Does performance during the ISWT truly reflect changes in physiological function?

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Does Performance during the ISWT Truly Reflect Changes in Physiological Function?

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Abstract

Title: Does performance during the Incremental Shuttle Walk Test (ISWT) truly reflect changes in physiological function?
Author: G.M.Innes

Objective: To evaluate whether changes in performance i.e. maximum distance walked (MDW) in the ISWT truly reflect improvements in physiological fitness in patients who have undergone a 3 month course of cardiac rehabilitation. (CR)
Statement of Methods: A retrospective analysis of 184 patients was carried out and data was collected from an ISWT before and after CR. A Wilcoxan Signed Rank test was used to analyse the variables of heart rate (HR), RPE, MDW and walking speed index (WSI) for all participants. The inclusion of a WSI, looking at peak HR in relation to speed of walking, was used to determine if there was a significant decline in HR at increasing workloads post CR. This was used to signify if a true physiological change in fitness had occurred.
Results: There was a 27% mean increase (p=0.0005) in MDW for all participants post CR. Peak HR increased an average 7% (p=0.0005) and RPE significantly increased from 12 to 13 (p=0.0005). WSI indicated an 8% average (p=0.0005) increase in physiological fitness, based on HR, in all participants. In Men MDW increased significantly from 440metres to 555 metres (26%), peak HR increased by an average 6% (p=0.0005), RPE from12.6 to 13.6 (p=0.0005) and WSI by 7% (p=0.0005). In women mean distance achieved rose 30% from 303metres to 393metres (p=0.0005), peak HR by 6bpm (p=0.001), RPE rose from 11.8 to 12.4, which was not significant (p=0.131) and WSI showed an average increase of 9%.
Conclusion: This study showed that 8% of a 27% increase in walking performance following a CR programme could be attributed to a true physiological (fitness) adaptation. In circumstances where a practice walk is not always carried out, the addition of HR in relation to a given walking speed should be used to assess and quantify the true physiological change related to a programme of exercise based CR.

Originality declaration

This work is original and has not been previously submitted in support of a degree, qualification or other course.

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Glossary of Terms

CR: Cardiac Rehabilitation

WHO: World Health Organisation

SIGN: Scottish Intercollegiate Guidelines Network

VO_2 peak: Peak oxygen uptake

CHD: Coronary Heart Disease

MET: Metabolic Equivalent

MI: Myocardial Infarction

CABG: Coronary Artery Bypass Graft

IHD: Ischaemic Heart Disease

ACSM: American College of Sports Medicine

AHA: American Heart Association

ISWT: Incremental Shuttle Walk Test

ADL: Activities of Daily Living

COPD: Chronic Obstructive Pulmonary Disease

HR: Heart Rate

MDW: Maximum Distance Walked

RER: Respiratory Exchange Ratio

MCID: Minimum Clinically Important Difference

bpm: beats per minute

WSI: walking speed index

PCI: Physiological Cost Index

MHR: maximum heart rate

RPE: rate of perceived exertion

HaH: Have a Heart

CI: Confidence Interval

Chapter 1

Introduction

1.1 Physical Activity and Cardiac Rehabilitation

The aim of cardiac rehabilitation (CR) is defined by the World Health Organisation(WHO) as “the sum of activity required to ensure cardiac patients the best possible physical, mental and social conditions so that they may, by their own effort, regain as normal as possible a place in the community and lead an active life.” The Scottish Intercollegiate Guidelines, (SIGN) summarise the components of CR as exercise training, behaviour change, education and psychosocial support. (SIGN 57, 2002) Early meta-analysis by Oldridge, Guyatt, Fischer & Rimm (1988) and O’Connor et al (1989) were instrumental in demonstrating that CR, including exercise, was associated with lower cardiovascular mortality for myocardial infarction (MI) patients. More recently the Cochrane review (Jolliffe, Taylor, Thompson, Oldridge & Ebrahim 2001) of 7600 CR patients revealed that the impact of this exercise based intervention on total mortality and cardiovascular mortality showed a reduction of 26% and 31% respectively. The majority of these studies were conducted on middle aged (<65 years) men making the results less applicable to the general population. They were however carried out before the widespread use of thrombolytic therapy, coronary stent placement and aggressive drug therapy**,** thus demonstrating the influence that exercise provided in decreasing mortality rather than the many drug interventions that are reducing mortality today**.** In these reviews, exercise training had been the core component with a focus on fitness training as the main mode of physical activity intervention. The main target for fitness training is an increase in aerobic or functional capacity, which has been shown to have a clear link with both all-cause and cardiac morbidity and mortality (Kavanagh et al 2002).

1.2 Cardiac rehabilitation and Functional Capacity

The SIGN Guidelines (2002) acknowledge the key role exercise plays in CR, and recommends that functional capacity be evaluated before and after completion of exercise training of at least 8 weeks.

Functional capacity is a measurement of VO_2 peak or physiological fitness i.e. the maximum amount of oxygen a patient can take in via the lungs, deliver to the exercising muscles by the cardiovascular system and utilised by these muscles. (McArdle, Katch & Katch 2001) It is measured in litres of oxygen per minute although it is typically expressed in millilitres of oxygen consumed per minute, per kilogram of body mass (mlO_2/kg/min), to facilitate inter-subject comparisons. Physiological fitness is the integration of the cardiac, circulatory, respiratory and muscular systems and reflects an individuals overall ability to function, therefore it is sometimes referred to as functional capacity (Arena et al 2007)

The main aim of the exercise component of CR is to improve a patients' physiological fitness or peak VO_2 (ACSM 2009) and his/her sub-maximal endurance, in order to work in a sustained manner at as high a proportion of this peak, without undue muscular fatigue or symptoms associated with cardiopulmonary dysfunction. Previous studies have indicated that CR improves physiological fitness levels. Ades (2001) showed an 11%-36% improvement in peak VO_2 post rehabilitation in a study of mostly middle aged (<65 years) men, with the greatest increase seen in the least fit. Other studies have shown that this improvement not only apply to this population, but in older coronary heart disease (CHD) patients (Ades, Maloney, Savage & Carhart, 1999**)** and in those with other diagnoses as well e.g. heart failure (Sheppard & Balady, 1999).

Many studies have shown the importance of exercise capacity to survival in asymptomatic populations (Paffenberger et al 1993 & Blair et al 1995). In the Aerobics Centre Longitudinal Study, Blair et al (1996) looked at the strength of association between cardio-respiratory fitness and cardiovascular disease mortality in comparison to other CHD risk factors. Over 33,000 subjects were followed up for 8 years. The results showed that high fit people with multiple risk factors of smoking, hyperlipidemia and hypertension had a reduced mortality of 64% compared to low-fit people who had no other predictors. This was evident again in a further cross section of the same study population in 1998 (Farrell et al), which suggested that improving from a low to moderate level of cardio-respiratory fitness was associated with a 42% reduction in all-cause mortality. Farrell and colleagues verified that a sedentary lifestyle was a major independent predictor of cardiovascular disease.

Myers et al (2002) demonstrated that exercise capacity was a strong predictor of risk of death in a coronary heart disease population. A large study of 6213 participants, both healthy (3679) and with cardiovascular disease (2534), over 6 years, was carried out to look at exercise capacity, from an early treadmill test, and how it affected survival. Peak exercise capacity was the strongest predictor of risk, after adjustment for age, among both groups. Each 1 MET (i.e. 3.5mlO_2/kg/min) increase in exercise capacity conferred a 12% improvement in survival. This study showed the importance of physical fitness for symptomatic men.

In a review by Morris, Ueshima, Kawaguchi, Hideg & Froelicher (1991) an exercise capacity of <6 METS indicated higher mortality. Myers et al (2002) confirmed that those with an exercise capacity of <5 METS had roughly double the risk of death from all causes than those subjects whose exercise capacity was more than 8 METS. This study validated the protective role of a higher exercise capacity, even in the presence of other risk factors such as arrhythmia, ST-segment depression and peak heart rate. Vanhees, Fagard, Thijs, Staessen & Amery (1994) looked at training effects after 3 months in myocardial infarction (MI) and coronary artery bypass graft (CABG) patients. They found that a 1% increase in peak VO2 after training was indicative of a 2% decrease in cardiovascular mortality.

Kavanagh et al (2002) also showed the importance of fitness improvements in relation to cardiovascular mortality in a retrospective cohort study of 12169 men referred for CR between 1968 and 1994. The study concluded that regardless of diagnosis of MI, CABG or Ischemic Heart Disease (IHD) the most important single predictor of cardiac and all cause death was VO_2 peak as measured by cardio-respiratory testing. The results showed that for every 1 MET improvement in fitness, mortality reduced by 9%. Thus, Kavanagh (2002) maintained that assessment of individual exercise capacity and progression of cardiovascular fitness is essential to the rehabilitation of the CHD patient.

1.3 Assessment of VO2 peak in Cardiac rehabilitation

Peak VO_2 i.e. how fit you are, carries important prognostic information for patients with CHD both prior to and following CR (Ades et al 2006). Vanhees et al (1994) showed the prognostic significance of peak oxygen uptake in patients with CHD in a group of male patients following MI. An exercise test was performed to exhaustion and results from the follow-up indicated that all-cause and cardiovascular mortality decreased with increasing peak oxygen uptake. They predicted that a 1 litre per minute increase could be associated with decreases in cardiovascular mortality by 71%.

In Phase III CR, peak VO_2 is used to stratify patients for risk of a further event during exercise. Risk tables have been formulated by various bodies such as the American Heart Association (AHA) and the American College of Sports Medicine (ACSM), (ACSM 2009 7th Edition). Risk categories were defined according to many factors including MET capacity, where <5 METS = high risk, 6-8 METS = intermediate risk and >8METS = low risk. Assessing VO_2 peak also assists the exercise specialist in prescribing a safe, effective and individualised training program pre- rehabilitation, and it may be utilized as an outcome measure, post rehabilitation, in assessing how well a patient with heart disease has progressed after exercise training (Vanhees et al 2005)**.**

To assess true maximum VO_2 in CHD, patients need to perform a maximal exercise test whilst having respiratory gases measured. The most common test used is the Bruce treadmill protocol which is a progressive speed and incline test performed on a treadmill, but other protocols such as the cycle ergometer or ramp protocol may take precedence depending on the evaluation required (ACSM 2009). When VO_2 max is not directly measured however, it is estimated using a regression equation relating treadmill performance, dictated by workload, to oxygen uptake. This gives an estimated VO_2 max which is often population specific and may overestimate VO_2 max in CHD patients (Bruce, Kusumi & Hosmer 1973, cited in Milani Lavie & Spiva 1995). In fact Milani et al (1995) conducted a maximum treadmill test on 50 patients entering CR and again after completing the 12 week exercise course. Two analyses were reported, the actual VO_2 improvement by gas air analysis and the estimated improvement using the ACSM calculations, based on speed and workload on the treadmill. A difference of 43% was found between the figures, (estimated METS being higher) and it was postulated that the differences could be due to familiarity with the test; and also an improved work efficiency resulting from exercising on the treadmill throughout the CR course. Lavie & Milani (2000) extended this study to a group of elderly (>70 years) and younger (<55 years) CR patients. Using a ramping treadmill protocol they analysed 183 patients before and after rehabilitation, comparing the effects of the intervention on estimated and measured METS, using the ACSM formula (2009). The elderly groups' estimated aerobic capacity improved by 32% while measured VO_2 increased by only 13%. In the younger group the estimated aerobic capacity was larger (44%) compared with the actual increase (14%). This study was limited by the absence of a non exercise control group and highlights the inaccuracies in the ACSM equation when calculated in non steady state exercise i.e. ramping protocol.

