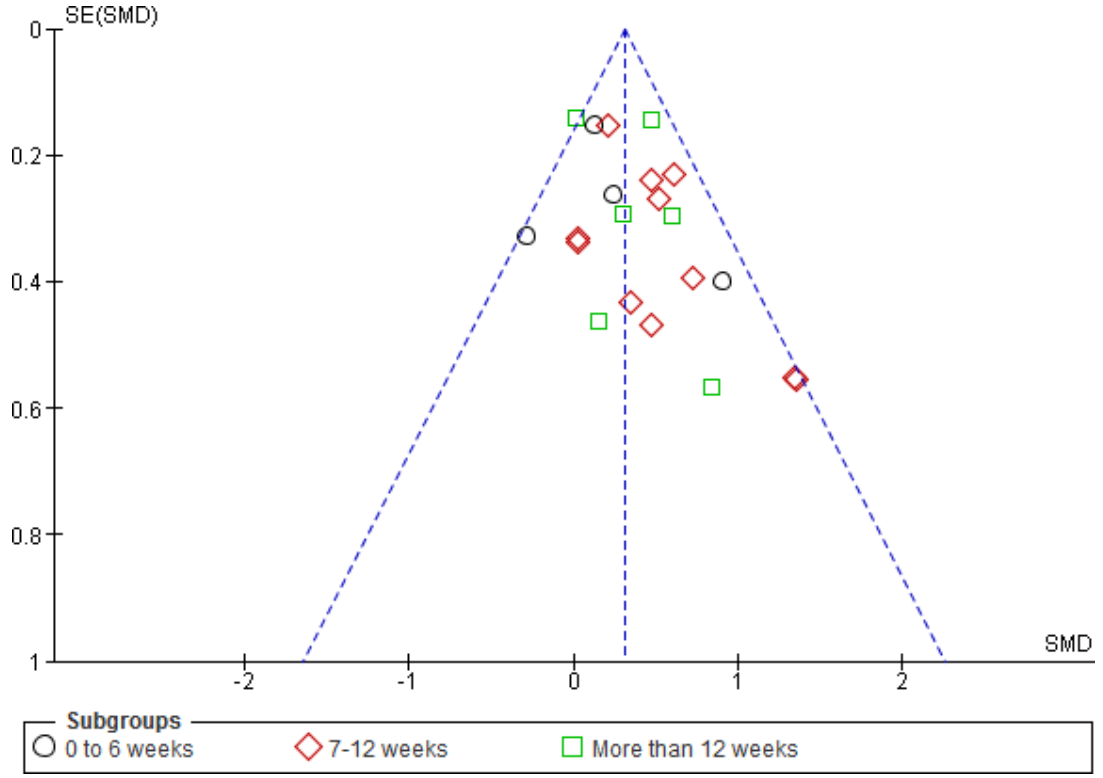


Figure 4. Funnel plot of publication bias

2.5.4 Adverse Events

Although the majority of trials (13/17; 76%) commented on adverse events resulting from exercise interventions (Amundsen et al., 2008; Benetti et al., 2010; Cardozo et al., 2015; Conraads et al., 2015; Currie et al., 2013; Jaureguizar et al., 2016; Keteyian et al., 2008; Kim et al., 2015; Mobius-Winkler et al., 2016; Moholdt et al., 2012; Moholdt et al., 2009; Rognmo et al., 2004; Warburton et al., 2005), no studies stated using a specific protocol to collect adverse events. Of those studies that reported events, no deaths or cardiac related events requiring hospitalisation occurred in either intervention group during training. One study (7%) reported three cardiac events occurred in the MICT training group. One of these was 24 hrs after exercise and two occurred after the intervention was completed and during the post intervention exercise test (Conraads et al., 2015). Although one study (7%) reported incidences of angina resulting in drop out occurred in both groups, specific details were not reported (Moholdt et al., 2012). Of the thirteen studies reporting adverse events, three studies (23%) reported additional adverse events for the HIIT intervention. These included ankle fracture (Rognmo et al., 2004), leg or hip pain, bronchitis (Moholdt et al., 2009), gastroenteritis, pancreatitis and intermittent claudication (Moholdt et al., 2012). Five studies (38%) reported additional adverse events in the MICT intervention branch. These included knee injury (Rognmo et al., 2004), pericardial effusion (Moholdt et al., 2009), gastrointestinal bleed, bronchitis, knee surgery, lower back pain and psychiatric disease (Moholdt et al., 2012), musculoskeletal injury unrelated to training (Currie et al., 2013) and limiting leg pain (Keteyian et al., 2014). In addition, two studies (14%) reported additional adverse events; however, they did not describe which intervention group the participants had belonged (Amundsen et al., 2008; Benetti et al., 2010). These included physical impairment not attributable to CVD (Amundsen et al., 2008), unstable angina and joint problems (Benetti et al., 2010). Table 4 depicts adverse events reported.

Table 4: *Summary of Adverse Events*

RCT Author	Cardiac Adverse events reported HIIT;(%)	Cardiac Adverse events reported MICT;(%)	Other adverse events HIIT;(%)	Other adverse events MICT;(%)	Events recorded but not classified by intensity (%)
Jensen et al. (1996)	Events not reported	Events not reported	Events not reported	Events not reported	Events not reported
Rognmo et al. (2004)	Nil events	Nil events	1 Ankle fracture (13)	1 Knee injury (11)	Nil events
Warburton et al. (2005)	Nil events	Nil events	Nil events	Nil events	Nil events
Amundsen et al. (2008)	Nil events	Nil events	Nil events	Nil events	Physical impairment not related to cardiovascular disease (6)
Moholdt et al. (2009)	Nil events	Nil events	Leg pain, hip pain, bronchitis (13)	Readmitted to hospital (reason not reported), pericardial effusion (4)	Nil events
Benetti et al. (2010)	Nil events	Nil events	Nil events	Nil events	Unstable angina x2(3) Joint problems (2)
Moholdt et al. (2012)	Nil events Angina caused drop out (3)	Nil events Angina caused drop out (2)	Gastroenteritis, pancreatitis, intermittent claudication (10)	Gastrointestinal bleeds, bronchitis, knee surgery, low back pain, psychiatric disease (8)	Nil events
Rocco et al. (2012)	Events not reported	Events not reported	Events not reported	Events not reported	Events not reported
Currie et al. (2013)	Nil events	Nil events	Nil events	1x musculoskeletal injury unrelated to training caused inability to perform post training test (10)	Nil event

RCT Author	Cardiac Adverse events reported HIIT	Cardiac Adverse events reported MICT	Other adverse events HIIT	Other adverse events MICT	Events recorded but not classified by intensity
Keteyian et al. (2014)	Nil events	Nil events	Knee pain x 1 requiring 2 weeks' rest (7)	1x limiting leg pain (8)	Nil events
Cardozo et al. (2015)	Nil events	Nil events	Nil events	Nil events	Nil events
Conraads et al. (2015)	Nil events	Nil during training Acute MI x 1 requiring PCI greater than 24 hours post training (3) Significant ST depression x 2 seen on exercise test requiring PCI after 6 weeks training (4)	Nil events	Nil events	Nil events
Currie et al. (2015)	Events not reported	Events not reported	Events not reported	Events not reported	Events not reported
Kim et al. (2015)	Nil events	Nil events	Nil events	Nil events	Nil events
Jaureguizar et al. (2016)	Nil events	Nil events	Nil events	Nil events	Nil events
Mobius-Winkler et al. (2016)	Nil events	Nil events	Nil events	Nil events	Progression of CAD x1 after 4 weeks training and increased angina requiring PCI (3)
Prado et al. (2016)	Events not reported	Events not reported	Events not reported	Events not reported	Events not reported

Less than half the studies (6/17; 35%) reported drop-out rates by intervention group. Of those that did, 39 participants were reported to drop out of the HIIT group, and 42 participants were reported to drop out of MICT.

2.5.5 Sensitivity Analysis

A sensitivity analysis was conducted within each subgroup. For the 0-6 weeks duration studies, heterogeneity dropped to 0% when Kim et al. (2015) was removed, and heterogeneity was similar (26%). For the studies that were 7-12 weeks' duration, removal of Conraads et al. (2015) results reduced the heterogeneity to 6%, however it increased the total heterogeneity to 31%. Removal of Rognmo et al. (2004) dropped the heterogeneity to 0% and the overall heterogeneity to 22%. Both these studies were of good quality (Pedro score 6).

In the subgroup which included studies of >12 week duration, removing the three month data from Jensen et al. (1996) dropped the heterogeneity to 0% and overall heterogeneity to 17%. The study by Jensen et al. (1996) was of good quality (Pedro score 7). Moreover, Jensen et al. (1996) had the lowest standard deviation variation and favoured HIIT; however, it included participants who had an ejection fraction < 50%. The exact measures were not recorded. As there was no mention of participants having been diagnosed with HF, we assumed their ejection fraction was >40% and included this study in the meta-analysis.

Rocco et al. (2012) and Prado et al. (2016) appear to be the same study with reported mean changes, being identical and with the first three authors being the same. However, Rocco et al. (2012) had two more participants and, therefore, both studies needed to be included in the meta-analysis. When both studies were removed, the heterogeneity in the subgroup dropped to 8%; however, the overall heterogeneity then increased to 32%. The overall effect remained the same throughout all sensitivity analyses, favouring HIIT.

2.6 DISCUSSION

The main aim of this systematic review and meta-analysis was to ascertain whether HIIT or MICT resulted in greater CRF gains for participants with CAD who did not have a diagnosis of HF. Furthermore, we aimed to gauge whether the duration of interventions had an effect on the results. Our review and meta-analysis supported our hypothesis that HIIT improves CRF to a greater extent than MICT. Interventions of > 12 weeks did not show larger gains in CRF from continued HIIT training, as was expected. In addition, programmes of ≤ six weeks did not result in significant changes.

Our findings that HIIT improved CRF significantly more than MICT is in agreement with reports from previous meta-analysis. Elliott et al. (2015) found a mean difference of 1.53 ml/kg/min (95% CI 0.84 to 2.23; p=0.0001) increase in CRF attributed to HIIT; Pattyn et al. (2014) found a mean difference of 1.6 ml/kg/min (95%CI 0.18 to 3.03; p=0.03) increase in CRF attributed to HIIT; and Liou et al. (2016) found a mean difference of 1.78 ml/kg/min (95%CI 0.45 to 3.11; p=0.009). It is important to highlight that we decided to use SMD, instead of MD, to account for differences in measurement procedures and interventions (0.34 ml/kg/min; 95% CI (0.2-0.48); p<0.00001; I^2 =28%). Had we used MD, our findings would be similar to those of previously reported reviews (1.15; 95% CI (0.76-1.55); p<0.00001) and the heterogeneity would have dropped to 13%.

To the best of the authors' knowledge, our systematic review has included the greatest number of RCTs and participants to date. Our study confirmed results of previous systematic reviews that HIIT improves CRF to a larger extent than MICT. Our findings that HIIT is superior to MICT in improving aerobic capacity are likely to be an underestimate of the true differences between groups. This is supported by the methodological decisions favouring using a conservative approach in the meta-analysis (by choosing random effects and standardised mean differences) and using the highest calculated standard deviation for studies where no information was published to allow standard deviation calculations.

The overall heterogeneity in our meta-analysis was minimal (28%). Test for subgroup differences revealed 0% heterogeneity. With respect to duration, all time frames of interventions favoured HIIT; however only the durations > six weeks were found to be significant. Although studies that were of < six weeks duration had

moderate heterogeneity (45%), and one study in this group favoured MICT, this was not significant (Mobius-Winkler et al., 2016).

It appears that performing HIIT for 7-12 weeks' duration elicited the largest SMD in CRF, with studies of greater duration eliciting slightly fewer overall improvements. This may have implications to delivery length of CR service, where programmes of < 7 weeks' duration or > 12 weeks may be suboptimal when implementing HIIT. We did not include a study which investigated the longer term benefits (one year post intervention) of HIIT versus MICT as it did not report that the intensity of exercise was monitored throughout the entire study (Pattyn et al., 2016). The authors, however, did conclude that the CRF levels were maintained in both groups. Based upon the sensitivity analysis, although the results suggest that interventions that were conducted five times a week resulted in greater gains of CRF favouring HIIT, the analysis only included two studies and may not be practical to implement.

The secondary outcome of this study was to investigate adverse events reported within RCTs implementing HIIT and MICT in the cardiac population. There was only one study that reported any cardiac related incidences (angina requiring withdrawal) and this occurred in both intervention groups (Moholdt et al., 2012). There were only a few studies reporting additional adverse effects (primarily musculoskeletal and digestive issues) with more of these events occurring with MICT.

Our investigation which reported no deaths or cardiac related events requiring hospitalisation in either the HIIT or MICT intervention branches supports the conclusion made by Rognmo et al. (2012) that the risk of adverse events was low in both modes of rehabilitative exercise. Rognmo et al. (2012) performed a retrospective analysis of 4,846 patients with cardiovascular disease, which analysed 175,820 hours of CR exercise training for rates of adverse events. They found one fatal event was reported per 129,456 hours of MICT and two non-fatal events per 23,182 hours of HIIT; therefore, the authors recommended the use of HIIT in CR for people with CAD due to the significant cardiovascular adaptations gained from its use.

There is conflicting evidence in the literature concerning drop-out rates with both exercise methods. Previous research suggests that HIIT would not be adopted, or maintained, by participants because they would not find this type of extreme exercise enjoyable and would, therefore, not be a viable public health strategy (Biddle &

Batterham, 2015). However, additional research has found HIIT to have a more positive affect than MICT (Jung et al., 2015; Martinez et al., 2015; Thum et al., 2017). Although our review reported more participants dropped out of MICT, reasons for dropouts were not well reported in the RCTs.

2.6.1 Strengths of the Review

There were a number of strengths to our review. To our knowledge, our review and meta-analysis has included the greatest number of trials to date, including studies not previously published in a review. Furthermore, our review and meta-analysis has the most up to date search date (end of July 2017), minimal heterogeneity, and investigated the effect of different durations of intervention on CRF changes. We used a random effects model to cater to the different methodologies used to assess CRF as well as the different modes of exercise intervention. Moreover, we used a conservative approach when calculating standard deviations. Upon inspection of the funnel plot, (Figure 3) publication bias does not appear to be a concern as all studies fell within the acceptable range (The Nordic Cochrane Centre, 2014).

Previously published meta-analyses have had high heterogeneity (Elliott et al., 2015; Liou et al., 2016; Pattyn et al., 2014) and did not publish adequate methodology surrounding standard deviation measurements (Elliott et al., 2015; Liou et al., 2016). They did not cater for differences in exercise intervention and CRF testing, as fixed effect model of statistical analysis was used. In addition, our research questions surrounding effects of duration of interventions could not be answered by previous reviews; therefore, this systematic review and meta-analysis was required.

2.6.2 LIMITATIONS

There were several limitations to our review. The search used databases which have been used in previous systematic reviews; therefore, the Cochrane Database was not searched. This systematic review included the recent study by Conraads et al. (2015) which involved 200 patients with CAD and compared aerobic capacity changes between HIIT and MICT. The authors found similar improvements between groups. HIIT participants were prescribed exercise at 90-95% HRpeak and MICT participants exercised at 70-75% HRpeak; however, the authors acknowledged that the MICT group exercised closer to 80% HRpeak and HIIT group closer to 88% HRpeak (Conraads et al., 2015). The higher intensity used by the MICT exercisers and lower intensities for the HIIIT participants may account for the non-significant results. This study was heavily weighted in the meta-analysis and may have contributed to the overall underestimation of the gains in CRF that may be potentially gained from HIIT. This, coupled with our conservative approach, may be disadvantaging the actual degree of CRF changes that can be contributed to HIIT and, perhaps, reduce the likelihood of its uptake. No studies reported using a specific protocol to collate adverse events and, therefore, recording of some adverse events may have been missed.

2.6.3 FUTURE DIRECTIONS

Future studies would benefit from being between seven and twelve weeks' duration and undertaking the intervention at least three times a week, ensuring correct intensity is maintained (eg ≥85% VO_2peak or ≥85% HRR or ≥ 90% heart rate max (HRM) interspersed with lower level exercise and MICT (50-75%VO_2peak or 50-75% HRR or 50-80% HRM)). This would allow a more accurate calculation of the true effects of HIIT versus MICT on CRF. Studies should report standard deviations, conceal allocation and blind assessors to improve study quality. Moreover, future studies should aim to recruit more women and older participants (<76 years) to ensure HIIT is more effective than MICT in improving CRF for a broader range of CR participants. Finally, further studies that investigate the longer-term benefits of HIIT and whether these adaptations are maintained would also be beneficial.

2.7 CONCLUSION

This study confirms that HIIT is significantly superior to MICT in improving CRF. When conducting a subgroup analysis, it was shown that interventions lasting more than seven weeks resulted in greater improvements in CRF in CR patients with CAD. This improvement does not appear to increase after twelve weeks' duration. Moreover, this study also shows that HIIT appears to be as safe as MICT as an exercise intervention tool for CR participants. This review may allow countries with guidelines that recommend lower intensity exercise, more confidence in including HIIT within their guidelines and improve international consensus.

2.8 SUPPLEMENTARY MATERIAL

Embase Search Strategy:

("cardiac disease" or "heart disease" or "cardiovascular disease").mp or Heart Diseases/ or "myocardial infarction".mp. or "myocardial infarct".mp. or "heart attack".mp. or "heart infarction".mp. or "heart infarct".mp. or Myocardial Infarction/ or "cardiac arrest".mp. or "coronary artery disease".mp. or CAD.mp. or Coronary Artery Disease/ or arteriosclerosis.mp. or atherosclerosis.mp. or "coronary heart disease".mp. or "coronary disease".mp. or Coronary Disease/ or "ischaemic disease".mp. or "ischemic disease".mp. or "cardiac ischemia".mp. or "cardiac ischaemia".mp. or "myocardial ischemia".mp. or "myocardial ischaemia".mp. or Myocardial Ischemia/ or "ischemic heart disease".mp. or "ischaemic heart disease".mp. or IHD.mp. or "angina".mp. or Angina Pectoris/ or "coronary angioplasty".mp. or angioplasty.mp. or Angioplasty, Balloon, Coronary/ or balloon.mp. or "percutaneous coronary intervention".mp. or PCI.mp. or Percutaneous Coronary Intervention/ or (percutaneous and (heart or coronary or cardiac)).mp. or ((revascularisation or revascularization) and (heart or coronary or cardiac)).mp. or "acute coronary syndrome".mp. or Acute Coronary Syndrome/rehabilitat*.mp. or Rehabilitation/ or Rehabilitation Centers/ or "physical therapy".mp. or physiotherapy.mp. or Physical Therapy Modalities/ or kinesiotherap*.mp. or Exercise Therapy/ or therap*.mp. ("interval training" or "interval exercise" or "interval or continuous" or "moderate intensity continuous exercise" or ("high intensity" and (exercise or training)) or HIIT or HIIE or "vigorous intensity" or ("low volume" and (exercise or training)) or (intermittent adj2 (training or exercise or continuous))).mp

CHAPTER 3: EXPLORING EXERCISE PARAMETERS IN AUSTRALIAN CARDIAC REHABILITATION

PUBLICATION: Hannan, A., Hing, W., Climstein, M., Coombes, J.S., Furness, J., Jayasinghe, R., Byrnes. J. (2018). Australian cardiac rehabilitation exercise parameter characteristics and perceptions of high intensity interval training: a cross sectional survey. *Open Access Journal of Sports Medicine, 9, 79-89.https://doi.org/10.2147/ OAJSM.S160306 under licence CC BY-NC 3.0.*

3.1 PREFACE

This chapter aligns to the second research thesis aim:

"To collect data surrounding current exercise prescription parameters, current usage and clinician perceptions about implementation of HIIT across Australia."

Firstly, the published paper listed above, is presented which outlines current exercise parameters, perceived costs and assessment practices being used in Australian CR programmes during Phase 2 outpatient settings and reports the degree to which HIIT is being implemented. The paper also discusses perceptions of health professionals working in CR (cardiac co-ordinators, exercise physiologists, nurses and physiotherapists) regarding implementation of HIIT, including safety, barriers, perceived pre-screening and monitoring requirements. Finally, under the heading, State Perspectives, additional results are presented that were not published, however, are of interest to clinicians and service delivery. The published manuscript is presented in the final format, as presented in the journal, at Appendix 2.

Australian Cardiac Rehabilitation Exercise Parameter Characteristics and Perceptions of High Intensity Interval Training: a cross sectional survey (Published manuscript, see Appendix 2).

3.2 ABSTRACT

3.2.1 BACKGROUND

This study explored current demographics, characteristics, costs, evaluation methods and outcome measures used in Australian CR programmes. It also determined the actual usage and perceptions of HIIT.

3.2.2 METHODS

A cross-sectional observational web-based survey was sent to 328 Australian CR programmes nationally.

3.2.3 RESULTS

A total of 261 programmes completed the survey (79.6% response rate). Most Australian CR programmes were located in a hospital setting (76%), offered exercise sessions once a week (52%) for six to eight weeks (49%) at moderate intensity (54%) for 46 to 60 minutes (62%) and serviced 101 to 500 clients per annum (38%). HIIT was reported in only 1% of programmes and 27% of respondents believed it was safe whilst 42% of respondents were unsure. Lack of staff (25%), monitoring resources (20%), and staff knowledge (18%) were the most commonly reported barriers to implementation of HIIT. Overall, Australian CR coordinators are unsure of the cost of exercise sessions.

3.2.4 CONCLUSION

There is variability in CR delivery across Australia. Only half of programmes reassess outcome measures post intervention and cost of exercise sessions is unknown. Although HIIT is recommended in international CR guidelines, it is essentially not being used in Australia and clinicians are unsure as to the safety of HIIT. Lack of resources and staff knowledge were perceived as the biggest barriers to HIIT implementation and there are inconsistent perceptions of pre-screening and monitoring requirements. This study highlights the need to educate health professionals about the benefits and safety of HIIT to improve its usage and patient outcomes.

3.3 INTRODUCTION

Cardiac rehabilitation (CR) is an important tool in secondary prevention of cardiovascular disease (CVD) and aims to assist participants to lead full, active lives, while reducing the risk of further cardiac events (Heran et al., 2011; Taylor et al., 2004). CR involves comprehensive education, lifestyle behaviour modification interventions, psychosocial counselling, and supervised exercise programmes (National Heart Foundation of Australia, 2010). These exercise programmes aim to increase the cardiorespiratory fitness (CRF) and the strength of participants.

CRF has a direct correlation with improved prognosis in cardiac patients (Keteyian et al., 2008; Meyer et al., 2002; Swain & Franklin, 2006), and CR programmes should, therefore, ensure that the exercise prescription improves maximal CRF. Evaluation of the extent of change should be measured to allow comparisons of the effectiveness of different exercise methods. Two commonly used exercise methods are moderate intensity continuous training (MICT) and high intensity interval training (HIIT). MICT involves exercising at moderate exercise intensity (usually 60-75% of maximal heart rate (MHR) continuously for a prolonged period (30 to 60min). HIIT involves intense exercise bouts (> 80% of MHR) for 30 secs to 4 mins interspersed with low intensity exercise (40 -50% MHR) for 30 secs to 4 mins as active recovery (Pescatello, 2014). Research has shown HIIT improves CRF levels, particularly VO_2peak by twice as much as MICT (Weston et al., 2014). In cardiac specific populations, there have been systematic reviews supporting that HIIT improves CRF more than MICT (Cornish et al., 2011; Elliott et al., 2015; Hannan, Hing, Simas, et al., 2018; Liou et al., 2016; Pattyn et al., 2014). A systematic review by Ismail et al. (2013) concluded that participants with HF increased peak oxygen consumption by 23% when engaged in HIIT compared with 13% when engaged in MICT.

Guidelines for patients with CVD strongly influence clinicians' practice worldwide as they are formulated from evidence-based research. The American Heart Association, American College of Sports Medicine, European Association for Cardiovascular Prevention and Rehabilitation, Canadian Association of Cardiac Rehabilitation, American Association of Cardiovascular and Pulmonary Rehabilitation Guidelines endorse moderate to vigorous intensity exercise, while Australia, New Zealand, Japan, and the UK favour lower intensity exercise (Price et al., 2016). Current

Australian CR guidelines recommend ≥30 minutes of low to moderate intensity physical activity. For CR participants with high levels of fitness who aim to return to high intensity physical activity, the Australian guidelines suggest that HIIT may be appropriate with medical consent (Woodruffe et al., 2015).

The usage of HIIT in CR is currently unknown in Australia. As emerging research is highlighting the superior ability for HIIT to improve CRF and thus reduce mortality compared to current practice, investigation into current exercise practice, evaluation, and usage of HIIT is timely. Understanding the perceptions towards HIIT implementation will provide greater insight and highlight barriers for usage. This may lead to improved adoption of HIIT as an exercise tool in Australian CR programmes.

The purpose of this paper was to 1) explore current demographics, characteristics, and cost of outpatient Australian CR programmes; 2) identify cardiorespiratory exercise evaluation practices and additional outcome measures; 3) establish the usage of HIIT; and 4) collate clinicians' perceptions around HIIT, particularly safety, barriers, pre-screening, and monitoring requirements.

3.4 METHODS

3.4.1 DESIGN

This was a cross-sectional, observational study using a web-based questionnaire (Survey Monkey Inc., Palo Alto California, USA) and ethics approval (RO 1846) was granted from the University's Human Research Ethics Committee. Questions included both drop-down selection options and open-ended response. Open-ended responses were then grouped into common themes. The survey comprised questions to investigate CR exercise parameters of dose (frequency, duration and intensity) mode, staff type, participation numbers, adherence and uptake rates, and cost. Additionally, questions regarding whether HIIT was safe and perceived barriers of HIIT implementation were asked. Finally, CR coordinators were asked whether reducing the exercise time per session would be beneficial for CR uptake.

The questionnaire was initially peer reviewed by members of the Australian Cardiovascular Health and Rehabilitation Association (ACRA) Executive Committee. In

addition, university academics reviewed the survey. Modifications were made by incorporating the feedback received. Eight Queensland (QLD), Australia sites were subsequently used to pilot the survey prior to distributing nationally.

3.4.2 Inclusion Criteria

Australian CR programmes that delivered on-site outpatient exercise sessions for people with coronary artery disease (CAD) were eligible to participate. CR programmes that were publicly listed on the National Heart Foundation of Australia and ACRA databases were screened for inclusion.

3.4.3 Exclusion Criteria

CR programmes that only delivered inpatient sessions, only provided education, or only serviced patients with HF were excluded.

3.4.4 Recruitment

The CR programme coordinators were initially contacted via email with an overview of the research, participant consent form and a link to the survey. Consent was assumed once participants accessed the link. These documents were accompanied by a letter of support from ACRA. Further reminder emails were sent on a monthly basis. To ensure a high response rate, a further email or phone call was made to remind the programme coordinators of the closing date of the survey.

3.4.5 Data Analysis

All responses were included in the analysis, despite whether the entire survey was completed by individual sites. Percentages were calculated using individual response rates for each question. Responses were downloaded into Excel and analysed as descriptive statistics, namely means, frequencies and percentages.

3.5 Results

3.5.1 Demographics and Characteristics

A total of 328 surveys were distributed, of which 261 programmes responded (79.6% of response rate). Table 5 presents demographic and exercise characteristics of Australian CR programmes.

Table 5: *Demographics and characteristics: responses and (percentages) of Australian CR programmes*

Setting: n=253		**Location: n=254**		**Size: n=246**		**States n= 261**	
Rural	105 (42)	Hospital	191 (76)	<50	74 (30)	New South Wales	88 (34)
Major City	88 (35)	Non-Hospital	63 (24)	50-100	66 (27)	Victoria	79 (30)
Regional	60 (23)			101-500	93 (38)	Queensland	43 (16)
				>500	13 (5)	South Australia	23 (9)
						Western Australia	20 (8)
						Tasmania	4 (2)
						Australian Capital Territory	3 (1)
						Northern Territory	1 (0.01)

Number of Participants/sessions: n=146		**Duration (weeks): n=181**		**Frequency (per/week): n=198**		**Duration of Individual Sessions (minutes) n=213**	
<8	33 (23)	4-6	78 (43)	1	103 (52)	15-30	13 (6)
8-11	63 (43)	6-8	88 (49)	2	86 (43)	31-45	36 (17)
12-15	34 (23)	8-10	1 (0.01)	3	4 (2)	46-60	133 (62)
>15	16 (11)	10-14	14 (8)	4	0 (0)	61-120	11 (6)
				5	5 (3)	Variable	20 (9)

Staff: Participant Ratio n=62		**Percentage Uptake: n=220**		**Percentage Adherence: n=202**	
<1:3	8 (13)	<30	22 (10)	<30	10 (5)
1:3	7 (11)	31-50	43 (20)	31-60	30 (15)
1:4	12 (19)	51-80	114 (52)	61-90	140 (70)
1:5	17 (28)	>80	41 (18)	>90	22 (10)
>1.5:<1:10	10 (16)				
>1:10	8 (13)				

Abbreviation: CR, cardiac rehabilitation

3.5.2 EXERCISE TRAINING INTENSITY

Reported exercise training intensity was used to determine whether programmes were implementing HIIT, which was defined as exercise at intensities >85% of maximal heart rate (MHR). A total of 171 programmes (79.2%) responded to this question. Of these, only 1% (two programmes) reported prescribing high intensity exercise. Figure 5 depicts the percentage of programmes that identified ranges of intensities including light - (50-60% MHR), moderate - (61-75% MHR), vigorous - (75-85%MHR), and high intensity exercise/vigorous to high (>85% MHR).

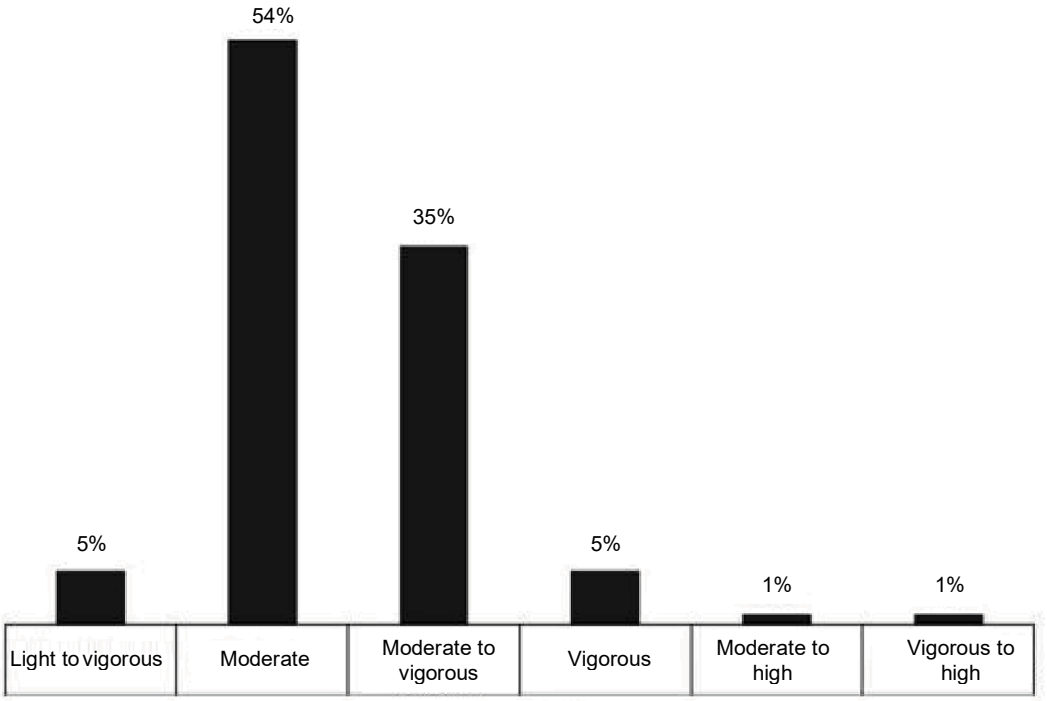


Figure 5. Percentages of national exercise intensity prescription in cardiac rehabilitation (n=171)

3.5.3 EXERCISE CAPACITY TESTING: TYPE/FREQUENCY

A total of 216 (83%) programmes responded to the question about type and frequency of exercise capacity tests performed. The majority (80%) of respondents reported performing a six-minute walking test (6MWT), 7% reported other walking tests, 4% reported using a cycle ergometer test, 3% utilised a stress test or step test, and 8% did no exercise capacity testing.

The frequency of exercise capacity evaluation included testing before participation, upon completion of CR, and at three, six- and twelve-months post completion of CR. The majority (90%) of programmes, performed exercise capacity tests before patients attended CR and 56% repeated these tests upon completion of the programmes. This post completion testing dropped to 16, 11 and 7% of programmes performing tests at three, six and twelve months follow up respectively. In addition, 8% of programmes performed no exercise capacity testing.

3.5.4 Additional Outcome Measures

The majority (92.1%) of programmes utilised outcome measures in addition to CRF tests. A third or more programmes assessed anthropometric measures. Two thirds of programmes measured height, body mass index and waist circumference, and the greatest percent of programmes (89%) measured weight. Less than a third of programmes screened for co-morbidities (musculoskeletal and sternal stability testing) and other measures including quality of life, depression scale, resting and peak exercising heart rates, blood pressure and balance tests. Strength was the least commonly used measure with 7% of programmes assessing it. Figure 6 depicts the percentages of additional outcome measures used within Australian CR.

