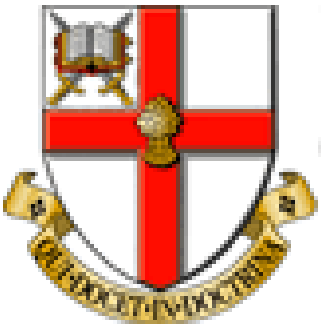

University of Chester

An intergroup analysis investigating the effects of holding a side handrail support on oxygen uptake values during the completion of the Chester Step Test

Dissertation submitted in accordance with the requirements of University of Chester for the degree of Master of Science

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Abstract

Purpose: To investigate what effects a side handrail support has on oxygen uptake during the completion of the Chester Step Test (CST) in younger healthy individuals, older healthy individuals and in cardiac patients who are participating in a cardiac rehabilitation programme.

Methods: This study was an intergroup analysis project which collaborated with two other University of Chester MSc research projects. Fifteen young healthy participants (5 males, 10 females), ten older healthy participants (3 males, 7 females) and seven cardiac patients (7 males, 0 females) were recruited for this study. The study followed a repeated measures design. The younger healthy participants completed three test protocols; performing the CST hands free, holding onto a side handrail with one hand and holding onto a side handrail with two hands. Due to time limitations, the older healthy participants and cardiac patients completed two CSTs; hands free and holding onto a side handrail with one hand. Oxygen uptake ($\dot{V}O_2$), heart rate (HR), metabolic equivalents (METs) and ratings of perceived exertion (RPE) were recorded at each stage of the CST. The exercise test was terminated if the participant: managed to complete all five stages of the CST, appeared to be stressed and indicated that they wanted to stop, reached their target heart rate point of 80% HR maximum or recorded an RPE value ≥ 15.

Results: In all three testing groups, handrail support was found to have no statistically significant effects ($p < 0.05$) on $\dot{V}O_2$ values at each stage of the CST. Handrail support was also found to have no statistically significent effects ($p < 0.05$) on MET, HR and RPE values in the three testing groups at each stage of the CST. The majority of participants found that handrail support made the test feel easier with 93% of the healthy young individuals, 57% of the older healthy participant group, and 86% of the cardiac patients stating that they preferred the test when handrail holding was allowed in comparison to hands free.

Conclusion: In accordance with the findings by Barnett (2010), the current study found that handrail support had no statistically significant effect on oxygen uptake values when individuals performed the CST. Results from the current study provide encouraging support for the use of a side handrail support during the CST when testing both healthy individuals and cardiac patients in a cardiac rehabilitation setting.

Keywords: $\dot{V}O_2$, rating of perceived exertion (RPE), metabolic equivalents (METs)

Originality declaration

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

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Chapter 1
Introduction

1.1 Cardiac Rehabilitation and Fitness Assessment

In 2002, the Scottish Intercollegiate Guidelines Network (SIGN) defined cardiac rehabilitation as “the process by which patients with cardiac disease, in partnership with a multidisciplinary team of health professionals, are encouraged and supported to achieve and maintain optimal physical and psychosocial health” (SIGN 57, 2002). Traditionally, cardiac rehabilitation in the UK has followed a four phase approach. The four phases of cardiac rehabilitation consist of, an inpatient stay in hospital after an acute event, an immediate post discharge period spent at home, an intermediate post discharge period which has traditionally been a supervised outpatient programme and finally a period of long term maintenance (Coats, McGee, Stokes & Thompson, 2003).

Cardiac rehabilitation is mainly offered to patients who have suffered a recent myocardial infarction or revascularisation procedure (e.g. following a coronary artery bypass graft (CABG) or percutaneous coronary intervention (PCI)). Patients with heart failure, heart transplant patients, patients undergoing surgery for implantable cardioverter defibrillators (ICD), patients undergoing heart valve replacement surgery and patients with exertional angina can also be offered cardiac rehabilitation (National Service Framework, 2000).