More recently Woolf-May & Ferratt (2008) looked at the potential error of estimating METS during a 10m shuttle walk test in 31 male post MI patients and 19 asymptomatic age-matched controls with other factors such as age, body weight, physical fitness, movement efficiency and co-morbidities taken into consideration. The results in the non cardiac patients showed similar METS for an Incremental Shuttle Walk Test (ISWT), a treadmill test using the ISWT speeds, and the ACSM calculations. However in the cardiac patients the results indicated that METS ranged between 29% and 35% higher during the ISWT. Unfortunately, ethical clearance was not granted in time for a treadmill test to be carried out on this group. The only other potential reason for the difference here was levels of fitness prior to testing. The authors stated that there was no significant difference between the self-reported habitual physical activity levels, but the non cardiac patients performed a greater number of shuttles (56metres) in comparison to the post-MI patients (42metres). This perhaps emphasises the need for population specific MET values.

Other factors that may influence VO_2 assessment include walking economy and psychological factors such as depression, motivation and confidence. For the CR practitioner these are important to recognise and play an important role in the success of a patients rehabilitation programme. How much these factors influence test outcomes is unclear. Distinguishing between a physiological improvement in fitness and an increase in confidence may even be irrelevant to some patients who gain a benefit from CR. However it is fitness that is linked to mortality. In relation to intervention success and potential future funding of UK programmes however, it is important to identify the reason for change and quantify successful outcomes.

1.4 Sub-Max Testing in Cardiac Rehabilitation

In the clinical setting of CR, it is often not possible to conduct a VO_2 max test, prior to entering Phase III, due to several issues such as time, safety, space, expensive equipment, funding, trained specialists to conduct the test and medical staff to supervise it. Therefore, sub-maximum tests are used at this time. Ades et al (1999a) reported that sub-maximum tests in older coronary patients are more relevant as they bare a similarity to activities of daily living (ADL) and are safer for the patient as they do not require the patient to be stressed to a maximum physical effort. It is suggested that they give a measurement within 10-20% of a normal individual VO_2 max (ACSM 2009).

There are two types of sub-max test. 1) The predictive tests are sub-maximal tests that are used to predict VO_2 max by extrapolating the relationship between heart rate and VO_2 to age predicted maximum heart rate. These however may lead to a significant error in predicting actual $VO_{2,}$ because of the inter-subject variability in heart rate response to exercise (Noonan & Dean 2000). In normal subjects, this has been reported to be a standard deviation of 10-12 beats per minute (McArdle et al 2001) and in patients with cardiac disease even greater, particularly for those on beta blocker medication (Lauer, Okin, Larson, Evans & Levy 1996, Brawner, Ehraman, Schairer, Cao & Keteylan 2004).

2) Performance sub-maximal tests involve comparing performance in METS to standardised physical activities encountered in everyday life. METS have been determined from a wide variety of activities and are specific to that particular physical activity (Ainsworth et al 2000). METS are generally estimated before and after an intervention, such as CR. utilising the recommended formulas of the ACSM (2009), and are conveyed by many programmes as an outcome measure of intervention success. There is evidence however to suggest that METS are easily over-estimated in CHD patients as the ACSM formulas use energy expenditure calculations derived from healthy subjects (Morris et al 1993, Woolf-May et al 2008). The most commonly used field test in CR is the Incremental Shuttle Walk Test (SIGN 57, 2002).

1.5 The Incremental Shuttle Walk Test (ISWT)

The SIGN Guidelines (SIGN 57, 2002) have recommended the ISWT as the sub-maximal field test of choice for CR, to aid exercise prescription and allow assessment of progression during the exercise intervention. It is a performance sub-maximal test, designed originally for Chronic Obstructive Pulmonary Disease (COPD) patients (Singh, Morgan, Scott, Walters & Hardman 1992) but has been used to assess functional capacity before and after rehabilitation in CABG patients (Tobin & Thow 1999, Arnott 1997 & Fowler 2005), in those with pacemakers to aid assessment and programming (Payne & Skehan 1996), and in patients with heart failure (Green, Watts, Rankin, Wong &

O’Driscoll 2001, Morales, Monte, Mayor & Martinez 2000).

The development of the ISWT was a key stage in sub-maximum testing as it differed from the other field tests being employed in clinical practice. Field testing became more reliable and valid in comparison with self-paced tests. Butland, Gross, Pang, Woodcock & Geddes (1982) introduced the 6 minute walk test (6 MWT) for use with COPD patients. It was a self-paced test over a 30 meter course with no standardised format and thus was influenced by encouragement and patient motivation, which made it difficult to reproduce (Guyatt et al, 1984). The ISWT strived to minimise the effect of learning and motivation on performance by incorporating external pacing, a standard protocol of testing and encouragement, a practice walk and an incremental workload (Singh et al 1992). Onorati et al (2003) compared the validity of the two tests and identified significant differences in the physiological responses. The response to the 6MWT showed that maximum heart rate (HR) was achieved after three minutes and maximum speed was achieved in the first minute, whereas physiological variables in the ISWT revealed a linear increase with workload. The distance covered on the ISWT was strongly related (r=0.86) to peak $VO_{2,}$ while there were no meaningful correlations for the 6MWT.

The advantages of the ISWT is that it is a simple inexpensive walking test, completed on a flat 10metre surface, that stresses the cardiac patient progressively to a symptom limited maximum or volitional fatigue. It has been validated as a reproducible measure of performance (i.e. MDW) in CABG patients and shows a correlation (r=0.87) between VO2 max with increasing levels of the test (Fowler et al, 2005). The end point of the ISWT is described as a symptom limited maximum. This differs to VO_2 max in maximum exercise testing of CHD patients, who may be limited by cardiac symptoms, respiratory symptoms or other co-morbidities prior to the true end points of a VO2 max test. During laboratory-based cardio-respiratory testing these true end-points are determined by several factors: i) A plateau of Vo2 with increasing workloads. ii) A respiratory exchange ratio (RER) >1.10, i.e. the ratio of metabolic gas exchange calculated by carbon dioxide production divided by VO_2. iii) A maximum heart rate (HRM) of within 15 beats per minute (bpm) of age predicted maximum (McArdle et al 2007). The end point for the ISWT therefore is often described as peak VO_2 depending on the patients' heart rate, rating of perceived exertion and reasons for ending the test.

The ISWT test is externally paced, with the aid of an audio signal, and therefore allows comparisons to be made between patients (Singh et al, 1992). Feedback from a group of CABG patients held that the initial stages of the test were too slow (Tobin et al 1999). Also, patients who travelled too quickly between the cones in the early stages of the test required to stop and wait for the "bleep" before continuing. This may subsequently affect pacing and produce heart rate levels that are too high in relation to speed. The performance outcome for the test is determined by several means 1) a percentage increase in distance walked, in the absence of gas analysis. 2) By comparing the percentage increase based on METS achieved for each level, by utilising the ACSM formulas (ASCM 2009). Or 3) utilising regression equations proposed in research in relation to specific groups i.e. CABG patients (Fowler et al 2005). The ACSM calculations however, are based on healthy individuals during steady state exercise that have previously been shown to overestimate fitness levels, in both elderly and young CR patients of varied diagnoses, quite significantly (Lavie et al 2000). This was more recently confirmed by the results of Woolf-May et al (2008), which reported that METS were being underestimated by as much as 35% when using the ACSM calculations for male post-MI patients in a study that looked at the ISWT and a treadmill protocol and compared gas analysis with estimated METS from the ACSM equations. If these results were to be considered, then not only is it difficult for practitioners to estimate a patients current functional capacity without gas analysis, but it also complicates giving advice to patients regarding others activities they should undertake at home, as these are all based on standardised MET calculations.

Table 1: Walking speeds and metabolic equivalents (METS) for each stage of a shuttle walking assessment, including ACSM estimates and actual METS for non-cardiac and cardiac (post-MI) participants

Stage	kph	mph	*ACSM METS	**ISWT METS Non Cardiac	**ISWT Mets Cardiac	Regression Equation METS
1	1.8	1.1	1.9/3.2	1.9	3.0	2.3-2.5
2	2.4	1.5	2.1/3.4	2.4	3.7	2.6-2.8
3	3.0	1.9	2.4/3.6	2.9	4.4	2.9-3.3
4	3.6	2.3	2.7/3.9	3.4	5.1	3.3-3.8
5	4.3	2.6	3.0/4.2	4.0	5.9	3.9-4.4
6	4.9	3.0	3.3/4.6	4.5	6.6	4.5-5.1
7	5.5	3.4	3.6/5.0	5.0	7.3	5.2-5.8
8	6.1	3.8	3.9/5.5	5.6	8.0	5.9-6.7
9	6.7	4.2	4.2/6.0	6.1	8.7	6.8-7.6
10	7.3	4.5	7.9/6.6	6.6	9.4	7.7-8.7
11	7.9	4.9	8.5/7.1	7.1	10.2	8-8-
12	8.5	5.3	9.1/7.7	7.7	10.9	

Adapted from: *Estimate equations from ACSM (2009 p. 158). **ISWT METS from Woolf-May & Ferrett (2008), Regression Equation METS from Fowler et al 2004.

The Table (1) above shows the inconsistency between various calculations of METS for the ISWT. The ACSM METS are most accurate in healthy participants during steady state exercise, up to a speed of 3.7 mph. Woolf-May et al (2008) demonstrated similar METS to the ACSM calculations for non-cardiac participants after level four on the

ISWT, but those for cardiac patients were consistently higher all the way through to level 12. The Regression equation by Fowler (2005) was found in a group of CABG patients, but is only validated up to 830m, as none of the participants went beyond that point.

1.6 Validity of the ISWT

The ISWT has been shown to be a valid outcome measure for CR following a practice walk, based on correlation studies that show a strong link (r=0.87, with 95% confidence intervals) between the distance walked on the test in metres, and directly determined VO_2 max using expired air analysis in a group of 31 CABG patients (Fowler et al 2005). A regression plot was drawn for MDW and VO2 peak in ml.kg.min, showing 95% CI, which led to a regression equation as follows: 7.81 + (0.03x ISWT distance (m)). Bradley, Howard, Wallace & Elborn (1999) also demonstrated a strong positive correlation between VO2 peak and distance walked (r = 0.95) in a group of cystic fibrosis patients in a modified ISWT that added 3 extra levels; and Green et al (2001) found a strong significant correlation (r =.83 7 p=0.05) between peak VO_2 from the treadmill and MDW when measured using a Cosmed K4b2 portable breath by breath analyser in congestive heart failure patients. This agreed with the previous work of Keell, Chambers, Francis, Edwards and Stables (1998) that demonstrated a correlation of r=0.84 in heart failure patients. However when direct measures of VO_2 have not been taken, researchers have still attempted to come up with normative values of VO_2 for patients entering CR (Ades et al, 2006); and have recommended that direct rather then estimated values of VO2 max should be used where possible. So how reliable are sub-maximum tests at giving the practitioner accurate information regarding VO2 on entering CR and for portraying outcome post intervention?