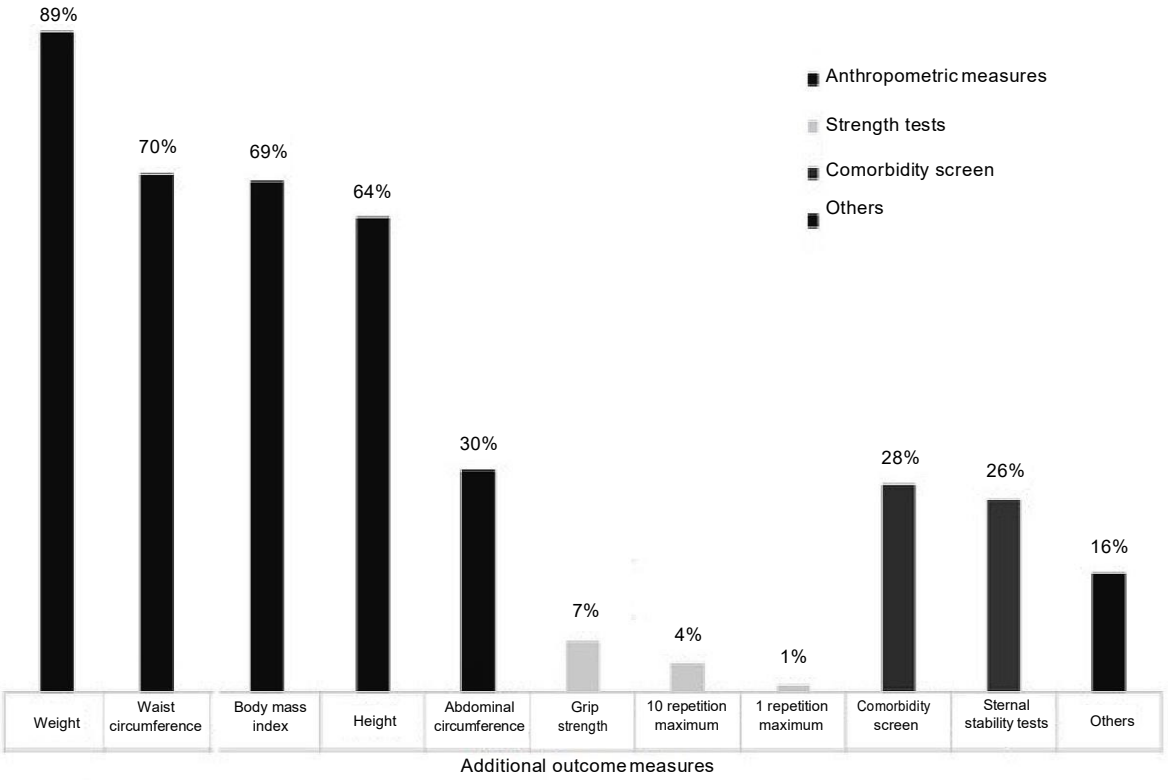


Figure 6. Percentages of additional outcome measures assessed nationally (n=199)

3.5.5 PERCEPTIONS OF HIIT

HIIT was thought to be safe by 27% of the 209 (80%) respondents with 42% being unsure and 31% believing it to be unsafe. There were 190 (73%) respondents who identified perceived barriers to HIIT implementation. The survey allowed each programme to identify multiple barriers. The most commonly identified barriers, lack of staff, monitoring resources and, staff knowledge was only identified by a quarter to one fifth of programmes. Additional barriers were identified by between 6% and 14% of programmes, and only 4% reported perceiving no barriers. Figure 7 shows the percentage of perceived barriers reported for each category.

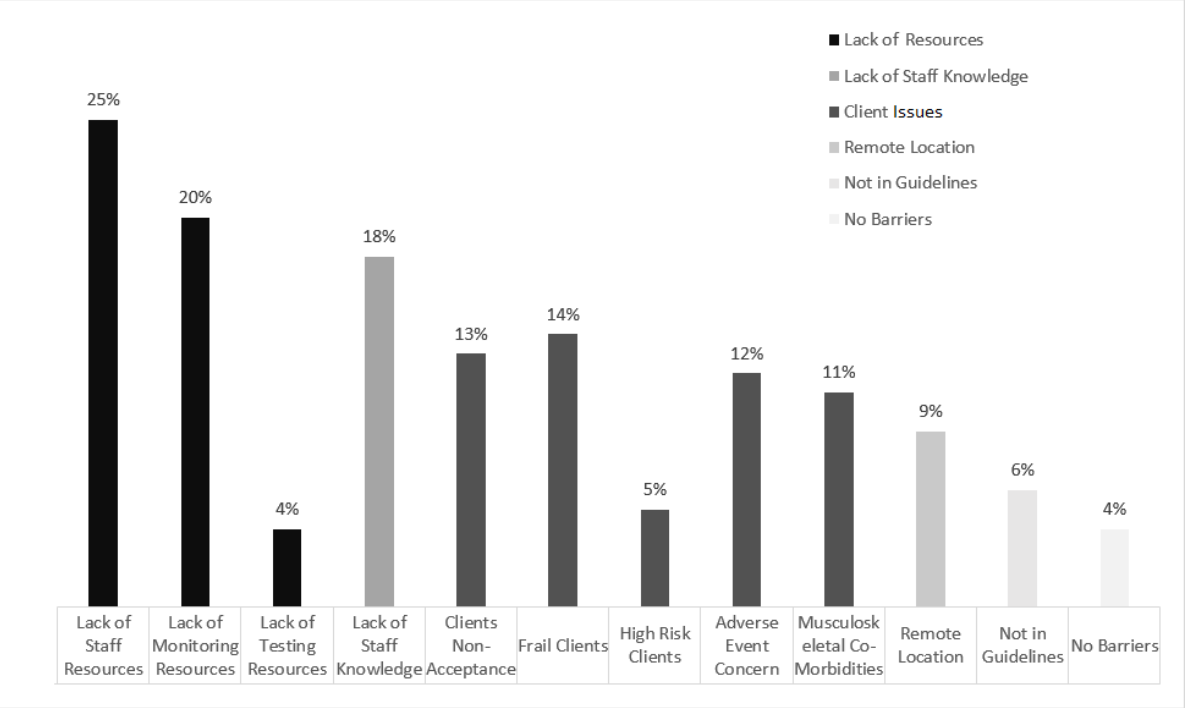


Figure 7. Percentage of national cardiac rehabilitation coordinators' perceptions of barriers to HIIT implementation (n=190).

Of the 201 (77%) respondents, 80% believed that different prescreening of fitness would be necessary if implementing HIIT, 56% of whom, reported that a submaximal graded exercise test would be necessary and 28% chose others (including step test and six-minute walk test). The need for different screening requirements were identified by 19% of respondents, however, this group were unsure as to what type of test should be used. Only 9% reported that testing could be the same as current practice and 6% felt a VO_2 max test should be used as a pre-screening tool for HIIT.

Of the 202 respondents (77%), more than one half (64%) reported monitoring using an external device would be required when implementing HIIT. These devices included a heart rate monitor (46%) 3 lead electrocardiogram (ECG) via telemetry (13%) and 12 lead ECG via telemetry (5%). In addition, a further 13% of respondents believed different monitoring was necessary, however, they did not identify the type of monitoring and 22% were unsure about monitoring requirements.

Of the 211 (81%) respondents, to the question asking whether halving the exercise session times would benefit the CR service, 44% of respondents reported

being unsure, 36% of respondents believed that it would not be beneficial, and 19% of respondents reported that it would benefit their CR service.

Of the 210 (80%) respondents, the majority (82%) believed that by reducing exercise time by half, there would be a <10% improvement in uptake into CR programmes. In addition, 12% of respondents felt that it would improve CR uptake between 11-50% and 6% of respondents believed it would increase uptake by > 50%.

Table 6: *Clinician perception of cost of cardiac rehabilitation in Australia*

Cost per session ($)	Number of respondents (%)	Cost per annum ($)	Number of respondents (%)
<149	19 (28)	15,000–50,000	5(7)
150–299	13 (19)	300,000–500,000	3 (4)
300–449	15 (22)		
450–600	6 (9)		
600–750	1 (1)		
750–999	1 (1)		
>1,000–3,000	6 (9)		

3.5.6 COST

CR coordinators were asked to estimate the cost of conducting an exercise session in their CR programme. There were 179 (67%) responses. Most respondents (61%) stated they were unsure of the cost, with only 39% responding with a dollar value. The majority of programmes (68%) estimated the sessions to cost < $449.

Alternatively, 4% provided a cost per annum ranging between $15,000 to $500,000 with the majority (63%) stating that costs were between $15,000-$50,000. Table 6 depicts the cost values of exercise sessions estimated by clinicians. Answers were given in cost per session and/or amounts per annum (Table 6).

3.6 DISCUSSION

This research aimed to collate national demographic information, characteristics, and economic cost of Australian CR programmes and ascertain the actual usage of HIIT and perceptions surrounding the safety, barriers, prescreening, monitoring requirements, and uptake of HIIT. The high response rate (79.6%) provided insight into Australian CR practice and perceptions surrounding HIIT.

There have been numerous international surveys published investigating CR practice (Benzer et al., 2017; Bethell et al., 2009; Borghi-Silva et al., 2014; Brodie et al., 2006; Delaney et al., 2006; Goto, 2014; Grace et al., 2014; Griffo et al., 2015; Humphrey et al., 2014; Kaminsky et al., 2013; Karoff et al., 2007; Korenfeld et al., 2009; Madan et al., 2014; McGee et al., 2001; Pack et al., 2015; Vromen et al., 2013; Zullo et al., 2012). Most of these focused on programme characteristics such as referral rates, adherence, location, staff mix, patient characteristics, programme duration and frequency (Benzer et al., 2017; Bethell et al., 2009; Borghi-Silva et al., 2014; Brodie et al., 2006; Delaney et al., 2006; Goto, 2014; Grace et al., 2014; Griffo et al., 2015; Humphrey et al., 2014; Kaminsky et al., 2013; Korenfeld et al., 2009; Madan et al., 2014; Pack et al., 2015; Zullo et al., 2012). Several surveys have collated information regarding exercise testing (Benzer et al., 2017; Brodie et al., 2006; Goto, 2014; Griffo et al., 2015; Vromen et al., 2013; Zullo et al., 2012) and only four describe intensity of exercise (Borghi-Silva et al., 2014; Goto, 2014; Korenfeld et al., 2009; Vromen et al., 2013). Five surveys collected data on costs of CR sessions (Bethell et al., 2009; Brodie et al., 2006; Goto, 2014; Karoff et al., 2007; Korenfeld et al., 2009).

3.6.1 DEMOGRAPHICS AND CHARACTERISTICS OF CARDIAC REHABILITATION PROGRAMMES

Most programmes responding to our survey were from New South Wales (NSW) and Victoria (VIC) and primarily geographically located in a rural, hospital-based setting (76%). This is similar to what has previously been reported internationally. Most international surveys reported > 70% of programmes are located in medical facilities, primarily hospitals (Grace et al., 2014; Zullo et al., 2012). In

England, the location of CR was reported as being 55% in the hospital setting, 23% in both hospital and community centres and 16% in leisure settings (Brodie et al., 2006).

We found that most CR programmes (42%) cater for between 101-500 participants annually. According to the National Heart Foundation of Australia, in 2012-2013, there were almost four and a half million admissions to hospital for CVD and an additional 3.4% of people reported a diagnosis of heart attack and ischemic heart disease (Nichols et al., 2016). If the 328 programmes identified by the National Heart Foundation and ACRA databases each catered for 500 participants per year (overestimation of capacity), this would only allow 164,000 participants access to CR. This suggests current capacity for CR may not be meeting demand.

Our study found that most CR exercise sessions are conducted between six- and eight-weeks' duration. This is similar to the duration offered in Europe (mean 8 weeks) (Benzer et al., 2017), England (mean 7.1 weeks) (Brodie et al., 2006), India (6-18 weeks) (Madan et al., 2014), and Ireland (mean 7.4 weeks) (Delaney et al., 2006). The duration is shorter than that offered in Brazil (3-6 months) (Borghi-Silva et al., 2014), Canada (5 months) (Grace et al., 2014), Latin America and the Caribbean (11-15 weeks) (Korenfeld et al., 2009). The United States of America did not report the number of weeks CR sessions were offered to participants, however, 19-36 individual sessions are offered instead (Kaminsky et al., 2013).

CR aims to assist participants to forge exercise as a life-long habit, There is research to support the need for exercise to be performed consistently four times per week for a minimum of six weeks to form a habit (Kaushal & Rhodes, 2015). However, we found that CR programmes in Australia only offer sessions once per week and rely upon participants performing exercise at home to compliment supervised CR sessions. Since the average rates of performance of exercise at home have been found to be only 47% (Sheeran, 2002), it is uncertain whether CR participants will perform exercises frequently enough for them to become a habit or meet recommended exercise guidelines (>150mins per week) (National Heart Foundation of Australia, 2010). If participants failed to perform the recommended amount of exercise, the degree of CRF gained, could be compromised. Australian programmes offer considerably less frequent sessions than international countries. Canada (Grace et al., 2014), England (Brodie et al., 2006), Netherlands (Vromen et al., 2013), Latin America

and Caribbean (Korenfeld et al., 2009) have reported offering sessions 2-3 times a week. Ireland (Delaney et al., 2006) and Europe (Benzer et al., 2017) reported offering sessions four times a week and the United States of America offered 3.6±0.9 sessions/week (Pack et al., 2015). Italy offered the most frequent number of sessions (5.16±1.4 per week) (Griffo et al., 2015).

Most reported 51-80% of eligible participants referred to CR, enrol, and a fifth of programmes reported an uptake of 80%. This is higher than has previously been reported as surveys across several countries have shown 14-43% of potential cardiac patients actually participate in CR programmes (Bethell et al., 2001). Previous literature states that one fifth to one third of patients enrolling complete CR (Bethell et al., 2001; Daly et al., 2002; Lynggaard et al., 2017; Yohannes et al., 2007). The current study found that the majority of programmes reported an adherence rate between 61-90%. This suggests adherence to Australian CR to be at least twice the rate previously reported. However, this higher rate may be due to programmes only offering sessions once per week.

3.6.2 Exercise Capacity Tests and Frequency

Most Australian CR programmes (80%) used the 6MWT to ascertain the exercise capacity of participants. This test is cost effective and requires minimal equipment. However, collection of information regarding blood pressure, heart rhythm or hemodynamic responses to exercise, can be problematic without expensive ECG telemetry equipment. Information pertaining to the hemodynamic response to exercise is particularly important for people with cardiac disease and <1% of programmes reported performing a maximal or submaximal exercise test, despite this test being identified as the gold standard by the American College of Sports Medicine and maximal exercise tests have been shown to be the most accurate in determining maximal aerobic capacity (Pescatello, 2014). The majority of research studies include VO_2peak testing use ECG monitoring, therefore, there appears to be disparity between research and clinical implementation of exercise. There is considerable variation worldwide in the exercise capacity testing methods and frequency used within CR. Canada reported the highest percentage of programmes (90%) that offer exercise

stress testing (Grace et al., 2014). This was followed by the Netherlands reporting that 76% of programmes perform a symptom limited test and 8% of programmes test respiratory exchange (Vromen et al., 2013). England reported 71% of programmes use a graded treadmill exercise test, 50% of programmes use a shuttle test, 25% of programmes use a step test and 29% do not perform any test (Brodie et al., 2006). In Ohio, in the United States of America, it was reported that 78% of programmes obtained stress tests for participants if an exercise physiologist was on staff compared with 56% of programmes with no exercise physiologist (Zullo et al., 2012). Japan reported low rates of cardiopulmonary testing (14-23%) (Goto, 2014) and in Italy, 89% of programmes perform a 6MWT to gauge exercise capacity (Griffo et al., 2015).

To evaluate the effectiveness of an intervention, assessments such as exercise capacity changes, should be performed before and following a CR intervention. In addition, as CRF is a strong predictor of subsequent events within this population (Swain & Franklin, 2006), long-term benefits (3, 6 and 12 months) of the intervention should be assessed. However, our survey results identified approximately one half (56%) of all CR programmes reassessed fitness levels post intervention. The percentage of programmes assessing fitness levels during 3,6, and 12 months follow ups steadily declined the longer the participant had been discharged from CR. This indicates that Australian CR programmes are not adequately re-assessing exercise capacity, and therefore, evaluation of the effectiveness of current exercise prescription techniques, is questionable. The reporting of the percentage of programmes that retest cardiovascular fitness is lacking worldwide, with only Europe reporting 16% of programmes retest (Benzer et al., 2017) and England reporting 55% of programmes retest fitness on completion of CR (Brodie et al., 2006).

3.6.3 Additional Outcome Measures

The current study found anthropometric measures were the most commonly used outcome measures and were used by over two thirds of programmes. A third of programmes also included abdominal circumference measures. This is not surprising as these tests are all inexpensive and quick to implement.

Muscular strength has been previously suggested to be an important component of CR (McCartney et al., 1991). However, we found only 10% of programmes assessed strength changes resulting from participation in CR. This suggests the evaluation of the effectiveness of current exercise prescription, in improving strength, seems to be lacking.

Patients who have undergone CABG comprise a large subsection of participants in CR programmes (Pescatello, 2014) and research has shown 16.3% of patients who undergo CABG via a median sternotomy, develop sternal instability that interferes with daily living (El-Ansary et al., 2000). Although patients who have had CABG should be screened for sternal instability prior to initiating a progressive resistance training programme, another interesting finding of our results was the apparent lack of testing for sternal instability. Only a quarter of CR programmes reported performing sternal stability testing. Our findings thus suggest that some participants may be unknowingly placed at risk of sternal injury or increased risk of dehiscence. These additional outcome measures have not been reported internationally.

3.6.4 High Intensity Interval Training

3.6.4.1 Usage and Perceptions of Safety

The survey identified an underutilisation of HIIT with only one percent of programmes reporting HIIT usage. Furthermore, only a quarter of CR coordinators believed HIIT was a safe form of rehabilitative exercise, despite no research, to the author's knowledge, supporting this belief. Using a retrospective analysis of 4,846 patients with CVD, Rognmo et al. (2012) analyzed 175,820 hours of CR exercise training for rates of adverse events. With regard to safety, they found that one fatal event was reported per 129,456 hours of MICT and two non-fatal events per 23,182 hours of HIIT and concluded that the risk of adverse events were low in both modes of rehabilitative exercise. Rognmo et al. (2012) recommended the use of HIIT in CR for people with CAD due to the significant cardiovascular adaptations gained from its use. In addition, twelve RCTs which compared HIIT to MICT (Amundsen et al., 2008; Benetti et al., 2010; Cardozo et al., 2015; Conraads et al., 2015; Currie et al., 2013;

Jaureguizar et al., 2016; Keteyian et al., 2014; Kim et al., 2015; Moholdt et al., 2012; Munk et al., 2009; Rocco et al., 2012; Rognmo et al., 2004) reported only one adverse cardiac event in the HIIT exercise groups, orthostatic collapse, which did not require hospitalization (Munk et al., 2009). In the MICT groups, one serious adverse event reported (acute MI requiring surgical intervention 24 hours post exercise) and two participants showed significant ST depression on exercise tests requiring PCI after six weeks of training (Conraads et al., 2015). Therefore, the current evidence does not suggest HIIT to be unsafe or lead to increased adverse cardiovascular events compared to MICT. Furthermore, as HIIT improves CRF to a greater extent than MICT, HIIT may provide participants a higher degree of risk reduction and reduce mortality, making it safer in the long term than MICT. The belief that HIIT is unsafe may be contributing to the lack of adoption of this model in Australian CR.

3.6.4.2 Perceived Barriers to HIIT Implementation

Our results showed that a lack of resources, specifically staffing (25%) and monitoring (20%) was the biggest perceived barriers to HIIT implementation. However, the National Heart Foundation of Australia recommends one staff member per ten participants for CR (National Heart Foundation of Australia, 2010) and our findings showed programmes currently cater for twice the recommended minimum staff. This seems to be incongruent with guidelines.

Lack of HIIT knowledge was a commonly (18%) reported barrier to HIIT implementation. This is not surprising as a recent Australian study reported nurses as being the largest group of health professionals supervising CR exercise (87%) and the second largest group to prescribe exercise programmes as treatment, with physiotherapists being the second largest to supervise exercise (66%) (Abell et al., 2016). Nursing staff may not have had formal training in exercise prescription as found in an American study, which reported 92% of nurses surveyed indicated they had no formal training in exercise prescription (Dauenhauer et al., 2006). It would be of interest to identify the level of formal exercise training given to Australian nursing staff. Furthermore, these results highlight the need to investigate whether Australian CR programmes are utilising health professionals who are best qualified to prescribe/supervise exercise within their programmes. Physiotherapists are more

commonly involved in CR than nurses in Germany (36 vs25%) (Karoff et al., 2007), Netherlands (93 vs12%) (Vromen et al., 2013), and India (Madan et al., 2014) where the majority of staff are physical therapists. Cardiologists (77%) and physical therapists (89%) staff the CR programmes in Italy (Griffo et al., 2015) and Latin America and Caribbean countries (100 and 94% respectively) (Korenfeld et al., 2009). Nurses (66%) and exercise physiologists (38%) dominate programmes in the United States of America with minimal physical therapy input (2%) (Kaminsky et al., 2013).

A total of 13% of respondents reported client's nonacceptance as being a barrier to HIIT implementation. It is unclear whether this is due to the perception by staff that participants would not enjoy this type of exercise or whether participants would believe it to be unsafe. A study using Physical Activity Enjoyment Scale results, reported that 92% of participants who engaged in HIIT enjoyed this exercise significantly more than MICT (Thum et al., 2017). This preference for HIIT was also found in another study where >50% of participants preferred HIIT over MICT (Jung et al., 2014), further highlighting the possible incongruence in respondents' beliefs about the degree of patient's non-acceptance.

3.6.4.3 Perceived Pre-screening Practices

The majority of respondents to the survey believed that a graded exercise test would be required prior to implementing HIIT. Australian practices would need to cater for the addition of such tests when implementing HIIT; however, it could be argued that these tests should become standard practice for all CR participants to allow an evidence-based exercise prescription (Pescatello, 2014).

3.6.5 Uptake

A lack of time has previously been reported in the literature as the most common reason that Australian adults do not engage in regular physical activities (Booth et al., 1997). A further study involving 2,236 adults and analysing barriers to physical activity found lack of time was most commonly identified (55%) as a barrier to participation (Sequeira et al., 2011).

This evidence suggests that reducing the time of exercise sessions in CR programmes by implementing HIIT may improve uptake; yet programme responders do not seem to agree.

3.6.6 Cost

Our study showed that Australian CR coordinators are unsure of the cost of a CR exercise session. This lack of knowledge costs by clinicians is similar to that found in Latin America and Caribbean which showed that 79% of programmes did not know the costs associated with CR, 9% of programmes reported the cost > $150 000/year and 9% reported in excess of this (Korenfeld et al., 2009). There is further variability in cost estimations of CR worldwide. In Germany, the cost was estimated to be €75-87/day (Karoff et al., 2007), England reported the mean cost per patient as £288 (Brodie et al., 2006) and Japan estimated the cost as $42 per hour (Goto, 2014). Further studies investigating the actual costs of Australian CR programmes would be beneficial in determining the most cost-effective treatment.

3.6.7 Limitations

The survey was not designed to require respondents to answer each question before proceeding to the next, which may have created some response bias. This resulted in missing data. Definitions were not given, and some open-ended questions were open to interpretation. Although a pilot survey was performed, no reliability testing was undertaken. The survey was sent to CR coordinators, however the type of health professional each respondent represented was not identified.

3.7 CONCLUSION

Results identified that CR in Australia is mostly performed once per week for 6 - 8 weeks for 41 to 60 minutes duration at a moderate intensity, which may not be sufficient in allowing participants to adopt exercise as a lifelong habit. The evaluation of the effectiveness of current Australian CR programmes in improving exercise capacity and muscular strength is lacking with just under half of programmes failing to perform re-assessments. CR coordinators are also unsure as to the cost of their current CR services.

Although HIIT has been recommended in international CR guidelines, it is not being utilised in Australia and programme respondents are unsure as to the safety of HIIT. Lack of resources and knowledge was perceived as the biggest barrier to HIIT implementation, and there are inconsistent perceptions of prescreening and monitoring requirements.

This study highlights the need to improve exercise capacity and muscular strength evaluation methods of current practice in CR. It also emphasises the need to educate Australian clinicians regarding safety, enjoyment and physiological benefits of HIIT. Failure to do so may hinder adoption of HIIT and potentially disadvantage suitable patients who could reap the superior physiological and cardio-protective benefits associated with HIIT.

Results of this survey could be helpful to the personnel responsible for designing CR programmes in Australia. Increasing the frequency of sessions, re-evaluating the effectiveness of the exercise sessions through repeated outcome measures, and introducing HIIT should be considered. A further survey may be warranted in a five-year timeframe to further assess Australian practices.

3.8 ADDITIONAL RESULTS; A STATE PERSPECTIVE

The following section presents additional unpublished results from the survey, particularly looking at further delineating results per state or territory of Australia. Australia is one of the least densely populated places globally and is divided into six

states [New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), Western Australia (WA), Tasmania (TAS)] and two territories [Northern Territory (NT), Australian Capital Territory (ACT)]. As the ACT, NT, WA and TAS have only small number of programmes responding, they were grouped together.

These additional results are useful to benchmark between states and territories to assist and inform service delivery provision. Additional results have been presented in five parts:

1. Broad demographics (location, size, uptake, adherence and cultural inclusiveness)
2. Individual exercise session parameters (number of participants, staff:participant ratio, frequency of attendance, duration of session and exercise equipment used and monitoring practices)
3. Assessment (types of fitness tests, timing of tests and other outcome measures used)
4. Types of health professionals that prescribe, supervise and progress exercise prescription).
5. HIIT perceptions by state (safety, barriers, perceived pre-screening requirements and perceived monitoring requirements)

3.8.1 Broad Demographics/State (size, uptake, adherence and cultural inclusiveness)

3.8.1.1 Location of Programme

There were 254 programmes nationally that responded to the question asking about the location of CR programmes. Three quarters of all programmes nationally reported CR programmes were held in the hospital setting. From a state perspective, the percentages that run CR programmes in the hospital setting ranged from 60.7% (ACT/NT/WA/TAS) to 84.6% (QLD). Both NSW (77%) and VIC (75%) also reported more than three quarters of programmes are run in the hospital setting (Table 7).

3.8.1.2 SIZE OF PROGRAMMES

There were 246 programmes nationally that responded to the question asking how many participants enrolled in individual CR programmes each year. Nationally, the greatest percentage of programmes (38%) indicated that 101-500 participants/year enrolled. From a state perspective, all states indicated the most programmes had between 101-500 participants, ranging between 25% (ACT/NT/WA/TAS) to 43.5% (SA). All states indicated the least number of programmes had >500 participants, ranging between 8.3% (ACT/NT/WA/TAS) to 0% (SA). VIC had the largest percentage of programmes that had >50 participants (79.4%) and NSW had the greatest number of programmes with <50 participants (36.9%). Most of WA's programmes are small with only three programmes catering for more than 100 participants in a year. Finally, ACT and TAS reported no programmes catered for < 50 participants/year (Table 7).

3.8.1.3 PERCENTAGE UPTAKE

There were 220 programmes nationally that responded to the question asking how many participants who were referred to a CR programme, subsequently enrol. Nationally, the 51-80% category was reported the most (52%) and <30% was reported least (10%). Interestingly, almost a fifth of programmes have an uptake of > 80%. With respect to the states, VIC had the greatest number of uptakes with 83.5% of programmes converting over half of all referrals into enrolments of which a quarter were above 80%. NSW had the highest percentage (13.6%) of programmes reporting less than a third of referrals resulted in enrolment. Only one programme in ACT/NT/WA/TAS reported uptake of less than a third and over two thirds of QLD programmes reported enrolling over 51% or more referred participants (Table 7).

3.8.1.4 ADHERENCE

There were 202 programmes nationally that responded to the question asking how many participants who enrolled into a CR programme, subsequently complete the programme. Nationally, the highest reported category was 61-90% with 69% of programmes indicating that greater than two thirds of participants complete CR programmes. From a state perspective, QLD reported the highest percentage of

programmes (15%) with a >90% completion rate. All states reported high adherence rates, above 70%, with SA, VIC and QLD all reporting completion rates above 80%. All states had small numbers of programmes (≤10%) reporting low (<30%) adherence rates (Table 7).

3.8.1.5 Cultural Inclusiveness

With respect to Australian CR programmes catering for people with Aboriginal and Torres Strait Islander descent, 94% of programmes identified catering for their needs within their usual class setting. Only 6% of respondents ran a separate class specifically for this population. With respect to the states, there were only a small number of programmes in each state which cater for people with Aboriginal and Torres Strait Islander descent by running a separate class with ACT/NT/WA/TAS combined which had the largest percentage of total programmes (12%) in a separate class setting, and VIC which had the least percentage of programmes running separate classes (1%) (Table 7).

3.8.2 Exercise Parameters

3.8.2.1 Duration of programmes/state

There were 181 programmes nationally that responded to the question asking what duration (in weeks) CR programmes are offered. Most programmes (92%) were between 4-8 weeks in duration. From a state perspective, NSW, VIC and SA had more than half their programmes lasting 6-8 weeks, whereas QLD reported over three quarters of programmes were only 4-5 weeks in duration. Only one programme (VIC) identified offering a programme of 9-10 weeks duration. ACT/NT/WA/TAS combined had the largest percentage of programmes (27%) running for 11-14 weeks' duration with the remaining states reporting less than 8% offered programmes of 10-14-week durations (Table 8).

3.8.2.2. FREQUENCY OF ATTENDANCE/STATE

There were 198 programmes nationally that responded to the question asking what frequency (times/week) CR programmes are offered. Most programmes (95%) offered sessions once (52%) or twice/week (43%). With respect to the states, QLD had the highest number of programmes (65%) offered twice per week and VIC had the highest number of programmes offering sessions once/week. The remaining states had similar numbers offering once and twice /week sessions. ACT/NT/WA/TAS combined reported 11% of programmes ran sessions three times a week, with the other states reporting less than 5% of programmes ran three or more times a week. Finally, there were no programmes that offered sessions four times a week (Table 8).

3.8.2.3 DURATION OF INDIVIDUAL EXERCISE SESSIONS

There were 208 programmes nationally that responded to the question asking how long (minutes) each individual CR programme ran. Most programmes (64%) indicated classes continued for between 46-60 minutes duration. From a state perspective, all states reported 57% or above of programmes ran between 46-60 minutes duration. Less than 10% of programmes in NSW, VIC and QLD offered longer duration programmes with no programmes in SA or ACT/NT/WA/TAS combined offering longer durations. Less than 24% of programmes reported durations of 30-45 minutes and less than 20% reported durations between 15-30 minutes with VIC reporting no programme identified as being this short. Ten percent of programmes or less in each state reported the classes varied in duration (Table 8).

3.8.2.4 INTENSITY OF INDIVIDUAL PROGRAMMES/STATE

There were 171 programmes nationally that responded to the question asking about the intensities prescribed within each individual CR programme. Most programmes (54%) prescribed moderate intensity exercise. With respect to the states, all, except SA, reported the most programmes between 49-64% prescribed moderate intensity exercise. SA reported three quarters of programmes prescribed moderate to vigorous exercise. Only 1% of all programmes prescribed high intensity exercise. NSW (3%) was the only state reporting the use of moderate to high exercise intensity and NSW and VIC, both reported one programme each which prescribed vigorous-high intensity exercise (Table 8).