One of the key aims of a cardiac rehabilitation programme is to improve an individuals physical fitness. Higher physical fitness levels have shown to be associated with a reduced incidence of all-cause mortality and a reduced incidence

of cardiac death (Taylor Brown, Ebrahim, Jolliffe, Noorani, Rees et al, 2004). Improvements to an individual's physical fitness are achieved in cardiac rehabilitation programmes through the use of structured, supervised exercise training. The British Association of Cardiovascular Prevention and Rehabilitation (BACPR) state that an individuals functional capacity should be measured both before and after the completion of the exercise component of cardiac rehabilitation (Coats et al, 2003). Fitness testing has become extremely valuable within cardiac rehabilitation programmes as it enables patients to receive an individual exercise prescription, it allows health professionals to monitor progress of each patient in cardiac rehabilitation and it also helps provide motivation to patients as they see progress in their fitness levels.

There are a number of ways patients can have their physical fitness measured. One way of measuring functional capacity is to use a submaximal exercise test known as the Chester Step Test (CST). The CST was originally designed by Professor Kevin Sykes at the University of Chester as a fitness screening test for entry into the British Fire Service. It is now used by many cardiac rehabilitation programmes throughout the UK as a way of assessing a cardiac patient's functional capacity. The CST is widely used in cardiac rehabilitation programmes as it is a very practical and easy test to perform, it is also inexpensive, easy to standardise, highly portable and can be safely controlled (Sykes, 2010).

1.2 What is the purpose of the study?

The BACPR (BACR, 2009) state that the CST is a suitable mode of exercise testing for a large number of cardiac patients as it is a submaximal test and reflects

movements used in daily life. A drawback to the CST however is its suitability for individuals with poor balance, a lack of mobility or pains in the knees (BACR, 2009). A large number of individuals entering cardiac rehabilitation are elderly so many of these physical limitations could apply to them. If it was possible to further develop the CST to include more patients groups, the test could then be used more widely in a cardiac rehabilitation setting. The use of a side handrail may help overcome these issues and could also offer physically impaired individuals the chance to undertake the CST as an exercise testing protocol.

The American College of Sports Medicine (ACSM) exercise testing guidelines suggest that handrail support may be required for exercise testing in older adults because of reduced balance, decreased muscular strength, poor neuromuscular co-ordination and fear (ACSM, 2009). There is evidence to suggest that the use of a handrail support during exercise testing alters the physiological responses elicited (Berling, Foster, Gibson, Doberstein & Porcari, 2006; Haskell, Savin, Oldridge & DeBusk's, 1982; and Christman, Fish, Bernhard, Frid, Smith and Mitchell (2000)). The studies examining the use of a handrail in these exercise tests have mainly looked at the effect in treadmill testing. There is a great need for standardised submaximal tests for people with impaired balance, people who are overweight, and people who are unable to walk on a treadmill for other reasons.

Following up on the work done by Barnett (2010) which investigated the physiological effects of a front handrail during the completion of the CST in healthy individuals, this current study would help to provide a more complete picture on handrail use during the CST by analysing both healthy individuals and cardiac patients. By incorporating the use of a side handrail to the CST, as opposed to Barnett's (2010) study which used a front handrail, this study would provide an

additional option for handrail configuration during the completion of the CST. Since participants in Barnett's (2010) study noted an elevated level of stability and confidence with the use of one front handrail, it would follow that incorporating two side handrails would further increase participants' security and reduce anxiety about falling during the test. This study performed an intergroup analysis using young and healthy participants, middle-aged and healthy participants, and cardiac patients which is distinct from Barnett's (2010) study that focused on only one population group. By analysing data from three different population groups this study provides a more robust analysis because it reduces the chances of an unknown variable mitigating the relationship between the independent variable, handrail use, and the dependent variable, oxygen costs. Additionally, this study diverges from Barnett's (2010) because it is the first study to examine the oxygen costs of holding onto a handrail with one hand, holding onto a handrail with two hands and without holding onto the handrail while doing the CST for both cardiac patients and healthy individuals.

1.3 Aim of the Study

The aim of this study is to perform an intergroup analysis on younger healthy individuals, older healthy individuals and on cardiac patients who are participating in a cardiac rehabilitation programme, to investitage the effects a side handrail support has on oxygen uptake during the completion of the Chester Step Test.

1.4 Hypotheses

1) There will be no difference in oxygen costs after completion of the Chester Step Test when holding a side handrail with one hand, two hands and hands free in younger healthy individuals.