1.7 Reliability

The ISWT has only been shown to be reliable after one practice walk in COPD patients (Singh et al, 1992). To obtain accurate results from the SWT in other patient groups however, there is some dubiety as to whether a practice walk is necessary. Arnott (1997) found reproducible results without the need for a practice walk in a group of CAGB patients. Although there was an increase of 4.7% between the first and second tests, the results were not significant**.** Green et al (2001) also found no significant difference in the test-re-test distance achieved by seven heart failure patients (513m vs. 517m), although the researcher does mention that patients were familiarised with the ISWT one week prior to the testing. Fowler et al (2005) also demonstrated that there was no significant difference between the first and subsequent tests, in a group of CABG patients, and that therefore no practice test was required. However, there was a difference between test one and two of forty two metres (4 shuttles approx) as opposed to only eight metres (less than 1 shuttle) between the second and third tests. Test one was completed one week prior to the other two and the maximum heart rate on each test was not significantly different. The authors highlighted that the repeatability of coefficients between test two and three was only twenty one metres, as opposed to one hundred and twenty two metres between test one and two. This basically meant that the difference in performance between test two and three could be reproduced 95% of the time, and be expected to be around two shuttle lengths.

Most recently Jolly, Taylor, Lip and Singh (2008) undertook an analysis using 353 CR participants from the Birmingham Rehabilitation Uptake Study (BRUM) study to determine if there was need for a practice walk. The results showed a significant difference (p=0.0001) between the first and second walk of 29.5 metres, with no significant change in heart rate, and thus concluded that the significant change in distance was due to familiarity and not motivation and that a practice walk was indicated. This equated to a 10% improvement based on familiarity. Whilst this is interesting and insightful, this study highlights the importance of including heart rate within the evaluation and outcomes of the test, especially when a practice walk is unable to be performed. Many CR programmes in the UK are resource limited and time for testing patients may not always be possible as only 16% of programmes have access to the recommended physiotherapy time (Audit BHF, BACR 2008). Furthermore, present guidance from the BRUM study (Jolly et al 2008) recommends carrying out a practice test and then performing the actual test within 30 minutes, which adds another question as to how reliable the test would be in periods of greater than 24hours.

1.8 ISWT as an Outcome Measure for Cardiac Rehabilitation:

At present there is no solid research to indicate what the minimum clinically important difference (MCID) is, or the minimum distance improvement needed to constitute change in physiological fitness for cardiac patients, and thus why the ISWT is not recommended as an outcome measure for programme success. It is vital that clinicians are able to identify the threshold of change required for improvement and to facilitate improved outcomes for the patient. It is also important for the patient to understand a level of change that is beneficial to their health post rehabilitation. Singh, Jones, Evans and Morgan (2008) conducted a study to determine the minimum clinical important difference (MCID) in performance during the ISWT for pulmonary rehabilitation. 353 paired tests were analysed pre and post rehabilitation. On conclusion of a 7 week pulmonary rehabilitation course, they were asked to identify from a 5-point Likert scale, the perceived change in their performance. The scale ranged from better to worse. A significant mean improvement of 47.5 metres (95% CI 38.6-56.5) was discovered in those who felt their exercise tolerance was “slightly better”, and a significant change of 78.7m (95% CI 70.5-86.9) in those who described their improvement as being “better”. They therefore concluded that the MCID was 5 shuttles.

So what evidence is there that the ISWT can detect a significant change? In a study by Fowler et al (2005), the question was raised as to whether the ISWT was sensitive to a physiological change in fitness in CABG patients. Eleven patients completed three ISWT’s prior to a six week CR programme, which consisted of mostly aerobic walking and a follow up home programme. On completion of the course they carried out a final ISWT and analysed the difference. There was a significant mean difference of 81.8 metres, however there was no control group, the number of patients was small and heart rate was not considered. The researchers commented merely on the potential of the ISWT to be sensitive to a change in exercise tolerance. Further studies are therefore required if the ISWT is to act as a successful intervention outcome measure for CR.

In relation to studies linking fitness improvement in VO2 to increases in distance walked, it sounds logical that if a patient walked further at the end of rehab during the ISWT that they would be fitter. However, if a patient can sustain exercise for longer, will they have a higher VO_2 peak or increased endurance to sustain exercise at a higher proportion of VO_2 peak or both? Although studies mentioned earlier have demonstrated that the correlation exists between an increase in distance walked during the ISWT and increased VO_2 peak (Singh et al 1994), there is no way of confirming such a question without cardio-respiratory testing. Is the patient fitter, or have they simply demonstrated a greater motivational effort due to increased endurance for exercise, due to familiarity in the absence of a practice walk, or due to increased confidence post recovery from their event. A post rehabilitation outcome of improvement in distance achieved may be sufficient knowledge for some CR practitioners that the patient is potentially fitter, or can tolerate a higher capacity for exercise without ischemia. It does not however tell the clinician categorically if the patient is physiologically fitter. Tobin et al (1999) suggested a unique way of using the ISWT along with a holter monitor in a group of 19 CABG patients, which allowed a comparison of heart rate to be made at each workload or level on the ISWT pre and post rehab. There was a mean significant difference (p=0.02) in heart rate at all levels 1-8 and an 18% improvement in distance walked. A comparison was not made however as to the relationship between percentage mean improvement in the maximum distance walked with percentage decrease in heart rate i.e. physiological fitness.

There is also the possibility that the patient could be fitter without having walked any further, if they demonstrate a lower heart rate for similar workloads post-rehabilitation (Astrand, Rodahl, Dahl & Stromme 2003). This can be assessed by observing heart rate (HR) at different workloads through each stage of the ISWT. For example, if a patient walks the exact same distance before and after rehabilitation and their peak HR is 120 beats per minute (bpm) pre-rehab and 110 (bpm) post-rehab, then the patient is fitter, as they are demonstrating less myocardial strain, and/or a greater stroke volume for the same workload and cardiac output, in the post rehabilitation exercise test.

The current protocol for the ISWT recommends recording HR at the end of every level but this is not carried out at all CR facilities as it can be difficult to read the HR monitor while a patient is in motion, particularly if they are jogging, without disturbing the test. Also, those that reach the jogging levels are in danger of “topping out”, i.e. finishing all the levels of the test before they would choose to stop. In fact, there are a small percentage of patients at the Royal Alexandra Hospital, Paisley who do not carry out a pre-rehabilitation ISWT as they have a baseline fitness (calculated by a treadmill test prior to discharge) of above 9 METS, which is the maximum MET level of the ISWT. Lavie & Milani (1994) demonstrated in a group of 163 patients, mean age 57 years that even those with higher baseline fitness (mean 8.8 METS) can benefit from a CR programme. In that study, functional capacity was improved by 22% and highlights that consideration needs to be given to this group long term, as to how outcomes can be met through exercise testing.

Rationale for this project

The rationale for this study is a need to determine whether improvements in performance i.e. distance walked and levels achieved, post rehabilitation actually equate to increases in physical fitness, to differentiate between a greater effort or tolerance and a physiological change in VO_2 peak. The study will inform practitioners of how to ensure that if they report an improvement in fitness using the ISWT that a change has truly occurred. The inclusion of HR into the evaluation will be the means by which to ascertain such an answer.

The project will show a feasible way of indicating whether or not a significant change in HR has occurred by using a walking index, based on HR and walking speed. The walking speed index (WSI) was based on the physiological cost index (PCI) by MacGregor (1979 cited in Hood, Granat, Maxwell & Hasler 2002), which was determined by dividing the difference between resting and steady state heart rate in beats per minute, by speed of walking in metres per minute, to obtain a PCI in beats per metres;

$$\text{Physiological cost index (PCI)} = \frac{\text{Resting Heart Rate – Peak Heart rate}}{\text{Metres per minute}}$$

The PCI was based on the known linear relationship between oxygen consumption and HR, with increase in workload. It was used to calculate a gait efficiency or energy cost primarily in patients with motor impairment. MacGreogor (1979) suggested it as an alternative to VO_2 measurements. Early research by Rose, Gamble, Mederios, Burgos & Haskell (1989) looked at the energy expenditure in normal children and in those with hemiplegic cerebral palsy. Using treadmill tests and PCI calculations, a strong linear relationship (r-.84) was found between VO_2 and heart rate through a range of walking speeds and a strong correlation coefficient (r=.99) between VO_2 and heart rate values. However, this data and study methodology was challenged by Keefer et al (2004) who revisited the study and discovered that the participants were allowed to use handrails during the treadmill test. On recreating the study comparing direct and indirect measures of walking energy expenditure, Keefer and colleagues found a weaker relationship at speeds of .67 metres per second (r=0.50), .89 metres per second (r=0.51) and 1.12 metres per second (r=0.64). Researchers such as Bailey & Ratcliffe (1995) and Nene et al (1993; cited in Keefer et al 2004) reported good reliability with the PCI in unimpaired subjects, but only when working HR reached a steady state. In comparison Danielsson, Willen & Sunnerhagen (2007) showed that the PCI had limited reliability and validity as a measure of energy cost after stroke due to extensive test/re-test variability. It is probably fair to say that the studies surrounding PCI as an alternative use for direct VO2 measurements would dismiss this index as reliable or valid, in patients with motor impairment. However, used as an indication of whether or not HR has changed significantly in relation to speed, for an individual from one test to another, it is potentially feasible if used as outlined below.

$$\text{Walking speed index (WSI)} \quad = \quad \frac{\text{Peak Heart rate (HR)}}{\text{Metres per minute}}$$

(See Appendix 1 for table of HR WSI by John Buckley)

If HR increases linearly with speed, the WSI can detect if peak HR obtained in the second ISWT is significantly lower than the first. It should be lower if the patient is physiologically fitter, because they should be able to demonstrate a lower HR at any given workload compared to the initial test. See Appendix 2

Aim of the Project

The aim of this project is to evaluate whether changes in performance in the ISWT truly reflect improvements in physiological fitness or functional capacity in patients who have undergone CR.

Hypothesis: There is a significant improvement in functional capacity based on performance, i.e. maximum distance walked during the ISWT before and after rehabilitation that equates to an increase in physiological fitness based on changes in HR at different workloads.

Null Hypothesis (H_o): The change in performance during the ISWT does not equate to the physiological changes, based on HR, before and after a 13 week course of CR.

The objective therefore of this project, is to assess the relationship between HR and peak walking speed, to evaluate whether improvements in performance are related to actual physiological adaptation as opposed to some other confounding variable (possibly familiarization/motivation). A WSI will be used to assess whether a decline in HR for a given walking speed occurred, thus showing an improved level of physiological fitness or not, in a group of Phase III CR patients.