Table 7: *Broad demographics/state (size, uptake, adherence and cultural inclusiveness)*

State	Location: number of programmes/states; (%) of state total			Size: number of participants/years; (%) of state total					Uptake: number of programmes with % of participants referred that subsequently enrol; (%) of state total					Adherence: number of programmes with % of participants finishing programme; (%) of state's total					Cultural Inclusiveness: number of programmes; (%) of state total		
	H	NH	T	<50	50-100	101-500	>500	T	<30%	31-50%	51-80%	>80%	T	<30%	30-60%	61-90%	>90%	T	Usual class	Separate class	T
NSW	68 (77.3)	20 (22.7)	88	31 (36.9)	17 (20.2)	31 (36.9)	5 (5.9)	84	10 (13.6)	15 (20.5)	35 (47.9)	13 (17.8)	73	5 (7.5)	10 (14.9)	44 (65.7)	8 (11.9)	67	79 (92.9)	6 (7.1)	85
VIC	58 (75.3)	19 (24.7)	77	15 (20.5)	26 (35.6)	29 (39.7)	3 (4.1)	73	3 (4.5)	8 (11.9)	39 (58.2)	17 (25.3)	67	2 (3.1)	9 (14)	47 (73.4)	6 (9.4)	64	38 (92.7)	3 (7.3)	41
QLD	33 (84.6)	6 (15.4)	39	13 (30.4)	9 (21.4)	17 (40.5)	3 (7.1)	42	4 (10.2)	10 (25.6)	20 (51.3)	5 (12.8)	39	1 (2.9)	5 (14.7)	23 (67.6)	5 (14.7)	34	20 (90.9)	2 (9.1)	22
SA	15 (68.1)	7 (31.8)	22	7 (30.4)	6 (26.1)	10 (43.5)	0 (0)	23	4 (20)	6 (30)	9 (45)	1 (5)	20	2 (10.5)	1 (5.3)	14 (73.7)	2 (10.5)	19	69 (98.6)	1 (1.4)	70
ACT/NT/WA/ TAS	17 (60.7)	11 (39.2)	28	8 (33.3)	8 (33.3)	6 (25.0)	2 (8.3)	24	1 (4.8)	4 (19)	11 (52.4)	5 (23.8)	21	0 (0)	5 (27.8)	12 (66.7)	1 (5.6)	18	22 (88)	3 (12)	25
NATIONAL TOTAL	191 (75.2)	63 (24.8)	254	74 (30.1)	66 (26.8)	93 (37.8)	13 (5.3)	246	22 (10)	43 (19.5)	114 (51.8)	41 (18.6)	220	10 (4.9)	30 (14.9)	140 (69.3)	22 (10.9)	202	228 (93.8)	15 (6.2)	243

Abbreviations: H, hospital; NH, non-hospital, T, Total number of programmes responding/state

Table 8: *Exercise Parameters/State*

State	Number of programmes/state that report duration (weeks) of CR programmes; total state (%)					Number of programmes/state that report frequency of sessions offered/week; total state (%)						Number of programmes that report duration of individual class sessions (mins); total state (%)						Number of programmes/states that reported intensity of exercise; total state (%)						
	4-5	**6-8**	**9-10**	**11-14**	**T**	**1**	**2**	**3**	**4**	**5**	**T**	**15-30**	**30-45**	**46-60**	**61-120**	**V**	**T**	**l-v**	**m**	**m-v**	**v**	**m-h**	**v-h**	**T**
NSW	19 (35.8)	30 (56.6)	0 (0)	4 (7.5)	53	33 (48.5)	30 (44.1)	2 (2.9)	0 (0)	3 (4.4)	68	5 (6.8)	12 (16.4)	42 (57.5)	7 (9.6)	7 (9.6)	73	1 (1.6)	30 (49.2)	22 (36.1)	5 (8.2)	2 (3.3)	1 (1.6)	61
VIC	20 (32.3)	37 (59.7)	1 (1.6)	4 (6.5)	62	41 (65.1)	20 (31.7)	0 (0)	0 (0)	2 (3.2)	63	0 (0)	14 (21.5)	47 (72.3)	2 (3.1)	2 (3.1)	65	2 (3.6)	34 (60.7)	18 (32.1)	1 (1.8)	0 (0)	1 (1.8)	56
QLD	26 (76.5)	6 (17.6)	0 (0)	2 (5.9)	34	12 (37.5)	20 (62.5)	0 (0)	0 (0)	0 (0)	32	3 (10.7)	4 (14.3)	17 (60.7)	2 (7.1)	2 (7.1)	28	3 (10.7)	18 (64.3)	6 (21.4)	1 (3.6)	0 (0)	0 (0)	28
SA	8 (47.1)	9 (52.9)	0 (0)	0 (0)	17	9 (56.3)	7 (43.8)	0 (0)	0 (0)	0 (0)	16	1 (4.8)	5 (23.8)	13 (61.9)	0 (0)	2 (9.5)	21	0 (0)	2 (16.7)	9 (75)	1 (8.3)	0 (0)	0 (0)	12
ACT/NT/WA/TAS	5 (33.3)	6 (40)	0 (0)	4 (26.7)	15	8 (42.1)	9 (47.4)	2 (10.5)	0 (0)	0 (0)	19	4 (19)	1 (4.8)	14 (66.7)	0 (0)	2 (9.5)	21	2 (14.3)	8 (57.1)	4 (28.6)	0 (0)	0 (0)	0 (0)	14
NATIONAL TOTAL	78 (43.1)	88 (48.6)	1 (0.6)	14 (7.7)	181	103 (52)	86 (43.4)	4 (2)	0 (0)	5 (2.5)	198	13 (6.3)	36 (17.3)	133 (63.9)	11 (5.3)	15 (7.2)	208	8 (4.7)	92 (53.8)	59 (34.5)	8 (4.7)	2 (1.2)	2 (1.2)	171

Abbreviations: T, total, V, variable lengths, l-v, low-vigorous intensity, m, moderate intensity, m-v, moderate-vigorous intensity, v, vigorous intensity, m-h, moderate to high intensity, v-h, vigorous to high intensity.

3.8.3 SIZE, STAFFING AND TIMING OF FITNESS TESTS/STATE

3.8.3.1. NUMBER OF PARTICIPANTS EXERCISING PER SESSION

As reported earlier, there were 146 programmes nationally that responded to the question asking about the number participants exercising together in an exercise session. Most programmes (43%) reported between 9-11 participants were in each class. An equal number of programmes (23%) reported <8 and 12-15 participants/class and the least percentage of programmes (11%) had >15 participants. From a state perspective, most states had similar spread of percentages having 9-11 participants, with QLD and SA having slightly more programmes in this category. QLD had only one programme with more than 11 participants and ACT/NT/WA/TAS combined had the greatest number of programmes (46%) with the least number of participants exercising per class (Table 9).

3.8.3.2 STAFF: PARTICIPANT RATIO

As reported earlier, there were only 62 programmes nationally that responded to the question asking about how many staff supervised exercise for every participant. The staff: participant ratio was similar across categories and ranged from 11% having a ratio of 1 staff for every 3 participants to 27% having 1 staff for every 5 participants. With respect to state perspective, only a small number of programs from each state answered the question about staff: participant ratio ranging from three (SA) to 24 (NSW). The least percentage of reported staff: participant ratios across all states except SA was >1:10; with SA reporting no programmes in this category. QLD and NSW reported the most programmes in the 1:5 category and the remaining states had an even spread across each category (Table 9).

3.8.3.3. TIMING OF FITNESS TEST/STATE

There were 216 responses nationally to the question asking about when fitness tests were conducted and repeated. Programmes could choose more than one response resulting in 410 responses. Therefore, national response percentages were based on the number of programmes responding (n=216), not total number of all responses as each program may have indicated several responses. As reported earlier, the majority (90%) of programmes, performed exercise capacity tests before patients attended CR and 56% repeated these tests upon completion of the programmes. The percentage of follow up fitness tests dropped markedly the longer time passed from discharge from CR. Only 16% of programmes assessed fitness at 3 months and this dropped to 7% by twelve months. In addition, 9% of programmes performed no exercise capacity testing. With regards to states, NSW and SA had the largest percentage of programmes not performing any fitness tests, however this was less than 10%, however all other states had less than 3% of programmes not performing fitness tests. All states had similar percentages of programmes performing tests before commencement of CR ranging between 43-53%. NSW, VIC and QLD indicated one third of programmes completed fitness tests on completion of the programmes and dropped to 16% in WA/ACT/NT/TAS combined. At 3 months, WA/ACT/NT/TAS (19%) combined reported the highest percentage of programmes that performed fitness tests. NSW and SA (5%) both had the lowest percentage of programmes perform fitness tests at 3 months post completion of programmes. All states reported less than 9% of programmes performed follow up fitness tests at 6 and 12 months post discharge from CR ranging from 4-8% and 0-8% respectively. No QLD programmes reported performing fitness tests at 12 months post completion of programme (Table 9).

Table 9: *Size, Staffing and Timing of fitness tests/State*

State	Number of participants/class/states; (%) of state total					Staff: Participant ratio/state; (%) of state total							Timing of fitness test/state; * (%) of state total (n=216)						
	<8	9-11	12-15	>15	T	<1:3	1:3	1:4	1:5	>1:5 <1:10	>1:10	T	N	BP	AP	3 m	6m	12 m	T
NSW	7 (15.9)	17 (38.6)	14 (31.8)	6 (13.6)	44	3 (12.5)	2 (8.3)	4 (16.7)	9 (37.5)	4 (16.7)	2 (8.3)	24	10 (6.8)	63 (42.6)	48 (32.4)	8 (5.4)	11 (7.4)	8 (5.4)	148
VIC	8 (17.4)	18 (39.1)	14 (30.4)	6 (13)	46	4 (22.2)	2 (11.1)	4 (22.2)	4 (22.2)	2 (11.1)	2 (11.1)	18	3 (2.4)	63 (50.4)	39 (31.2)	11 (8.8)	5 (4)	4 (3.2)	125
QLD	10 (37)	16 (59.3)	1 (3.7)	0 (0)	27	0 (0)	1 (16.7)	1 (16.7)	3 (50)	1 (16.7)	0 (0)	6	2 (3.1)	33 (51.6)	19 (29.7)	7 (10.9)	3 (4.7)	0 (0)	64
SA	2 (12.5)	9 (56,2)	3 (18.8)	2 (12.5)	16	1 (33.3)	0 (0)	0 (0)	1 (33.3)	1 (33.3)	0 (0)	3	3 (8.1)	17 (45.9)	9 (24.3)	2 (5.4)	3 (8.1)	3 (8.1)	37
ACT/NT/WA/TAS	6 (46.1)	3 (23.1)	2 (15.4)	2 (15.4)	13	0 (0)	2 (18.2)	3 (27.3)	0 (0)	2 (18.2)	4 (36.3)	11	1 (2.8)	19 (52.8)	6 (16.7)	7 (19.4)	2 (5.6)	1 (2.8)	36
NATIONAL TOTAL	33 (22.6)	63 (43.2)	34 (23.3)	16 (10.9)	146	8 (12.9)	7 (11.3)	12 (19.4)	17 (27.4)	10 (16.1)	8 (12.9)	62	19 (8.8)	195 (90.3)	121 (56)	35 (16.2)	24 (11.1)	16 (7.4)	216*

Abbreviations: T, total/state N, none, BP, before programme commencement, AP, after programme completion, 3 m, 3 month follow up, 6m, 6 month follow up, 12 m, 12 month follow up,

* Programmes could indicate more than one response.

3.8.4 TYPES OF EQUIPMENT AND MODE OF EXERCISE

There were 215 programmes who responded to the question asking about types of equipment used within CR programmes. With respect to the types of equipment used within Australian CR programmes, a cycle ergometer (93%) was most commonly reported. Resistance training, walking and treadmills were used in 80% or more of programmes. Two thirds of programmes used an arm ergometer and a third of programmes using steppers, calisthenics and stair climbers. One fifth of programmes used rowers, cross trainers and other (such as therabands, swiss balls, staircase, mini tramp, wii fit, thai chi, circuit, chair exercise, balance, arm pedals) and less than 10% of programmes utilised games/sport, swimming and pool exercises. This spread was similar across states. VIC and QLD did not use water as a training medium and no programme in SA used swimming and no programmes in WA/ACT/NT/TAS combined used games/sport (Table 10).

Table 10: *Percentage of programmes utilising types of equipment/state*

Equipment	NSW (%)	QLD (%)	SA (%)	VIC (%)	WA/ACT/NT/TAS (%)	TOTAL Number of Programmes nationally*
Cycle Ergometer	92	100	90	94	86	200 (93)
Resistance training	84	80	90	86	86	179 (83)
Walking (not on treadmill)	84	67	95	86	71	176 (82)
Treadmill	79	94	90	77	62	173 (80)
Arm Ergo	66	77	60	62	43	137 (64)
Calisthenics	42	40	10	27	43	81 (38)
Stepper	37	46	45	35	29	74 (34)
Stair Climber	29	20	20	24	5	65 (30)
Rower	25	54	50	18	29	49 (23)
other	19	26	25	21	14	45 (21)
Cross-trainer	14	31	30	21	19	45 (21)
Games/sport	12	11	5	6	0	18 (8)
Pool	3	0	5	0	19	7 (3)
Swimming	1	0	0	0	5	2(1)

(n=215;NSW (73), VIC (66), QLD (35), SA (20), WA/ACT/NT/TAS (21), *programmes use more than one type of equipment

3.8.5 OUTCOME MEASURES

There were 199 responses nationally to the question asking about additional outcome measures assessed within CR programmes. The majority (92.1%) of programmes utilised outcome measures in addition to CRF tests. As reported previously, two thirds of programmes measured height, body mass index and waist circumference. Weight was measured by the greatest percent of programmes (89%). Less than a third of programmes screened for co-morbidities (musculoskeletal and sternal stability testing) and other measures including quality of life, depression scale, resting and peak exercising heart rates, blood pressure and balance tests. Strength (including grip, 10 or 1 repetition maximum) was the least commonly used measure. This trend was mirrored by the states except for WA/ACT/TAS/NT combined, which reported over half of programmes measured 1 repetition maximum. Furthermore, 100% of QLD programmes reported measuring weight (Table 12).

Table 11: *Percentages of outcome measures collected/state*

Outcome measure:	NSW (%)	VIC (%)	QLD (%)	SA (%)	WA/ACT/TAS/NT (%)
1 repetition maximum	0	0	0	0	58
10 repetition maximum	4	2	3	6	5
Abdominal Circumference	30	20	49	24	37
BMI	70	59	83	71	68
Co-morbidity musculoskeletal assessment	25	28	34	29	26
Grip Strength	7	7	6	12	0
Height	67	48	86	71	63
Other	19	10	11	12	37
Sternal stability tests	31	21	26	29	21
Waist Circumference	70	57	86	82	74
Weight	91	85	100	88	79

n=199; NSW (67), VIC (61), QLD (35), SA (17), WA/ACT/TAS (19)

3.8.6 MONITORING PRACTICES

There were 213 responses nationally to the question asking about monitoring practices during exercise sessions. National data was collected regarding monitoring practices that occur before, during and after exercise along with monitoring only when indicated by symptoms. Blood pressure, and heart rate using an external device, were the most common monitoring practices occurring before exercise. Rate of perceived exertion and heart rate monitoring using an external device were most commonly used during and after exercise. Blood pressure, blood glucose levels and heart rate using an

external device were most commonly used only when indicated by symptoms. ECG was the least commonly used monitoring practice before, during and after exercise and rate of perceived exertion was the least commonly used practice when symptomatic monitoring was required (Table 13).

Table 12: *Monitoring practices in Australian cardiac rehabilitation programmes (percentages) (n=213)*

Type of Monitoring	Before Exercise Session (%)	During Exercise Session (%)	After Exercise Session (%)	Only when indicated by symptoms (%)
Blood Pressure	76	18	42	45
ECG	4	2	2	31
Heart Rate Monitor (polar)	71	50	58	45
Heart Rate by Palpation	38	23	28	36
Rate of Perceived Exertion	40	74	44	11
Respiratory Rate	22	14	15	37
Blood Glucose Level	26	6	15	45
No Monitoring	4	3	2	1

3.8.7 METHOD OF DETERMINING EXERCISE INTENSITY PRESCRIPTION

There were 101 responses nationally to the question asking about methods used to determine exercise intensity prescription. The most commonly reported method (47%) used nationally was utilisation of the Modified Borg Scale (0-10 scale). A third of programmes used the Borg scale (6-20 scale), 5% used heart rate measured via exercise testing, 4% predicted percent of heart rate based on age predicted MHR, 2% reported using the Karvonen method, 0.9% used the Gellish method (207-(0.7*age) to determine heart rate and 0.5% used a maximal or submaximal heart rate via exercise testing or assessment of the maximum volume of oxygen attainable by an individual (VO_2max) exercise testing. This trend was similarly spread across states. WA was the only state to record any programme measuring heart rate via formal exercise testing and TAS was the only state to report using VO_2max measured via exercise testing. Both of these only had one programme each utilising these methods.

3.8.8 HEALTH PROFESSIONALS PRESCRIBING, SUPERVISING AND PROGRESSING EXERCISE

There were 230 responses nationally to the question asking about the types of staff used to prescribe, supervise and progress exercise prescription. Throughout Australia, physiotherapists (70%) were the main health professionals prescribing exercise, followed by nurses (33%), exercise physiologists (31%) and physiotherapy assistants (6%). Doctors and occupational therapists infrequently (1%) prescribed exercise. Other health professionals reported as being involved in exercise prescription were fitness coaches, heart moves instructors and students.

With respect to prescribing exercise in specific states, all states utilised physiotherapists as the main health professional to prescribe exercise. ACT/WA/NT/TAS, NSW and SA reported nurses as the second most common health professional to prescribe exercise, whereas QLD and VIC reported exercise physiologists as the second most common health professional to prescribe exercise (Table 13). NSW and VIC reported one programme each where a cardiologist, medical professional and occupational therapist prescribed the exercise and SA reported one programme each that utilised a medical professional and occupational therapist.

Table 13: *Percentage of Programmes utilising different health professionals to* ***prescribe*** *exercise/ state (n=230)*

State	Nurses (%)	Physiotherapist (%)	Exercise Physiologist (%)	Physiotherapy Assistants (%)
NSW	29	39	18	8
VIC	18	51	22	2
QLD	18	49	33	0
SA	17	55	10	7
ACT/WA/NT/TAS	23	52	19	0

The main health professionals supervising exercise nationally were nurses (79%), physiotherapists (61%), physiotherapy assistants (33%) and exercise physiologists (31%). 0.8% of programmes were reported as being unsupervised and no programme identified doctors as supervising exercise, whilst occupational therapists infrequently supervised exercise (1%).

Table 14: *Percentage of Programmes utilising different health professionals to **supervise** exercise/state*

State	Nurses (%)	Physiotherapist (%)	Exercise Physiologist (%)	Physiotherapy Assistants (%)
NSW	43	26	14	11
VIC	32	29	14	23
QLD	41	27	21	10
SA	43	33	5	14
ACT/WA/NT/TAS	21	39	18	13

(n=230)

All states except ACT/WA/NT/TAS had more nurses supervising exercise than both physiotherapists and exercise physiologists (Table 14). VIC and SA had more physiotherapy assistants supervising exercise than exercise physiologists. One programme in each of NSW, VIC and QLD reported using an occupational therapist to supervise exercise and one programme each in NSW and VIC reported classes were unsupervised.

Physiotherapists were mainly responsible for progressing the exercise prescription nationally (66%), followed by nurses (45%), exercise physiologists (30%) and physiotherapy assistants (9%). Doctors and occupational therapists infrequently (0.4%) progressed exercise. Other health professionals reported as being involved in exercise prescription were fitness coaches, heart moves instructors and students. From a state perspective, the health professional with the greatest percentage of programmes utilising them to progress exercise were physiotherapists, however this was only half of programmes per state and only one third of programmes in NSW. NSW reported 36% of programmes utilise nurses, whilst 35% recorded physiotherapists as performing this role. QLD and ACT/WA/NT/TAS were the only states where exercise physiologists were used more than nurses for progressing exercises. Cardiologists and doctors did not progress exercise in all states except VIC which only recorded one programme where a doctor had this role. Occupational therapists also did not progress exercise in all states except NSW which only recorded one programme where occupational therapists prescribed exercise (Table 15).

Table 15: *Percentage of Programmes utilising different health professionals to **progress** exercise/state (n=230)*

State	Nurses (%)	Physiotherapist (%)	Exercise Physiologist (%)	Physiotherapy Assistants (%)
NSW	36	35	18	7
VIC	25	46	20	6
QLD	25	45	28	0
SA	32	45	6	10
ACT/WA/NT/TAS	20	50	23	3

3.8.9 HIIT Perceptions Per State and Home Exercise

As reported previously, nationally, HIIT was thought to be safe by 27% of the 209 respondents with 42% being unsure and 31% believing it to be unsafe. Queensland was the only state reporting more clinicians who thought HIIT was safe than those who thought it was unsafe. All states had more clinicians report uncertainty as to whether HIIT was safe compared with the number that reported it was safe or unsafe.

With respect to perceptions surrounding whether different prescreening practices would be required if implementing HIIT, as reported previously at a national level, 80% of clinicians believed different pre-screening of fitness would be necessary. Half of clinicians believed a submaximal graded exercise test would be necessary, 28% chose other (including step test and six-minute walk test) and 19% reported different screening, however, were unsure as to what test should be used. Only 9% reported testing could be the same as current practice and 6% felt a VO_2max test should be used as a pre-screening tool for HIIT. From a state perspective, ACT/WA/NT/TAS combined was the only state where no programmes thought different methods of pre-screening was necessary and SA was the only state that had no programmes believe a VO_2max test would be necessary. All states had the most percentage of programmes indicate they believed a graded exercise test would be necessary before implementing HIIT.

With respect to perceptions surrounding whether different monitoring practices would be required if implementing HIIT, as previously reported, more than one half (65%) of programmes reported monitoring using an external device would be required (heart rate monitoring), 47% believed 3 lead ECG via telemetry should be used and 5% thought 12 lead ECG via telemetry monitoring would be necessary. Thirteen percent reported they believed different monitoring would not be needed and 22% were unsure about monitoring requirements. From a state perspective, the greatest percentage of programmes across all states believe heart rate monitoring would be necessary when implementing HIIT. A third to one fifth of all programmes across states believed no differences in monitoring would be required, except SA where only 3% believed no change in monitoring would be required. The state spread was similar to the national spread for telemetry monitoring requirements.

With respect to perceptions surrounding barriers to HIIT implementation, as previously reported, lack of staff (25%), monitoring resources (20%), and staff knowledge (18%) were the most reported barriers nationally to implementation of HIIT. From a state perspective, all states reported lack of staffing and monitoring resources as the largest percentage of reported barriers whilst high-risk patients and lack of exercise testing resources were reported least often for all states. SA and ACT/WA/NT/TAS combined were the only states with no programmes reporting there are no barriers to HIIT implementation. NSW only had two programmes believe there were no barriers and VIC and SA only had one programme each with this belief.

3.8.9.1 HOME EXERCISE

Only 48% of programmes (120/249) indicated that they gave advice about the number of days a week participant should do home exercise. A further 10% stated they gave home exercise advice but did not specify what this entailed.

Of the programmes that specified they gave home exercise advice, most programmes encouraged home exercise 5-7 days per week (76%) and used logbooks, diaries, verbal discussions and progress notes to monitor adherence.

Only a quarter of Australian programmes offered a maintenance exercise programme and an additional 30% of programmes simply issued participants with a list of services

in the community who could provide exercise options such as yoga classes, walking and Heart Moves. This was not accompanied by exercise advice from CR staff.

3.9 SUMMARY; A STATE PERSPECTIVE

There has been no previous research, to the author's knowledge, where researchers have explored service delivery provision across different states or provinces. Previous research have only reported at a national level (Delaney et al., 2006; Goto, 2014; Grace et al., 2014; Griffo et al., 2015; Humphrey et al., 2014; Jelinek & Bunker, 2007; Karoff et al., 2007; Madan et al., 2014; McGee et al., 2001). The publication presented in this chapter discusses national Australian findings and compares them to other countries. It is helpful, however, for clinicians managing CR programmes, to benchmark their service with other states. This helps to inform quality improvement practices and ensure people with cardiac disease have similar experiences and opportunities, regardless of residency. As there are no other publications that break their results down to the state level, we cannot compare our state results to other countries, however the summary presented below is designed to summarise key points of interest for each state, after comparing other states results.

NSW has the largest population (7.6 million people) followed by VIC (5.9 million), QLD (4.7 million), WA (2.5 million), SA (1.6 million), TAS (516 000), ACT (390 000) and NT having the smallest population (244 000). ACT has the highest population density (171.4 persons/Km^2) by six-fold with VIC having the second highest population density of 26.11 persons/Km^2. NT has the smallest population density with just 0.18 persons/Km^2 (Chepkemoi, 2019). According to the Australian Bureau of Statistics, ACT residents have the largest median wage of $64000/year and Tasmania having the lowest median wage of $44 600. NT has the youngest median age of 33 years and TAS have the oldest median age of 42 years. The state with the most people identifying as Aboriginal and/or Torres Strait Islander is NSW (265,685), followed by QLD (221,276), WA (100,512) and NT (75,546), with the least number of people of this ethnicity residing in ACT (7,513) (Australian Bureau of Statistics, 2018).

NSW had the largest number of CR programmes respond to the survey which is to be expected due to having the largest population. However, it also had the lowest percentage uptake to these programmes. It would be beneficial to investigate further

why NSW is reporting lower percentages of referred patients subsequently enrol compared to other states. It was also one of two states that had the greatest percentages of programmes indicating they did not perform any fitness tests and the lowest percentage of programmes performing reassessment fitness tests at three months follow up. Therefore, NSW appears to be less effective than other states in its ability to evaluate the effectiveness of the exercise component of CR programmes compared to other Australian states. This is concerning particularly as NSW has the largest population and number of programmes. NSW also had the largest percentage of programmes with the highest staff:participant ratios and was one of two states that had programmes report exercise sessions were unsupervised. Both findings indicate participants have less ability to be individually monitored and supervised than residents in other states. NSW used similar percentages of nurses and physiotherapists to progress exercise and indicated that some programmes utilised a cardiologist to prescribe exercise, despite physiotherapists and exercise physiologists having been trained in exercise physiology and exercise prescription. This advanced knowledge is even more essential when progressing patients with CVD.

VIC also had some programmes indicate that they were unsupervised and used a cardiologist to prescribe exercise, however exercise physiologists were the second most common health professional to prescribe exercise. Victoria had the highest percentage uptake of all states, however also had the greatest percentage of programmes that offered the least frequent sessions/ week (once/week), indicating that Victorian residents do not have the opportunity to exercise in supervised, monitored sessions as many times a week as other state residents and are required to rely on unsupervised, home exercise for the majority of their exercise. Additionally, VIC is one of two states that did not have any programmes utilise water activity for CR.

QLD has the greatest percentages of CR programmes based in the hospital setting and have the highest adherence rate. However, on average, CR programmes are delivered over a shorter duration (4-5 weeks) than other states, indicating residents have less time to allow exercise to form a life-long habit and less time to exercise in a supervised and monitored environment. QLD is the other state to have no programmes embracing water as a medium to provide CR. Finally, QLD and is the only state which had no programmes indicate they reassessed fitness at 12 months post discharge from CR and therefore the long term CRF effects of CR in QLD cannot be ascertained.

SA has the lowest staff:participant ratio and participants exercise at the highest intensity of any states, indicating that participants may have superior gains in CRF, however it is one of two states with the lowest percentage of programmes performing reassessment fitness tests at 3 months follow up and also had the largest percentage of programmes indicating they did not perform any fitness tests, therefore the superior gains attributed to higher intensity activity cannot be quantified. Finally, SA is the only state that uses a doctor and occupational therapist to prescribe exercise, despite these professions lacking formal tertiary education in this area.

ACT/WA/NT/TAS combined provided the greatest percentage of programmes for Aboriginal and Torres Strait Islanders in separate classes despite NSW having the largest number of Aboriginal and Torres Strait Islanders (Health*InfoNet*, 2019) residing there. This minority group have a different concept of health which focuses less on the individual and more on community and well-being. They have cultural and spiritual beliefs that impact health and recovery (Health*InfoNet*, 2019) which differ from Western societal beliefs.(Smith, 2016) This, coupled with the higher incidence of CVD seen in Aboriginal and Torres Strait Islander people compared to non-indigenous Australians, suggests that separate targeted classes (indigenous specific programmes) may be more beneficial (Smith, 2016). Current models of CR delivery primarily focus on individual lifestyle modification, rather than catering for the distinct, intricate needs of this population.

ACT/WA/NT/TAS combined had the least number of participants per class yet had the largest percentage of programmes offering the most frequent sessions/week (3 times/week) of all states. The ACT reported the greatest percentage of CR programmes offering the longest number of weeks and WA had the most percentage of programmes with smaller numbers/year. ACT/WA/NT/TAS combined were the only state performing 1 repetition maximum strength tests and indicated that over half of programmes performed this test, indicating that the strength component of the exercise programmes could be prescribed more accurately than other Australian states. Finally, ACT/WA/NT/TAS was the only state not to include games/sport as a medium to deliver CR.

It is difficult to deduce specific reasons for differing results across the states. It appears that population, median wage, and median age differences across states, had little effect on how programmes are being run. However, some results were surprising, particularly findings in NSW as it has the largest population, number of programmes and largest population identifying as Aboriginal and Torres Strait Islanders. It was expected that they had the most programmes respond, however not expected for NSW to have suboptimal reassessment practices compared with other states, particularly having low percentages of programmes performing outcome measures to assess strength, a low percentage of separate classes catering for people of Aboriginal and/or Torres Strait Islander descent and the lowest percentage of uptake. It would be beneficial for further research to be conducted to analyse state differences in greater depth, however this was beyond the scope of research for this thesis.

Finally, the results of the survey regarding home exercise, highlighted that options for home exercise and specific advice given to participants on discharge from outpatient CR is lacking in Australia. Most of the recommended options to continue exercise involve low intensity exercise which may result in deconditioning. There is a need therefore to improve the quality of care and provide alternative options for continued exercise. An alternative option that helps motivate clients to engage in lifelong exercise and increase intensity of exercise is essential to maintain cardiovascular risk reduction obtained from outpatient CR.

CHAPTER 4: EXPLORING THE UTILISATION OF WEARABLE PHYSICAL ACTIVITY MONITORING DEVICES IN THE CARDIAC POPULATION

PUBLICATION: **Hannan, A**., Harders, M., Hing, W., Climstein, M., Coombes, J.S., Furness, J. (2019). Impact of wearable physical activity monitoring devices with exercise prescription or advice in the maintenance phase of cardiac rehabilitation: systematic review and meta-analysis. *BMC Sports Science, Medicine and Rehabilitation, 11 (14), 1-21. https://doi.org/10.1186/s13102-019-0126-8 under licence CC BY-NC 4.0.*

4.1 PREFACE

This chapter aligns to the third research thesis aim:

"Investigate the effect of WPAM devices within the cardiac population on CRF."

The results of the previous chapter highlight that home exercise and advice given to patients entering the maintenance phase of CR is lacking in Australia. Finding alternate methods to assist people with cardiac disease is essential to enable lifelong exercise habits to form. This will subsequently maintain CRF and reduce mortality. WPAM devices have been shown to increase physical activity. However, there have been no systematic reviews investigating the effect these devices have on physical activity for people with cardiac disease.

This chapter, therefore, presents a published systematic review, meta-analysis and qualitative analysis investigating the use of WPAM within the cardiac population, particularly the effect WPAM had on CRF, amount and intensity of daily physical activity and sedentary time. Additionally, the review collated information from relevant RCTs on outcome measures reported, reasons for drop out, adverse events, and psychological impact from utilising a WPAM. The published manuscript is presented in final format, as presented in the journal, at Appendix 8.

Impact of wearable physical activity monitoring devices with exercise prescription or advice in the maintenance phase of cardiac rehabilitation: systematic review and meta-Analysis (Published manuscript, see Appendix 8).

4.2 ABSTRACT

4.2.1 BACKGROUND

Physical activity is a component of CR. However, life-long engagement in physical activity is required to maintain benefits gained. WPAM devices are thought to increase physical activity. There appear to be no reviews which investigate the effect of WPAM in cardiac populations. We firstly aimed to systematically review RCTs within the cardiac population that investigated the effect WPAM had through the maintenance phase of CR. We specifically examined the effect on CRF, amount and intensity of daily physical activity, and sedentary time. Secondly, we aimed to collate outcome measures reported, reasons for drop out, adverse events, and psychological impact from utilising a WPAM.

4.2.2 METHODS

A systematic search (up to January 2019) of relevant databases was completed, followed by a narrative synthesis, meta-analysis and qualitative analysis.

4.2.3 RESULTS

Nine studies involving 1,352 participants were included. CRF was improved to a greater extent in participants using WPAM with exercise prescription or advice compared with controls (MD 1.65 mL/kg/min;95% confidence interval [CI; 0.64–2.66]; $p = 0.001$; $I^2 = 0\%$). There was no significant between group difference in six-minute walk test distance. In 70% of studies, step count was greater in participants using a WPAM with exercise prescription or advice, however the overall effect was not significant (SMD 0.45;95% [CI; − 0.17-1.07] $p = 0.15$; $I^2 = 81\%$). A sensitivity analysis resulted in significantly greater step counts in participants using a WPAM with exercise prescription or advice and reduced the heterogeneity from 81 to 0% (SMD 0.78;95% [CI; 0.54–1.02]; $p < 0.001$; $I^2 = 0\%$). Three out of four studies reporting on intensity, found significantly increased time spent in moderate and moderate-vigorous intensity physical activity. No difference between groups was found for sedentary time. Three of six studies reported improved psychological benefits.

No cardiac adverse events related to physical activity were reported and 62% of non-cardiac adverse events were primarily musculoskeletal injuries. Reasons for dropping out included medical conditions, lack of motivation, loss of interest, and technical difficulties.

4.2.4 CONCLUSION

Our meta-analysis showed WPAM with exercise prescription or advice are superior to no device in improving CRF in the maintenance phase of CR and no cardiac adverse events were reported with WPAM use. Our qualitative analysis showed evidence in favour of WPAM with exercise prescription or advice for both CRF and step count. WPAM with exercise prescription or advice did not change sedentary time. Psychological health and exercise intensity may potentially be enhanced by WPAM with exercise prescription or advice, however further research would strengthen this conclusion.

4.3 INTRODUCTION

Deaths from cardiovascular disease (CVD) have risen by 14.5% globally between 2006-2016 (Naghavi et al., 2017). A systematic analysis for the Global Burden of Disease, which analysed 264 causes of mortality in 195 locations between 1980 and 2016, reported CVD as being responsible for 17.6 million deaths, of which 85.1% were attributed to coronary artery disease (CHD) and stroke. Deaths attributed to CHD alone, rose 19% to 9.48 million. Additionally, the analysis reported CHD as being the leading cause of years of life lost (YLL) in 113 countries for men and 97 for women (Naghavi et al., 2017).

For those who have suffered a myocardial infarction, the risk of subsequent cardiovascular events increases by 20% within five years (Hamilton-Craig, 2009). Globally, secondary prevention guidelines and action plans have been developed to combat this healthcare burden (National Heart Foundation of Australia, 2010; Smith et al., 2006; Wood et al., 1998). For people diagnosed with cardiac disease, attending CR is recommended to aid secondary prevention (Balady et al., 2007; National Heart Foundation of Australia, 2010; Wood et al., 1998; Wood et al., 2005; Woodruffe et al., 2015). Cardiac rehabilitation (CR) utilises a multidisciplinary approach to improve health through education, risk factor reduction, lifestyle behavior modification, psychosocial strategies and exercise programmes (Anderson, Oldridge, et al., 2016; Balady et al., 2007; National Heart Foundation of Australia, 2010; Wood et al., 2005; Woodruffe et al., 2015). This is usually delivered across are three phases, namely, phase 1 (inpatient setting), phase 2 (outpatient setting) and phase 3 (maintenance) (National Heart Foundation of Australia, 2010).