2) There will be no difference in oxygen costs after completion of the Chester Step Test when holding a side handrail with one hand and hands free in older healthy individuals.

3) There will be no difference in oxygen costs after completion of the Chester Step Test when holding a side handrail with one hand and hands free in cardiac patients.

Chapter 2
Literature Review

2.1 Functional Capacity

The assessment of an individual's physical fitness provides health professionals with important diagnostic and prognostic information in clinical settings (Fleg, Pina, Balady, Chaitman, Fletcher, Lavie et al, 2000). The term functional capacity is often used to describe an individuals physical fitness or the ability of an individual to perform aerobic work as defined by the maximal oxygen consumption ($\dot{V}O_2max$). Maximal oxygen uptake is the product of the maximal cardiac output (L blood·min-1) and arterial venous oxygen difference ($(a-\bar{v})O_2$ diff) at physical exhaustion. This is shown in the following Fick equation (McArdle, Katch & Katch 2010):

$$\dot{V}O_2max = (Heart\ Rate \times Stroke\ Volume) \times (a-\bar{v})O_2\ difference$$

$\dot{V}O_2max$ is often measured in millimetres of oxygen per kilogram of weight per minute to facilitate inter-subject comparisons (Arena, Myers, Williams, Gulati, Kligfield, Balady et al, 2007). Additionally, functional capacity can also be measured in metabolic equivalents (METs) with 1 MET representing a value of about 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. METs are used as a measurement of functional capacity, particularly when functional capacity is measured from the work rate rather than directly measured oxygen consumption (Arena et al, 2007). $\dot{V}O_2max$ varies widely across the population. In cardiovascular disease, $\dot{V}O_2max$ is influenced by many factors

depending on disease severity, genetics and an individual's physical activity level (Coats et al, 2003).

2.2 Importance of Functional Capacity in Cardiac Rehabilitation

The British Association of Cardiovascular and Preventative Rehabilitation (BACPR) state that there are several important reasons for measuring a patients functional capacity in a cardiac rehabilitation programme: diagnosis of disease, prognostic information, exercise prescription and as a treatment or rehabilitation outcome measure (BACR, 2009).

Most of the evidence on the benefits of exercise in cardiac rehabilitation, relate closely to an individuals ability to increase their functional capacity through a structured exercise programme (BACR, 2009). A study conducted by Ades (2001) found that cardiac patients (< 65 years) were able to increase their functional capacity by around 11% to 36% after a cardiac rehabilitation programme. A Cochrane review by Jolliffe, Rees, Taylor, Thompson, Oldridge and Ebrahim (2000), also found that exercise in cardiac rehabilitation can reduce all causes of mortality by 27% and reduce cardiac death by 31%.

A number of studies have shown the importance of physical activity and exercise on risk of mortality in healthy individuals and individuals with cardiac disease. One of the largest and most important studies conducted by Blair, Kohl, Paffenbarger, Clark, Cooper and Gibbons (1989) examined the relationship between physical fitness and mortality. In this large prospective study by Blair et al (1989), 10224 men and 3120 women had their physical fitness measured by a maximal

treadmill exercise test. After an average follow up of eight years, it was found that low fitness levels were an important risk factor for mortality rates in both men and women. Further research conducted by Sui et al (2007) also showed that fitness was a significant mortality predictor in older adults (Sui, LaMonte, Laditka, Hardin, Chase, Hooker & Blair, 2007).

Vanhees and colleagues (1994) also discovered that exercise capacity was a strong prognostic indicator of all cause and cardiovascular mortality in cardiac patients (Vanhees, Fagard, Thijs, Staessen & Amery, 1994). Vanhees et al (1994) concluded that an increase in oxygen uptake by 1 litre/min could be associated with decreases in all cause and cardiovascular mortality of 57% and 71% respectively. Recently a comparable study by Keteyian and colleagues (2008) found a more modest value indicating that every 1 $ml \cdot kg^{-1} \cdot min^{-1}$ increase in peak $\dot{V}O_2$ was associated with an approximate 15% decrease in risk of death in patients with coronary heart disease (Keteyian, Brawner, Savage, Ehrman, Schairer, Divine et al, 2008).