Chapter 2

Methodology

2.1 Background

This study was a retrospective analysis of the ISWT in Phase III CR. Records were collected from a large data set that existed as part of a government funded project called Have a Heart (HaH) Paisley, Phase I, at the Royal Alexandra Hospital Paisley, in Scotland from May 2003- April 2004. The HaH Paisley project was designed to assess the effectiveness of menu-based CR. Data collected looked at nutrition, psychology input, education and patient risk factors, which included cholesterol, smoking, blood pressure, weight and physical activity. Patients were referred to the HaH project on a voluntary basis and consent forms were obtained from all those who agreed to have their data stored and analysed.

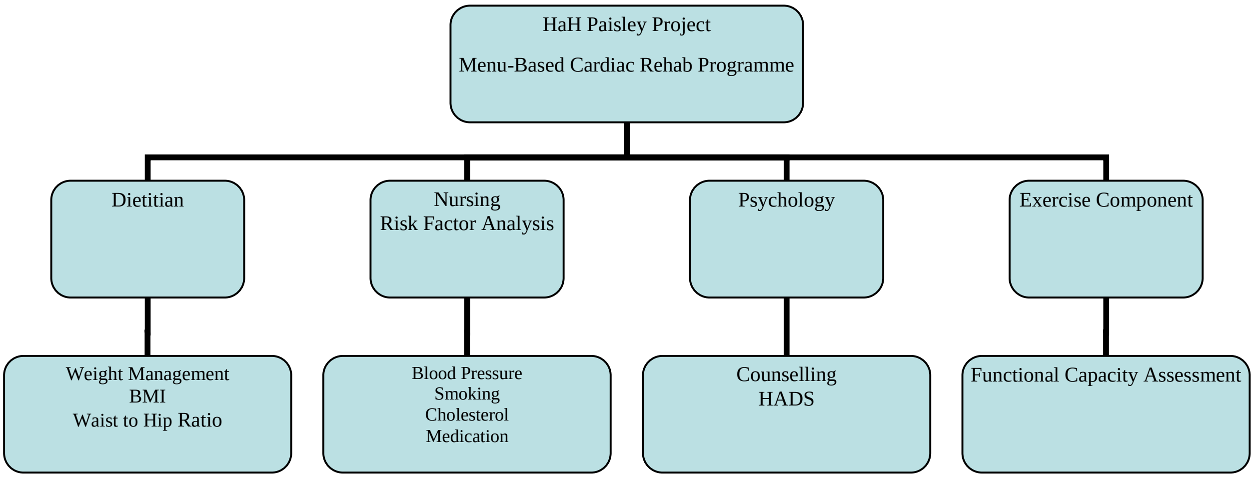

Figure 1: Flowchart for HaH Paisley Menu-Based Cardiac Rehabilitation Programme

2.2 Functional Capacity Assessment

Participants entering CR were assessed by a physiotherapist or exercise physiologist using the ISWT. This is a walking test most commonly used in CR in the UK. It is an externally paced test using a pre recorded audio signal, it is designed to stress the patient to an individual symptom limited maximum. The patient is required to walk along a 10 metre course on a flat surface, turning around a cone at each end. The test has twelve levels, each one minute in length and of increasing pace (Singh 1992). Appendix 2 outlines in detail the levels, speed in mph and kph, and distance in metres for the entire test.

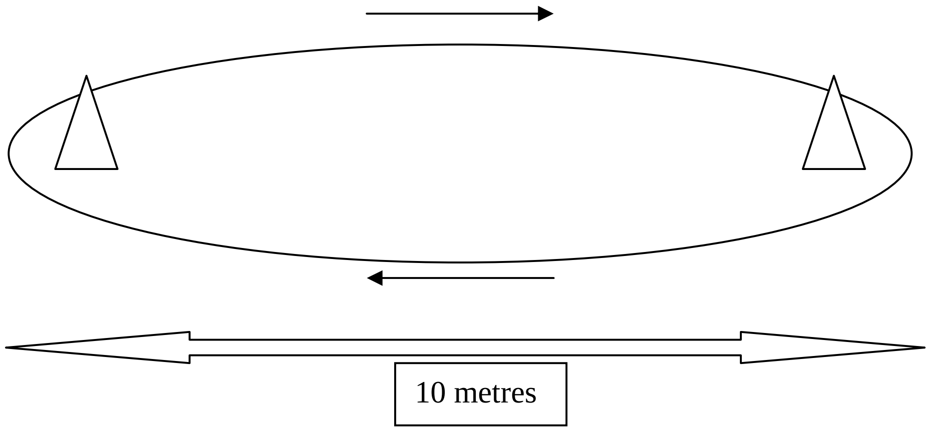

Figure 2: Layout of the ISWT

The ISWT was performed as per the guidelines outlined in SIGN 57 (2002), with two exceptions;

1. Recording of HR at the end of each level. Only two heart rates were recorded, one prior to commencing the test, and one at peak HR, on completion of the test. A polar HR monitor was used to obtain accurate HR readings
2. There was no practice test undertaken due to time constraints and funding available for physiotherapy staff.

All tests were performed in the same gymnasium, at similar times, prior to and after a 13 week course of menu-based CR. The following test data was then gathered from ISWT and recorded in a database.

- Maximum distance walked (MDW) during the test
- Maximum heart rate (MHR)
- Peak rate of perceived exertion (RPE)

2.3 Ethical Consideration

Exercise and cardiovascular disease brings with it patient risk of a further event. All exercise sessions were staffed with appropriately trained Physiotherapists and/or Exercise Physiologist and were overseen by a nurse with intermediate or advanced life support training. Participants' blood pressure was monitored prior to the test and a series of questions asked to ascertain that subjects were safe to take part in the test. Please see Appendix 3: Shuttle Walk Test "Pre-Test Checklist" for further details.

2.4 HaH Cardiac Rehabilitation Exercise Class

The CR exercise programme consisted of a one hour exercise class twice a week. The exercise component was made up of circuit or gym based classes, with a recommended third day a week of equivalent home-based exercise.

The circuit class was split into four sections

- 15 minute warm-up with stretching
- 20 minutes of circuit stations. 10 exercises with three different levels
- 10 minute cool down
- 10 minute relaxation session or 10 minute resistance training

The gym based class contained

- 10 minute warm up on a bike with 5 minutes stretching
- 25 minute cardiovascular section, patients had use of treadmills, bicycles or Concept II rowing machines
- 10 minute resistance training programme
- 10 minute cool-down.

2.5 Participating Patients for the Retrospective Study

234 patients were identified from the HaH Paisley database with full ISWT details. After exclusion criteria, which is outlined below, 184 were used in the final analysis. The subjects consisted of 112 (61%) men, mean age 64 years (+/- 8) and 72 female (39%), mean age 66 years (+/-8). Ethics approval was obtained through the Have a Heart Paisley Project Phase I. (See Appendix 4: Ethics Approval letter)

2.6 Study Design and Dataset for the Retrospective Study

A retrospective study design was chosen for this project due to the ease of access to a large amount of data compiled through HaH Paisley, Phase I from May 2003-April 2004. The data set for this retrospective analysis was gathered from those participants who completed an ISWT prior to and after a13 week course of menu-based CR, post cardiac event, at the Royal Alexandra Hospital in Paisley, Scotland.

Patients were identified by the following methods: a) a search of the HaH Paisley research database to gather all those with a full data set, b) a trawl through archived patient handwritten physiotherapy profiles to identify those who were eligible for inclusion. Physiotherapy records of the ISWT results were confirmed by hand and subjected to strict exclusion criteria, which included the following; 1) manual recording of heart rate, 2) commencing or changing dose of beta blocker medication during rehabilitation and 3) termination of the ISWT by the instructor rather than the patient and any other factors not adhered to in the SIGN 57 guidelines (2002), excluding exceptions already mentioned..

2.6.1 Inclusion Criteria

1. All Patients referred to CR at the Royal Alexandra Hospital, Paisley following a step change i.e. either an acute cardiovascular event or worsening of the existing CHD e.g. worsening angina.

2. Diagnosis included:
    a. Myocardial Infarction (MI)
    b. Coronary Artery Bypass Graft (CABG)

    c. New Diagnosis Angina/ Increasing Onset of Angina
    d. Percutaneous Transluminal Coronary Angioplasty (PTCA)
    e. Acute Coronary Syndrome (ACS)
    f. Valve Replacement (VR)
    g. Congestive Heart Failure (CHF)

3. Patients who performed an ISWT before an after a 13 week course of CR
4. Records from the ISWT that contained the following information
    a. Resting and peak HR.
    b. Peak RPE
    c. MDW in meters
    d. Medication
    e. Reason for concluding the test

2.6.2 Exclusion Criteria

196 patients were confirmed by hand by trawling the individual handwritten patient profiles. 12 were excluded from the final analysis for reasons such as Manual recording of HR and Peak HR not being recorded during the test. Full details of reasons for exclusion can be found in the Appendix 5.

2.7 DATA

The following data was then collected for each participant during the ISWT, before and after rehabilitation, and a new dataset created using SPSS containing:

- Maximum distance walked (MDW)
- Maximum heart rate (MHR)
- Maximum rate of perceived exertion (RPE)

Additional calculations were then included for analysis.

- walking speed index (WSI)
- speed in metres per minute

At this point a decision was taken to assist the accuracy of the analysis, regarding speed and level attained on the ISWT. Each participant was only awarded a new level in speed if they completed 30 seconds of the stage. The cut off points for each level are shown below.

Table 1: Cut off Points for assignment of speed in the WSI analysis

Level 1 = 20 metres	Level 2 = 50 metres	Level 3 = 100metres	Level 4 = 150metres
Level 5 = 220metres	Level 6 = 290metres	Level 7 = 380metres	Level 8 = 470metres
Level 9 = 580metres	Level 10=690metres	Level 11=820metres	Level 12=950metre

This was only changed to calculate the WSI, i.e. dividing HR by speed in metres per minute; the speed was assigned on the basis of the levels above. No other changes were made to the true MDW, HR or RPE for the overall analysis.

2.8 Walking Speed Index (WSI)

A WSI was created for the analysis to aid comparison of peak HR after the ISWT. In this data an assessment could not be made of all heart rates at increasing workloads as only two heart rates were obtained during the test, one at the beginning and one at the end. The study undertook to evaluate peak HR to determine if it changed significantly following 13 weeks of CR. If the patient demonstrated improved physiological fitness then HR at any given workload post rehabilitation would decrease (McArdle et al 2007).

The WSI was based on the physiological cost index (PCI) created by MacGregor in 1979. The PCI was proposed as an alternative to VO_2 measurements in locomotive experiments on various disabled groups such as cerebral palsy (Rose et al 1989) because of the difficulty with equipment required for gas air analysis.

The WSI works on the principle of the linear relationship between work rate, HR and VO_2, where changes in HR response is a valid substitute to changes in VO2. (McArdle et al 2007). It is calculated by taking peak HR and dividing it by speed in metres per minute to obtain an index rating. This number will be lower post rehab if HR has changed significantly for any given walking speed and thus work-rate (VO_2). See Appendix 3.

2.9 Data Analysis

184 participants were included for analysis, following exclusion criteria. All analyses were performed using Statistical Package for Social Sciences software program (SPSS) 14 for windows (SPSS Inc, Chicago, IL, USA).