Physical activity is an essential component of CR (National Heart Foundation of Australia, 2010). Physical activity is any movement that requires the expenditure of energy above resting requirements (Pescatello, 2014). The exercise component of CR aims to improve physical functioning [cardiorespiratory fitness (CRF), muscular strength and flexibility] of participants. CRF is defined as the maximum rate of oxygen consumption of the heart, lungs and skeletal muscle during exercise (Pescatello, 2014). It has been shown to be inversely proportionate to mortality and predicts prognosis in patients with CHD (Keteyian et al., 2008; Myers et al., 2002; Swain & Franklin, 2006). Research has shown every metabolic equivalent increase in CRF results in a 13-17% reduction in cardiovascular and all-cause mortality (Keteyian et al.,

2008; Myers et al., 2002; Swain & Franklin, 2006). Additionally, Martin et al. (2013) specifically showed a 13% decrease in overall mortality for every metabolic equivalent (MET) increase in CRF following 12 weeks of CR. Furthermore, each MET increase was associated with a 25%-point reduction in all-cause mortality, for those who maintained CRF gains at 1 year (Martin et al., 2013). A recent systematic review and meta-analysis focusing on exercise-based CR in Phase 2, which included 22 studies with 4,834 participants, found the exercise model currently being used, although reducing hospital admissions, had no effect on all-cause mortality (Powell et al., 2018). This suggests the CRF gains achieved in CR must, therefore, be maintained long-term to offer a potential reduction in mortality. This is further supported by studies reporting the deleterious effects of physical inactivity (F. Booth et al., 2012; Davies et al., 2018; Olsen et al., 2008). Large reductions in daily step count over a two week period, significantly decreases CRF, insulin sensitivity and lower limb muscle mass whilst increasing body fat, liver fat and LDL cholesterol (Davies et al., 2018).

Several countries have reported between one fifth to one third of patients eligible enrol in CR (Bethell et al., 2001; Daly et al., 2002; Lynggaard et al., 2017; Yohannes et al., 2007). Australia has reported a higher enrolment rate (51-80%) (Hannan, Hing, Coombes, et al., 2018). To improve this low uptake, researchers have investigated alternate models of CR delivery. A systematic review by Clark et al. (2015) identified 83 studies describing alternate ways of providing CR. These studies were based primarily in Phase 2. They included multifactorial individualised telehealth, internet-based delivery, telehealth interventions focused on exercise, telehealth interventions focused on recovery, community or home-based CR, rural and remote programmes and multiple models of care and alternative, complimentary models. The authors concluded that community or home-based CR produce similar reductions in cardiovascular risk factors compared with hospital-based programmes. Furthermore, a systematic review and meta-analysis by Rawstorn et al. (2018) also found telehealth to be as effective as centre-based exercise and a meta-analysis by Clark et al. (2010) found home based programmes are an effective and low-cost alternative to hospital based CR.

In contrast to the numerous studies conducted specific to Phase 2 CR, there are few studies investigating physical activity in Phase 3 (Bock et al., 2003; Claes et al., 2017; Pinto et al., 2011; Reid et al., 2006; Smith et al., 2011). Of those, Reid et al. (2006) found participants did not maintain increased exercise levels beyond two

months' post discharge from Phase 2. Furthermore, Bock et al. (2003) reported that only 56% of patients were meeting exercise guidelines at 12 months post-discharge from CR. However, Bock et al. (2003) also showed those who participated in a Phase 3 programme were significantly more likely to continue regular and more vigorous activity.

A systematic review and meta-analysis published by Claes et al. (2017) investigated the longer term effects of home based exercise in CHD patients compared with usual care or centre based rehabilitation. Seven studies were included in the meta-analysis on exercise capacity. Results showed no significant differences in exercise capacity between home based and usual care. However, they also found a significant difference in exercise capacity in favour of home-based exercise when compared with centre-based exercise of small effect size (SMD 0.25, 95%CI 0.02-0.48). Therefore, encouraging life-long physical activity for patients with CHD at home seems a feasible option to maintain CRF and therefore, potentially reduce mortality.

Activity trackers, are worn by over 10% of adults (DiFrancisco-Donoghue et al., 2018) and wearable technology was named number three in the top twenty worldwide fitness trends in 2018 (Thompson, 2017). Wearable technology is thought to improve the amount of, and adherence to, physical activity (Ehn et al., 2018; Finkelstein et al., 2016; Gualtieri et al., 2016; Jang et al., 2018). A 2016 systematic review identifying 13 RCTs and 6 quasi-experimental studies utilising a pedometer, found 79% of trials were effective in increasing physical activity (Afshin et al., 2016). However, a review by Coughlin and Stewart (2016) to determine the efficacy of wearables in improving physical activity, concluded that larger studies with greater sample sizes, coupled with longer durations, are required to fully support the adoption of wearables with exercise prescription or advice to increase physical activity in healthy populations.

Previous research within the CHD population found lack of motivation and time were the most common barriers cited, to engaging in physical activity (Alharbi et al., 2017). This was further supported by Bravata et al. (2007) who concluded lack of motivation negatively influenced self-efficacy for exercise. Studies investigating exercise monitoring, in the home of people diagnosed with CHD have used varying monitoring devices from pedometers through to electrocardiographic transmission (Beatty et al., 2018; Butler & Dwyer, 2004; Butler et al., 2009; Cheng et al., 2016; Dalleck et al., 2011; Furber et al., 2010; Pinto et al., 2011; Sangster et al., 2017;

Scalvini et al., 2013; Thorup et al., 2016; Worringham et al., 2011). There is conflicting evidence of the benefits of wearables in the CHD population. A systematic review by Bravata et al. (2007) found the use of a pedometer significantly increased physical activity. Similarly, a study by Butler et al. (2009) also found that pedometers increased adherence and physical activity in patients with CHD. In contrast, an earlier study by Butler and Dwyer (2004) found no difference in the amount of walking completed by participants wearing a pedometer displaying the step counts, compared to the step counts being obscured from patients. To the authors' knowledge there appear to be no systematic reviews of RCTs that investigated the effect of WPAM on the maintenance of physical activity and CRF/physical capacity in phase 3 CR. Furthermore, no systematic review has collated the CRF outcome measures, reasons for dropouts or adverse events in studies investigating WPAM in the CHD population.

The firstly aimed to systematically review RCTs within the cardiac population that investigated the effect WPAM with exercise prescription or advice had through the maintenance phase of CR. We specifically examined the effect on CRF, amount and intensity of daily physical activity and sedentary time. Secondly, we aimed to collate outcome measures reported, reasons for drop out, adverse events, and psychological impact from utilsiing a WPAM. Our hypothesis was WPAM with exercise prescription or advice would improve CRF and step count, intensity of exercise, quality of life and decrease sedentary time.

4.4 METHODS

A narrative synthesis and meta-analysis was performed in line with the protocol registered with PROSPERO, an international database of prospectively registered systematic reviews in health and social care (Registration Number: CRD42019106591) (A. Booth et al., 2012). In January 2019, a systematic search of RCTs was completed by two authors (AH and MH) who followed the methodology proposed in the Preferred Reporting Items for Systematic Reviews and Mata-Analysis (PRISMA) guidelines (Moher et al., 2009).

4.4.1 STUDY SELECTION

4.4.1.1 INCLUSION CRITERIA

This systematic review included RCTs, which were full-length research articles published in peer-reviewed academic journals. No limits were set on language, date of publication or gender. The RCTs must have compared standard care or an attention control group to the use of a WPAM during the maintenance phase (Phase 3) of CR. We define WPAM to be a small, wearable device with accelerometer and/or pedometer capabilities. This may include pedometers, watches or smartphones (if the accelerometer function was used). To be eligible for inclusion, studies required at least four weeks follow up after outpatient (Phase 2) CR. Standard care groups could include advice on physical activity and/or phone calls to encourage physical activity, however, not receive unblinded physical activity self-monitoring devices. The WPAM required data to be visible to the subjects in the intervention groups. Eligible studies included participants with a diagnosis of CAD, MI, ACS or who have undergone PCI or a history of cardiac surgery (CABG, valvular repair or replacement). Participants were required to be older than 20 years and must have completed Phase 2 of CR. Studies were required to have reported at least one outcome measure evaluating physical activity or CRF (e.g. change in VO_2peak or change in steps per day). These outcome measures were used in the meta-analysis.

4.4.1.2 Exclusion Criteria

Abstracts, poster presentations, conference presentations, unpublished books and letters to the editor or book chapters were excluded. Studies that used WPAM solely as an outcome measure, rather than an intervention, and which did not require participants to wear the devices throughout the study period were excluded. In addition, studies that did not allow the participants to view the device data throughout the intervention period were also excluded.

4.4.2 Literature Search

Databases systematically searched included CINAHL, Cochrane Library, Embase, Medline/Ovid, Scopus, SPORTDiscus and Web of Science. A unique search strategy was identified, using the assistance of a university librarian, for each of the databases and is available in the supplementary material. Reference lists of eligible articles and conference abstracts were also searched.

4.4.3 Data Extraction

Two authors (AH and MH) independently conducted a systematic search to identify relevant titles and abstracts from the databases. Search results were entered into a reference management tool (Endnote v 9) and duplicates from different databases were removed. Both authors screened titles/abstracts for eligibility before viewing full text. In addition, reference lists of eligible studies were screened for further eligible studies. The primary author attempted to source full length text for eligible conference abstracts. The two reviewers compared studies for inclusion and exclusion. A third author (WH) was used to resolve discrepancies in decision making. The selection process was recorded into a PRISMA (Moher et al., 2009) diagram (Figure 8).

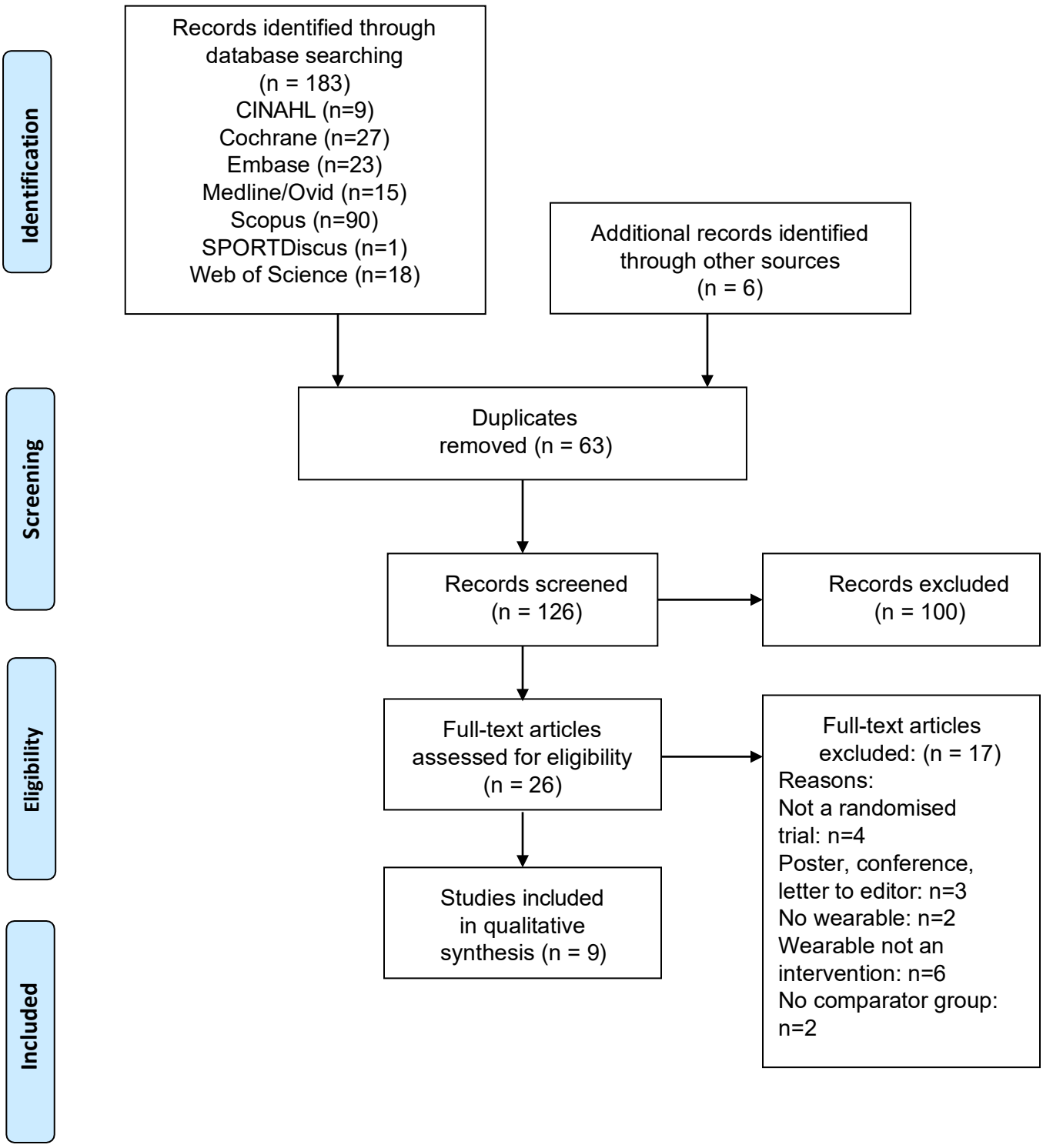


Figure 8. PRISMA diagram of literature search strategies CC BY 4.0

Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analysis.

For each RCT that met the inclusion criteria, the primary author (AH) completed the data extraction which included author, year of publication, country of trial origin, number of participants, participant characteristics (gender, age and diagnosis), percentage of participants that completed the RCT, reasons for drop-out and adverse events. Furthermore, trial characteristics (type of wearable, timing of recruitment, length of trial and a description of the intervention) were also extracted. Finally, fitness and physical activity measures, specifically CRF and step count changes were collated.

This data entry was subsequently checked by a second author (MH). Discrepancies were resolved by a third author (WH). Authors of included studies were contacted if the paper stated relevant outcome measures were obtained but not reported. Two authors (ter Hoeve et al., 2018; Varnfield et al., 2014) were contacted and both provided additional information.

4.4.4 Study Quality

Methodological study quality was assessed and rated using the Physiotherapy Evidence Database Scale (PEDro Scale) which was demonstrated to be a reliable and valid tool (de Morton, 2009; Macedo et al., 2010; Maher et al., 2003). It identifies studies that are internally valid and was developed based on the Delphi list published by Verhagen et al. (1998) For this review, we allocated points if subjects were randomly allocated and concealed; participants had comparable baseline measures; subjects, therapists and assessors were blinded; more than 85% of starting subjects completed outcome measure assessment; participants received the allocated treatment; analysis included intention to treat; and if there was evidence of statistical comparison and variability of measures. Blinding of subjects and therapists was not possible because participants were required to wear a visible WPAM and therapists were required to discuss results of WPAM data with participants. Reporting of eligibility criteria is assessed for external validity; however, this is not included in the final score as per PEDro Scale marking requirements (de Morton, 2009). Therefore, removal of these criteria from the final scoring, left a maximum possible score of 8. Two authors (AH and MH) independently used the PEDro scale's criteria checklist to produce a score (between 0 and 8) to rate each studies' quality. The same authors compared scores and discussed differences of opinion. Studies were deemed to be of good quality if the trial received a score >61% of available points (≥5/8). Fair-quality studies

received 45.4-61% of available points (4/8). Studies which received <45.4% of available points (<4/8) were deemed of poor quality, as described by Kennelly and Handler (2011).

4.4.5 Statistical Analysis

Review Manager (Version 5.3; The Nordic Cochrane Centre, Copenhagen) (Higgins et al., 2011) was used to perform a meta-analysis to investigate the effect wearing a WPAM with exercise prescription or advice had on CRF (change in VO2peak) and change in daily step count. Effect sizes for continuous variables were calculated as either mean difference or standardised mean differences (SMD), otherwise known as Cohens D effect size (Cohen, 1988). Standardised mean difference was used in cases where different methods across studies were used to assess CRF (treadmill test vs cycle ergometer) and because different types of WPAM were used across trials. The effect size was calculated as the difference in outcome measure reported from baseline to the end of the trial. Standardised mean difference was used to quantify the effect size in place of mean differences (steps per day) due to standard deviations being too wide for visual representation. Subgroups were used to represent overall influence of effect; where SMD >0.8 represented a large effect, 0.5-0.79 represented a moderate effect, and 0.2-0.49, a weak effect. This has been used in previous research (Cohen, 1988).

Where standard deviation of the change was not published, we estimated it using the *p*-value between groups, then within groups, as recommended by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011). Random effects with standardised means model was implemented due to the variability of duration, delivery and assessment across studies. Raw data was received from ter Hoeve et al. (2018) as the actual step count in their publication was not reported. We therefore derived the steps by entering raw data into a statistical software package (IBM SPSS statistics, version 25) and performed a paired t-test.

A forest plot was completed on CRF changes (VO_2peak). These were the only outcome measures found in three or more studies. Heterogeneity, using I^2 was considered significant at $p<0.1$. If I^2 was 0-30%, it was considered minimal, 31-50%, moderate, 51-90% substantial and considerable if >90% (Simas et al., 2017).

Finally, due to the small number of studies that were included in the meta-analysis, we also performed a qualitative best evidence synthesis. This was

considered as inferior evidence to the quantitative analyses' method of meta-analyses. This method was based on previous research (van Tulder et al., 2003) which provided recommendations on how to conduct a qualitative analysis using five levels of evidence from strong to no evidence. A best evidence synthesis approach has widely been used within systematic reviews where quantitative approaches are not possible (Barrett et al., 2014; Matthews et al., 2018; Moran, 2017; Prowse et al., 2016). From this, we adapted the criteria due to the small number of studies in our review as below:

1. Strong Evidence: significant findings provided by two or more studies with high quality and by generally consistent findings in all studies (more than 75% of the studies reported consistent findings).
2. Moderate Evidence: significant findings provided by one study with high quality and/or two or more studies with low quality, and by generally consistent findings in all studies (more than 60% of the studies reported consistent findings).
3. Limited Evidence: significant findings provided by only one study with low quality.
4. Conflicting Evidence: inconsistent findings in multiple studies (less than 60% of studies reported consistent findings).
5. No Evidence: when no studies could be found

4.5 RESULTS

Initially, the search strategy resulted in 183 articles. This was reduced to 126 articles after duplicates were removed. The titles and abstracts were screened, and 100 studies were excluded due to not meeting the eligibility criteria. Of the 26 articles that were screened, nine were identified as meeting the inclusion criteria for the systematic review.

4.5.1 STUDY QUALITY

The PEDro-Scale was used to gauge the quality of individual trials. Nine studies were scored by two authors (AH and MH) independently and discrepancies were discussed and agreed. Of the nine studies, none were of poor quality, two were of fair quality (2/9) and seven were of good quality (7/9) (Table 16).

Table 16: *Quality analysis using PEDro-Scale (Cross indicates study did not meet this criterion)*

	Eligibility Criteria Specified (Not included in final score)	Randomly Allocated	Allocation Concealed	Similar Baseline Measurements	Blinding of Assessors	Less than 15% dropout both groups	Intention to Treat	Statistical Comparisons	Variability Measures	Score
Avila et al. (2018)	✓	✓	X	✓	X	✓	✓	✓	✓	6
Butler et al. (2009)	✓	✓	X	✓	X	X	✓	✓	✓	5
Cupples et al. (2013)	✓	X	X	✓	X	✓	X	✓	✓	4
Duscha et al. (2018)	✓	✓	X	✓	X	X	X	✓	✓	4
Guiraud et al. (2012)	✓	✓	X	✓	X	✓	✓	✓	✓	6
Houle et al. (2012)	✓	✓	X	✓	X	✓	X	✓	✓	5
Skobel et al. (2017)	✓	✓	X	✓	✓	X	X	✓	✓	5
ter Hoeve et al. (2018)	✓	✓	✓	✓	X	X	✓	✓	✓	6
Varnfield et al. (2014)	✓	✓	✓	✓	X	X	X	✓	✓	5

4.5.2 STUDY CHARACTERISTICS

All eligible studies were published in English and were included in the narrative analysis (Avila et al., 2018; Butler et al., 2009; Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; Skobel et al., 2017; ter Hoeve et al., 2018; Varnfield et al., 2014). Five studies (56%) were from Europe (Avila et al., 2018; Cupples et al., 2013; Guiraud et al., 2012; Skobel et al., 2017; ter Hoeve et al., 2018) including Belgium (n = 1) (Avila et al., 2018), Ireland (n = 1) (Cupples et al., 2013), France (n = 1) (Guiraud et al., 2012), Netherlands (n = 1) (ter Hoeve et al., 2018) and a multicenter study across Germany, Spain and Britain (n = 1) (Skobel et al., 2017). Two studies (22%) were based in Australia (Butler et al., 2009; Varnfield et al., 2014), one was from the United States of America (Duscha et al., 2018) and one study from Canada (Houle et al., 2012). The studies were published between 2009 and 2018.

The total number of participants across all studies was 1,352. Of the 870 participants that were analysed,192 (22.1%) were female and 678 (77.9%) were male. The lowest percentage (4%) of a specific gender in the control and intervention groups across studies was females in a single control group (Cupples et al., 2013). Mean ages of participants ranged from 42 to 73.7 years. In five studies (Cupples et al., 2013; Houle et al., 2012; Skobel et al., 2017; ter Hoeve et al., 2018; Varnfield et al., 2014), (56%), the mean age for the control group was < 60 years (range 56.2±10.1 to 59.1±8) and four studies (Avila et al., 2018; Butler et al., 2009; Duscha et al., 2018; Guiraud et al., 2012) reported mean ages > 60 years (range 61.7±7.7 to 66.5± 7.2). In contrast, six studies (Avila et al., 2018; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; ter Hoeve et al., 2018; Varnfield et al., 2014) (67%) reported the mean age for the intervention group as < 60 years (range 54.5±12.6 to 59.9±8.1) and three studies (Butler et al., 2009; Cupples et al., 2013; Skobel et al., 2017) reported the mean ages as ≥60 years (range 60–63±10.4). Seven studies (Avila et al., 2018; Butler et al., 2009; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; ter Hoeve et al., 2018; Varnfield et al., 2014) (78%) reported younger mean ages for the intervention group compared to the control group, however this was not significantly different.

Common presentations of participants reported by studies included MI (n = 7), CABG surgery (n = 6), PCI (n = 7), ACS (n = 2), and CAD (n = 2). Four studies (Avila et al., 2018; Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012) (44%) had durations between 1.5 and 3 months in length, three studies (Butler et al., 2009; Skobel et al., 2017; Varnfield et al., 2014) (33%) were 6 months duration and two

studies (Guiraud et al., 2012; Houle et al., 2012) (22%) were longer than 6 months duration. Individual trial breakdowns for patient characteristics can be seen in Table 17.

All studies utilised a WPAM for the intervention group. The devices utilised included Yamax Digiwalker pedometer (Butler et al., 2009; Cupples et al., 2013; Houle et al., 2012; ter Hoeve et al., 2018), Garmin Forerunner (Avila et al., 2018), Fitbit Charge (Duscha et al., 2018), My Wellness Key Accelerometer (Guiraud et al., 2012), Gex vital signs sensor (Skobel et al., 2017), Nokia smartphone with pre- installed applications (Varnfield et al., 2014) and a Sensewear Mini armband (Avila et al., 2018). The timing of recruitment for study participants ranged from 6 weeks to 18 months post cardiac event. Participants completed a supervised phase 2 CR programme prior to participation in all studies, except one (Varnfield et al., 2014). The one exception commenced the intervention period at the onset of phase 2 CR and continued into phase 3 with final outcomes measured at 6 months (Varnfield et al., 2014).

The duration of interventions varied across studies. In seven studies (Avila et al., 2018; Butler et al., 2009; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; ter Hoeve et al., 2018; Varnfield et al., 2014) (78%), the control group received a pamphlet and/or face-to-face sessions on physical activity and lifestyle factors. One study (Cupples et al., 2013) included on- going weekly facilitator support for the attention control group, and another had participants in the control group report daily physical activity in a paper diary (Skobel et al., 2017). Seven of the studies (78%) included goal setting in the interventions. This was performed by phone calls, emails, text messages or a web-based interface (Avila et al., 2018; Butler et al., 2009; Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012; Skobel et al., 2017; Varnfield et al., 2014). One study received a socio-cognitive intervention led by a clinical nurse specialist (Houle et al., 2012). All studies encouraged self-management using the WPAM to track their physical activity. Individual trial characteristics can be seen in Table 17.

Table 17: *Study and Participant Characteristics*

Study	Country of Origin	No. Participants	Gender (f/m)	Age (years±SD)	Diagnosis	Study Duration (months)	% of participants completed study
Avila et al. (2018)	Belgium	30 c 60 i 84[a]	3/27 c 4/26 i	61.7 ± 7.7 c 58.6 ± 13 i	CAD, MI, CABG, PCI	3	86.67 c 93.33 i
Butler et al. (2009)	Australia	60 c, 62 i 6/52: 50 c, 48 i; 98[a] 6/12: 46 c, 44 I; 90[a]	10/45 c 17/38 i	64.5 ± 11.2 c 63 ± 10.4 i	MI, CABG, PCI, ACS	6	6/52: 90.9 c; 87.3 i 6/12: 83.64 c; 80 i
Cupples et al. (2013)	Northern Ireland	26 c 19 i	1/25 c 3/16 i	59.2 ± 8.9 c 61.6 ± 11.3 i	Not published	1.5	96 c 90 i
Duscha et al. (2018)	America	11 c 21 i; 25[a]	3/6 c 3/13 i	66.5 ± 7.2 c 59.9 ± 8.1 i	MI with PCI or CABG, PCI, CABG, VR	3	81.8 c 76.2 i
Guiraud et al. (2012)	France	10 c 19 i	3/7 c 2/17 i	62.9 ± 10.7 c 54.5 ±12.6 i	CAD, CABG, PCI, HF	2	100 c 100 i
Houle et al. (2012)	Canada	33 c 32 i	8/25 c 6/26 i	59 ± 9 c 58 ± 8 i	MI, CABG, PCI, UA	12	Data not published
Skobel et al. (2017)	Germany, Spain, Britain	63 c 55 i 54[a]:42 c,12 i	8/55 c 5/ 50 i	58 c* 60 i*	MI, PCI	6	66.7 c, 21.8 i
ter Hoeve et al. (2018)	Netherlands	163 c 161 i	32/131 c 32/129 i	59.1 ± 8 c 58.8 ± 9 i	MI, CABG, PCI, ACS	18	3/12: 78 c, 80.1 i 12/12: 75 c,75 i 18/12: 74.7 c,74.8 i
Varnfield et al. (2014)	Australia	41 c 53 i 6/52:28 c 48 i; 76[a] 6/12: 26 c, 46 i; 72[a]	7/34 c 5/48 i	56.2 ±10.1 c 54.9 ± 9.6 i	MI	6	6/52:46.7 c, 80 i 6/12:43.3 c,76.7 i

Abbreviations: f,female, m, male, SD, standard deviation, t, total, c,control, i,intervention, [a] analysed, CAD, coronary artery disease, MI, myocardial infarction, CABG, coronary artery bypass graft surgery, PCI, percutaneous coronary intervention, ACS, acute coronary syndrome, VR, valve repair, HF, heart failure, UA, unstable angina, wks, weeks, m,months,*: SD not published.

Five (56%) of the studies exercise interventions were based at home (Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; Skobel et al., 2017), three (33%) used both home-based and centre-based locations (Avila et al., 2018; ter Hoeve et al., 2018; Varnfield et al., 2014) and one study did not report on the location of exercise (Butler et al., 2009). There was a large variety of different recommended parameters for individual exercise sessions. Thirty minutes of daily moderate intensity activity was recommended to the control group participants in two studies (Butler et al., 2009; Cupples et al., 2013) (22%) whilst two others (22%) reported general advice to stay active (Duscha et al., 2018; Guiraud et al., 2012). Exercise parameters for home-based exercise were all unique and exercise prescription varied in the amount of specific instruction given to intervention participants. One study did not specify any exercise prescription (Houle et al., 2012) and another three (33%) provided general advice only; to exercise at moderate intensity for most days of the week (Avila et al., 2018; Guiraud et al., 2012; Varnfield et al., 2014). Two studies (22%) recommended increasing steps per day (Cupples et al., 2013; Duscha et al., 2018), two (22%) prescribed a specific heart rate range and duration (Avila et al., 2018; Butler et al., 2009). Two further studies (22%) incorporated additional exercise modes, other than walking [resistance training (Skobel et al., 2017) and gymnastics (ter Hoeve et al., 2018)]. Only one study (Skobel et al., 2017) gave participants a detailed prescription on how to progress the exercise, however this was only for the centre-based participants. Individual trial breakdowns for study characteristics can be seen in Table 18.

Table 18: *Study Parameters*

Study	Type of wearable	Timing of recruitment	Intervention Description			
			control	intervention	parameters for individual sessions	
					control	intervention
Avila et al. (2018)	Garmin Forerunner 210 Sensewear mini armband	3 months post ambulatory CR	advised to remain physically active	home-based exercise with telemonitoring guidance weekly emails or phone calls centre-based	data not published	150 mins of activity/week 6-7 days /week moderate intensity exercise (70-80% Heart rate reserve)
Butler et al. (2009)	Pedometer Yamax Digiwalker 700B	following attendance of group CR	given 2 generic PA brochures	6-week self-monitored activity with pedometer, daily step calendar, generic PA brochure approximately 15-minute-long phone call after 1,3,12,18 weeks 2 behavioural counselling and goal setting sessions week 1 and 3	30 mins of moderate intensity activity on all or most days of the week	data not published

Study	Type of wearable	Timing of recruitment	Intervention Description			
			control	intervention	parameters for individual sessions	
					control	intervention
Cupples et al. (2013)	Pedometer Yamax CW-701	following completion of supervised CR	ongoing weekly facilitator support but no feedback on step counts	worked with a clinical facilitator pedometer set daily step count goals with weekly reviews record daily steps in a diary home-based	30 minutes of moderate intensity activity daily	gradual increase of 10% of steps aiming for 10, 000 steps/day
Duscha et al. (2018)	Fitbit Charge	2 weeks prior to discharge from group CR	patients wore Fitbit during last 2 weeks of group CR usual care as advised by physician Fitbit worn for last 2 weeks of study	patients wore Fitbit during last 2 weeks of group CR plus following 12 weeks exercise prescription of step counts weekly health coaching (1-2 times/week for 30-60 min) text messages and educational material Vida Health app home-based	advice given by individual physicians specifics not published	weeks 1-4 increase PA by 2,500 steps above baseline weeks 5-8 increase a further 1,250 steps weeks 9-12 increase a further 1,250 steps

Study	Type of wearable	Timing of recruitment	Intervention Description			
			control	intervention	parameters for individual sessions	
					control	intervention
Guiraud et al. (2012)	My Wellness Key Accelero-meter	2 months or 1 year after discharge from group CR	wore accelero-meter in last week only advice on importan ce of adhering to exercise prescripti on given	accelerometer worn throughout telephone support given every 15 days identifying barriers and strategies home-based	no contact given	moderate intensity PA
Houle et al. (2012)	Yamax Digiwalker NL-2000 – blinded Yamax Digiwalker SW -200	within 4 weeks of discharge from hospital	usual advice by nurse or physician no restrictio ns to go to centre-based CR	pedometer PA diary Socio-cognitive intervention led by clinical nurse specialist home-based	usual advice- specifics not published	given pedometer-based programme

Study	Type of wearable	Timing of recruitment	Intervention Description			
			control	intervention	parameters for individual sessions	
					control	intervention
Skobel et al. (2017)	Gex sensor of vital signs and smartphone	during group CR	Report PA in paper diary	Guided exercise system (Gex) individual performances monitored and exercise prescription reviewed web based tool, patient station and portable station home-based	specifics not reported	endurance training plus resistance training (both isometric and isotonic exercises using a rubber band) Week 1-3; 2 x wk, 3x10 mins, Borg 11 Week 4-6; 2 x wk, 3x10 mins, Borg 12-13 Week 7-9; 2 x wk, 3x15mins, Borg 12-13 Week 10-12; 3 x wk, 3x15mins, Borg 12-13 Week 12+; 3+ x week, 3x20 mins, Borg 12-13
ter Hoeve et al. (2018)	Yamax Digiwalker SW-200 Tri-axial accelerometer over 8-day period	during group CR	standard CR for 3 months no after care general information of benefits of PA	Standard CR for 3 months + 3 face to face group PA counselling sessions and pedometers. Booklet with goal setting barrier identification and relapse strategies. Education about sedentary time given Home-based and centre-based	2 x week 75 mins gymnastics, walking sports for 3 months followed by no after care	2 x week75 mins gymnastics, walking sports for 3 months 9 months after care programme: 3 face to face sessions: 1-hour exercise programme and 1-hour behavioural counselling programme

Study	Type of wearable	Timing of recruitment	Intervention Description			
			control	intervention	parameters for individual sessions	
					control	intervention
Varnfield et al. (2014)	CAP-CR via Nokia smartphone pre-installed with step counter and health diary with accelero-meter	patients eligible for a CR referral average day post cardiac event: control: 68 days CAP-CR: 53 days	centre based CR for 6 weeks encouraged to maintain lifestyle changes achieved during CR	CAP-CR App home-based and centre-based	2 x week exercise for 6 weeks circuit based exercise light to moderate intensity followed by self-management	weekly telephone consultation: 15 min each for 6 weeks 30 mins exercise most days of the week moderate intensity walking followed by self-management

Abbreviations: CR, cardiac rehabilitation, PA, physical activity, CAP-CR, Care Assessment Platform

4.5.3 Reasons for Dropout

Completion rates amongst trial groups ranged from 22% (Skobel et al., 2017) to 100% (Guiraud et al., 2012). The collective mean drop-out rate percentage was slightly lower for the intervention groups compared with the control groups (22% versus 23% respectively). For studies of less than or equal to 3 months (4/9), the mean dropout rate for the control groups was 9% and 10% for the intervention group. For studies greater than 6 months (5/9), the mean dropout rate for the control groups was 31% and 34% for the intervention group.