Similar to Vanhees et al (1994), Myers et al (2002) found that exercise capacity was the strongest risk factor of mortality in cardiac patients even when other risk factors were taken into account (Myers, Prakash, Froelicher, Partington & Atwood, 2002). Their large study of 6213 men, both healthy (2534) and with cardiovascular disease (3679), was conducted through treadmill exercise testing. A follow up assessment was conducted six years later and the results were analysed. Myers et al (2002) found that after adjustment for age the peak exercise capacity measured in METs was the strongest predictor of mortality for both healthy men and

men with cardiovascular disease. In addition, each 1 MET increase in exercise capacity conferred a 12% improvement in survival.

Kavanagh et al (2002) also showed the benefits of high physical fitness on the risk of mortality (Kavanagh, Mertens, Hamm, Beyene, Kennedy, Corey et al, 2002). Kavanagh et al (2002) took peak cardiorespiratory exercise test data for 12,169 male cardiac rehabilitation candidates (aged > 55 years) which was collected over a period of 4 to 29 years. Kavanagh et al (2002) found that patients who had a MET value between 4.3 and 6.3 or a MET value above 6.3 had a 38% and 61% reduction in the risk of cardiac death respectively, compared to a patient with a MET value below 4.3. Kavanagh et al (2002) stated that no matter whether a cardiac patient was referred for rehabilitation after myocardial infarction, coronary artery bypass graft, or the onset of ischemic heart disease, the most important single predictor of both cardiac and all-cause deaths was the $\dot{V}O_2$peak as measured by cardiorespiratory testing.

In addition to providing cardiac patients with important diagnostic information about their disease, functional capacity is also an important tool in cardiac rehabilitation programmes for risk stratification. It is essential before beginning exercise in cardiac rehabilitation that cardiac patients are risk stratified as low, medium or high risk patients. As part of the risk stratification process, each patient should have their functional capacity measured (BACR, 2009). The most commonly used and detailed risk stratification guidelines are the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) guidelines (2004), the American College of Sports Medicine (ACSM) guidelines (2010) and the American Heart Association (AHA) guidelines (Fletcher, Balady, Amsterdam, Chaitman, Eckel,

Fleg, et al, 2001). According to these guidelines, patients can be classified as high risk (functional capacity < 5 METs), moderate risk (functional capacity < 6 METs) or low risk (functional capacity > 7 METs). Functional testing is an important component in cardiac rehabilitation as it allows health professionals to prescribe a safe and effective exercise prescription for each patient. The BACR (2009) state that whether a patient has a high or low fitness, it is vital that the cardiac practitioner knows the patients initial functional capacity and their threshold of clinical changes. This information provides the cardiac specialist with the knowledge to prescribe an appropriate volume and intensity of exercise suitable for each patient.

The Department of Health (DOH) commissioned a new set of guidelines for cardiac rehabilitation and introduced a seven stage pathway. Thia now includes a compulsory pre exercise programme fitness assessment and a post exercise programme fitness assessment (DOH Service Specifications for Cardiac Rehabilitation Services, 2011). The introduction of the new commissioning guideline highlights the importance that the DOH has placed on measuring functional capacity in cardiac rehabilitation.

2.3 Measuring Functional Capacity

There are numerous ways clinicians can measure oxygen uptake in individuals. The choice of exercise protocol used for each patient is largely dependent on an individuals functional status and the objective of the test. Traditionally, maximal exercise tolerance tests such as the Bruce protocol, the modified Bruce protocol and the Balke protocol treadmill test are all used for calculating cardiorespiratory fitness. Maximal cardiopulmonary exercise testing has

the advantage of being the 'gold standard' measurement in the prediction of $\dot{V}O_2$max (Palange, Ward, Carlsen, Casaburi, Gallagher, Gosselink et al, 2007)). A major drawback to maximal exercise testing however is that it requires individuals to exercise to the point of volitional fatigue which can be dangerous, especially in a cardiac disease population. In the absence of maximal cardiopulmonary exercise testing which requires specific clinical laboratory time, specially trained staff, immediate medical emergency care, highly motivated participants and is costly to run; cardiac rehabilitation programmes require other alternatives for exercise testing (BACR, 2009).