The variables that were examined included:

- MDW
- HR in beats per minute (bpm)
- RPE (RPE 6-20 scale)
- WSI in beats per metre

The study design was repeated measures with ratio level data and therefore a parametric paired t test was indicated. As participants equalled more than 100 the Kolmogorov-Smirnov test was used to test for normality of distribution. However the distribution failed the assumption of normality (p=>0.05) and therefore a non parametric equivalent test, the Wilcoxan Sign Rank test, was chosen. The level of significance was set at p=0.05. Summary data was expressed as mean (SD) due to the level of data involved.

From the data analysis a significant difference was evaluated to determine whether or not the participants increased their physiological fitness. This was assessed by comparing any average increase in MDW with the average decrease in WSI (this indicates an increase in physical fitness) to evaluate whether they agreed i.e. if there was an average increase of 30% in the distance walked there should also be a 30% average decrease in WSI.

Chapter 3

Results

3.1 Basic demographic data

This was a retrospective study of data from 184 patients from the Have a Heart database of 234 patients who attended CR at the Royal Alexandra Hospital, Paisley, Scotland from April 2003-March 2004. 38 patients did not have a corresponding hand-written profile, which was necessary for inclusion. 12 were excluded from the study for changes in medication or dose, or incorrect recording of HR. Participants included 112 (61%) male and 72 (39%) female. The mean age (+/-S.D.) for men was 64 (+/- 8) years and woman 66 (+/- 8) years. The difference between mean age and gender was not significantly different (p=0.926). The majority of participants were between 55 and 74 years of age.

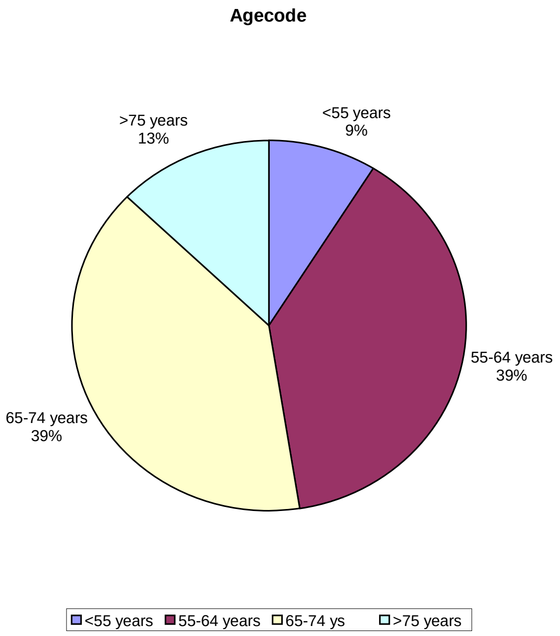

Figure 3: Age code of Participants. **<55 years** = 9%, **55-64 years** = 39%**, 65-74 years** = 40%, **>75 years** = 13%

Diagnosis was divided as follows, and shown in Figure 4 below. MI accounted for 34% of patients, Ang 21%, CABG 19% and PTCA in 15% of patients. The remaining participants were made up of ACS, VR and CHF. Beta-blocker medication was prescribed in 71% of participants.

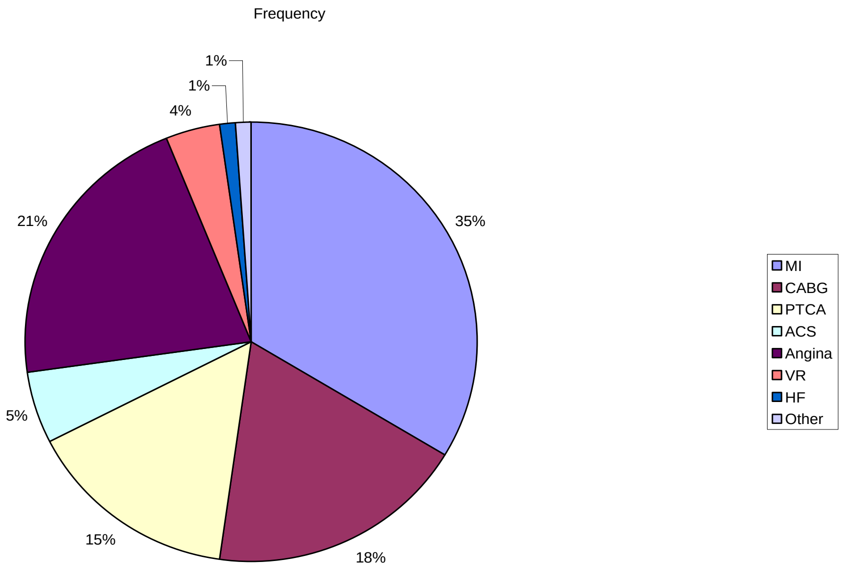

Figure 4: Diagnosis of Participants

3.2 (ISWT) Results.

3.2.1 Results by Levels

The ISWT consists of twelve one minute levels. If Level 5 indicates approximately 5 METS (Woolf-May et al 2008) then 75% of patients recorded level 5 or above pre-rehabilitation (see figure 5) and 88% post-rehabilitation (see figure 6). 1% of patients reached the last level of the test (n=12) pre-rehabilitation and 7% post rehabilitation. The mean level achieved pre-rehabilitation was seven and post-rehabilitation was eight. The mean distance achieved for all participants pre-rehabilitation was 387 metres (95% CI 360m-414m) and post-rehabilitation was 492 metres (95% CI 460m-523m).

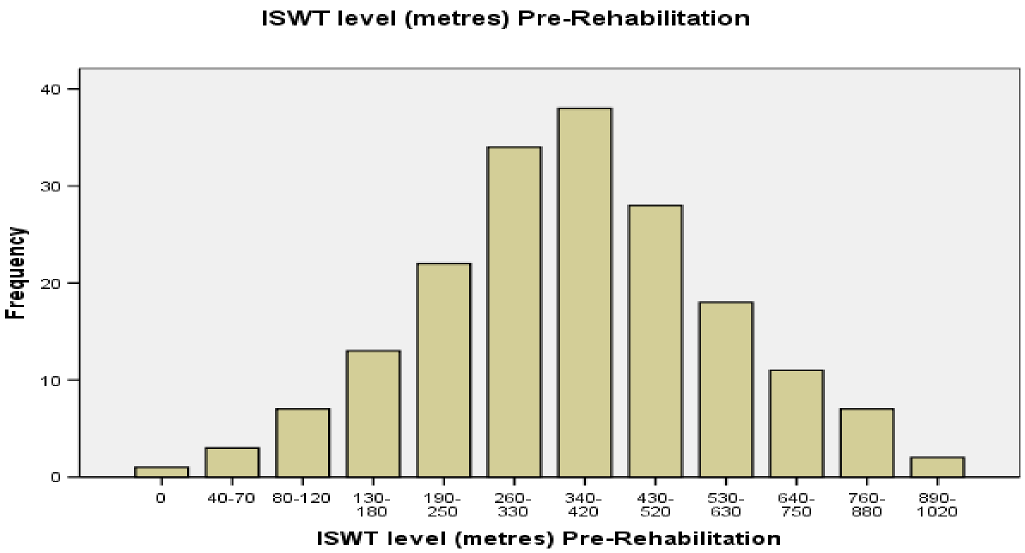

Figure 5: ISWT Level Pre-Rehabilitation

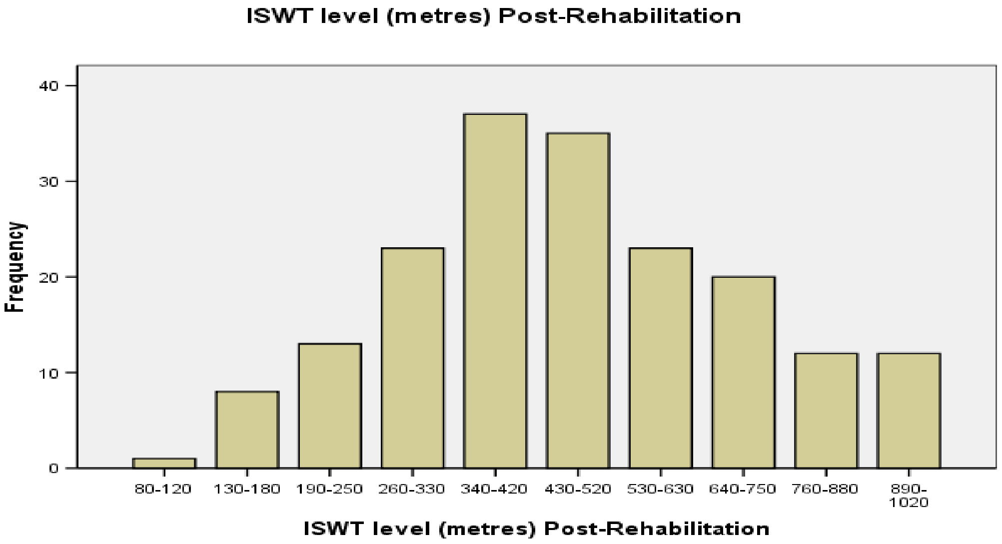

Figure 6: ISWT Level Post-Rehabilitation: The graph does not include the first two levels as all participants reached at least level 3 post rehabilitation.

3.2.2 Results by Age Groups

The age group 55-64 years walked the furthest pre (453 metres) and post-rehabilitation (557 metres). The distance post-rehabilitation was between 4% and 68% further than the other three groups and represented a 27% increase in distance achieved before and after a 13 week course of CR. Both the <55 year and the 65-74 year groups improved the average distance achieved on the test post rehabilitation by 25% and 26% respectively. The >75 year group, while walking the least average distance pre-rehabilitation i.e. 269 metres (+/- SD) made the largest relative improvement of 88 metres post-rehabilitation, an increase of 33%. Peak heart rate increased between 4% and 9% (4 beats per minute – 9 beats per minute) and RPE increased from between 5% and 9% with the 55-64 age groups showing the biggest increase.

3.2.3 Results by Diagnosis

For the purpose of reporting results by diagnosis, the following categories of MI and ACS were combined as Myocardial Infarction (n=72), and CABG and PCI as Re-vascularisation (n=62). Patients with angina (n=39) were treated as an individual group and the remaining categories of VR and CHF were not included as numbers were too small (n=9) to give detail. The MDW pre and post rehab for the MI Group was 378 (+/-188) metres and 484m (+/-219) respectively (see fig. 7). This was a significant increase (p=0.0005) of 28%. HR increased by 6 bpm (p=0.002) and RPE increased from 12.14 (+/- 2.0) to 12.90 (+/- 2.5). The Revascularisation Group improved the MDW by an average 111 metres (see fig 7), a significant increase (p=0.0005) of 27%. HR increased from 106 to 110, which was not significant (p=0.177), and RPE changed significantly (p=0.014) from 12.16 (+/-1.8) to 13.18 (+/- 2.0). Finally in the Angina Group, the MDW was on average 96 metres further (p=0.0005, see fig 7), HR increased by 6bpm, which was also significant (p=0.002) and RPE did not change significantly only rising from 12.92 to 13.19.