Common reasons participants dropped out of studies included loss of interest/withdrew (Avila et al., 2018; Butler et al., 2009; Skobel et al., 2017; ter Hoeve et al., 2018), family commitment (Butler et al., 2009), work commitment (Butler et al., 2009; Varnfield et al., 2014), medical reasons (Butler et al., 2009; Cupples et al., 2013; Skobel et al., 2017; ter Hoeve et al., 2018; Varnfield et al., 2014), lack of time (Skobel et al., 2017; Varnfield et al., 2014), technical issues (Skobel et al., 2017; Varnfield et al., 2014), and lack of motivation (Duscha et al., 2018; Skobel et al., 2017; ter Hoeve et al., 2018; Varnfield et al., 2014). Individual trial breakdowns for reasons for drop out can be seen in Table 19.

4.5.4 Adverse Events

Five studies (56%) reported adverse events during the trial period (Avila et al., 2018; Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012; Skobel et al., 2017). No adverse events related to exercise occurred in two of these studies (Avila et al., 2018; Guiraud et al., 2012). Adverse events, which were non-cardiac related [ankle (Cupples et al., 2013), knee (Cupples et al., 2013; Duscha et al., 2018), back injuries (Cupples et al., 2013), shortness of breath (Cupples et al., 2013), rare blood disease (Duscha et al., 2018), and fishing hook wound (Duscha et al., 2018)], were reported in two studies (Cupples et al., 2013; Duscha et al., 2018). One study (Skobel et al., 2017) reported adverse cardiac events, of which there were seven incidents (new onset atrial fibrillation, new onset angina at rest and femoral artery aneurysm post PCI), however, none were deemed to be related to exercise. Individual trial breakdowns for adverse events reported can be seen in Table 19.

Table 19: *Reasons for Dropouts and Adverse Events*

Study	Reasons for Drop Out (n)			Adverse Events
	control	**intervention**	**unclassified/other**	
Avila et al. (2018)	loss of interest (2) new cardiac intervention (2)	loss of interest (2)		nil events occurred
Butler et al. (2009)	6- week follow up: unrelated medical reasons (3) work (1) withdrew consent (1) excluded (5) 6- month follow up: unrelated medical reasons (3) deceased (1)	6- week follow up: unrelated medical reasons (4) work (1) withdrew consent (1) excluded (7) 6- month follow up: unable to be contacted (2) family needs (1) work (1)		data not published
Cupples et al. (2013)	influenza (1)	anaemia (1) depression (1)		ankle injury knee injury back pain shortness of breath (no events prevented completion of study)
Duscha et al. (2108)	reason not published (2)	reason not published (3) unusable data: failed to give a good effort on CPX; ICD reset (2)	lost to follow up (2)	randomised group not published knee injury from falling on ice rare blood disease diagnosis severe fishing hook wound
Guiraud et al. (2012)	nil	nil	nil	nil events occurred
Houle et al. (2012)	data not published	data not published	data not published	data not published

Study	Reasons for Drop Out (n)			Adverse Events
	control	intervention	unclassified/other	
Skobel et al. (2017)	withdrew (18) cancelled follow up (3)	withdrew (15) poor compliance (17) lack of time, internet issues, demotivation (21) chronic infection (1) back pain (1)	technical problems (21)	control new onset atrial fibrillation (1) new angina at rest (1) pseudo aneurysm of femoral artery after PCI (1) intervention: none related to exercise patients required angiography (not related to training) (2) chest pain requiring CABG before exercise (2)
ter Hoeve et al. (2018)	lost to follow up (62) prematurely quit (52) declined further participation: poor motivation (5) unknown (4) medical complications (1)	pedometer: lost to follow up (57) prematurely quit (43) declined further participation: poor motivation (5) unknown (8) medical complications (1)		data not published
Varnfield et al. (2014)	logistical: time16% location 7% transport 24% competing life demands: work 10% stress 4% change in circumstances: deterioration of health unrelated to CR 14% lack of motivation 4%	change in circumstances deterioration of health unrelated to CR 9% difficulty using IT tools 7%		data not published

Abbreviations: CPx, cardiopulmonary exercise test, ICD, implantable cardioverter-defibrillator, PCI, percutaneous coronary intervention, CABG, coronary artery bypass graft surgery, CR, cardiac rehabilitation, IT, information technology

4.5.5 Outcome Measures

Outcome measures used in the studies were varied. CRF was assessed by five studies (56%) (Avila et al., 2018; Butler et al., 2009; Duscha et al., 2018; Skobel et al., 2017; Varnfield et al., 2014). Step count was measured by five studies (56%) (Avila et al., 2018; Cupples et al., 2013; Duscha et al., 2018; Houle et al., 2012; ter Hoeve et al., 2018) over a one week period (Cupples et al., 2013; Houle et al., 2012; ter Hoeve et al., 2018) or two week (Duscha et al., 2018) period, using pedometers (Cupples et al., 2013; Houle et al., 2012) or accelerometers (Avila et al., 2018; Duscha et al., 2018; Guiraud et al., 2012). Avila et al. (2018) did not report the time period that step counts were measured. Exercise duration was reported by three studies (33%) (Avila et al., 2018; Butler et al., 2009; Cupples et al., 2013), exercise intensity was reported by four studies (44%) (Avila et al., 2018; Duscha et al., 2018; Guiraud et al., 2012; ter Hoeve et al., 2018), and two studies reported on sedentary time (Avila et al., 2018; ter Hoeve et al., 2018). Individual trial outcome measures can be seen in Table 20.

Table 20: *Physical Activity Outcome Measures*

Study	Steps/Day		VO_2 peak (mean ±SD)		Physical Activity Duration (mean mins ± SD)		METS at AT	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**		
Avila et al. (2018)	6419 (2227-13181) c[b]	6408 (296-12041) c[b]	26.6 ± 4.9 c	26.4 ± 5.4 c	114 ± (30-311) c[e]	114 ± (6-382) c[e]		
	7896 (2018-12554) i[b]	6469 (473-12554) i[b]	26.7±6.6 i	27.8 ± 6.8 i *p*=0.03	145± (34-299) i[e]	141 ± (51-259) i[e]		
Cupples et al. (2013)	7869 ± 4209 c[a]	42 ± 2,624 c[ch]						
	6123 ± 3151 i[a]	2742 ± 3164 i[ch] p=.004						
Duscha et al. (2018)	7411 ± 2811 c[a]	7243 ± 3209 c[a]	20.7±5.6 c	19.1±5.5 c				
	9003 ± 2694 i[a]	9414 ± 3051 i[a]	21±5.7 c	21.7±5.6 c				
Houle et al. (2012)	41 c[d]	55 c[d]						
	31 i[d]	83 i[d] *p*=.042						
ter Hoeve et al. (2018)		514 ± 115 c[ch]						
		1504 ± 1835 i[ch]						
Skobel et al. (2017)			12.8* c	19.5±4.8				
			13.8* i	21.9±8.3 *p*=.005				
Butler et al. (2009)					367 ± 268 c[f]	355 ± 271 c[f]	3.6±0.8c	3.9±1.3c
					343 ± 275 i[f]	455 ±361 i[f] *p*=.025	3.5±0.7 i	3.9±1.1 i

Abbreviations: c: control group, i:, intervention group, SD: standard deviation, [a]: mean ± SD, [b]: mean (range), [ch] : resulting change mean ± SD, [d]: % of participants achieving > 7500 steps/day, %: percentage, VO_2peak: maximal oxygen uptake, METS: metabolic equivalents, AT: anaerobic threshold, *p*: p value, [e]:>3 METS; mins/day± (range), [f]: mins/week; mean ± SD; Active Australia Survey.

Timepoints for outcome measure acquisition can be seen in Figure 9. The figure shows the wide range of study lengths (12 weeks to 18 months) and timing of main outcome measures. Two studies (22%) (Cupples et al., 2013; Duscha et al., 2018) were less than 6 months' duration, four studies (44%) (Avila et al., 2018; Butler et al., 2009; Skobel et al., 2017; Varnfield et al., 2014) were between five- and seven-months' duration, and three studies (33%) (Guiraud et al., 2012; Houle et al., 2012; ter Hoeve et al., 2018) ran for 12 months or more. The longest duration was 18 months (ter Hoeve et al., 2018). Duscha et al. (2018) did not report the length of time of Phase 2 CR, only the number of sessions, and Guiraud et al. (2012) used two groups of participants that had either 2 months or 12 months of no intervention between the completion of their Phase 2 CR and the onset of the Phase 3 CR.

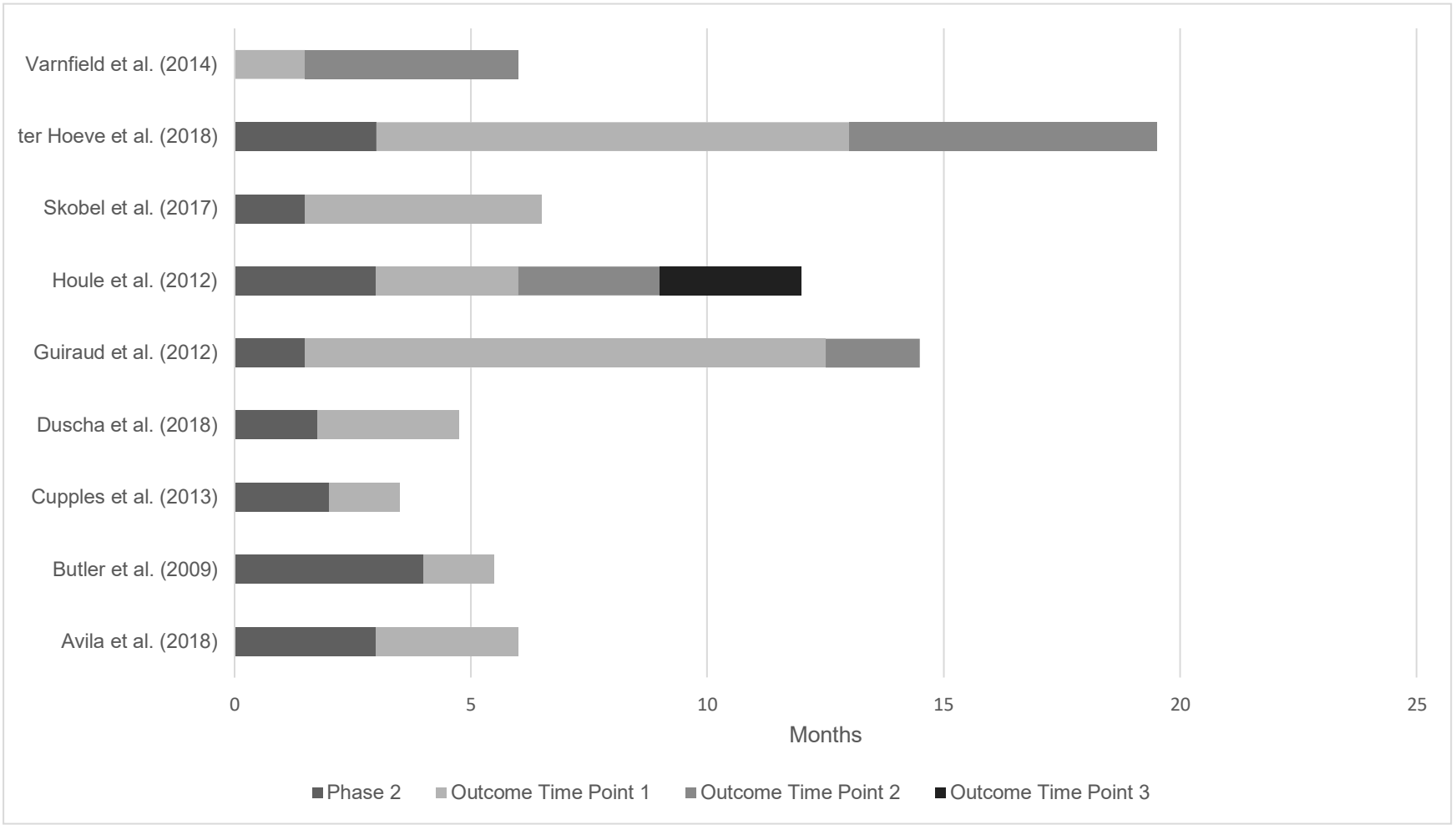


Figure 9: Timepoints for outcome measure acquisition and duration of studies

4.5.6 CARDIORESPIRATORY FITNESS/EXERCISE CAPACITY

Five studies (56%) (Avila et al., 2018; Butler et al., 2009; Duscha et al., 2018; Skobel et al., 2017; Varnfield et al., 2014) measured CRF/exercise capacity changes. The outcome measure varied across studies. Three studies (Avila et al., 2018; Duscha et al., 2018; Skobel et al., 2017) (33%) measured VO_2peak. Two of these, used a cycle ergometer with expired gas analysis (Avila et al., 2018; Skobel et al., 2017) and one used a maximal treadmill test with expired gas analysis (Duscha et al., 2018). Another study measured AT using a cycle ergometer with gas analysis (Butler et al., 2009) and one study (Varnfield et al., 2014) utilised a six-minute walk test (6MWT). Figure 10 depicts the meta-analysis and forest plot results performed for VO_2peak changes. The meta-analysis identified three studies (Avila et al., 2018; Duscha et al., 2018; Skobel et al., 2017) that had assessed change in VO_2peak. All three studies showed WPAM with exercise prescription or advice significantly improved VO_2peak as compared to not utilising a WPAM; (MD 1.65 mL/kg/min; 95% CI [0.64–2.66]; p = 0.001; I^2 = 0%).

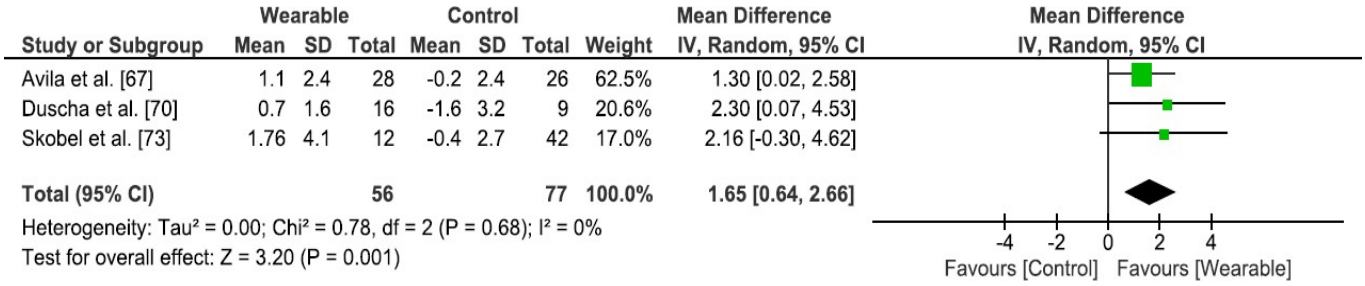


Figure 10. Forest Plot: Aerobic capacity changes.

Abbreviations: IV, inverse variance, CI, confidence interval, SD, standard deviation

A sensitivity analysis was performed by removing Avila et al. (2018) This resulted in a larger mean difference (1.65 [0.64–2.66] versus 2.24 [0.58–3.89]). The heterogeneity remained at I^2 = 0% (Figure 11). A sensitivity analysis that removed the weighting of Avila et al. (2018) was employed due to the heterogeneity of the results of daily step count compared to the three other studies included in the meta-analysis. The VO_2peak results extracted from Avila et al. (2018) were, however, significantly more homogenous. Avila et al. (2018) utilised a heart rate monitor (Garmin Forerunner) to guide the participant's exercise sessions. Therefore, participants of this study may not have engaged solely in walking or running during

the intervention period, but rather may have chosen numerous other forms of exercise such as cycling or gymnastics.

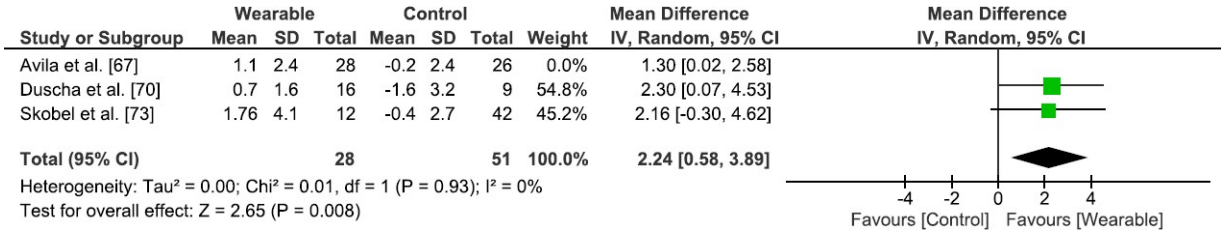


Figure 11. Sensitivity Analysis: Aerobic capacity changes.

Abbreviations: IV, inverse variance, CI, confidence interval, SD, standard deviation

A qualitative analysis of the effect WPAM with exercise prescription or advice had on CRF/physical capacity was undertaken. The analysis showed a moderate level of evidence for WPAM improving physical capacity to a greater extent than no WPAM (Table 21).

Table 21: *Qualitative Analysis of Physical Capacity Outcome Measures*

	Study Quality	Outcome Measure	Effect	Best Evidence Synthesis
Avila et al. (2018)	Good	VO_2 peak	+	Moderate [a]
Butler et al. (2009)	Good	METs at AT	=	
Duscha et al. (2018)	Fair	VO_2 peak	+	
Skobel et al. (2017)	Good	VO_2 peak	+	
		6MWT		
Varnfield et al. (2014)	Good		=	

+, significant difference favouring WPAM, −, significant difference favouring control, =, no significant difference between groups. [a]Moderate Evidence: significant findings provided by one study with high quality and/or two or more studies with low quality, and by generally consistent findings in all studies (more than 60% of the studies reported consistent findings)
Abbreviations: *VO_2peak* peak aerobic capacity, *METs* metabolic equivalents, *AT* anaerobic threshold, *6MWT* six-minute walk test

4.5.6.1 SIX-MINUTE WALK TEST

Varnfield et al. (2014) completed a 6MWT test to determine the impact of their Care Assessment Platform CR intervention on exercise capacity at 6 weeks and 6 months. They found both groups significantly increased distance from baseline to 6 weeks and 6 months, however there was no significant difference between groups.

(6 weeks: control 537 ± 86 m to 584 ± 99 m; $p = 0.001$ vs intervention 510 ± 77 m to 570 ± 80; $p < 0.001$); (6 months: control 537 ± 86 m to 601 ± 95; $p < 0.05$ vs intervention 510 ± 77m to 571 ± 88; $p < 0.05$). Adjusted mean difference at 6 weeks was not found to be significant $p = 0.4$.

4.5.6.2 PEDOMETER STEP COUNT

Five studies (56%) (Avila et al., 2018; Cupples et al., 2013; Duscha et al., 2018; Houle et al., 2012; ter Hoeve et al., 2018) reported on the number of steps completed by participants. Figure 12 depicts the meta-analysis and forest plot results performed or step count change pre and post intervention. Three studies (75%) (Cupples et al., 2013; Duscha et al., 2018; ter Hoeve et al., 2018) showed improved step counts when using a WPAM versus not utilising one, however the overall effect was not significant. (SMD 0.45; 95% CI [− 0.17–1.07]; $p = 0.15$; $I^2 = 82\%$). The SMD of 0.45 equates to a medium effect size.

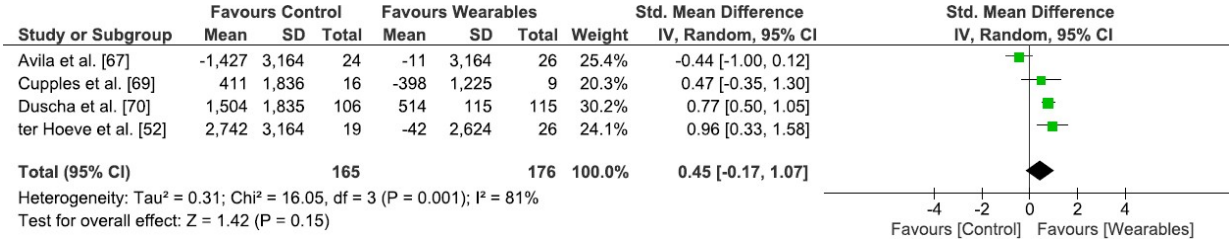


Figure 12. Forest Plot: Step Count

Abbreviations: IV, inverse variance, CI, confidence interval, SD, standard deviation

A sensitivity analysis was performed by removing Avila et al. (2018) This resulted in a significant difference in step count, favouring WPAM with exercise prescription or advice (SMD 0.78; 95% CI [0.54–1.02]; $p < 0.001$). The increased SMD of 0.78 also equated to a moderate effect size. Removing Avila et al. (2018) also reduced the heterogeneity to 0% (Figure 13). Houle et al. (2012) also reported on steps of participants, however published percentage of participants reaching > 7,500 steps per day and therefore could not be included in the meta-analysis. They did find a significant difference between groups. The intervention group significantly increased the percentage of patients achieving > 7,500 steps per day more than the

control group at 6, 9 and 12 months (75% vs 41%; 68% vs 36%; 83% vs 55%, respectively; $p < 0.05$).

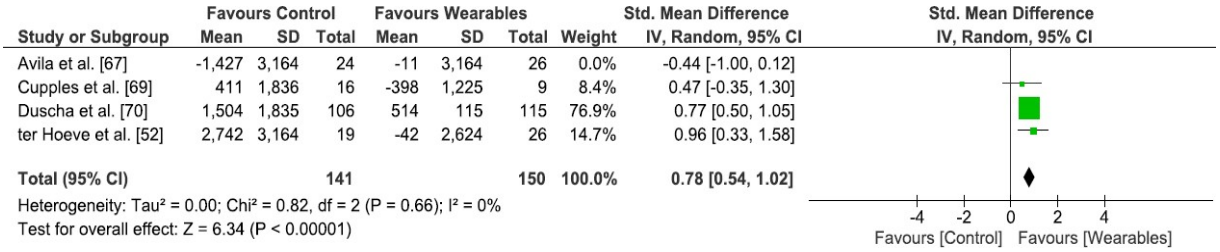


Figure 13. Sensitivity Analysis: Step Count

Abbreviations: IV, inverse variance, CI, confidence interval, SD, standard deviation

A qualitative analysis of the effect WPAM with exercise prescription or advice had on the amount of physical activity performed by participants was undertaken. The analysis showed a moderate level of evidence for WPAM improving physical activity to a greater extent than no WPAM (Table 22).

Table 22: *Qualitative Analysis of Physical Activity Outcome Measures*

	Study Quality	Outcome Measure	Effect	Best Evidence Synthesis
Avila et al. (2018)	Good	Steps/day and PA Duration	=	Moderate [a]
Butler et al. (2009)	Good	PA Duration	+	
Cupples et al. (2013)	Fair	Steps/day	+	
Duscha et al. (2018)	Fair	Steps/day	=	
Guiraud et al. (2012)	Good	Total Active Energy Expenditure	+	
Houle et al. (2012)	Good	% of participants over 7,500 steps/day	+	
ter Hoeve et al. (2018)	Good	Steps/day	+	

+, significant difference favouring WPAM, −, significant difference favouring control, =, no significant difference between groups. [a]Moderate Evidence: significant findings provided by one study with high quality and/or two or more studies with low quality, and by generally consistent findings in all studies (more than 60% of the studies reported consistent findings)

Abbreviations: *PA,* physical activity, % percentage

4.5.7 Intensity/Accelerometry Data

Four studies (44%) (Avila et al., 2018; Duscha et al., 2018; Guiraud et al., 2012; ter Hoeve et al., 2018) reported on intensity of physical activity. Avila et al. (2018) did not record how long the intensity was measured. Guiraud et al. (2012) recorded intensity data throughout the intervention period in the wearable group and

for one week in the control group and ter Hoeve et al. (2018) collected intensity data over 8 days. The final study recorded intensity data for two weeks at the beginning and two weeks at the end of the intervention period (Duscha et al., 2018).

One study found no significant differences in the intensity of exercise performed by participants in either the intervention or control group.(Avila et al., 2018) The three remaining studies (Duscha et al., 2018; Guiraud et al., 2012; ter Hoeve et al., 2018) reported different findings. One study reported the intervention group significantly increased the time spent in moderate-high intensity activity compared to the control group (intervention; 3 ± 15 mins/day increase versus control; −7±5 mins/day decrease; $p < 0.05$) (Duscha et al., 2018). In addition, the authors found the control group significantly decreased the time in moderate-low and moderate-high intensity. The change between the groups was significant in both categories (moderate-low; −10 ± 12 mins/day $p < 0.05$; moderate-high −7± 5 mins/day; $p < 0.05$). The second study reported the duration of moderate intensity physical activity increased significantly at the 8-week compared to baseline in the intervention group only (70.1 ± 32.4 min/ week to 137 ± 87.5 min/week); ($p < 0.0004$) (Guiraud et al., 2012). The final study showed no significant change in moderate to vigorous intensity physical activity between control and intervention groups ($p = 0.529$), however time in prolonged moderate- vigorous physical activity of the intervention group improved more at 3 months compared with the control group. ($p = 0.054$) (ter Hoeve et al., 2018).

4.5.8 Sedentary Time

Two studies reported on changes to time spent sedentary (Avila et al., 2018; ter Hoeve et al., 2018). Avila et al. (2018) found no significant differences between the control and home-based groups (control: 1100; range: 825–1355 min/day to 1062; range: 484–1402 versus intervention: 1039 range: 688–1260 to 1032 range:790–1455 min/day). In addition, ter Hoeve et al. (2018) also reported no change in sedentary behaviour time.

4.5.9 PSYCHOLOGICAL MEASURES/QUALITY OF LIFE

A third of the studies (3/9) did not have outcome measures to investigate the effect of WPAM with exercise prescription or advice on quality of life (QoL) or psychological factors (Duscha et al., 2018; Guiraud et al., 2012; ter Hoeve et al., 2018). Each study that did assess psychological effects (6/9) used different tools, however the EQ. 5D and Kessler scales were used in several studies. Three (Avila et al., 2018; Cupples et al., 2013; Skobel et al., 2017) of the six studies (Avila et al., 2018; Butler et al., 2009; Cupples et al., 2013; Houle et al., 2012; Skobel et al., 2017; Varnfield et al., 2014) that used psychological outcome measures found no significant differences in health related quality of life (Avila et al., 2018; Cupples et al., 2013), general health status (EQ. 5D) (Cupples et al., 2013; Skobel et al., 2017), hospital anxiety and depression scale (Skobel et al., 2017) or stage of behavioural change (Cupples et al., 2013). However, the remaining three studies (Butler et al., 2009; Houle et al., 2012; Varnfield et al., 2014) did report significantly improved overall quality of life (Houle et al., 2012), health related quality of life (Varnfield et al., 2014), general health status (EQ. 5D) (Varnfield et al., 2014) and decreased depression, anxiety and stress scale (DASS21) (Varnfield et al., 2014) and psychological distress scale (Kessler 6 (Butler et al., 2009) and Kessler 10 (Varnfield et al., 2014) scores.

Specifically, Butler et al. (2009) reported the intervention group had significantly greater improvement in behavioural ($p = 0.039$); and cognitive strategies ($p = 0.024$) compared to the control group at 6 weeks, however, at 6 months only the cognitive strategies remained significantly greater when adjustments were made for baseline differences ($p = 0.001$).

At six weeks, Varnfield et al. (2014) reported significant improvements in several components of the Kessler 10 for both groups, however, these were not significantly different between groups (psychological distress scale, DASS- anxiety). The EQ. 5D scores significantly improved in the intervention group compared with the control group ($p < 0.001$). At six months, the between group differences were not significant for Kessler 10 nor EQ. 5D.

Houle et al. (2012) used the Quality of Life Index-cardiac version 111 and reported the health and functioning score (p = 0.048) and family score (p = 0.048) were statistically improved compared to control group at 6 weeks. They also found overall QoL (p = 0.048) and the health and functional score (p = 0.036) were significantly improved compared to the control group at twelve months.

4.6 DISCUSSION

The aim of this systematic review and meta-analysis was firstly to determine whether using a WPAM with exercise prescription or advice during the maintenance phase of CR was effective in maintaining or improving CRF and/or the amount of daily physical activity and sedentary time. Secondly, we aimed to collate the outcome measures used in the studies, reasons for drop out, adverse events, and QoL/psychological impact resulting from WPAM during the maintenance phase of CR. Our review of the literature identified that there are no other systematic reviews investigating the effect of WPAM on the above parameters within the cardiac population.

4.6.1 MAIN FINDINGS

The main findings of the reviewers were that using a WPAM with exercise prescription or advice significantly improved CRF to a greater extent than having no device for people with cardiac disease who are exercising through to the maintenance phase of CR. The review also showed that WPAM did not result in any cardiac adverse events and may assist in improving step count and some components of psychological measures (cognitive and behavioural strategies, psychological distress, anxiety, overall QoL).

4.6.2 Study Quality

Overall, our results showed the quality of individual studies in our review was good. When scoring the methodology of the studies using the PEDro scale, only two studies (Cupples et al., 2013; Duscha et al., 2018) were found to be of fair quality, with the remainder being of good quality. In future studies, the addition of blinding assessors and incorporating intention to treat in data analysis, would assist in improving study quality.

4.6.3 Study Characteristics

Our results showed that research into the effectiveness of WPAM in the cardiac population, although limited, has been conducted primarily in the northern hemisphere (78%), with only two studies occurring south of the equator. Most participants across the included studies were male (78%), which represents male dominated enrolment seen in CR (Samayoa et al., 2014). Future studies investigating whether the effects of WPAM and exercise prescription or advice differ depending on sex would be beneficial.

The participant diagnoses and cardiac interventions across the studies represented the main patient presentations seen at CR programmes and therefore, were a good representation (National Heart Foundation of Australia, 2010). However, no studies investigated whether patients' specific diagnosis influenced the outcomes from WPAM. This would be valuable for future studies as this could ascertain, for instance, whether patients who are re-perfused benefit more from utilising a WPAM than those on medical management.

There were many different WPAM used across studies. Therefore, the results need to be viewed with caution as none of the studies included in this review compared the effectiveness of different devices at increasing physical activity. A study by Cadmus-Bertram et al. (2015) showed Fitbits to be more effective than pedometers at increasing exercise intensity of participants, therefore comparisons between devices would be useful.

Our review noted that the duration of less than half the studies was 3 months or less and the longest study duration was 18 months. Most studies, therefore, were too short to predict the effect of WPAM with exercise prescription or advice on mortality, hospital admission and long-term adherence to physical activity. Our results found greater dropout rates were seen in the studies lasting more than 6 months compared with those lasting three or fewer months. Longer duration studies are warranted to determine whether adherence to the usage of a WPAM decreases over time.

There were large variations across studies regarding exercise advice given to participants, recording practices of daily exercise, and additional input given to improve adherence. It is difficult to determine whether WPAM alone are responsible for the improvements shown and what contribution these confounding variables may have made to the results.

4.6.4 Reasons for Drop Out

According to a review by Dishman (1982) 50% or more of participants drop out of exercise in clinical settings within 6 months. Apart from one study by Skobel et al. (2017) the dropout rate for the studies in our review was found to be less (< 33%) than this. Our results also suggested that using a WPAM did not affect the dropout rates compared to using no device. The review by Dishman (1982) reported that attitudes to exercise, self-perceptions, health beliefs, goals, and motivation were the main influencing factors to adherence. Our findings were similar as most participants reported lack of interest and motivation, other commitments and medical reasons as the main reasons for drop out across all trials.

4.6.5 Adverse Events

Although only half the studies reported on adverse events, most were non-cardiac related. No cardiac events reported were related to exercise training, which suggests that exercise and the addition of WPAM does not increase incidences of cardiac events. This is in line with numerous studies that have shown low adverse

event rates with CR exercise (Hannan, Hing, Coombes, et al., 2018; Pavy et al., 2006; Rognmo et al., 2012). The specific effect of WPAM on safety cannot be determined from these studies, as only one reported which group (control or intervention) the participants who suffered an adverse event were in.

4.6.6 Outcome Measures

4.6.6.1 Cardiorespiratory fitness/exercise capacity

Our results showed WPAM with exercise prescription or advice improved CRF to a greater extent than no device with the mean overall difference being 1.65 mL/kg/min. A study by Laukkanen et al. (2016) observed a 9% reduction in all-cause mortality in those that increased CRF by 1 mL/kg/min over an 11-year period. Our results were higher than Laukkanen et al. (2016) suggesting our results are clinically significant. The qualitative best evidence synthesis we conducted also mirrored the results of the meta-analysis in favour of WPAM and suggests there is moderate evidence to support the use of WPAM with exercise prescription or advice on improving CRF/ physical capacity in Phase 3 CR populations.

To the authors' knowledge, there appears to be no other systematic reviews that have investigated the effect of WPAM with exercise prescription or advice on change in CRF in any population group. It is therefore difficult to directly compare our results to previous studies. However, two studies compared CRF changes as a result of using mobile phone interventions, rather than WPAM. Direito et al. (2015) investigated fitness changes in 51 active, young people. CRF was assessed using the 1- mile run/walk test. Our study results contrasted with the results found by Direito et al. (2015) as they reported no significant difference in physical fitness compared to the control group. Similarly, another study by Maddison et al. (2015) found peak oxygen uptake did not change as a result of a mobile phone intervention including text messages, websites and video messages. The results of this review contrast with studies based within the healthy population as it showed improvements in CRF and may support the use of WPAM with exercise prescription or advice to improve CRF in the cardiac population.