Submaximal exercise tests are commonly used as an alternative to maximal testing in cardiac rehabilitation to calculate the functional capacity of cardiac patients. Submaximal exercise tests are useful as they are able to predict $\dot{V}O_2$max based on heart rate responses and oxygen uptake at various submaximal levels of work. $\dot{V}O_2$max can also be estimated using prediction equations given by the ACSM (2010). This is especially beneficial for cardiac patients in cardiac rehabilitation as the intensity of exercise can be kept to a level which is below the threshold for the patient to develop cardiac symptoms or clinically significant changes (e.g. ischemia or ST segment depression). Many patients in cardiac rehabilitation are likely to be limited physically by pain, fatigue, abnormal gait or impaired balance (Noonan & Dean, 2000). Submaximal testing would also be more beneficial for older individuals in cardiac rehabilitation who are more prone to physical limitations as it is not susceptible to many of the restrictions which occur during maximal exercise testing.

Compared to maximal exercise tests, submaximal exercise tests have had limited development and research. This is unfortunate as there are a large number of

patient types and individuals who would benefit greatly from submaximal testing (Noonan & Dean, 2000). Submaximal tests such as the incremental shuttle walk test, the six minute walking test and the CST are all currently used in cardiac rehabilitation programmes in the UK. These tests are especially helpful for use in cardiac rehabilitation as a highly accurate value of oxygen uptake is not always necessary. Generally, cardiac patients who have a low starting fitness level only need an exercise test to evaluate their functional capacity and to monitor the effectiveness of the treatment. In most cases, cardiac patients do not perform maximal bouts of activity in everyday life, so submaximal tests appear to more accurately reproduce everyday activities like walking or climbing the stairs (Metra, Nodari, Raccagni, Garbellini, Boldi, Bontempi et al, 1998). Another benefit of submaximal tests is that they require less equipment and are easier to conduct, compared to maximal tests which require advanced laboratory equipment and trained staff to operate it.

2.4 Chester Step Test

The CST is a submaximal, multistage fitness test which measures heart rate and RPE continuously during exercise, to provide a simple, yet effective way to assess an individuals aerobic capacity (Sykes, 2010). Step testing is not a new concept to measure $\dot{V}O_2$max. The Canadian step test (Shephard, Bailey & Mirwald, 1976) has been used for many years to predict $\dot{V}O_2$max. This step test did not measure heart rate during exercise but measured a recovery heart rate post exercise to predict $\dot{V}O_2$max. The CST, however, measures heart rate during exercise, providing a more accurate measuring technique (Sykes, 2010).

The CST has many practical advantages as an exercise testing protocol. The equipment required to complete the test are a step, a portable compact disc player, a CST recording sheet, a heart rate monitor and a rate of perceived exertion (RPE) measurement scale (Buckley, Sim, Eston, Hession and Fox, 2004). This makes the CST very portable, inexpensive and also allows the test to be performed in a very limited space. The test is a submaximal test and requires an individual to exercise at 80% of their maximum heart rate, thereby allowing the test to be safe and controlled. Another very practical advantage is that the stepping is familiar to most people.

The CST has been found to be a valid exercise test in assessing aerobic capacity in healthy individuals (Sykes and Roberts, (2004), Cook, (1996)). An early study by Cook (1996), investigated the relationship in $\dot{V}O_2$max values between a maximal incremental treadmill test and CST in 26 subjects. $\dot{V}O_2$max was not found to be significantly different between the two exercise protocols (treadmill $\dot{V}O_2$max = 60.5 ± 9.96 ml·kg^{-1}·min^{-1}, CST $\dot{V}O_2$max = 56.9 ± 7.95, $p > 0.05$). This trial must be viewed with caution however, as the numbers of participants in the study were relatively small, questioning the statistical power of the results. The study was also carried out exclusively on a healthy young student population so is not a true representative sample of the entire population and possibly even less applicable to cardiac patients.