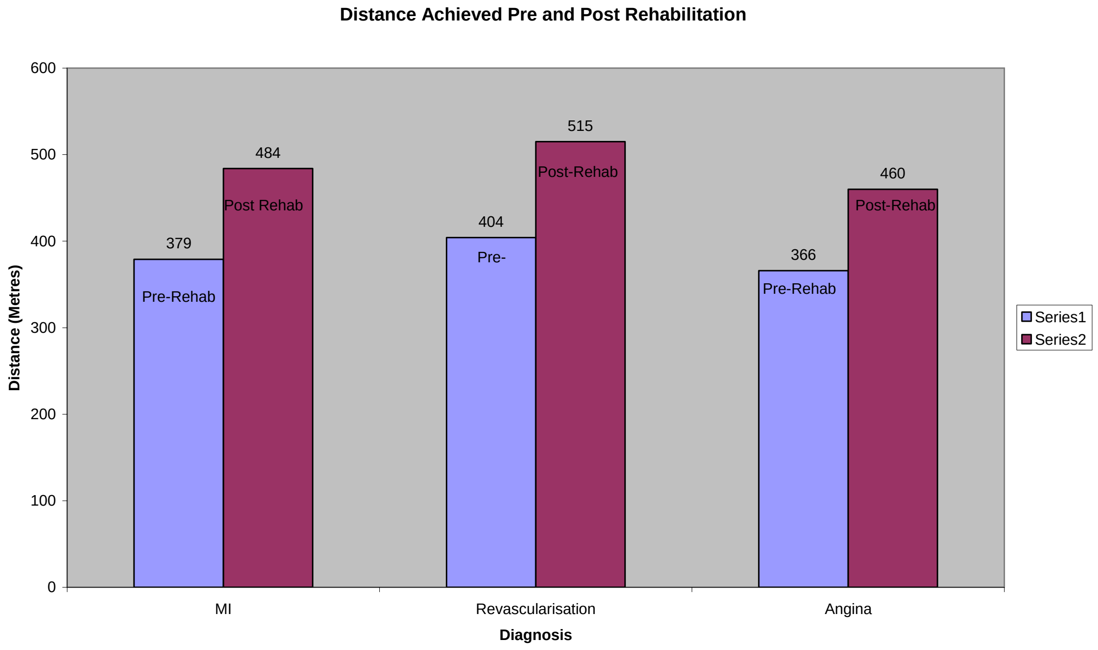

Figure 7: Maximum Distance Walked Pre and Post Rehabilitation

3.2.4 Results by Gender

For male participants (n=122) the average distance walked pre-rehabilitation was 440 metres (level 8) and post rehabilitation was 555 metres (level9). Whereas for females the distance achieved pre-rehabilitation was 45% less at 303 metres (level 6), and post-rehabilitation averaged 41% less at 393 metres (level 7). In male participants 17% reached level 10 or above pre-rehabilitation as opposed to 1% of female patients. However female participants showed a mean increase in percentage walked post-rehabilitation of 30% as opposed to men 26%. Male peak HR increased 6% to 112 post-rehabilitation and RPE went from 12.6 (+/-SD 1.8) to 13.6 (+/-SD 2.0). Female HR showed an average increase of 6 beats per minute and RPE rose from 11.8 (+/-SD 1.8) to 12.4 (+/- SD 2.1) after 13 weeks of CR.

3.3 Analysis

The variables of HR, MDW, WSI and RPE were ratio level data. However the variables, analysed over two time points, did not pass the test of normality by failing to yield results of p=>0.05, making the distribution abnormal, and therefore a non parametric test, the Wilcoxan Signed Ranks test was used instead of a parametric test. A significance level of p=0.0125 was set, which included a Bonferroni adjustment for the four variables (p=0.05*4). The results were calculated for all participants (184) except for RPE which was conducted on 79% (145) of the group.

Table 2: Pre Rehabilitation (PR) and Post Rehabilitation (PtR) Results for Maximum Distance Walked (MDW), HR (heart rate), RPE (rate of perceived exertion) and WSI (walking speed index)

	MDW metres PR	**MDW** Metres PtR	**HR** bpm PR	**HR** bpm PtR	**RPE** PR	**RPE** PtR	**WSI** PR	**WSI** PtR
Total Group	387	492	101	108	12.3	13.1	1.25	1.15
Men	440	555	106	112	12.6	13.6	1.21	1.12
Women	303	393	95	101	11.8	12.4	1.32	1.20

Table 3: Percentage change in MDW, HR, RPE and WSI between base-line and follow-up. Levels of significance annotated below.

	Maximum Distance Walked	Heart Rate	Rate of Perceived Exertion	Walking Speed Index
Total Group	27%*	7%*	7%*	8%*
Men	26%*	6%*	8%*	7%%*
Women	30%*	6%**	5% ns	9%**

* p<= 0.0005, ** p<= 0.001, ns = not significant.

The results (table 3) reveal that there was a significant increase (p=0.0005) in the MDW of 105 meters (387m +/- 186m to 492m +/-216m) between pre and post rehabilitation for all participants. Peak HR significantly increased (p=0.0005) from 101 (+/- 22) bpm to 108 (+/- 25) bpm, RPE significantly increased (p=0.0005) from 12 to 13 and WSI significantly decreased (p=0.0005) from 1.25 (+/- 0.31) beats per meter (bpmet) to 1.15 (+/- 0.26) bpmet. See Tables 2 & 3 above.

3.3.1 Males and Females

When gender was calculated separately, MDW for females increased significantly (p=0.0005) from 303 (+/- 133) metres to 393 (+/- 155) metres. HR increased significantly (p=0.001) from 95 (+/- 18) bpm to 101 (+/- 22) bpm and WSI decreased significantly (p=0.001) from 1.32 bpmet to 1.20 bpmet. For males, MDW increased significantly (p=0.0005) from 440 (+/-195) meters to 555 (+/-227) metres. HR significantly increased (p=0.0005) from 106 (+/-24) bpm to 112 (+/-26) bpm and WSI significantly decreased (p=0.0005) from 1.21 bpmet to 1.12 bpmet. See Table 6&7. The average difference in distance post rehabilitation for the genders was 115 (+/-129) metres for males and 89 (+/-78) for females. This was not significantly different (p=0.145).

3.4 Maximum Distance Walked versus Physiological Fitness

When MDW i.e. a change in performance was calculated as a percentage increase from base-line to follow-up the results indicated that the participants showed a significant mean increase of 27%. To determine how much of this change was due to physiological gains it was compared to WSI, which indicates a physiological gain based on a decrease in heart rate at any given level. The results show that a physiological change in fitness increases by an average 8%. The remaining 19% is thus a function of some other factor such as familiarisation, confidence or movement efficiency (practice). When genders were considered separately a similar result was demonstrated. For woman, an average increase in performance of 30% was demonstrated by the increase in distance walked while significant changes in fitness (WSI) only rose by a mean 7%. For men, the mean percentage increase in MDW was 26% while WSI showed an average increase in fitness of 5%.

Therefore, the hypothesis that percentage improvement in functional capacity based on performance, i.e. MDW, during the ISWT should equal the change in physiological fitness, based on a decrease in HR at different workloads, can be rejected.

Chapter 4

Discussion

4.1 Overview

This study set out to evaluate whether changes in performance during the ISWT, reflected in maximum distance achieved, truly echo improvements in physiological function, or functional capacity, in patients who have undergone a 13 week course of CR.

All 184 participants were compared using the variables of peak MDW, Peak HR, RPE and WSI. A non-parametric Wilcoxan Signed Rank t-test was indicated to examine the difference between the variables. The results suggested there was a mean significant increase in both distance achieved and fitness for all participants, but that they were not equal. The statistics demonstrated that there was a significant mean increase of 27% in MDW (p=0.0005) after rehabilitation and an average 8% increase in fitness, based on the percentage change in WSI. Both peak HR and RPE significantly increased by 7% respectively.

When gender was looked at separately, the men walked on average 115 metres (p=0.0005) further in the follow-up test, while the women averaged an increase of 93 metres (p=0.0005) post rehabilitation. This represented an average performance increase of 26% and 30% in distance achieved post rehabilitation. There was also a significant increase in peak HR of 6 beats per minute (p=0.0005) for both men and women; and an increase in RPE of 8% for men (p=0.0005) and 5% in woman, the latter being non significant (p=0.131). When a WSI was calculated, by gender, for peak HR before and after a CR programme, this study revealed that there was an average increase in physiological fitness of between 5% and 7%. Therefore, the difference between performance and true physiological (fitness) adaptation was approx 20%-23%. This difference was a function of some other cause similar to familiarisation, confidence or movement efficiency (i.e. practice). Subsequently, in relation to the aims and hypothesis of this study the results confirmed that changes in performance do reflect changes in cardiovascular fitness, but that this increase is not equal.

There is a need to distinguish therefore between the factors that may affect performance and those that truly make a person fitter. The factors that may affect a positive performance can include cardio-respiratory fitness, gait or movement efficiency, familiarity with the test, motivation and exercise tolerance. Any one of these factors may result in an improved outcome during an ISWT in the absence of a practice walk. However, for cardio-respiratory fitness to be enhanced, a physiological decrease in HR at the same workload has to occur during the follow-up test (McArdle et al 2007). CR practitioners acknowledge that there are many exercise-based benefits for patients post cardiac event, all of which are not merely physical. Patients that demonstrate an improvement in the distance achieved during the ISWT post rehabilitation may be benefiting from an enhancement of confidence, which allows them to exert a greater effort during the test. CR is therefore also a tool for restoring patient self-esteem and confidence post-event.

But how can one differentiate between a psychological benefit and a physiological one, based on standard ISWT outcomes of an increase in distance walked in the absence of a practice walk? It is only possible to calculate approximately, based on correlation statistics, that the percentage improvement in MDW is also a physiological improvement in fitness. Based on the results of this study, one would argue that the percentage increase in fitness is actually being over-estimated. In fact, this study suggests that approximately 19% of the increase was performance related and only 8% was an increase in physical fitness. Practitioners require a clear indication of the minimum percentage increase in distance walked in the ISWT that is physiologically significant for patients, so that a true increase in cardiovascular fitness can be reported.

There are no previous studies that looked at the results of the ISWT in this way, comparing physiological markers of heart rate and rate of perceived exertion with percentage increase in performance. Discussion surrounding this study will refer to similar research to determine if the findings can be compared with previous studies, and to evaluate if a clearer approach to observing changes in functional capacity in cardiac rehabilitation patients can be attained.

4.2 Discussion of Results

4.2.1 Participants

80% of patients fell between the ages of 55 and 75 years. This does not necessarily reflect the breakdown of age attending CR at the Royal Alexandra Hospital in Paisley as likely exclusions could have occurred in the older (>75 years) or younger (<55 years) groups. Some more elderly patients undertake a 6 minute walking test for reasons relating to co-morbidities or higher risk stratification i.e. congestive heart failure. In the younger patient group those who performed an ETT of > 8.5 METS as an in-patient would not have undertaken an ISWT prior to entering CR. Furthermore, patients who reached level 12 or completed the ISWT pre-rehabilitation would not repeat the test post-rehabilitation. This group are not evaluated for improvement in functional capacity rendering the programme unable to accurately present the physiological improvements made by all its patients. Should this perhaps be a requirement of Cardiac Rehabilitation programmes throughout the UK?