Few studies have investigated the effect of WPAM with exercise prescription or advice on six-minute walk test distance. We found only one study in our review that used the 6MWT as an outcome measure (Varnfield et al., 2014). Varnfield et al. (2014) reported both control and intervention groups improved six-minute walk test distance, however there was no significant difference between groups. To the authors' knowledge, there has only been one other study investigating WPAM that used the 6MWT as an outcome measure and was performed with people diagnosed with HF (Evangelista et al., 2005). Evangelista et al. (2005) reported that patients who showed improvements in their pedometer scores over 6 months also improved their 6MWT distance when compared with patients whose pedometers reflected minimal change in distance walked. Our findings cannot be directly compared; however, the study suggests that participants who adhere more to WPAM with exercise prescription or advice may increase their functional capacity to a greater extent than those adhering less.

4.6.6.2 PEDOMETER STEP COUNT

Although our results did not show a significant total effect increase in step count, 70% of the studies reported significant increases in step counts. The sensitivity analysis which removed one study (Avila et al., 2018) however, did result in a significant difference in step count. It also changed the heterogeneity from substantial to minimal. The sensitivity analysis also increased the effect size (SMD) from 0.45 to 0.78 indicating a moderate effect size (Kennelly & Handler, 2011). As previously stated, the sensitivity analysis was carried out due to an identified methodological factor which predisposed the results to a poorer outcome. This may explain why VO_2peak data supported the hypothesis, whilst daily step count data contradicted the hypothesis, and the results of the other three studies. Our qualitative analysis, which compared the results from seven studies, suggests there is moderate evidence to support the use of WPAM with exercise prescription or advice on improving physical activity in the maintenance phase of CR.

As there have been no systematic reviews investigating the effect of WPAM on step count in the cardiac population, our results cannot be directly compared to the literature. There have been two recent systematic reviews surrounding the effect

of smartphone technology and WPAM on the amount of physical activity performed in healthy subjects. Bort-Roig et al. (2014) found five studies with participant numbers ranging from 12 to 42 that investigated physical activity duration. All studies used step count as the outcome measure. Of the five studies, four (80%) reported increased step count ranging from 800 to 1,104 more steps/day. The duration of the studies ranged between 2 weeks and 6 months. The second systematic review by Muntaner et al. (2015) included 12 publications. The authors investigated the impact of mobile devices on physical activity. All participants were healthy subjects. The trials used mobile applications, self-reported questionnaires, accelerometers and pedometers. Half of these (6/12) reported significant increases in physical activity. However, only two of the studies utilised WPAM. Both studies did not investigate the effect of using a WPAM in improving physical activity. Both groups used pedometers or accelerometers for outcome measures, rather than an intervention. The results of this review resemble findings from the healthy population and suggest the use of WPAM with exercise prescription or advice may improve step count in the cardiac population.

4.6.7 Intensity/Accelerometry Data

There are minimal studies investigating the effect of WPAM with exercise prescription or advice on intensity of exercise. Our results showed 75% of studies which measured intensity found a significant increase in the amount of moderate and moderate-high intensity physical activity of participants compared to the control group for at least one time point. Our results are similar to that found in the Fitbit group by Cadmus-Bertram et al. (2015) who investigated the effect of wearing a Fitbit versus wearing a pedometer. Those who wore a Fitbit increased moderate-vigorous activity by 62 ±108 mins/week. However, those who wore a pedometer did not significantly increase intensity.

A further study by Ayabe et al. (2010) who investigated WPAM within a chronic disease population, found after 3 weeks, participants who could monitor their intensity using an accelerometer increased time spent in moderate-vigorous activity significantly more than participants who only wore a pedometer. Another study by

Finkelstein et al. (2016) found the WPAM group performed significantly more moderate- vigorous activity than the control group at 12 months. However, this was not significant at 6 months and further supports the need for longer duration studies. Our results are similar to that reported previously in the literature and suggests WPAM with exercise prescription or advice may assist in increasing exercise intensity for people diagnosed with cardiac disease.

4.6.8 Sedentary Time

Our review identified two studies that investigated the effect of WPAM with exercise prescription or advice on sedentary time in the cardiac population. Both studies found no significant differences in sedentary time between the intervention and control groups. These results are similar to that found by Sloan et al. (2018) who investigated the effect WPAM had on sedentary behaviour in the healthy population. Sloan et al. (2018) reported increases in step counts resulted in a decrease in sedentary time, however there was no significant decrease between groups. It appears sedentary time is not influenced by utilising WPAM with exercise prescription or advice.

4.6.9 Psychological Measures

Our analysis revealed mixed results relating to the improvement of psychological measures when using WPAM with exercise prescription or advice in the maintenance phase of CR. Half the studies showed some statistical difference between group differences in some categories of the respective outcome measure (EDQ5, DASS 21, Kessler 6, overall quality of life) suggesting there may be an effect, although, the studies used a broad range of different measures to investigate psychological effects. There appears to have been no previous reviews or studies that have explicitly aimed to examine the psychological effects of WPAM in people with CVD. However, Maddison et al. (2015) did explore the effect of a mobile phone on changes in self efficacy and quality of life. They reported significant improvements in self efficacy and general health domain of the SF 36. In addition, Thorup et al. (2016) found participants who used a pedometer reported increased competence to achieve step goals and feelings of support. Participants also reported improved

motivation to exercise. Due to our mixed findings, it is therefore difficult to conclude whether WPAM with exercise prescription or advice improve psychological measures or not which is similar to that found by previous literature.

4.7 Strengths of the Review

The strengths of this review include its methodology and statistical analysis. As previously stated, this review is the only analysis of the effectiveness of WPAM with exercise prescription or advice during the maintenance phase of CR. The review also used strict methodology under PROSPERO registration and PRISMA guidelines. Statistical analysis used a conservative approach to calculating standard deviations and reporting was transparent.

4.7.1 Limitations

There were several limitations to this review. Using the PEDro scale, we determined that although approximately two thirds of studies were of good quality, and approximately one third were of fair quality. There are several improvements that could be made to all studies to increase the confidence in the results. For example, only one study blinded assessors (Skobel et al., 2017) and only two concealed allocation (ter Hoeve et al., 2018; Varnfield et al., 2014).

Study quality assessed through the PEDro scale numerical rating method does not allow for the individual reporting of significant other bias. There were several significant other biases identified during the appraisal of the studies. This included poor completion rates [22% in the intervention group (Skobel et al., 2017)] and 43% in the control group (Varnfield et al., 2014) that may have introduced attrition bias by only analysing participants who finished the trial. Poor female representation (Avila et al., 2018; Butler et al., 2009; Cupples et al., 2013; Duscha et al., 2018; Guiraud et al., 2012; Houle et al., 2012; Skobel et al., 2017; ter Hoeve et al., 2018) can influence results by measuring a disproportionate gender sample of the population, therefore the results may not have been representative of the general CR population and may be more relevant to males. Finally, one study (Cupples et

al., 2013) used block randomization that delivered treatments over different times of the year. This study was conducted in Ireland where outside temperatures and daylight hours during seasons vary greatly and may have introduced a significant bias by reducing adherence to exercise.

Another significant limitation of this review is the use of concurrent educational/motivational therapies based on the information that a WPAM gives a participant about their activity levels by all studies. Additionally, some studies prescribed specific exercise interventions along with WPAM. These confounding variables make it difficult to distinguish how much influence the WPAM itself or additional exercise prescription, and/or educational/motivational strategies had on the results. However, this review still provides valuable insight into the potential effects of WPAM in the cardiac population despite uncontrolled, concurrent treatments such as exercise prescription potentially contributing to improvements made to key outcomes.

The studies had low homogeneity in several attributes such as timing, length of study, type and parameter of intervention, as well as and type and parameters of control conditions. This is because our review used data from studies that had different aims to the review, but still, collected appropriate data on the use of a WPAM in the maintenance phase of CR. For example, one study's main aim was to evaluate the effectiveness of WPAM in a specific subgroup of non-compliant participants that were up to 1 year post cardiac incident (Guiraud et al., 2012). In particular, the varying commencement of intervention (end of phase 2 or phase 3) may have potentially influenced the results.

Outcome measures used were also a significant source of heterogeneity. Therefore, despite including nine studies in the review, the meta-analysis could only include three studies (Avila et al., 2018; Duscha et al., 2018; Skobel et al., 2017) for VO_2peak and four studies (Avila et al., 2018; Cupples et al., 2013; Duscha et al., 2018; ter Hoeve et al., 2018) for daily step count. These factors imply that although the meta-analyses and review support the hypothesis that WPAM with exercise prescription or advice help to maintain physical activity in the maintenance phase of CR, these results are based on a small number of studies.

4.7.2 Future Directions

Additional primary research is needed to investigate the effectiveness of WPAM with exercise prescription or advice on maintaining physical activity, peak aerobic capacity, intensity of exercise and psychological effects in patients diagnosed with cardiac disease in the maintenance phase of CR. Future studies should attempt to use an attention control group to further strengthen their results by reducing the variables of extra forms of therapy such as specific exercise prescription and motivational therapies. Future studies should blind assessors and incorporate intention to treat analysis to improve quality of trials. With respect to psychological measures, future studies may benefit from investigating general health status (EQ. 5D), psychological distress, (Kessler 6) and Quality of Life index (cardiac version 111), as only these tools showed significant differences between groups in our review. Future studies should focus on good quality methodology, include a large sample number, and utilise consistent outcome measures over a longer follow up period. This would allow analysis of the effects WPAM may have on hospital readmission and mortality rates to be conducted. Comparing effect of WPAM on different genders, specific diagnoses and ensuring reporting which group (control or intervention) participants are in if adverse events occur would be of interest. This would also improve the evidence base for future systematic reviews and strengthening confidence in the results.

4.8 Conclusion

This systematic review and meta-analysis showed that WPAM with exercise prescription or advice significantly improves CRF in the cardiac population to a greater extent than no WPAM. Additionally, our qualitative analysis showed moderate evidence in favour of WPAM for both CRF and step count. The wearing of a WPAM did not change sedentary time. Psychological effects and exercise intensity may potentially be enhanced by using a WPAM. There were no reported cardiac events related to exercise and unrelated medical conditions, lack of motivation and loss of interest were reported as the main reasons for dropping out of trials. Additional longer-term good quality research is required to strengthen these conclusions.

4.9 SUPPLEMENTARY MATERIAL

Ovid Medline Search Strategy

(("myocardial infarction".mp. or "myocardial infarct".mp. or "heart attack".mp. or "heart infarction".mp. or "heart infarct".mp. or Myocardial Infarction/ or "cardiac arrest".mp. or "coronary artery disease".mp. or Coronary "coronary heart disease".mp. or "coronary disease".mp. or Coronary Disease/ or "ischaemic disease".mp. or "ischemic disease".mp. or "cardiac ischemia".mp. or "cardiac ischaemia".mp. or "myocardial ischemia".mp. or "myocardial ischaemia".mp. or Myocardial Ischemia/ or "ischemic heart disease".mp. or "ischaemic heart disease".mp. or IHD.mp. or "coronary angioplasty".mp. or angioplasty.mp. or Angioplasty, Balloon, Coronary/ or balloon.mp. or "percutaneous coronary intervention".mp. or PCI.mp. or Percutaneous Coronary Intervention/ or (percutaneous and (heart or coronary or cardiac)).mp. or ((revascularisation or revascularization) and (heart or coronary or cardiac)).mp. or "acute coronary syndrome".mp. or Acute Coronary Syndrome/) AND (rehabilitat*.mp. or Rehabilitation/ or Rehabilitation Centers/ or "physical".mp. or physiotherapy.mp. or Physical Therapy Modalities/ or Exercise Therapy/ or exercise physiology or exercise-based) AND (fitbit* or wearable* or activity tracker* or step counter* or pedometer* or heart rate monitor* or heart rate sensor* or mobile app* or smartphone or iphone) AND (Motivat*) AND (Exercis* OR activ*

CHAPTER 5: EFFECT OF PERSONAL ACTIVITY INTELLIGENCE (PAI) MONITORING IN THE MAINTENANCE PHASE OF CARDIAC REHABILITATION: A MIXED METHODS EVALUATION

5.1 PREFACE

SUBMITTED PUBLICATION: Hannan, A., Hing, W., Coombes, J.S., Gough, S., Climstein, M., Adsett, G., Jayasinghe, R., Furness. J. (2020). Effect of Personal Activity Intelligence (PAI) monitoring in the maintenance phase of cardiac rehabilitation: A mixed methods evaluation.

This chapter aligns with the fourth and final research thesis aim:

"Investigate the effect of monitoring PAI scores, using a WPAM, had on intensity, adherence and motivation in cardiac populations, during the maintenance phase of CR and in the home environment."

This chapter presents findings from a six week concurrent mixed methods trial. Twenty participants monitored their PAI via a WPAM. Both quantitative data (measures of Total PAI and PAI earned/day) and qualitative data (semi-structured interviews) were performed and comparisons made between blinded and un-blinded periods. Participants were in the maintenance phase of CR.

Effect of Personal Activity Intelligence (PAI) monitoring in the maintenance phase of cardiac rehabilitation: A mixed methods evaluation.

5.2 ABSTRACT

5.2.1 BACKGROUND

Personal Activity Intelligence (PAI) is a single physical activity metric based upon heart rate responses to exercise. Maintaining 100 PAI/week is associated with a 25% risk reduction in cardiovascular disease mortality and 50 PAI/week provides 60% of the benefits. The effect of utilising this metric within a cardiac population has not been investigated.

5.2.2 OBJECTIVE

We determined the effect of PAI monitoring on the amount and/or intensity of physical activity for people with cardiac disease and explored participants' perceptions of this approach.

5.2.3 METHODS

A concurrent mixed methods approach was undertaken. Twenty participants in the maintenance phase of cardiac rehabilitation monitored PAI for six weeks via a wearable physical activity monitor (WPAM). In the first three weeks participants were blinded to their PAI score. A quality of life questionnaire (EQ-5D-5L) was completed, and semi-structured interviews conducted to investigate attitudes to PAI monitoring.

5.2.4 RESULTS

PAI earned/day was significantly increased after participants could view their data (mean difference: 2.1 PAI/day (95% CI: 0.3,4.0), p=0.027). The median change in percentage of days participants achieved a Total PAI score of 25 (p=0.023) and 50 (p=0.015) were also significantly increased. The mean change in total scores for the EQ-5D-5L and EQVAS were significantly improved after six weeks (0.6±1.05; 95% CI; (0.11-1.09); p=0.019); (5.8/100; 95% CI (2.4-9.2); p=0.002 respectively). Thematic framework analysis identified three global themes (perceptions on the WPAM, PAI and factors affecting exercise). Most participants stated motivation to exercise increased after they could view their PAI data. Many of the participants believed they would continue to use PAI long-term. Others were undecided; the latter

primarily due to technical issues and/or preferring devices with greater functionality and attractiveness. All participants would recommend PAI.

5.2.5 Conclusion

PAI monitoring significantly increased physical activity within the cardiac population. Participants found PAI interesting, beneficial, and motivating. If technical issues, aesthetics, and functionality of the WPAM were improved, participants would continue to use the approach long-term. PAI may be a viable strategy to assist people with cardiac disease maintain long-term exercise adherence.

Keywords: personal activity intelligence, physical activity maintenance, motivation, barriers, exercise therapy, exercise, fitness, wearable

5.3 INTRODUCTION

According to the World Health Organisation (2019) cardiovascular disease (CVD) is the leading cause of death worldwide resulting in 17.9 million deaths per year; of which 85% were myocardial infarctions and strokes. A systematic analysis by Naghavi et al. (2017) reported coronary heart disease (CHD) as the leading cause of years of life lost to premature death, surpassing lower respiratory infections. Australia mirrors the global CVD mortality climate. According to the Australian Institute of Health and Welfare (2018) more than a quarter of deaths were due to CVD in 2018. The Australian Bureau of Statistics (2019) reported 17,533 deaths (11%) from ischaemic heart disease, rating it the leading cause of death and responsible for one death every twenty-eight minutes. Once a person suffers a cardiac event they are at greater risk for subsequent events. A retrospective cohort study by Jernberg et al. (2015) reported a 18.3% increase risk of future cardiac events within the first year, and 20% increased risk within the subsequent three years.

Coronary heart disease (CHD) is a large contributor to health costs. According to Deloitte Access Economics (2011) individuals suffering a subsequent myocardial infarction cost Australian residents $8.4 billion/year. More recently, National Heart Foundation of Australia (2018) estimated the cost of associated with acute coronary syndrome (ACS) to be $1,930.2 million in 2017-2018. Additionally, Schofield et al. (2019) projected the number of people out of the workforce due CHD will rise from 6700 in 2015 to 8100 in 2030. This would result in an increase in costs due to lost income from $273 million in 2015 to 443 million in 2030 (Schofield et al., 2019). Although CVD mortality appears to be decreasing in developed countries, the global aging population, growth, and longer-term survival rates from acute myocardial infarction is increasing the global economic burden. Deaths from CHD have been predicted to remain high into the next decade (Jernberg et al., 2015; Johansson et al., 2017).

Cardiac rehabilitation (CR) is an important secondary prevention strategy involving patients with cardiac disease accessing supervised exercise, education, lifestyle behaviour modification and counselling. This health professional input is generally focused within the first three months post event, despite the risk of reinfarction remaining for several years (Jernberg et al., 2015).

Adhering to life-long physical activity and maintaining a high level of cardiorespiratory fitness (CRF) is of paramount importance for people with cardiac disease, particularly as CRF has been shown to be inversely proportionate to all-cause, and CVD mortality (Keteyian et al., 2008; Meyer et al., 2002; Moholdt et al., 2008; Swain & Franklin, 2006). Additionally, recent research has shown higher levels of CRF independently reduces risk of future events, even in people with concurrent additional risk factors of heart disease such as hypertension, obesity and diabetes (Myers et al., 2015). Furthermore, the intensity of exercise has also been shown to be critical in reducing the risk of all-cause mortality, with more frequent, intense activity providing superior protection (Hannan, Hing, Simas, et al., 2018; Moholdt et al., 2014; Moholdt et al., 2008).

There is minimal research investigating the amount and intensity levels of physical activity completed by patients after the sub-acute phase of CR. However, from the limited available data, it appears few people who have been diagnosed with acute coronary syndrome (ACS) continue to meet aerobic exercise guidelines long term. These guidelines recommend 150-300 minutes of moderate intensity physical activity per week or 75-150 minutes of vigorous intensity physical activity per week. Interchanging both intensities to an accumulated equivalent degree is also advocated (Brown et al., 2012). For people over 65 years of age, at least 30 mins of moderate exercise on most days is recommended (Brown et al., 2008). A study by Kronish et al. (2017) found that at five weeks post discharge, only 16% of participants were meeting the exercise guidelines recommended for those at two weeks post discharge. Further, a study by Reid et al. (2006) found participants did not maintain increased exercise levels beyond two months' post discharge from Phase 2. A third study by Bock et al. (2003) also reported only 56% of patients at 12 months post-discharge from CR, were meeting exercise guidelines. This suggests CRF improvements gained during CR are not likely to be maintained in the longer term and, therefore, the benefits of increased survival from higher CRF levels are not being realised in the cardiac population.

Lack of time and poor motivation have been identified in the literature as the most common barriers to performing regular physical activity in both healthy and cardiac populations (Alharbi et al., 2017; Bravata et al., 2007). In recent years,

wearable physical activity monitors (WPAM) have been introduced in an attempt to address these barriers (Ehn et al., 2018; Finkelstein et al., 2016; Gualtieri et al., 2016; Jang et al., 2018) and have become number one in the top twenty worldwide fitness trends in 2020 (Thompson, 2019). A systematic review and meta-analysis by Brickwood et al. (2019) reported consumer based wearable activity devices significantly increased step count, moderate and vigorous intensity exercise, and energy expenditure. Therefore, WPAM may be an answer to the call out for innovative solutions and novel technology to assist in increasing physical activity levels across the lifespan as recommended by Peterman and Bassett (2019).

A systematic review found that the use of WPAM in people with cardiac disease leads to a greater improvement in CRF, when coupled with exercise prescription or advice (Hannan et al., 2019). The review identified only one study which focused on exercise intensity of participants throughout the intervention (Guiraud et al., 2012), despite research showing HIIT is superior to moderate continuous training in this population (Hannan, Hing, Simas, et al., 2018). Therefore, mainstream exercise advice to walk 10,000 steps a day, or guidelines based on time alone, do not emphasise the superior benefits in improving CRF gained by engaging in higher intensity activity and thus may be hindering cardiac patients' ability to achieve optimal cardio-protection.

While the main demographic of cardiac conditions is middle aged or older, research shows older adults are receptive to, accept and can easily master WPAM (Mercer et al., 2016a; O'Brien et al., 2015). Smart wristbands [WPAM with Bluetooth capabilities that transmit data to an application (app) on a mobile phone or tablet] have also been shown to assist in empowering health behaviours and improving commitment to physical activity (Nelson et al., 2016) and health outcomes (Lunney et al., 2016; Mercer et al., 2016b). In addition, Hwang et al. (2017) explored patient perceptions of telerehabilitation in a cardiac (heart failure) population and found it to be a positive intervention which assisted motivation to exercise.

While there are numerous activity trackers, very few allow cardiac patients to track their activity and link this to useful information about cardiovascular risk reduction. Personal Activity Intelligence (PAI) was developed in 2016 by a group of Norwegian researchers investigating the amount of physical activity required to

prevent CVD (Nes et al., 2016). The PAI metric uses the heart rate response to exercise and was derived using an algorithm based upon individual heart rate reserve calculations over a seven-day rolling period. These measures are translated into an accumulated PAI score which is individually calculated based upon age, gender, resting heart rate, and maximal predicted heart rate, therefore allowing individual responses to physical exertion to influence scores. The PAI approach provides a simple metric providing feedback to users about whether the physical activity being performed is optimal to produce a reduction in risk for CVD, both in the apparently healthy population and for those with known CVD (Kieffer et al., 2018; Nes et al., 2016).

The accumulation of 100 PAI/week is associated with a 25% reduced risk of mortality in healthy adults and 36% in patients with CVD ($p<0.001$), regardless of whether traditional exercise guidelines were met (Kieffer et al., 2018). It has been determined that approximately 40 minutes of high intensity exercise (≥83% heart rate reserve) is required to reach 100 PAI in a week (Kieffer et al., 2018). PAI calculations are dependent upon accurately measuring heart rate and the higher the intensity of exercise, the greater the accumulation of PAI points. Therefore, it could be hypothesised that measuring PAI may address the common barriers to long-term exercise adherence, such as lack of time, by reducing the amount of activity per week required to reduce CVD risk and encouraging higher intensity exercise to improve CRF. Currently, there appears to be no published studies evaluating the above hypothesis in a cardiac population, nor whether patients with cardiac disease would embrace a WPAM to allow for PAI monitoring.

We aimed to firstly determine whether monitoring PAI would influence the amount and/or intensity of physical activity performed by people with cardiac disease in the maintenance phase of CR. Secondly, we aimed to explore perceptions about WPAM use, PAI, impact on motivation, barriers to exercise, and predictions of long-term use.

5.4 METHODS

The study protocol was approved by the University's Human Research Ethics Committee (173657). Participants were recruited from August through to November 2019 through contacting cardiology clinics, CR programmes, a newspaper advertisement to the general community, word of mouth and expressions of interest at a local cardiac centre.

5.4.1 INCLUSION CRITERIA

Individuals who were eligible for the maintenance phase of CR (≥ four weeks post-ACS, percutaneous coronary intervention, coronary artery bypass graft, and/or valvular surgery), with medical clearance from their treating cardiologist were eligible for the study. In addition, participants were required be ≥18 and ≤80 years, own a smartphone with Bluetooth capability, be fluent in English to provide informed consent, be available to meet with the researchers on three separate occasions and be willing to wear a WPAM over the intervention period of six weeks.

5.4.2 EXCLUSION CRITERIA

Participants were excluded from the study if they were diagnosed with uncontrolled cardiac arrhythmias (particularly chronic atrial fibrillation), unstable angina, severe aortic stenosis, frequent premature ectopic beats, uncontrolled metabolic disease, chronic infectious disease, pregnancy, acute infection, undergoing chemotherapy or dialysis, uncontrolled positive exercise stress test, ejection fraction of <40%, congestive heart failure, musculoskeletal, neurological, autoimmune disease or psychological issues significantly impairing the ability to engage in physical activity.

5.4.3 STUDY PROTOCOL

A concurrent mixed method protocol was used. Figure 14 summaries the concurrent mixed methods protocol and methodologies used to answer the research aims.

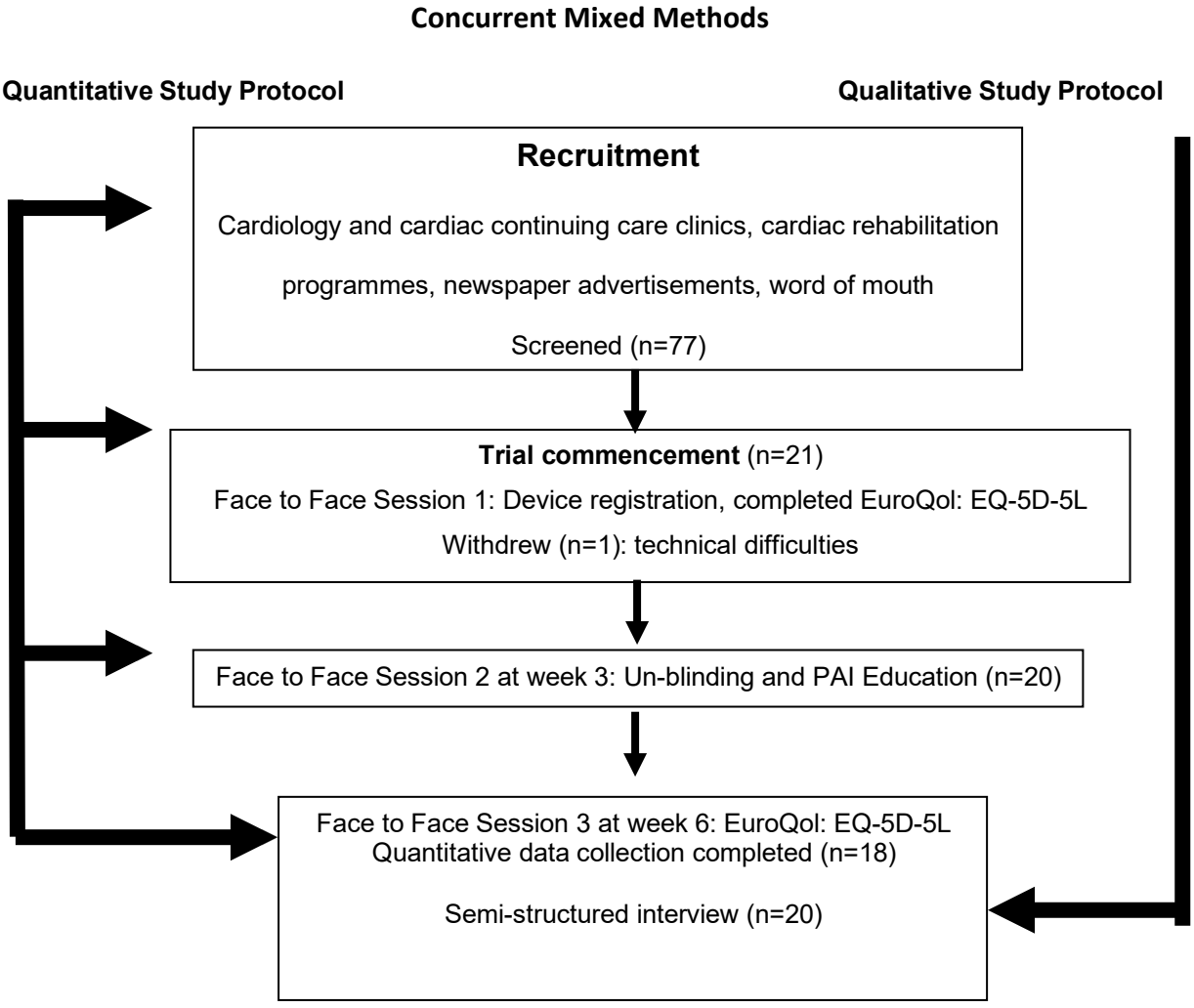


Figure 14. Concurrent Mixed Methods

During the trial, researchers accessed the cloud based PAI Health research portal every two to three days to ensure data was uploading. Participants who required a new charger or had technical difficulties with syncing the device were assisted to rectify the problem. No additional education or discussion about the trial occurred.

5.4.3.1 FACE TO FACE SESSIONS

Participants were required to meet the primary researcher individually on three separate occasions for thirty minutes each. Table 23 describes the procedures occurring at each session.

Table 23: *Face to Face Session Procedures*

Session 1 Individual Face to Face	**Session 2 Face to Face**	**Session 3 Face to Face**
• Participant informed consent form completed and signed • Issued WPAM wearable device • Register participant with PAI Health (age, gender, weight, height, resting heart rate, maximal heart rate calculated using formula from PAI Health App [211-0.64xage]) ** • Download blinded test-flight PAI research APP onto participants' smartphone • Instructed on daily syncing procedures, cleaning procedures (wiping to avoid grime and sweat interfering with accuracy of heart rate recording), charging procedures, and correct placement (2-3 fingers above the distal radius and ulna for the wristwatch: or two fingers below the deltoid muscle when using the arm strap) • Education on switching between all day and workout mode on device and to maintain usual activity level • Euro Quality of Life -5 Dimension-5 Level Health Questionnaire: English version for Australia (2009) completed • **For participants on beta blockers or calcium channel blocker medication, 15 beats per minute was subtracted from the calculated maximum heart rate; or the maximum achieved heart rate on an exercise stress test was used.	• Blinded App removed and un-blinded App installed on smartphone • Education about PAI given (verbal and written (handout) and three-minute video shown) • Explanations given that PAI is based on heart rate responses to exercise, and that higher intensity exercise would result in greater accumulation of PAI points • Educated on current research surrounding PAI, including the health benefits of maintaining 100 PAI • Participants who accrued under 10 PAI during blinding were encouraged to aim for 50 PAI initially to avoid unrealistic goal setting and disappointment in not achieving 100 PAI • Education about how to interpret the PAI APP, where to find the PAI score, seven-day bar graph, heart rate information and how to continue to sync the device was provided	• Euro Quality of Life -5 Dimension-5 Level Health Questionnaire: English version for Australia (2009) repeated • Audiotaped interview (either individually or in pairs) • Otter (speech to text software) used. • Questions pertained to their experiences and opinions during the trial and projected thoughts for the future

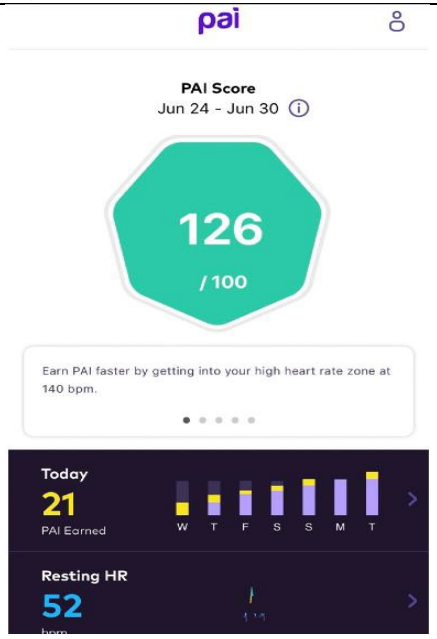
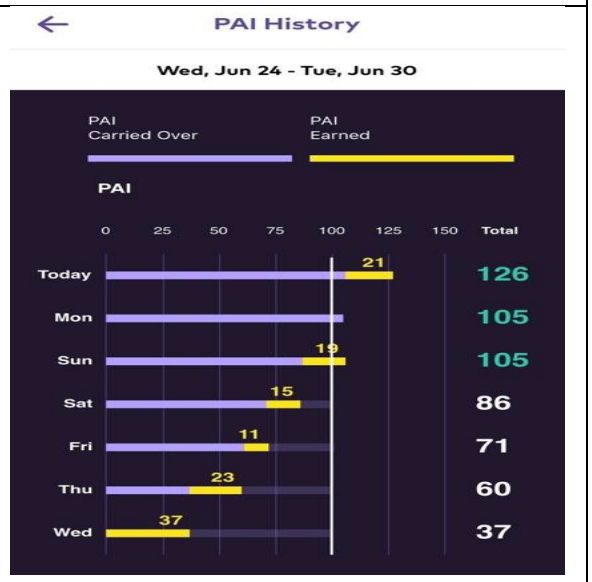
5.4.3.2 WPAM

The WPAM used for this study was a Lynk2 (NCI Technology, Inc. Oakbrook Terrace, Ill., USA). The Lynk2 uses photoplethysmography to continuously monitor heart rate with a display that uses a five colour LED light system which flashes and changes colour, and vibrates, as you move within heart rate intensity zones. It does not have a digital display. The device has a workout mode that allows more frequent sampling of heart rate data. Data (PAI, calories burned, training zones) is viewed on a smartphone/tablet using the PAI Health App. In this study we used the PAI Research App that has the same features as the commercially available PAI Health App but allows for independent PAI data extraction from the PAI Health Database. During the blinded phase participants did not have access to data from the App.

5.4.4 QUANTITATIVE DATA

Table 24 illustrates the main PAI outcome measures. Total PAI scores were calculated using the last two of the three weeks, prior to and following, un-blinding of data. This is because the first week was needed to generate a weekly PAI score. PAI earned/day was calculated for the two three-week periods (before and after un-blinding).

Table 24: *PAI Metric Explanation*

PAI Metric	Explanation		
Total PAI	Measured from the PAI earned during the last seven days. In the screenshot example this is 126.		
PAI earned/day	The amount of PAI earned per day. In the screenshot example, 19 was gained on Sunday		
Days >25/50/75/100 PAI (%)	The number of days the Total PAI score was >25/50/75/100 as a % of the number of days data was collected. In the screenshot example, over the last 7 days: PAI >25 on 7 days = 100% PAI >50 on 6 days = 86% PAI >75 on 4 days = 57% PAI >100 on 3 days = 43%		

Abbreviations: PAI, Personal Activity Intelligence Score; HR, heart rate; Jun, June; Mon, Monday; Sun, Sunday; Sat, Saturday; Fri, Friday; Thu, Thursday; Wed, Wednesday; %, percentage; >, greater than; =, equals.