Sykes and Roberts (2004) found similar results to those of Cook in 68 healthy subjects examining the relationship of $\dot{V}O_2$max values achieved between a maximal incremental treadmill test and the CST. A high correlation was found between maximal treadmill testing and the CST ($r=0.92$) with a standard error of 3.9 ml·kg^{-1}·min^{-1}. The error of margin in this study means that $\dot{V}O_2$max, measured by the

CST, may be underestimated by about 5-15% in comparison to a maximal incremental treadmill test. This finding indicates that although the CST may give a good predicted $\dot{V}O_2$max value in these individuals, there is still a margin for error that needs to be taken into account in any testing. In research conducted by Buckley et al (2004) looking at the reliability and validity of the CST, this underestimation of $\dot{V}O_2$max from the CST was found to have an even greater margin of error at 19%. Such a large margin of error could have a significant effect on the viability of these results in predicting $\dot{V}O_2$max.

The CST is a valid measure of predicting $\dot{V}O_2$ no matter what arm action is used. Elliot, Abt and Barry (2008) examined the effect of an active arm swing versus a passive arm swing on heart rate and the predicted $\dot{V}O_2$ during the CST. Elliot et al (2008) discovered that the use of an active arm swing increased heart rate on average by about 7 beats per minute at each stage of the CST although this was deemed to be not statistically significant. These results indicate that when performing the CST, participants are able to adopt an arm action that is compatible with their own personal preference.

The CST is also a reliable exercise test in assessing aerobic capacity in both healthy individuals and individuals with cardiac disease (Cook, (1996), Reardon, (2008) and Buckley et al, (2004). Cook (1996) showed that the CST had a high retest reliability (r=0.92) in healthy individuals. Similarly, Reardon (2008) found that a practice test was not required for the CST in patients undergoing cardiac rehabilitation. Reardon also showed that there was no significant difference in oxygen consumption when cardiac patients performed a CST at baseline and then again one week later (1^{st} test = 28.9 ± 7.97 ml·kg^{-1}·min^{-1}, 2^{nd} test = 27.8 ± 7.98

ml·kg^{-1}·min^{-1} p > 0.05). The research does suggest that the CST could be used over a wide range of ages and abilities and its use in cardiac rehabilitation is certainly of value.

2.5 Handrail Support

The use of handrail support in exercise test modalities is not uncommon. In health club settings, exercisers are often seen holding onto handrails on a treadmill or stair-climber. This is especially apparent when individuals are finding it difficult to keep up with the speed or grade of the exercise machine. The American College of Sports Medicine (ACSM) testing guidelines state that during treadmill exercise testing, individuals may hold onto a handrail lightly for balance and stability (ACSM, 2009). However, the ACSM (2009) also mention that tight gripping of a handrail should be avoided as this could reduce the accuracy of estimating aerobic capacity. The American Heart Association (AHA) believe that handrail use during exercise testing should be avoided altogether as handrail use can actually overestimate aerobic capacity by decreasing the metablic cost of the work rate (Myers, Arena, Franklin, Pina, Kraus, McInnis & Balady (2009) and Arena et al, (2007)).

There have been several studies that have investigated the use of handrail support in exercise testing. Most of these studies have investigated the oxygen costs of handrail support in treadmill testing and motorised stair-climbers. A recent study by Berling, Foster, Gibson, Doberstein & Porcari (2006) examined the effect of handrail support on HR and $\dot{V}O_2$ responses during steady state treadmill exercise. Four healthy men and six healthy women were recruited for this study (age 28 – 60 years). Each participant performed a modified Bruce protocol on a treadmill until they

reached exhaustion to define their $\dot{V}O_2$ max and ventilatory threshold. Following this, the volunteers performed 3 randomised steady state exercise bouts on a treadmill. Each individual performed the exercise with a free arm swing, then with their hands resting on a front handrail and finally with hands gripping a front handrail. Each exercise was performed in three, 5 minute stages, at intensities corresponding to 75%, 85% and 95% of each individual's ventilatory threshold.