The following results convey the levels attained during the ISWT by all participants and differences in results by diagnosis, age group and gender. These can be compared with previous studies, but were not included in the statistical analysis as they did not relate to the main aim of the study. The average level achieved pre rehabilitation by all participants was level 7 (387m) and post rehabilitation was level 8 (492m). Only 6% of the female participants completed level nine or above pre-rehabilitation, however this increased to 17% post- rehabilitation. In comparison, 35% of males reached level nine or above pre-rehabilitation and 49% achieved this post-rehabilitation. The gender difference here is not surprising as men have a greater functional capacity than women due to body size and muscle mass (ACSM 2009). Level 9 is set at a speed of 4.2 miles per hour (6.7kph) and the point at which most patients would need to change from walking to jogging. Rotstein (2005) estimated transition speeds from walking to jogging to be approximately 7.2 kph in fit, non running students. So it is perhaps plausible to suggest that CR patients, who are older, heavier and less fit, would transition to jogging a little earlier. It is also possible that patients who undertake the ISWT may stop when speed increases beyond the point of walking. Without a practice walk patients do not know what to expect and may feel a little anxious about exerting themselves post event. If participants are expected to jog at this point, should the test be called a walking test? In fact, protocol for the ISWT does not at any stage suggest that you tell the patient they can jog.

Some comparisons were able to be made for distances achieved pre and post rehab during the ISWT with other studies in cardiac patients’, however the majority of research carried out to establish peak functional capacity used treadmill protocols. In a study by Fowler et al (2005), a group of 34 male CABG patients walked a mean distance of 478m i.e. level 8, prior to 6 weeks of CR. This was established on the third practice walk. The group improved by and average of 82 metres post rehabilitation but these results were only available for 11 patients. The furthest distance achieved during the test was 830m (level 11). In a more recent study on reproducibility of the ISWT (Jolly et al 2007) a mean MDW of 415m was achieved, following a practice walk, in 353 patients in the BRUM study. Finally, in Woolf-May et al (2008) 31 male post MI patients completed an ISWT with a practice test, and achieved a mean distance of 420m. None of the participants in this study went beyond Level 9. Collectively these studies may highlight two issues to consider. 1) Do all patients entering CR, in these studies, have a similar functional capacity or are patients stopping when they feel they have to transition to jogging? 2) Is the speed at this point a limitation of the test?

A further observation will now detail the inclusiveness of the ISWT and how previous cardiac groups compared with the current study. Although the ISWT was originally designed for COPD patients (Singh et al, 1992), it has been shown to be an objective assessment tool for CABG patients and also and an outcome measure for CR (Arnott et al 1997, Tobin et al 1999). Tobin et al (1999) made the significant inclusion of a holter monitor during the ISWT. The results were able to demonstrate a significant decrease in resting HR and also a decrease in HR at all sub-maximum workloads post rehabilitation. This however was a small study of 19 patients, mean age 61 years, and the introduction of holter monitors into CR was never looked at subsequently. The highest level achieved during the study was level 8 and from that the author surmised that the ISWT was of adequate length for CR patients. If this is compared with the current study, those with a diagnosis of CAGB can be separated and the results examined. On inspection of the CABG group alone, there were 34 patients with a slightly older mean age of 65 years. More than 25% of the study group completed level 8 pre rehabilitation and almost half (47%) the group were above this level post rehabilitation, with 3 patients completing the test (level 12). For this group there was a significant (p = 0.0005) difference in the MDW of 25%, but the mean percentage increase in physical fitness was only 5%. Perhaps changes in treatment and medication has meant that patients have a greater tolerance for exercise than before, but these results also suggest evidence that the test is not all inclusive for the CACB population, and would perhaps require further levels to generate a true outcome of maximum distance achieved post rehabilitation, if this is going to be the only parameter assessed.

Results based on diagnosis showed a significant increase (p=0.0005) in MDW prior to and following CR for the MI, re-vas and angina group of 28%, 27% and 26% respectively. Ades et al (2006) found that CAGB patients entering CR had the lowest age adjusted levels of fitness; and those who did not have an MI but underwent PTCA had the best exercise tolerance. In this study all the group demonstrated similar improvements in MDW. The MI Group (n=72) walked a mean distance of 379m (Level 7) pre rehabilitation and 484m (Level 8) post rehabilitation, an increase of 104m (28%). The Re-vascularisation group (n=62) also averaged level 7 (404m) pre rehabilitation and Level 8 (515m) post rehabilitation, an increase of 27%; and the Angina group achieved a mean distance of 366m (level 7) pre-rehabilitation an 460m post-rehabilitation, a 26% increase in performance.

Age Group results indicated that all groups improved the distance achieved on the ISWT post rehabilitation by 25%, 27%, 26% and 33% respectively. A comparison of the average distance achieved between age groups pre and post rehabilitation revealed that the youngest group (<55 years) walked approximately 65% further than the oldest group (>75 year) pre rehabilitation, but only 56% further post rehabilitation, thus indicating that although the older group were less fit to begin with, they made a greater gain post rehabilitation. Stahle, Mattsson, Rydent, Undent & Nordlander (1999) demonstrated in 101 elderly (mean age 71) cardiac patients that functional capacity increased by 17% after 3 months of CR, as opposed to a control group who showed a 3% increase**.** Ades et al (1992; cited in Williams et al 2002) showed that older cardiac rehab patients make as big a gain in cardiovascular fitness as younger patients, and Lavie and Milani (1995) indicated that they can in fact make a greater improvement, 43% vs. 32%, in a cohort of 199 elderly patients (>65 years)**.** In this study participants <65 years tended to take part in a gym-based classes, which consisted of 25 minutes of cardiovascular exercise and 15 minutes of resistance training at 60%-80% of HRR, two days a week. The majority of those over 65 years participated in circuit classes that included 20 minutes of circuit exercises twice a week and 10 minutes of resistance work once a week. They exercised at 55%-75% of HRR. This allocation of class was based on personal ability during the initial ISWT pre-rehabilitation and was decided by the exercise specialist in conjunction with patient preference. The patient was however required to reach level 10 on the ISWT before the gym-based class became available as an option. Whether or not this influenced the improvement in fitness gained between the groups is unclear, and it was not possible to separate results from the retrospective data into which classes were attended.

4.2.2 Analysis

The statistical analysis undertook to determine how much of an increase in performance, reflected by an increase in MDW in the ISWT, was as a result of an increase in physical fitness; and how to determine this without the use of a practice walk. The results revealed that the MDW increased significantly by an average 27% (p=0.0005), HR by 7bpm (p=0.0005) and RPE by 7% (p=0.0005). The WSI decreased significantly by 8% (p=0.0005), which is an indication of an average physiological increase in fitness of 8%. This suggests that percentage performance increased more than percentage fitness. In fact, the analysis shows that 19% of the increase in performance is related to other factors besides an increase in fitness. This difference highlights the fact that HR and MDW should be used in conjunction with one another when reporting outcomes from the ISWT in CR patients. The fact is that it is difficult to know how much of the improvement in distance achieved is a physiological improvement without a practice test, although some researchers in cardiac patients found no need for one (Arnott 1997, Woolf May et al 2008, Fowler et al 2005, Green et al 2001). However, the MI patients in the study by Woolf-May (2008) undertook the ISWT approx 8 months after their event and it is not clear whether they previously completed an ISWT as part of rehabilitation. Also in the study by Green and colleagues (2001), the seven heart failure patients were familiarised with the test by completing a few levels prior to testing.

In facilities that are unable to perform a practice test, it is surely wise to enlist the aid of physiological markers such as HR combined with distance achieved and RPE to ensure that outcomes reflect true physiological change. In this study the WSI allowed assessment of the results in this way by comparing peak HR in both the pre and post rehabilitation ISWT and relating it to speed or workload attained.

The analysis of males and females separately indicated that there was a significant increase (p=0.0005) in distance walked of 26% and 30% respectively. This was compared to a 5%-7% improvement for both men and woman in physiological fitness. The average difference in distance achieved post rehabilitation between men (115m +/-129) and woman (89 +/-78) was not significantly different (p=0.145). When compared with a study by Lavie and Milani (1995a) improvements in functional capacity by gender were slightly higher in men (40%) versus woman (33%). These figures were not attained through breath by breath analysis but by using Bruce treadmill protocols and standardised formulas, which later were identified by the same researchers to dramatically over-estimate functional improvements (Lavie et al 2000). In this study therefore, an average difference of between 20% and 24% was performance related rather than fitness related. It is evident from Jolly et al (2008) that as much as 10% of the improvement made in the absence of a practice walk was potentially performance related. If that theory were applied to this study there is still a further 10-14% increase that could be attributed to either familiarisation or gait efficiency.

But how can this information be applied to current practice when the ISWT is carried out without the use of breath by breath analysis? This study does not question the validity of the ISWT to correlate significantly with VO2 peak in a linear fashion with increasing level of the test, as it has been demonstrated in many studies mentioned previously (Singh et al 1994, Bradley at al 1999, Green et al 2001, Fowler et al 2005). In day to day CR programmes there are many uncertainties as to which is the most accurate way of suggesting a physiological improvement based on the results of metres achieved on the ISWT test in CR patients. The most recent work by Fowler et al (2005) has documented a regression equation for a group of CABG patients up to level 10 of the

ISWT based on a strong relationship found between distance walked during three consecutive ISWT's (r=0.79, r=0.86, r=0.87) and peak VO2 peak measured by gas analysis during a treadmill protocol. Other researchers (Woolf-May 2008) have suggested that perhaps performance levels (in METS) have been under-estimated in a group of MI patients compared with standard formulas most commonly used (ACSM 2009).

On the issue of reliability, this study attempted to highlight that if UK programmes do not have the time to undertake a practice walk on patients, they need another method of presenting significant clinical outcomes. If the current research is looked at and combined, then the following comments can be made and possibly considered to improve reporting. Jolly et al (2008) attributed 10% of an improvement between two ISWT, conducted on the same day, to familiarity. Arnott (1997) found a 6% improvement in two groups (24metres and 31 metres) not to be significant as did Fowler et al (2005) who documented an 8% change (34metres) between test 1 and test 3 not to be statistically significant. The key is not then the extra distance in metres but the percentage difference for the individual i.e. a person who goes from 300 to 330 pre and post-rehabilitation will have demonstrated a 10% increase, whereas a person with a pre-rehabilitation maximum of 600 metres would have to travel 60 metres further in the follow-up test to also gain a 10% improvement. In this study two further sub group were looked at to establish if any information could be attained regarding MCID. The groups were, those who demonstrated an increase in fitness post-rehabilitation, group 1 (n=131) and those who did not, group 2 (n=53). The difference in MDW walked by group 1, pre and post-rehabilitation was 112 metres. This was a performance increase of 30%. HR increased by 10%. In group 2, the difference in MDW was 88 metres, a percentage increase of 20% and HR increased by 18%. Could we begin to surmise that an increase in MDW of greater than 20% is required for a physiological difference to be made, if only this parameter is considered? Further work is required to investigate a MCID for the ISWT in cardiac patients.