Raw data was collected and exported to the research group from PAI Health via password protected zip files. This raw data was imported into Excel and IBM SPSS (version 26) for analyses. Descriptive statistics were reported as mean (SD) or median (IQR), depending on the distributions of continuous variables over the course of the assessment. A paired *t*-test was used to investigate differences between the un-blinded and blinded phases. A simple linear regression was performed to determine whether age, body mass index, gender, medication use, time (months) since event and baseline PAI levels assisted with changes in the results. Multiple regression was performed for any significant results.

5.4.4.1 Quality of Life

The Euro Quality of Life -5 Dimension-5 Level (EQ-5D-5L) (Herdman et al., 2011; Rabin & de Charro, 2001; The EuroQol Group, 1990) survey was completed immediately prior to and on completion of the trial. This comprised two sections. The first was a rating score from 1-5 on perceptions about mobility, personal care, usual activities, pain/discomfort, and anxiety/depression, with 1 indicating no limitations and 5 indicating inability to perform the activity or extreme pain, anxiety, and depression. The total score was out of 25. The second component (EQVAS) (Herdman et al., 2011) involved participants rating themselves on a visual analogue scale. Participants rated their health on a scale of 1-100 (1 being the worst health they could imagine and 100 being the best health they can imagine).

5.4.5 Qualitative Data methods

Each participant who completed the trial undertook a semi-structured interview of approximately thirty minutes duration, comprising eighteen questions. The questions were written to explore the participants' perceptions surrounding their experience of partaking in the trial and focused on whether the WPAM influenced their physical activity; particularly comparing the blinded period versus being able to visualise the PAI score. Participants were also asked questions to determine their understanding of the concept of PAI, to identify barriers to their exercise; both generally and during the trial period, whether they attended a CR programme and whether they felt they had been

given adequate guidelines surrounding exercise after their cardiac event. Finally, the participants were asked whether they believed they would continue to use the device and/or PAI concept in the future as well as the likelihood they would recommend the concept to other people. Additional questioning was used to clarify answers if required, and to reach saturation, hence not all interviews were identical.

These semi-structured interviews were conducted using Otter software and downloaded to a word document. Recordings were replayed verbatim to check for accuracy and develop transcripts. Changes to the transcripts occurred to improve accuracy when software incorrectly recorded words or sentences. Transcripts were uploaded to NVIVO 12 software (QSR International, 1999) for thematic analysis.

A systematic approach of thematic framework analysis as described by Ritchie and Spencer (1994) was implemented to identify common themes. This approach consisted of five steps:

1. familiarisation of data (notes were made when key ideas, thoughts or concepts were similar across participant transcripts)
2. identifying a thematic framework (key ideas and priori issues were used to start the coding and further refinements made as additional similarities of themes emerged). A second researcher reviewed the data and a consensus on themes/subthemes were determined to reduce researcher bias and ensure a valid and reliable analysis was performed (Boyatzis, 1998).
3. indexing (within NVIVO 12, all textual data in individual transcripts were indexed to correspond with the global themes)
4. charting and mapping (data was extracted from the original transcripts and placed in a chart consisting of headings and subheadings that were derived during steps 1-3). and,
5. interpretation (transcripts were mapped to identify further commonalities and interpretation of the data was presented).

Finally, the perceived effect of PAI on motivation, intention to use the device in the future, ease of use, comfort, usage of device features, understanding of PAI, attending CR, perception of receiving adequate exercise guidelines and number of barriers to exercise identified, were explored to ascertain whether these affected Total PAI and PAI/earned/day.

5.5 RESULTS

5.5.1 DEMOGRAPHICS

21 participants (16 males; 5 females) were enrolled in the study. One 79-year-old female participant withdrew from the trial due to technical difficulties with syncing the device and time constraints. Another two participants' (1 male and 1 female) data were excluded from the quantitative analysis due to a decreased opportunity to undertake physical activity in the un-blinded part of the trial. This was due to external factors (bushfire evacuation, moving overseas and sustaining an injury), which were out of their control. Table 25 depicts participant characteristics and breakdown of individual participant diagnoses.

Table 25: *Participant Baseline Characteristics* n=18; (values are mean ± SD or number (%))

Male sex, n (%)	15 (83)
Age, years	56±15.5
Body Mass Index, kg/m^2	26.5±4.4
Cardiac History n, (months since event)	
Percutaneous intervention	6 (1,18x3,24,36x2)
Myocardial infarction	1 (6)
Myocardial infarction with stent insertion	3 (4,5,8)
Coronary artery bypass graft surgery	1 (24)
Myocardial infarction and coronary artery bypass graft surgery	1 (4)
Coronary artery bypass graft surgery with stent insertion	1 (5)
Valve surgery	3 (9,24,36)
Valve Surgery with pacemaker	1 (10)
Myocardial infarction with stent and ICD insertion	1 (6)
Medication affecting heart rate	
Beta blockers, n (%)	3 (17)
Calcium channel blockers, n (%)	2 (11)
Attended CR Phase 2, n (%)	10 (56)
Perceived adequate exercise guidelines advice given post event, n (%)	6 (33)

Abbreviations: SD, standard deviation; kg, kilograms; cm, centimetres, CR, cardiac rehabilitation

Of the twenty participants who were interviewed as part of the qualitative analysis, 60% attended a CR programme post cardiac event, 15% were offered admittance to CR, however subsequently declined and 25% of participants were never offered CR. Only 35% of participants believed they were given adequate exercise guidelines post event, 10% were unsure whether the guidelines given were appropriate and 55% of participants expressed they were not given adequate exercise guidelines post cardiac event. The mean average time from cardiac event was 15.2 (12.1) months.

Besides the three face to face sessions, additional assistance was required for 45% of participants. Of these, one participant required assistance six times due to inability to navigate the syncing (WPAM with smartphone app) process, one participant required assistance when the registration with PAI Health failed and on three occasions when technical difficulties arose with the device. A further three participants experienced failed registration and technical difficulties (one participant required changing of the device twice as the charging mechanism failed due to a faulty connection) and the remaining three participants had one episode each where technical issues required assistance. No additional advice or discussion around the study was given to participants during resolution of technical difficulties.

5.5.2 PAI DATA

Table 26 provides the PAI data for the blinded and un-blinded phases. The amount of PAI accumulated whilst exercising at low intensity decreased, whilst both medium and high intensity mean differences increased after viewing PAI, although not to statistically significant levels (p=0.07-0.15). There were statistically significant (P<0.05) increases in the percentage of days participants achieved 25 and 50 PAI.

Table 26: *Personal Activity Intelligence (PAI) Metrics during the Blinded and Unblinded Phases*

	Blinded **Mean (SD)**	**Un-blinded** **Mean (SD)**	**Mean difference** **(95% CI)**	***p*-value**
Total PAI	68.4 (65.2)	97.6 (73.5)	29.2 (7.2, 51.2)	0.012*
PAI earned/day	9.9 (8.47)	12.0 (7.49)	2.1 (0.3, 4.0)	0.027*
PAI in low intensity	1.5 (1.65)	1.4 (1.5)	-0.5 (-0.2,0.2)	0.71
PAI in medium intensity	5.4 (5.1)	6.4 (5.2)	1.0 (-0.3-2.1)	0.07
PAI in high intensity	3.1 (4.4)	4.2 (3.7	1.0 (0.4,3.0)	0.15
	Median (IQR)	**Median (IQR)**	**Change; Median (IQR)**	***p*-value**
Days >25 PAI (%)	71.0 (5.77,100)	100 (73.5,100)	0 (-57.9,1.3)	0.023*
Days >50 PAI (%)	18.3 (0,100)	80.77 (28.9,100)	0 (-50,0)	0.015*
Days >75 PAI (%)	0 (0,100)	45.39 (0,100)	0 (-23.8,0)	0.116
Days >100 PAI (%)	0 (0, 94.65)	10 (0,100)	0 (-2.8,0)	0.344

Abbreviations: SD, standard deviation; CI, confidence interval; IQR, inner quartile range, *statistically significant $p<0.05$.

There was a significant increase in change in PAI earned/day and Total PAI (Figure 15) once participants could view their data.

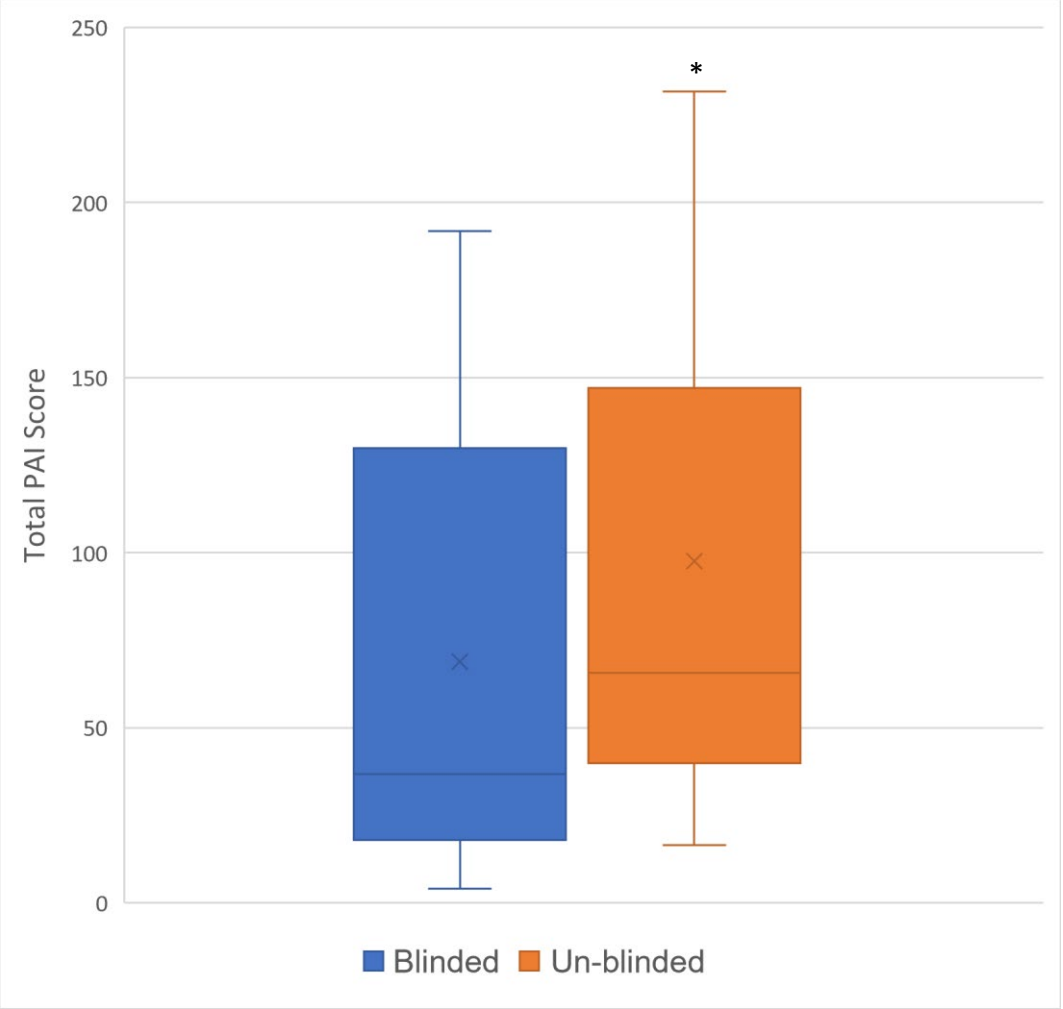


Figure 15: Mean Total PAI Score Before and After Un-blinding. Where: * = $p \leq 0.05$

Explanation of box plot: The cross represents the mean. The vertical lines depict the minimum and maximum values. The horizontal line represents the median. The bottom line of the box depicts the median of the first quartile. The top line of the box depicts the median of the third quartile.

Figure 16 shows the individual participant changes in Total PAI Score before and after un-blinding. A total of 89% (16/18) of participants increased their Total PAI after being educated on PAI and able to view their PAI data. In the blinded period (3 weeks), six participants (33%) were achieving less than 25 PAI per week and this reduced to one participant (5%) at the completion of the trial. One participant (5%) was achieving between 50 and 75 PAI at three weeks and this increased to three (17%) at six weeks. The number of participants reaching 50 PAI or above increased from 7 (39%) (at 3 weeks) to 11 (61%) at six weeks with a further two participants achieving close to 50 PAI (46 and 44). For the six participants who were already

achieving 100 PAI per week at baseline (3 weeks), half of them increased PAI score to over 200 PAI per week, two participants achieved >230 PAI and one participant dropped below 100 PAI to 93 once data was un-blinded.

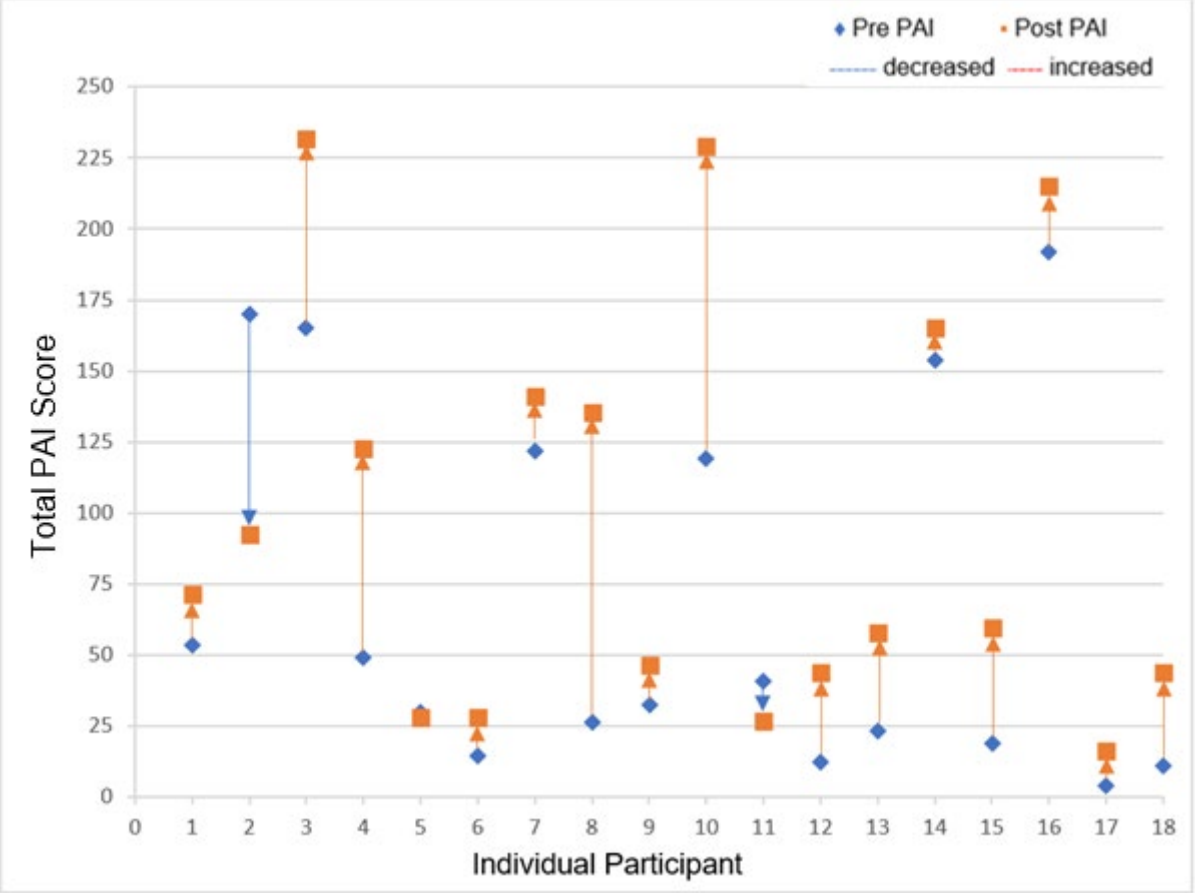


Figure 16: Individual Participant Changes in Total PAI Score Before and After Un-blinding

5.5.3 Linear Regression

Linear regression looked at associations between the change in PAI earned/day and change in Total PAI with age, gender, body mass index, medications affecting heart rate, time from cardiac event in months and PAI at baseline of each phase. Table 27 shows that time from cardiac event was significantly associated with the change in Total PAI (p=0.008) and trending with change in PAI earned/day (p=0.051) and PAI at baseline (p=0.051). This indicated that participants were more likely to increase their PAI if their cardiac event had occurred closer to the study. Multiple regression showed the association between time from cardiac event and change in Total PAI was independent of the other factors and for every month further from participants' cardiac event, the change in Total PAI significantly decreased by 2.2 (coefficient, 95% CI = -2.2, -3.8 to -0.5; p=0.013) (Table 28).

Table 27: *Simple linear regression for change in PAI earned/day and change in Total PAI*

	Change in PAI earned/day			Change in Total PAI		
Factor	**Coefficient**	**95%CI**	***p*-value**	**Coefficient**	**95%CI**	***p*-value**
Age, years	-0.1	(0.2,0.1))	0.2	-0.4	(-1.9,1.1)	0.57
Gender (Female)	0.8	(-4.3,6)	0.74	3.7	(57.9,64.6)	0.91
Medication (No)	0.3	(-4.3,4.9)	0.89	7	(-47.8,61.7)	0.79
BMI kg/m^2	-0.3	(-0.7,0.2)	0.21	-2.4	(-7.6,2.8)	0.34
Time from event, months	-3.4	(-6.8,0.1)	0.051	-2.2	(-3.8, -0.6)	0.008*
Baseline PAI	0.2	(0, 0.4)	0.051	0.1	(-0.3,0.5)	0.58

*statistically significant $p<0.05$.

Table 28: *Multiple Regression Results: Change in Total PAI*

Factor	**Coefficient**	**95%CI**	***p*-value**
Constant	1.8	(-37.8,41)	0.93
Time event, months	-2.2	(-3.8, -0.5)	0.013*
Baseline PAI Total	0.0	(-0.3, 0.3)	0.834

*statistically significant p<0.05.

Triangulation of data was performed on the association between information gained from the semi structured interviews and changes in Total PAI and PAI earned/day. No significant results were found for the effect of motivation reported (p=0.4; p=0.86 respectively), intention to use in the future (p=0.38; p=0.09 respectively), ease of registering (p=0.47; p=0.95 respectively), charging (p=0.18; p=0.15 respectively), syncing (p=0.93; p=0.39 respectively), use of features (p=0.49; p=0.87 respectively), perceived comfort (p=0.6; p=0.75 respectively), number of barriers identified (p=0.84; p=0.23 respectively) or level of understanding of PAI (p=0.7; p=0.36 respectively). Overall, the participants' who stated they believed PAI motivated them the most, did not translate into greater changes in PAI.

There was no significant difference found in either baseline Total PAI or baseline PAI earned/day for those attending CR versus not attending (p=0.28, p=0.63 respectively); nor was baseline Total PAI or baseline PAI earned/day significantly different for those perceiving they received adequate exercise guidelines versus those who did not (p=0.9, p=0.36 respectively).

5.5.4 Quality of Life

Data from the EQ-5D-5L Health Questionnaire indicated that there was a significant improvement in the total quality of life score from enrolment levels to six weeks (mean change 0.6±1.05;95%CI; (0.11-1.09); p=0.019). The EQVAS score also was found to be significantly different from enrolment levels after six weeks (5.8/100; 95% CI (2.4-9.2); p=0.002).There were no significant changes across the EQ-5D-5L domains of mobility (p=0.16), personal care (p=0.33), usual activities (p=0.33), pain/discomfort (p=0.06) or anxiety/depression (p=0.49).

5.5.5 Qualitative Results

The thematic framework analyses identified three global themes which were further broken into fourteen subthemes as illustrated in Figure 17. Table 29 represents each global theme, subthemes and presents examples from the participant transcripts for each subtheme.

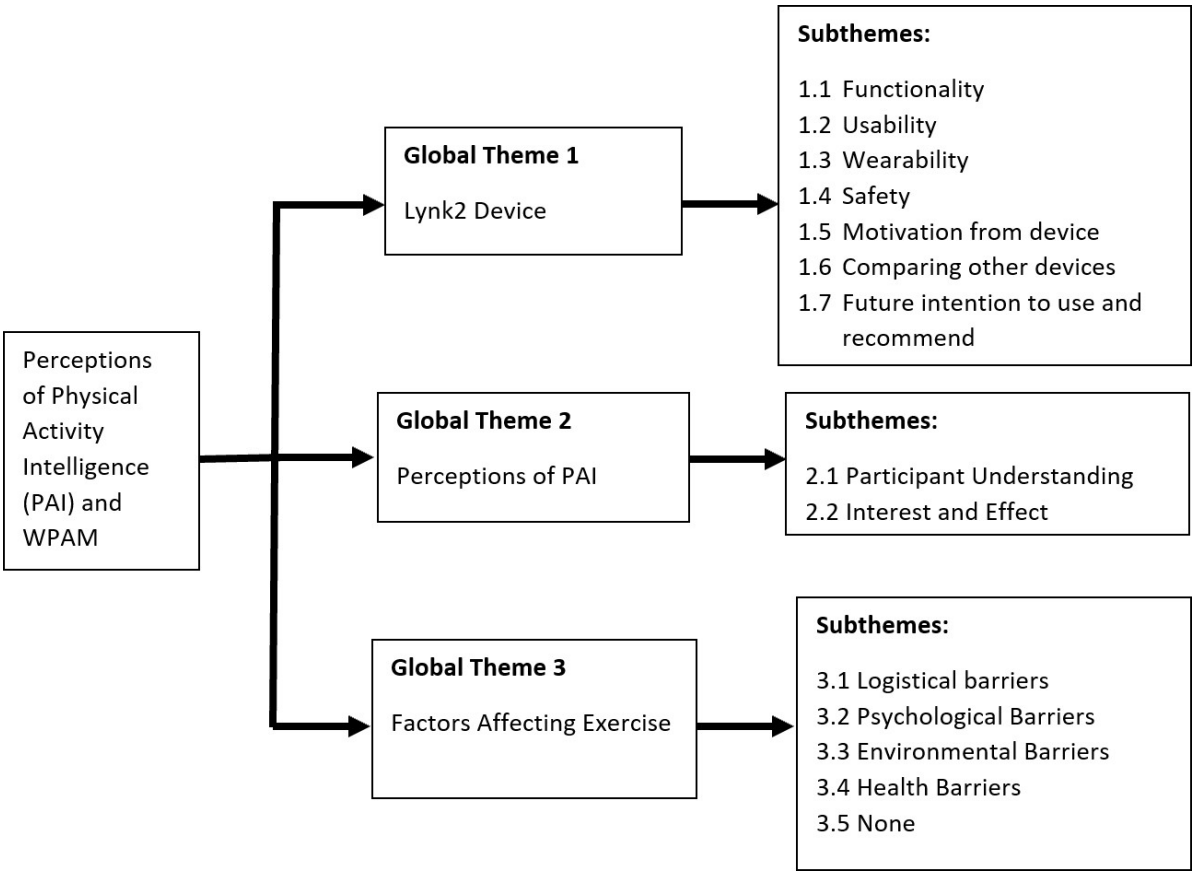


Figure 17: Diagrammatic Representation of Themes and Subthemes within the Thematic Framework

Table 29: *Themes, Subthemes and Transcript Examples*

Global Theme 1 Lynk2 Device	
Subtheme	**Examples**
1.1 Functionality	“In terms of being able to use the device itself, I found it really easy to use.” (P14)
1.2 Usability	“I noticed that quite often on the hill because I sort of, there were three ups and down, so on the down I could feel it vibrate coming down or up and yeah, I know I would press it to look at the colour and see how it's going.” (P15)
1.3 Wearability	“I didn't even know it was there at any time unless I was particularly attending to it.” (P10)
1.4 Safety	“It gets caught on your clothing.” (P16)
1.5 Motivation from device	“Yes, well, I had a bit of a sticky start because I didn't know I wasn't well so but once I got over that, I found it motivating too. You want to see the mechanics of it working.” (P13)
1.5 Comparing other devices	“I like the idea of this, over a Fitbit because I've also had a Fitbit but the fact that when I was working with the Fitbit I was doing 20,000 steps a day, but I mean I could do that just for a stroll.” (P15)
1.7 Future intention to use and recommend	“So, you're highly likely to continue to wear the Lynk2 device so could you talk to me about why you want to keep wearing it?” (Interviewer) “Just so I can monitor my training, it's actually giving me something; a goal to achieve. Yes, I found that quite, quite good, in the sense that I've been able to watch and monitor my training as I go during the day.” (P8)
Global Theme Two: Perceptions of Personal Activity Intelligence	
Subtheme	**Examples**
2.1 Participant Understanding	“Well, I thought just walking or doing, you know, the 10,000 steps, just walking would be adequate. But, you know, I learned that through the PAI that it's not just exercise. It's exercise with increasing the heart rate that actually provides you with PAI. So that that was a real eye opener. So, walking all day at work, was not necessarily going to give me the PAI that I required.” (P18)
2.2 Interest and Effect	“You can, I guess, be healthier and less chance of another heart attack and possibly more years to your life if you keep over that hundred, hundred PAI and although it probably didn't affect me as much as it's probably affected some of the others, that haven't done a lot of training. But some days where you think you’re going to do 30 PAI and you do 10 PAI, it was interesting to see some of the exercise sessions that I do that are really probably not working as hard as you think it might have been. Especially if I'm doing heavy weights. Yeah. So, it doesn't tend to tax the heart that much.” (P3)

Global Theme 3 Factors Effecting Exercise	
Subtheme	**Examples**
3.1Environmental Barriers	“a couple of times, it was just really hot and that affected not so much my capacity to exercise just my motivation to exercise.” (P7)
3.2 Logistical Barriers	“It's hard like working in Brisbane. I get up at quarter past three and leave here at four o’clock and I don’t get home until night-time.” (P4).
3.3 Psychological Barriers	“I find exercise boring.” (P17)
3.4 Health Barriers	“Only barrier is, I have, is I can't run as I snapped my Achilles Tendon, so I need to do something like rowing or boxing, something that doesn't involve sprinting.” (P5)
3.5 No Barriers	“No, no barriers at all.” (P19)

5.5.5.1 GLOBAL THEME 1 PERCEPTIONS OF WPAM DEVICE (LYNK2)

5.5.5.1.1 FUNCTIONALITY

The perception of the WPAM functionality pertained to ease of registering, charging, and syncing the device. These functions are mandatory requirements to allow ongoing use of the device.

5.5.5.1.2 REGISTERING

With respect to registering, most participants found registering straight forward and easy to complete. Some participants had difficulty registering. There were difficulties with the PAI App at time of registration where the email address and internet connection caused registration to fail; *“Well, initially, it was a few days of touch and go trying to get it to register*.” (P1). One participant had an old phone whereby outdated software needed upgrading*; “I just think it was the phone.*” (P6) and a further participant had problems with the App not coming up *“I did have a little bit of trouble initially. Sometimes, it wouldn't come up at all.”* (P5).

5.5.5.1.3 CHARGING

Charging the device was perceived as a positive experience for the majority of participants and one participant commented positively on the battery life [*"that (registering) was really easy, actually. So, and it's such a small item you could just click it beside your bed each night and, but the other thing I found which was really positive, was it lasted a long time. Wearing it full time, so that was, I was happy about that."* (P19)]. The main reasons identified by participants who found charging more difficult were remembering to charge the device, malfunctioning of the charger itself, and the charger playing up.

5.5.5.1.4 SYNCING

Participants commented syncing the device was easy or they had no difficulties. However, some participants found it more challenging [*"… it was messy and tricky for me. Sometimes I had to try ten times a day to sync."* (P18)]. Comments also included difficulty with it syncing when you wanted it to, internet issues and difficulties with the phone application.

5.5.5.1.5 USEABILITY AND WEARABILITY

Useability pertained to understanding the features, and their usefulness. Features included the vibration and colour change to indicate change of intensity, workout mode, and the application on the phone, including the PAI score. Some participants reported not understanding all aspects of the features [*"I have had some difficulties electronically because I keep forgetting what the flashes are for.*" (P10)]. For those participants who did use the features, the vibration, colours, exercise/sport mode, bar graph and application/PAI were all found to be useful by different participants. However, a couple of participants found the features confusing *["That seems awfully strange because I've been sitting on the lounge and it's vibrated a couple of times … and I'm just sitting around watching TV."* (P11)]. Finally, several participants also commented they would have preferred the device if it had a watch component as a feature.

Wearability pertained to device comfort. The device was described as comfortable by the majority of participants however there was mention of some unfavourable aspects. Favourable comments included not even noticing the device was on and having no problems with it. Less favourable comments included it was annoying, uncomfortable, hot, and interfered with their job. Finally, one participant was bothered that it did not match her jewellery [*"I had jewellery on, and it just didn't quite go yeah, I had to ditch the Black, but I didn't want to ditch the device. So yeah, that's just me being honest and vain all at the same time."* (P14)].

5.5.5.1.6 SAFETY

Safety concerns of the device included catching on clothing and a couple of participants developed skin irritation [*"Might not do it to everybody else obviously but to me that gave me a bad rash about my shoulder." (P15]).*

5.5.5.1.7 MOTIVATION FROM DEVICE

Results revealed strong agreement from participants that they were motivated to perform more, or higher intensity exercise when they were able to view the PAI data, although some described no change in motivation. No participants reported having decreased motivation as a result of wearing the device, however one participant mentioned not attaining his PAI made his mental health worse *["I am a stressful type of person and when I see that go down it really stresses me out and I don't know, probably good for my health but not good for my mental stuff*." (P9)].

Reasons participants gave for their increased motivation from the device included that it helped them get started for the day, they wanted to increase PAI points, and it helped participants work harder. Participants who were already doing 100 PAI at baseline reported their motivation to exercise stayed the same, despite achieving higher PAI scores after viewing PAI data. Two participants decided to delay regular exercise until the New Year and identified motivation to exercise did not change once PAI data was made available ["*I want to change myself after Christmas, when everything settles down."* (P11)].

5.5.5.1.8 Comparing Other Devices

Numerous participants had never used any type of fitness device before the trial. Of those that did, there were varying views as to whether they preferred the Lynk2 device or another device they had used previously. Reasons given by those who preferred the Lynk2, were they felt it was more accurate and they liked the PAI score because it was more individualised and was based on intensity of exercise. Other participants preferred a Garmin® device, with one mentioning they preferred a Polar and another a Fitbit or Apple watch. Reasons given were these devices offered further features such as telling time, notifying phone calls/texts and being more aesthetically pleasing.

5.5.5.1.9 Future Intention to Use and Recommend

Participants' views about whether they believe they would continue to use the device on an ongoing basis was variable. Some participants expressed strong indications they would continue to utilise the device for health benefits, motivation, and monitoring training. Other participants were hesitant to commit to continued use. For participants who were undecided, views were expressed that if the device also told time and the syncing improved, they would be more likely to utilise the device in the future. Finally, the remaining participants remarked they would not continue to wear the device after the trial as they found the device annoying or because it didn't show data in real time on the device, only through the phone application.

Despite, varying opinions about future use, there was overwhelming agreement from participants that they would recommend the device to others. Reasons for recommendation included believing it was beneficial, liking the PAI concept, improving motivation to exercise and it is a great tool. Only one participant stated he would not recommend the device as he believed it did not have enough features compared to other devices; however, he also mentioned he would recommend the PAI concept:

> *"I don't know. the device, probably not. The PAI, yes, I would, but not the device. I get the PAI. I think the problem is these days people have these devices, and they do 1000 things. Someone wants something more that they can wear all day, and all monitor the heart, you know, most smartphones well*

they can do that these days. Yeah. And if I'm going to wear a device it's going to tell me about a text message, phone call, and it's going to probably track my sleep patterns and so forth. So probably not the device." (P9)

5.5.5.2 GLOBAL THEME 2 PERCEPTIONS OF PERSONAL ACTIVITY INTELLIGENCE (PAI)

5.5.5.2.1 PARTICIPANT UNDERSTANDING

Most participants reported that they understood the concept of PAI.

"After the three weeks where you can actually, when you understand what you're, where you're heading with it all, and you understand what PAI means and you can actually see the numbers that, I think being a guy too, you kind of, maybe the competitiveness, you want to keep it over a certain number." (P3)

Other participants had difficulty understanding that to gain PAI, you had to do exercise that increased your heart rate ["*one day, I thought I'd done quite well, and it came up with zero. Yeah. and I thought I did quite well and had pushed myself. I thought there must be something wrong with it. I'd done all that work and got zero."* (P6)].

5.5.5.2.2 INTEREST AND EFFECT

All participants found the concept of PAI of interest, particularly mentioning the individualised nature of it and being able to monitor activity [*"Okay, well, this is the first time I learned about PAI. I think it's a really interesting concept, and I like the fact that it's a personal thing as opposed to a whole population thing…."* (P7)]. However, a couple of participants reported they only did the trial to help the researchers [*"I just thought I'd have done the trial and that was it."* (P6)]. In addition, some participants commented they became more aware of the amount and intensity of the exercise they were performing and increased their intensity *["I'll take longer walks and I find hills, I found a hill to walk up and this morning I did it twice."* (P6)].

5.5.5.3 Global Theme 3 Factors Effecting Exercise

5.5.5.3.1 Logistical Barriers

Participants reported logistical difficulties such as commuting to work; caring responsibilities, lack of time, and travel contributed most to a reduction in exercise over the trial period. As the trial for some participants ran over Christmas, additional shopping needs also competed with time to exercise. Finally, a couple of participants mentioned the logistics of having to remember to wear the device also contributed to a reduction in PAI.