A significant difference in $\dot{V}O_2$ and HR was found between handrail support gripping versus handrail support resting and then between handrail support gripping and free arm swing at 75%, 85% and 95% ventilatory threshold intensities ($P < 0.05$). At the heaviest workload (95% ventilatory threshold) the difference in $\dot{V}O_2$ between handrail support gripping and free arm swing was 7 $ml \cdot kg^{-1} \cdot min^{-1}$ (2 METs). This difference equates to a 15 – 20% reduction in aerobic demand. A significant difference was also found for HR between handrail support resting and free arm swing at 75% ventilatory threshold and for $\dot{V}O_2$ between handrail support resting and free arm swing at 95% ventilatory threshold ($P < 0.05$). The results from this study indicate that gripping a handrail during treadmill exercise alters both the $\dot{V}O_2$ and HR responses when compared to a free arm swing. There is also some evidence to show that resting hands on a handrail support during treadmill exercise alters $\dot{V}O_2$ and HR but the evidence of this is not as conclusive. The small number of participants used in this study (N = 10) is a limiting factor and may question the validity of the results. The exercise sessions were limited to 5 minute periods and were restricted to steady state exercise; therefore the results of this study may not be comparable to the ramped treadmill Bruce protocol.

Christman, Fish, Bernhard, Frid, Smith and Mitchell (2000) found comparable results to Berling et al (2006) in a study which investigated the effects of handrail support during exercise on a stairmaster exercise machine in healthy women. Christman et al (2000) discovered that handrail support significantly lowered $\dot{V}O_2$ and heart rate compared to a hands free exercise at a corresponding exercise intensity.

A study investigating the effects of upper body support on $\dot{V}O_2$ and heart rate (HR) responses on an electronic stepping ergometer was produced by Howley, Calacino and Swensen (1992). They recruited 12 healthy male volunteers (age 20 - 33 years). Of the 12 volunteers, 6 participated in the handrail part of the study. The other 6 participants were excluded from handrail part of the study due to insufficient data. The 6 eligible participants performed exercise on the stepping ergometer on 3 occasions, each time at a different work rate (4 METs, 7 METs & 10 METs) for a period of 12 minutes each. For the first 6 minutes of exercising the participants did not hold on to the handrails and for the second 6 minutes the participants were allowed to hold onto the handrail. Values for HR ($P = 0.017$) and $\dot{V}O_2$ ($P = 0.002$) were found to be significantly lower with handrail support at the 10 MET work rate. Howley et al (1991) noted that the differences in HR and $\dot{V}O_2$ were largest at the 10 MET level when participants had a “heavy hold” of the handrail compared to a “light hold” and “no hold” at all. Contrary to the findings by Christman et al (2000), the results found by Howley et al (1992) showed there was no significant difference in $\dot{V}O_2$ and HR when handrails were used compared to hands free at the lower intensity work rates (4 METs & 7 METs). This study indicated that light handrail use to aid balance could be used on an electronic step ergometer but, at higher levels of

exercise, heavy handrail support could affect HR and $\dot{V}O_2$ responses. The low numbers of participants in this study may also reduce the statistical power of these results.

Manfre, Yu, Varma, Mallis, Kearney & Karageogis (1994) investigated the effects of fingertip support on total treadmill time and $\dot{V}O_2$max prediction. Eleven healthy men (mean age 58 ± 9.6 years), 15 healthy women (mean age 53 ± 7 years) and 34 male cardiac patients (mean age 65 ± 6.8) were recruited for this study. The cardiac patients recruited for the study had either a documented angioplasty procedure or had a history of myocardial infarction. Every participant in the study performed 2 modified Bruce treadmill tests, one with no handrail support and another with limited handrail support (fingertip only) on a front handrail. There was found to be no significant difference ($P > 0.05$) in measured $\dot{V}O_2$max within each patient group between the handrail support test and no handrail support test. There was also no significant difference ($P > 0.05$) in percent of predicted maximal heart rate within each patient group between handrail support and no handrail support. Holding onto the handrail with fingertips did significantly increase total treadmill time in healthy women and cardiac patients but this significant difference was not seen in the healthy male group. Although treadmill time was significantly higher when a handrail support was used in cardiac patients, this did not appear to affect their $\dot{V}O_2$max value.

McConnell, Foster, Conlin and Thompson (1991) similarly found that both $\dot{V}O_2$peak (31.0 v 31.9 $ml \cdot kg^{-1} \cdot min^{-1}$) and peak HR (157 v 158 $beats.min^{-1}$) were not significantly different ($p > 0.05$) in 41 patients during treadmill exercise either with or without handrail support. However, just as was found by Manfre et al (1994) total

treadmill time was significantly longer with handrail support in comparison to hands free.