Being armed with this information allows practitioners to come to an objective assessment of performance outcomes in the absence of an all important “clinically significant improvement”, which research to date has failed to supply. The object of looking at the outcome of the ISWT in this fashion is to better understand the factors that are likely to be involved in MDW. Ultimately, exercise specialists require solid results that tell them and their patients what improvements have been made so that the beneficial effects of that increase in fitness can be discussed. It is essential that exercise practitioners in CR have the ability to assess their patients accurately but also safely. Field testing in this area is currently accepted as the method of choice for exercise prescription and functional capacity. Maximum exercise testing although considered the gold standard for assessing maximum aerobic or functional capacity may not be appropriate for out-patient CR. The role of such testing in CHD patients is indicated after an acute event for determining prognosis and treatment, whereas sub-maximum testing and specifically the ISWT has been recommended to be used in CR programmes across the UK (Sign 57 2002). Does this allow fitness outcomes to be determined and how important a factor is this? The ISWT currently allows the exercise specialist to test patient response to exercise and prescribe an appropriate programme. However, as identified by current research (Fowler et al 2005) the application of the ISWT as an outcome measure for cardiac patients needs further research. Fowler and colleagues (2005) acknowledged that while the ISWT proved to be a valid measure of cardiovascular fitness, based on its correlations with VO2, it warranted further research as an outcome measure for intervention in CR. This would enable a minimum clinical significant difference to be established for practitioners. Furthermore, CR needs to produce objective outcomes that demonstrate its beneficial effects on aerobic capacity, in order to authenticate the exercise component of CR as effective and necessary for CHD patients. Demonstrating an ability to effect change on patients that reduce mortality and decrease re-admission rates is vital. The crucial question is what is the primary purpose of the exercise component of CR? This question may be responded to differently across physiotherapy departments in the UK. If the answer is to increase the functional capacity (VO_2) of its patients' then is the ISWT the correct tool to enable practitioners to assess that? Regular exercise may provide many benefits, simply by increasing energy expenditure, but it is only an increase in VO2 that is a biological marker for an improved ability of the heart and cardiovascular system to deliver oxygenated blood to the working muscles. (McArdle et al 2001) Therefore, exercise assessments need to be able to determine physiological outcomes that reflect this. The ISWT has not to date defined a MCID in CHD patients. Studies attempting to show it sensitivity to change have lacked numbers (Jolly et al 2008), and have been left suggesting that more research is required. The difficulty for UK CR programmes at present is how to state outcomes, particularly when practice walks are not conducted prior to rehabilitation, and this study has shown the potential for difference between how fit the patient actually became post rehabilitation as opposed to how much extra effort they managed post intervention.

4.3 Limitations

The Walking speed index used was an amended, un-validated version of the PCI which failed to subtract resting HR prior to dividing by speed, thus any single (1bpm) change, increase or decrease, at a similar speed would detect a change. Between levels, an increase of <9bpm was required to show an improvement in fitness for that workload. The PCI has been shown to be more reliable in steady state exercise at a self selected pace (Hood et al 2002). Therefore, the decision was taken to only assign speed to HR if the patient achieved at least 30 seconds of the 1 minute level, thereby giving HR an opportunity to adjust to the new walking/jogging pace. However, when speed was re-adjusted, HR had to remain the same as we did not have HR results for all the levels. This is perhaps not hugely significant as results were also calculated prior to re-adjusting speed and the difference in fitness versus performance was only 1%.

The participants in this study were a mix of those on beta blocker therapy and those who were not. It is realistic to assume that the beta blocked patients may have demonstrated a lower heart rate at increasing workloads. Having looked at them as a separate group (n=131) it was however interesting to note that this group demonstrated similar results to the non beta blocked patients. MDW during the ISWT increased by an average 25% and aerobic fitness calculated using the WSI showed a mean increase of 8%. This agrees with the work of Woolf-May et al (2008) who demonstrated that beta-blocked patients did indeed demonstrate a significantly lower HR for each increasing level of the ISWT but that there was no difference in VO_2.

A further limitation with this project was that the retrospective data failed to capture HR at each level of the ISWT. This has been amended within the programme at the Royal Alexandra Hospital for some time. Calculations of the difference between pre and post rehabilitation heart rates would have been made easier and more accurate if similar workloads could have been compared.

Furthermore, the absence of a practice walk made teasing out the reasons for improvement more difficult. However, it was not the intention of this project to identify exactly what could be responsible for an increase in performance but to identify what markers indicate an increase in aerobic fitness and which do not.

4.4 Conclusion

There is a large evidence base to justify that improvements in cardiovascular fitness have been seen to decrease mortality post rehabilitation (Kavanagh et al, 2002, Myers et al, 2002), therefore CR programmes should look at psychological and physiological outcomes separately for audit purposes, and make sure that when a cardiovascular benefit is conveyed for the patient, that a change in physiological markers have been identified and not simply how much further the patients' have walked.

This study attempted to emphasise the importance of physiological markers in outcome measures for CR. In practice at the Royal Alexandra Hospital in Paisley, time constraints and funding mean that a practice walk is not undertaken by patients prior to a baseline assessment of functional capacity. From a practitioner's point of view, perhaps this study and others will highlight that without a practice walk any increase in functional capacity documented post rehabilitation could be more assured if familiarity, HR and PCI were considered. Jolly et al (2008) have outlined that familiarity can account for as much as 10% of the results of an ISWT; therefore observed results should take this into account. This alone however will not provide a full picture of whether the patient has increased their fitness. If HR is then considered additionally and peak HR prior to CR is compared to the same workload post-rehabilitation, a better judgement can be made. Any reduction in HR post intervention would be favourable. This would indicate that stroke volume has increased and HR is lower, while still achieving the same cardiac output. Therefore, if a patient achieved a HR of 110 at level 10 of the ISWT pre rehab, then in the post-rehabilitation ISWT the HR at level 10 should be compared regardless of whether the patient goes beyond this. It should be lower if the patient has become fitter. The third measurement that could be included is using the formula of PCI (i.e. peak HR minus resting HR pre and post-rehabilitation, divided by speed in metres per minute) to determine if there is a decrease in the walking index achieved on the test. A few thoughts are important here, beta-blocked patients should not have had a change in dose and indeed any new patient commenced on beta blocker medication would need to be excluded from this type of measurement. A standardised method of assigning speed would also need to be decided.

It is important that CR is not seen as just a vehicle for reducing mortality and re-infarction rates. Modern medicine may argue that patients are becoming lower risk due to more extensive use of thrombolysis, improved myocardial revascularisation techniques and aggressive pharmacological treatments; and that CR interventions cannot lower risk any further in terms of survival. CR from an exercise perspective therefore needs to stand up and be counted! Physical activity interventions that demonstrate improvements in VO_2 and other interventions that enhance quality of life, functional independence and improved performance of daily activities should be used to show the effectiveness of CR long term. Then perhaps, mortality and re-infarction would not be the only endpoints for evaluating CR. In fact, Paterson et al (2004) identified VO_2 peak as the only variable besides age and co-morbidity to be predictive of future dependence in a group of elderly

CHD patients, a vital insight perhaps, into the growing importance of physical fitness in our society. How physically fit should patients to be is the next question? Will the structure and intensity of CR come into question as more studies highlight that vigorous rather than moderate intensity exercise is a more effective means of actually reducing cardiovascular risk further post event (Swain & Franklin 2006). For the future of CR it is essential that practitioners have the ability to document and demonstrate that patients are benefiting physically from this service. This study highlighted the inherent difficulties of doing that at present and would suggest that further research should look into alternative field tests to make obvious these outcomes.

Appendices

Appendix 1: Heart Rate Walking Speed Index

Appendix 2: ISWT Stages, Levels and Speed

Appendix 3: Shuttle Walk Test “Pre-Test Checklist”

Appendix 4: Ethics Approval Letter

Appendix 5: Reasons for exclusion from the analysis

Appendix 6: SPSS Output & Wilcoxan Signed Rank Analysis for All Participants Pre and Post-Rehabilitation

Appendix 2: ISWT Stages, Levels and Speed

Stage	Metres	Speed in Metres per minute	kph	mph
1	10-30	30	1.8	1.1
2	40-80	40	2.4	1.5
3	80-120	50	3.0	1.9
4	130-180	60	3.6	2.3
5	190-250	70	4.3	2.6
6	260-330	80	4.9	3.0
7	340-420	90	5.5	3.4
8	430-520	100	6.1	3.8
9	530-630	110	6.7	4.2
10	640-750	120	7.3	4.5
11	760-888	130	7.9	4.9
12	890-1020	140	8.5	5.3

Each stage of the ISWT last for 1 minute. In the first stage the patients will cover 30 metres in distance i.e. 3 lengths of the 10 metre course, each stage after this increases by 10 meters. The speed increases by approx 0.4mph per stage.

Appendix 3: Shuttle Walk Test "Pre-Test Checklist"

1. Is your blood pressure adequately controlled?
2. Have you had any angina at rest?
3. Is there any pattern of change to your usual angina?
4. Have you taken you medication today?
5. Have you suffered form any illness or fever over the last 24 hours?
6. Are you taking any antibiotics?
7. Have you consumed a large amount of alcohol over the last 24 hours?
8. Have you consumed any large amounts of food in the last two hours?
9. Is you pulse regular and less than 110 beats per minute/
10. Have you done any strenuous exercise today, prior to the test?
11. Are you a diabetic? Any hypoglycemic episodes in the past week?

Appendix 5: Reasons for exclusion from the analysis

5	Manual recording of Heart Rate
2	Change in beta blocker medication prior to post rehabilitation shuttle walk test
2	Dose change of beta blocker medication during rehab
1	Peak heart rate not recorded
1	Beta blocker medication not taken prior to test
1	Beta blocker dose couldn’t be confirmed

Appendix 6: SPSS Output & Wilcoxan Signed Rank Analysis for All Participants Pre and Post-Rehabillitation

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Pre Maximum Distance Walked	184	95.3%	9	4.7%	193	100.0%
Post MDW	184	95.3%	9	4.7%	193	100.0%
Peak HR pre	184	95.3%	9	4.7%	193	100.0%
Peak HR post	184	95.3%	9	4.7%	193	100.0%
WSIpre	184	95.3%	9	4.7%	193	100.0%
WSIpost	184	95.3%	9	4.7%	193	100.0%
level Pre Rehab	184	95.3%	9	4.7%	193	100.0%
level post rehab	184	95.3%	9	4.7%	193	100.0%
Speed metres per minute pre	184	95.3%	9	4.7%	193	100.0%
Speed metres per minute post	184	95.3%	9	4.7%	193	100.0%

Test Statistics(c)

	Post MDW - Pre Maximum Distance Walked	Peak HR post - Peak HR pre	Speed metres per minute post - Speed metres per minute pre	WSIpost - WSIpre	level post rehab - level Pre Rehab
Z	-10.435(a)	-4.859(a)	-9.576(a)	-6.203(b)	-9.534(a)
Asymp. Sig. (2-tailed)	.000	.000	.000	.000	.000

a Based on negative ranks.
b Based on positive ranks.
c Wilcoxon Signed Ranks Test

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