5.5.5.3.2 Psychological Barriers

Psychological barriers were identified as lack of enjoyment of exercise, fear of having another cardiac event or exercising too hard, anxiety and mental stress.

5.5.5.3.3 Environmental Barriers

Participants identified environmental factors including outside temperature (heat was identified as contributing to fatigue, discomfort and demotivation, air pollution (smoke), bushfires and rain as being barriers to exercise participation during the trial.

5.5.5.3.4 Health Barriers

Health issues from illness and injury prior to and during the trial were reported as contributing to the type and amount of exercise performed. Previous injuries included shoulder dislocations, back, foot/ankles, Achilles tendon rupture, knee problems and periods of bad health. During the trial, three participants went to hospital due to previous health struggles, and for a pre-scheduled minor operation. Another participant had a skiing accident and was unable to exercise for two weeks. Additional health factors identified as affecting exercise included premenstrual issues, cold and flu, lack of energy, blood pressure issues and shin splints.

5.5.5.3.6 NO BARRIERS

There were some participants who expressed having no barriers affecting exercise.

5.6 DISCUSSION

This is the first study to investigate the use of PAI in a CR population. We aimed to determine whether monitoring PAI, would influence the amount and/or intensity of physical activity performed by people with cardiac disease in the maintenance phase of CR. Secondly, we aimed to explore perceptions about the ease of use of the WPAM, impact on motivation, barriers to exercise, and predictions of long-term use. The main findings from the study were that Total PAI and PAI earned/day significantly increases after participants were able to see their PAI score and all participants would recommend PAI monitoring to others suggesting it was effective and well received in the cardiac population.

5.6.1 DEMOGRAPHICS

Most participants who completed the trial were male (83%), which represents male dominated enrolment as seen in CR (Samayoa et al., 2014), however the trial under represented females. The breadth of participant diagnoses and cardiac interventions were also a good representation of the cardiac population (National Heart Foundation of Australia, 2010).

Our results showed no significant difference in PAI scores between participants who did or did not attend Phase 2 CR nor between those who believed they were given adequate exercise guidelines post cardiac event or not. This is surprising as one would have thought with greater health professional input, Total PAI score and PAI earned/day may have been greater.

5.6.2 TOTAL PAI AND PAI EARNED/DAY

Overall, our analyses showed the Total PAI scores and PAI earned/day significantly increased after participants where educated about PAI and were able to see their PAI values. This coupled with almost ninety percent of participants increasing their scores and all participants stating they would recommend PAI monitoring to others suggests it was effective and well received in the cardiac population. This was also supported by the qualitative results showing the majority of participants commented their motivation to exercise increased when being able to view the data and they tended to exercise harder to try to accumulate more PAI points.

The accumulation of 100 PAI/week is associated with a 25% reduced risk of mortality in healthy adults and 36% in patients with CVD ($p<0.001$) and resulted in five years longer lifespan (Kieffer et al., 2018; Nes et al., 2016). Additionally, 100 PAI/week reduces the risk of mortality by 30.5% for people who are overweight, 31.5 % for those with hypertension, 54% with type 2 diabetes and 31.5% for those who smoke (Kieffer et al., 2018). In addition, for those maintaining a Total PAI score of 50/week, around 60% of the health benefits are gained (Kieffer et al., 2018). Our results showed two thirds of participants (61%) reached 50 PAI/week or above once data was able to be viewed compared with 39% at three weeks. Furthermore, 89% of participants increased Total PAI/week to some extent, likely reducing CVD risk compared to pre-trial levels.

Our evaluation indicated that age, gender, taking medication which affects heart rate, body mass index, and baseline PAI score were not associated with the change in PAI earned/day nor change in Total PAI achieved. However, for every month further from participants' cardiac event, the change in Total PAI significantly decreased regardless of blinded PAI scores. This concurs with research by Claes et al. (2020) who found that two years after outpatient CR, a decline in steps and minutes of physical activity was observed suggesting the further from a cardiac event, the less exercise is performed.

Our findings indicated that the change in PAI scores was not significantly influenced by participants' perception of ease of use of device, whether they used the vibration and colour features on the device, found the wearing of the device comfortable, the level of understanding of the PAI concept or by the number of

exercise barriers identified. Similarly, the perception of participants regarding whether they would continue to wear the device was not influenced by the amount of change in PAI achieved. The small sample size, however, may have underestimated the effect of these parameters. As this is the first study, to the authors' knowledge to investigate PAI in the cardiac population, there is no literature to compare these results with.

EQ-5D-5L total scores and EQVAS scores were significantly different between the start and end of the trial. These results cannot be interpreted as being influenced by PAI as a further survey was not completed at 3 weeks when data became un-blinded. However, our results indicate that by enrolling and completing the trial participants significantly improved overall quality of life.

5.6.3 Perceptions of the WPAM

5.6.3.1 Functionality

The registering and charging were generally viewed as being straightforward, however the syncing was more problematic. Previous literature found wearables that are perceived to be easy to use were more likely to be utilised (Lunney et al., 2016). Wang et al. (2020) reported factors such as performance expectancy and effort required were main contributing factors in consumer acceptance of healthcare wearable devices. As syncing was reported as requiring more effort than expected, this requires improvement to ensure long-term feasibility of continuing to use the PAI. With advances in technology and with the addition of PAI into more WPAM, it is expected that these technical difficulties will be improved.

With respect to useability, participants that used the features including colour change, vibration and workout mode found these useful and the PAI score was of interest to many participants. According to Nelson et al. (2016) this gamification and interest may improve health empowerment in smart wristband users, however these authors also identified attractiveness as being important. Our interview findings supported this as a couple of female participants identified lack of attractiveness of the WPAM as a deterrent to long term use.

The results of our thematic framework identified participants were dissatisfied with some aspect of the comfort of the device. This may contribute to non-adherence long term and a couple of participants developed skin irritation. Buenaflor and Kim (2013) identified physical comfort and safety an essential consideration in participant acceptability of a device with harm being a significant barrier to long term acceptance.

5.6.3.2 MOTIVATION

Having participants autonomously monitoring PAI resulted in increased motivation to exercise and no participants reported the use of the approach demotivating. It is encouraging to see that the percentage of days where Total PAI and PAI earned/day between 25 and 50 PAI/week significantly increased in people with cardiac disease whose blinded score was less than 50 PAI/week. For participants already achieving 100 PAI/week in the blinded period, monitoring PAI resulted in participants remaining above 100 PAI, with half of these reaching 200 PAI and above. Literature has shown that keeping PAI above 100 PAI/week maximises health benefits (Kieffer et al., 2018), however there is no data on whether a score may be too high and result in harm. This knowledge would be particularly important for people with cardiac disease. One participant performed less PAI in the un-blinded period as he was already doing well above 100 PAI and as this higher level is unknown, he reduced his activity.

A systematic review by French et al. (2014) reported goal setting, if specific and related to desired behaviours in older adults, significantly increased physical activity and resulted in greater motivation to be physically active and a qualitative analysis by Floegel et al. (2015) reported self-regulation behaviours may enhance physical activity. Monitoring PAI creates self-regulation of physical activity and provides an avenue for goal setting which may therefore positively influence long term use. This is further supported by a review by Petter et al. (2009) which showed an association between self-regulatory and task self-efficacy with exercise. French et al. (2014) also showed that heart rate monitoring, as a physiological feedback mechanism allowed increased self-efficacy when exercise was performed with no adverse effects. PAI may therefore improve self-efficacy through similar mechanisms.

5.6.3.3 COMPARING OTHER DEVICES

Of those participants who had previously utilised a different WPAM our results showed most preferred the Lynk2 device as it was perceived as more accurate and participants found the PAI concept of interest. Those that preferred other devices stated increased functionality such as displaying time, phone calls and texts outweighed the WPAM. This is in line with previous research that showed smartwatch usage is influenced by perceived usefulness more so than ease of use (Choi & Kim, 2016).

5.6.3.4 FUTURE INTENTION TO USE AND RECOMMENDATION

At the end of the trial period, many participants indicated that they were intending to continue to wear it or were still considering continuation. Participants stated they would recommend the device to others based on their interest in the PAI concept and its ability to monitor their health. If the WPAM improved syncing, added a time display and other functionalities and it was more attractive, ninety percent of participants perceived they would continue to monitor their PAI. As stated earlier, device attractiveness has been found to be important for some people for long term usage of wearable devices and a couple of our female participants mentioned this would have an impact on their decision to use the WPAM long term. This requirement is further supported by Choi and Kim (2016) who found the ability of a device to allow for unique self-expression through choices in fashion such as changeable watchbands and colours were imperative for some consumers to continue to use smartwatches long term. Those participants who believed they would not continue utilising the WPAM found wearing anything on their wrist or arm annoying or did not view the trial as a long term option from inception, only volunteering to help the researchers with the trial.

5.6.3.5 Perceptions of PAI

As stated earlier, participants unanimously found the concept of PAI interesting and believed it was beneficial for monitoring their health. Some participants struggled with understanding that the more higher intensity exercise performed, the faster the PAI points would accumulate and became discouraged when walking for an hour did not result in many PAI points.

5.6.3.6 Factors affecting exercise

There has been ample literature reporting on the barriers to exercise identified by cardiac patients. A literature review by Santaularia and Jaarsma (2013) identified logistical problems, lack of motivation to exercise, lack of time to exercise, laziness and inadequate social support as key factors influencing adherence to exercise in cardiac patients. Our participants identified similar barriers, except for inadequate social support. Additionally, our participants also found environmental factors and health status were key influencers in engaging in exercise. Health status was also found to be a barrier for exercise in cardiac patients in a review by Petter et al. (2009) Our findings also identified similar barriers to that found in a systematic review for non-completion of HIIT exercise research trials (lack of interest and motivation, other commitments and medical issues) (Hannan, Hing, Simas, et al., 2018).

5.6.4 Strengths and Limitations of Study

Using a concurrent mixed methods approach, described in detail to improve dependability, allowed us to quantify the effect PAI monitoring via WPAM had on the amount and/or intensity of exercise. This method also allowed us to explore participants perceptions of ease of use, preferred functionality and comfort of the device; concept of PAI, future intention to use and likelihood of recommending the device and PAI to others. This resulted in a richer representation of participant experiences and views of the usefulness of PAI for people with cardiac disease and improved trustworthiness of the data. This methodological framework assisted in answering the breadth of our research questions, improving the quality of the trial.

To improve the rigour and credibility of our findings, a second researcher was tasked to agree on themes for our thematic framework analysis. Authors have different professional backgrounds further adding confirmability to our findings by implementing peer review from different perspectives. Vigour was improved by our use of verbatim quotations.

The trial had several methodological limitations. The sample size was small and therefore a power calculation was not performed and the clinical difference was not identified. Females were underrepresented. The small sample size may have underestimated the contribution of factors analysed in the linear regression analyses.

Another limitation was that participants started the trial having been given varying degrees of education about exercise. Some attended formal cardiac rehabilitation, whilst others did not. The different levels of knowledge may have potentially influenced their understanding of PAI and therefore the results.

A further limitation was the time of year the trial was conducted. The exercise period extended across the Christmas/New Year period with competing responsibilities which appeared to have negatively influenced exercise habits. This, along with the heat of summer, reduced the ability of participants to exercise and may have underestimated the potential impact PAI monitoring may have within the cardiac population. In addition, there may have been potential bias due to variability of contact time with participants whereby those with technical issues and device faults were assisted more than other participants, however, the researchers were careful not to discuss the trial during this time. Researchers only engaged in resolving technical issues.

The trial period was of short duration and the first week of the three was needed to generate a weekly Total PAI score, leaving two weeks to average the daily Total PAI score. Due to the short duration of data collection, results cannot be transferable to long term exercise, nor females. However, our results are promising and found that PAI monitoring significantly increased exercise amount and/or intensity and most participants planned to continue to monitor PAI after completion of the trial.

5.6.5 Future Studies

The results of our study indicate a larger sample size with longer duration monitoring is warranted to support our findings that PAI monitoring is of value and assists people with cardiac disease to increase the amount and/or intensity of physical activity. Longer duration studies could also investigate the effect of PAI monitoring on mortality in this population.

Having a more even distribution of sex of participants would also be beneficial to learn more about the effect of sex on PAI monitoring and WPAM. Consideration of time of year, spanning across seasons, may be beneficial to further explore barriers to exercise. Further collection of data about other barriers such as social support, income level, and occupational status would also be advantageous as these have been identified as barriers to exercise in the cardiac population in previous literature.

There were some participants who did not fully understand how to gain PAI and consideration of introducing individual sessions to further educate by comparing different activities and intensities in real time may assist in future studies.

Finally, PAI monitoring on a device with improved syncing processes, increased functionality and attractiveness is also recommended to improve the likelihood of longer-term use.

5.7 Conclusion

The monitoring of PAI via a WPAM was effective in significantly increasing the amount and/or intensity of physical activity within the cardiac population. Participants found the concept of PAI interesting, beneficial, and motivating. If WPAM syncing and aesthetics improved, along with offering greater functionality in line with comparative smart devices, participants would continue to use the device long term. The study strongly supported the use of PAI as an effective strategy to increase amount of physical activity performed by people with cardiac disease. Participants would recommend monitoring PAI to others, particularly due to the individual calculation which is affected by intensity of exercise. PAI may be a viable strategy to assist people with cardiac disease maintain long term exercise adherence.

CHAPTER 6: SUMMARY

6.1 PREFACE

This chapter concludes the thesis. A summary of the hypotheses, aims, results, limitations, implications for practice and recommendations for future research is discussed. Finally, an overall conclusion for the entire body of work is presented.

6.2 Discussion and Summary of Findings

This thesis was designed and implemented to explore exercise intensity in outpatient CR and home environments to address identified research gaps in this field. The first chapter of this thesis identified CVD as the leading cause of premature death worldwide. CVD makes a large contribution to the economic burden on society with costs in Australia estimated as being as high as $443 million by 2030 (Schofield et al., 2019). The importance of secondary prevention in the management of CVD is emphasised and CR is an integral component in assisting reduce the likelihood of further cardiac events. CR involves education, lifestyle behaviour modification and exercise training and has high level evidence to show attendance reduces mortality and morbidity by 13-27% (Heran et al., 2011).

Exercise is an essential component of CR; however, there appears to be no studies that had previously investigated whether evidence based practice and re-evaluation of outcome measures were being implemented within Australian CR programmes and therefore evaluation of the effectiveness of service delivery was problematic and warranted. As mortality has been reported as being inversely proportionate to CRF, it is paramount clinicians are focused on improving CRF to the greatest extent within the cardiac population. Exercise prescription practices should utilise the most effective methods to achieve CRF gains. In particular, there is growing interest in the benefits of HIIT and its use within clinical populations. Prior to our systematic review and meta-analysis, four systematic reviews were identified confirming HIIT is superior to MICT in improving CRF in the cardiac population (Cornish et al., 2011; Elliott et al., 2015; Liou et al., 2016; Pattyn et al., 2014). However, no studies had determined whether the length of intervention affected the degree of improvement nor had there been a collation of adverse events resulting from RCTs in the area.

Therefore, the first aim of the thesis was to evaluate and synthesise current literature comparing improvements in physiological benefits, particularly CRF (VO_2peak) between participants diagnosed with CHD engaged in MICT versus HIIT and analysed the effect of VO_2peak changes resulting from different durations of interventions. The hypothesis was that HIIT would be superior to MICT in improving CRF and this improvement would increase with longer durations of training. To address this aim, in chapter two of this thesis, a systematic review and meta-analysis

was performed. This provided an up to date synthesis of RCTs to provide further insight as to which form of exercise prescription, particularly which intensity, was most effective in improving CRF in the cardiac population. Our results supported the hypothesis that HIIT is superior to MICT in improving CRF, however, interestingly, this did not improve further with longer duration training. CR programmes of less than six weeks duration increased CRF less than longer duration programmes, however, was not significantly different between groups. In addition, those greater than three months duration also resulted in less CRF changes than those of 7-12 weeks duration. Although there was a small significant change in CRF in the 7-12 weeks and greater than 12 weeks groups, favouring HIIT, our conservative approach to statistical analysis and heavy weighting of Conraads et al. (2015) whose participants in both groups did not always train at prescribed intensities, may have underestimated the true impact of HIIT on CRF. Additionally, small changes in CRF have been shown to improve mortality and the results were still clinically relevant.

Although HIIIT is superior to MICT in improving CRF, there is anecdotal evidence that clinicians are concerned about the safety of exercising a participant diagnosed with CAD to a near maximal level. Therefore, we also collated the adverse events reported across the RCTs comparing types and numbers of adverse events reported within HIIT versus MICT groups. The hypothesis was that HIIT may produce more adverse events than MICT due to the higher physiological stress placed on the heart during active acute bouts of high intensity exercise. Interestingly, we found more adverse events reported in the MICT participants (n=14) compared with HIIT participants (n=9) and both groups reported no serious cardiac events requiring hospitalisation directly related to exercise. There was only one study that reported any cardiac related incidences (angina requiring withdrawal) and this occurred in both intervention groups (Moholdt et al., 2012). There were only a few studies reporting additional adverse effects, primarily musculoskeletal and digestive issues. Therefore, our findings did not support the hypothesis that HIIT would result in more adverse events and added to the literature in support of HIIT being as safe as MICT for people with cardiac disease.

Having ascertained HIIT as being a more effective exercise prescription in improving CRF, investigating the actual exercise parameters being used in Australian CR programmes was essential to understand whether this form of exercise was being

embraced in Australia and to what extent. In addition, understanding current clinicians' beliefs about HIIT implementation, particularly perceptions surrounding safety, barriers, staffing, testing, and monitoring requirements would provide further insight. There was no research directly investigating exercise practices and outcome measure evaluation methods being implemented by Australian CR programmes at that time. Therefore, the second aim of the thesis, was to collate data surrounding current exercise prescription parameters, current usage, and clinician perceptions about implementation of HIIT across Australia. The hypothesis was that Australian CR programmes were under-utilising HIIT, particularly as current guidelines recommend MICT for most patients. The survey results supported this hypothesis with only a couple of programmes reporting utilisation of HIIT.

The results of the survey presented in chapter 3, have improved knowledge surrounding what actual exercise practices were being utilised in Australian CR programmes. Most programmes were located in rural settings and were hospital based. CR in Australia was mostly performed once per week for 6 - 8 weeks for 40 to 60 minutes duration prescribed at a moderate intensity. The lack of frequency of sessions being offered may not be sufficient in allowing participants to adopt exercise as a lifelong habit. The findings also highlighted that evaluation of the effectiveness of current Australian CR programmes in improving CRF was lacking with just under half of programmes failing to perform any type of CRF re-assessments, with this dropping to 7% of programmes at twelve months post discharge from outpatient supervised exercise programmes. Concerningly, 8% of programmes did not perform any CRF tests at any time. Evaluation of muscular strength changes was extremely poor in Australia with less than 5% of programmes performing 1 or 10 repetition maximum assessments and only 7% performing grip strength. Therefore, there was minimal ability to evaluate whether current practice is having any effect on improving strength of participants and highlighted the urgent need to improve exercise capacity and muscular strength evaluation methods of Australian CR programmes. Furthermore, the survey results also determined that although physiotherapists were the main health professional to prescribe and progress exercise, many programmes were not utilising the most qualified staff to supervise this higher risk population with the main health professional supervising exercise being nurses. Finally, the results highlighted that only one quarter of programmes screen participants who have undergone a CABG

procedure for sternal stability and CR coordinators were unsure as to the cost of their current CR services.

The survey also provided a deeper understanding into CR exercise and evaluation practices in each state. NSW appeared to be less effective than other states in its ability to evaluate the effectiveness of the exercise component of CR programmes compared to other Australian states as less programmes indicated they performed re-evaluation assessments. NSW participants had less ability to be individually monitored and supervised than residents in other states with larger reported staff:participant ratios.

Victorian programmes had the least frequent sessions/ week (once/week), indicating that Victorian residents do not have the opportunity to exercise in supervised, monitored sessions as many times a week as other states. Queensland programmes were delivered over a shorter duration (4-5 weeks) than other states, indicating residents had less time to allow exercise to form a life-long habit and less time to exercise in a supervised and monitored environment. Residents were required to rely on unsupervised, home exercise for most of their exercise. QLD was the only state where all programmes indicated they did not reassess fitness at 12 months post discharge from CR. Therefore, the long-term effects on CRF from CR in QLD could not be ascertained.

South Australia had the largest percentage of programmes that indicated they did not perform any fitness tests. The Australian Capital Territory reported the greatest percentage of CR programmes offering the longest number of weeks. ACT/WA/NT/TAS combined were the only states performing 1 repetition maximum strength tests and over half of programmes performed this test, indicating that the strength component of the exercise programmes could be prescribed more accurately than other Australian states. Finally, ACT/WA/NT/TAS was the only state not to include games/sport as a medium to deliver CR. These specific differences in each state's practices can be used by key decision makers to improve practice with a more targeted approach for each state.

In terms of exploring clinicians' perceptions of HIIT implementation, the survey found most clinicians believed HIIT was unsafe or were unsure as to its safety, despite HIIT being recommended in international CR guidelines. There is, therefore, a need to

educate Australian clinicians regarding safety, enjoyment and physiological benefits of HIIT. Lack of resources and knowledge were perceived as the biggest barrier to HIIT implementation, and there were inconsistent perceptions of prescreening and monitoring requirements.

The survey identified most of the recommended advice/options to continue exercise after outpatient CR involved low intensity exercise which may result in deconditioning. There was a need therefore to improve the quality of care and provide alternative options for continued exercise. An alternative option that helps motivate clients to engage in lifelong exercise and increase intensity of exercise is essential to maintain cardiovascular risk reduction obtained from outpatient CR. Activity trackers, are worn by over 10% of adults (DiFrancisco-Donoghue et al., 2018) and wearable technology was named number one in the top twenty worldwide fitness trends in 2020 (Thompson, 2019). Wearable technology is thought to improve the amount of, and adherence to, physical activity (Ehn et al., 2018; Finkelstein et al., 2016; Gualtieri et al., 2016; Jang et al., 2018).

With this in mind, the third aim of this thesis was to investigate the effect of WPAM devices on CRF within the cardiac population to determine whether this may be a viable solution to improve CRF long term. Our hypothesis was that WPAM would improve step count, however as these devices do not measure intensity, therefore they would have little effect on CRF. To address this aim, a systematic review and meta-analysis was undertaken coupled with a qualitative analysis within the cardiac population. Specifically, the effect WPAM had on CRF, amount and intensity of daily physical activity and sedentary time were investigated. The review also collated information from relevant RCTs on outcome measures reported, reasons for drop out, adverse events, and psychological impact from utilising a WPAM.

The results of the systematic review, meta-analysis and qualitative analysis did not support our hypothesis. Step count was improved in 70% of studies, however the overall effect was not significant and CRF was improved to a significantly greater extent in participants using WPAM with exercise prescription or advice compared with controls. Additionally, the qualitative analysis showed evidence in favour of WPAM with exercise prescription or advice for both CRF and step count. Encouragingly, no cardiac adverse events related to physical activity were reported and 62% of non-

cardiac adverse events were primarily musculoskeletal injuries. Reasons for dropping out included medical conditions, lack of motivation, loss of interest, and technical difficulties. No conclusion could be made regarding psychological benefits of WPAM, with half the studies reporting significant differences whilst the other half reported no significant differences. Finally, three quarters of studies reporting on intensity, found significantly increased time spent in moderate and moderate-vigorous intensity physical activity, however there was no difference found between groups for sedentary time

These results suggest that further research investigating the use of WPAM in the maintenance phase of CR was warranted to strengthen the conclusion that WPAM is more effective at improving CRF and may encourage higher intensity activity. Common WPAM such as pedometers and accelerometers, however, do not monitor intensity of exercise and few allow people with cardiac disease to link their activity to useful information about cardiovascular risk reduction.

Personal Activity Intelligence (PAI) is a single metric which uses the heart rate response to exercise. It was derived using an algorithm based upon individual heart rate reserve calculations over a seven-day rolling period which allows individual responses to physical exertion to influence scores. The PAI approach provides feedback to users about whether the physical activity being performed is optimal to produce a reduction in risk for CVD (Nes et al., 2016). PAI calculations are dependent upon accurately measuring heart rate and the higher the intensity of exercise, the greater the accumulation of PAI. The accumulation of 100 PAI/week is associated with a 25% reduced risk of mortality in healthy adults and 36% in patients with CVD ($p<0.001$) (Kieffer et al., 2018; Nes et al., 2016).

Therefore, it could be hypothesised that measuring PAI may address the common barriers to long-term exercise adherence by reducing the amount of activity per week required to reduce CVD risk and encouraging higher intensity exercise to improve CRF. Therefore, the final aim of this thesis was to investigate the effect of monitoring PAI scores, using a WPAM, had on intensity, adherence and motivation in cardiac populations, during the maintenance phase of CR and in the home environment. We hypothesised having knowledge of PAI will assist cardiac patients to

gain a better understanding of exercise required to improve their heart health and adherence to exercise and may increase the intensity of exercise performed.

The results of the original research supported the hypothesis that participants gained a better understanding of exercise required to improve heart health as indicated by the qualitative results whereby all participants found the concept of PAI interesting, beneficial, and motivating. Participants believed it was beneficial for monitoring their health and would recommend monitoring PAI to others, particularly due to the individual calculation, which is affected by intensity of exercise.

The study strongly supported the use of PAI as an effective strategy to increase amount of physical activity performed by people with cardiac disease. Monitoring PAI via a WPAM was effective in significantly increasing the amount of physical activity within the cardiac population. In terms of exercise intensity, the amount of PAI accumulated whilst exercising at low intensity decreased, whilst both medium and high intensity mean differences increased after viewing PAI, although not to statistically significant levels. However, there were statistically significant increases in the percentage of days participants achieved 25 and 50 PAI and 89% of participants increased their Total PAI after being educated on PAI and able to view their PAI data. Our qualitative data found most participants were motivated to perform more, or higher intensity exercise when they were able to view the PAI data.

There were difficulties with the device itself with just under half of participants finding syncing and charging the device challenging. Some participants were confident they would continue to utilise the device for health benefits, motivation, and monitoring training. Others were unsure, however, stated that if WPAM syncing and aesthetics improved, along with offering greater functionality in line with comparative smart devices, participants would continue to use the device long term. These findings suggest PAI may be a viable strategy to assist people with cardiac disease maintain long term exercise adherence.

6.3 STRENGTHS AND LIMITATIONS

The strengths of the studies within this thesis were many. The systematic review and meta-analysis in chapter two included the greatest number of trials to date, had the most up to date search at the time, minimal heterogeneity, used a conservative approach to calculate standard deviation and used a random effects model. All studies fell within the acceptable ranges in the funnel plot, indicating publication bias was unlikely. The second systematic review and meta-analysis was the first published review investigating the effect of WPAM during the maintenance phase of CR. Both systematic review and meta-analyses used strict methodology under PROSPERO registration and PRISMA guidelines.

The survey was the first investigation into exercise prescription parameters used within Australian CR programmes and was an excellent representation of practice, having 261/328 (80%) programmes responding. Finally, the original research in chapter 5, used a concurrent mixed methods approach which allowed deeper exploration of participant perceptions of PAI coupled with quantitative data analysis. This methodological framework assisted in allowing a greater breadth of understanding when answering our research question and improved the quality of the trial.

There were limitations to the research in this thesis as described previously in chapters 2-5. In summary, when interpreting the systematic review in chapter two, there were methodological limitations in the included RCTs. Particularly, in the most heavily weighted study by Conraads et al. (2015) who reported intensities of participants in both groups exercised outside prescribed intensities, resulting in some participants in both groups potentially exercising at similar intensities. This may have resulted in an underestimation of the amount of change in CRF contributed to HIIT training. The collation of the adverse events was also relying on accurate reporting methods and because there was no specific protocol used in any study, recording of some adverse events may have been missed.

The survey in chapter three was not designed to prevent respondents progressing through the survey if a question was not answered. This may have created some response bias. This resulted in missing data. Specific definitions were not given, and some open-ended questions were open to interpretation. Although a pilot survey was performed, no reliability testing was undertaken.

There were limitations to the review undertaken in chapter four. There are improvements that could be made to all studies included in the review to increase the confidence in the results including blinding assessors, concealed allocation and improving poor completion rates and adherence to exercise. In addition, there was variability in exercise advice and prescription given concurrently with the WPAM, differences in characteristics of interventions and outcome measures resulting in small numbers eligible for the inclusion on the meta-analysis.

Several methodological limitations were also identified in chapter five. The sample size was small, and females were underrepresented. The time of year and environmental impact on exercise influenced participants' exercise and the trial period was of short duration.

6.4 Implications For Practice and Recommendations for Future Research

There are numerous implications for practice resulting from this thesis. Revision of the exercise component of Australian CR is warranted to ensure evidence-based practice delivery and evaluation of its effectiveness can be ascertained. Clinicians working in CR have a duty of care to assist people with cardiac disease to improve CRF to as high a level as possible safely as CRF has been reported to be inversely proportionate to cardiovascular all-cause mortality. Current evidence is indicating HIIT is superior to MICT across several physiological parameters and appears to be safe, therefore the implementation of HIIT should be encouraged and should be considered an integral tool within Australian CR exercise prescription practices. However, clinicians require more education on the safety, resource requirements, enjoyment, and physiological benefits of HIIT. A re-evaluation of the length of our service delivery methods is also warranted to deliver the most effective CRF gains as results of this thesis reported HIIT improved CRF to a greater extent in programmes of 7-12 weeks duration.

Future studies would benefit from reporting of standard deviations, concealment of allocation and blinding assessors would improve study quality. Future studies should recruit more women and older participants (>76 years) to ensure HIIT is more effective

than MICT in improving CRF for a broader range of CR participants and studies that investigate the longer-term benefits of HIIT would also be beneficial.

The survey highlighted the need to increase the number of CR sessions being offered in Australian programmes per week as current practice may not be frequent enough to adopt exercise as a lifelong habit. The results also revealed that the exercise component of CR cannot be adequately evaluated currently as many programmes are lacking re-evaluation practices of CRF and strength. Programmes need to adopt these practices to ensure evidence-based practice delivery.

A review of sternal instability screening practices for those participants who have undergone a sternotomy procedure is imperative to ensure the exercise prescription is not hindering healing and/or placing participants at higher risk of sternal dehiscence. Reviewing the type of health professional supervising the exercise sessions is also warranted to ensure the most qualified staff are utilised, especially because patients with CAD are at higher risk of experiencing further cardiac events during exercise.

With respect to repeating the survey in chapter 3, it is recommended this be repeated in five years as practice is constantly changing with greater evidence emerging. It is recommended that the survey questions include code which does not allow progression to another question until the previous question is answered and definitions should be provided to aid accuracy and ensure similar interpretation from respondents is more likely as well as identifying the type of health professional responding. In addition, research investigating the amount of training nurses have in their undergraduate degree surrounding exercise physiology, exercise prescription practice and education about executing exercise with proper technique, would be beneficial, especially as they are the largest group identified as supervising CR programmes. If nurses are not receiving this education, there may be a need for further training before working within CR to ensure best practice is delivered.

The work undertaken in this thesis also highlights WPAM with exercise prescription and/or advice significantly increases CRF more than not utilising one and consideration of adopting WPAM in this population group should also be encouraged.

Future studies should attempt to use an attention control group to further strengthen their results and standardising variables such as specific exercise prescription and motivational therapies. When assessing psychological measures in the future, investigating general health status (EQ. 5D), psychological distress, (Kessler 6) and Quality of Life index (cardiac version 111) is recommended, as only these tools showed significant differences between groups in our review. To further improve quality, studies should include a larger sample number, blind assessors and use intention to treat analysis along with utilising consistent outcome measures over a longer follow up period. This would allow analysis of the effects WPAM may have on hospital readmission and mortality rates to be conducted. Comparing effect of WPAM on different genders, specific diagnoses and ensuring reporting which group (control or intervention) participants are in if adverse events occur would be of interest. This would also improve the evidence base for future systematic reviews and strengthening confidence in the results.

The results in chapter five of this thesis, strongly supports the need for further investigation of PAI monitoring to aid motivation and adherence to lifelong exercise in this population group. With respect to researching the effects of PAI monitoring in the future, an RCT with larger sample size and longer duration monitoring is warranted. Longer duration studies could also investigate the effect of PAI monitoring on mortality in this population. Recruiting more females, collecting data about social support, income level, and occupational status would also be advantageous as these have been identified as barriers to exercise in the cardiac population in previous literature. Educating patients further about how to gain PAI by introducing individual sessions and comparing different activities and intensities in real time may assist in future studies. Utilising outcome measures to specifically investigate the effect of PAI monitoring on quality of life would also be beneficial. Finally, PAI monitoring on a device with improved syncing processes, increased functionality and attractiveness is also recommended to improve the likelihood of longer-term use.

6.5 CONCLUDING REMARKS

In conclusion, this thesis has resulted in numerous insights to improve CR delivery in Australia. The results should aid in encouraging uptake of HIIT as an important tool in exercise prescription for people with cardiac disease as it is superior to current exercise prescription practices in improving CRF. Important considerations to improve Australian CR practices have been highlighted, particularly addressing the lack of reassessment and screening currently being performed within the exercise component by Australian programmes. CR is also not being offered frequently nor long enough to encourage lifetime exercise behaviour changes.

During the maintenance phase, this thesis indicates that participants should utilise a WPAM as greater gains in CRF was shown. Monitoring a new exercise metric, PAI, is a promising adjunct and should be encouraged as it significantly increased the amount of exercise performed. In addition, all participants found the concept of PAI interesting and most participants stated it increased their motivation to exercise. These findings are original contributions to improve the knowledge in the area of exercise prescription and intensity in outpatient CR and the home environment.

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