A recent study by Dalton (2008) examined the physiological effects of handrail use during submaximal walking and jogging exercise in 12 young healthy individuals. The participants were asked to perform two 10-minute walking stages (at 3.5mph) and two 10-minute jogging stages (at 5.5 mph) both with and without handrail support. The physiological variables compared in this study were $\dot{V}O_2$, cardiac output (Q), volume of carbon dioxide (VCO2), expired ventilation (VE), frequency of breaths (Fb), Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), Stroke volume (SV), arteriovenous oxygen difference ($(a-\bar{v})O_2$ diff), systemic vascular resistance (SVR), myocardial oxygen consumption ($M\dot{V}O_2$), and tidal volume (TV). After performing statistical analyses on the data, it was found that handrail support did not significantly change ($p > 0.05$) any of these physiological variables in comparison to no handrail support. The study sample was small, but it was still concluded that handrail support did not alter the physiological variables elicited during submaximal exercise.

To date, there has only been one study that examined the effects of holding onto a handrail during the CST. A recent study by Barnett (2010) examined the physiological effects of holding a front handrail during the completion of the CST compared to completing it hands-free. Ten healthy males and 20 healthy females completed the study (age 19 – 39 years). Every participant completed the CST under two conditions in a randomised order; completing the CST holding a handrail and completing the CST hands free. The test was terminated when an individual

recorded an RPE value above 14, or if their heart rate reached 90% of its predicted maximum.

This study found no statistically significant differences ($p > 0.05$) in ratings of perceived exertion, oxygen uptake, respiratory exchange ratio, respiratory rate, tidal volume and minute ventilation, between holding a handrail, and having hands free during each stage of the CST. A statistically significant difference was observed in the prediction of $\dot{V}O_2max$ (handrail, 44.8 (SD 8.3) $ml \cdot kg^{-1} \cdot min^{-1}$and hands free, 41.4 (SD 7.5) $ml \cdot kg^{-1} \cdot min^{-1}$ ($p<0.05$)). The mean $\dot{V}O_2max$ prediction was significantly overestimated by 3.4 $ml \cdot kg^{-1} \cdot min^{-1}$, equating to a value of around 1 MET. It could be argued that this overestimation falls within the standard error of the CST and that for individuals with a high functional capacity this would not be of major concern. This overestimation of 1 MET however, may cause problems when exercise prescriptions of cardiac patients are required for cardiac rehabilitation programmes.

2.6 Safety of Exercise Testing

Although participation in exercise testing carries an element of risk, with appropriate supervision, risk stratification and monitoring, exercise testing is safe to perform for both healthy individuals and individuals with cardiac disease. In a large US study investigating the incidence of cardiac events in medical centres, Stuart and Ellestad (1980) found that in 518,448 symptom limited exercise tests, the incidence of cardiac events was low. The authors found that in a mixed population, the incidence of a patient suffering a myocardial infarction occurred in approximately 4 patients for every 10,000 exercise tests performed. The risk of death was even lower with approximately 0.5 deaths per 10,000 exercise tests. These results were based

on symptom limited testing so it would be expected that the risk of submaximal testing in a similar population would be even lower (ACSM, 2009).

Chapter 3
Methodology

3.1 Overview

This study was an intergroup analysis project which collaborated with two other University of Chester MSc research projects. The aim of this study was to perform an intergroup analysis of three different population groups: young and healthy, middle-aged and healthy, and cardiac patients. The collaborators who contributed to this study were fellow MSc students Amy Fairhurst and Jerry Ikkattumannil. The study by Amy Fairhurst investigated the physiological effects of holding a side handrail during a CST in a group of cardiac rehabilitation patients. The study by Jerry Ikkattumannil investigated the physiological effects of holding a side handrail during a CST in a group of middle-aged, healthy Asian individuals. My study investigated the physiological effects of holding a side handrail during the CST in younger healthy individuals, and I performed an intergroup analysis comparing oxygen costs between the three participant groups. My collaborators did a more detailed analysis of their respective groups while I primarily focused on oxygen costs within the young and healthy group and between the three groups. The most notable difference between the three collaborating studies was the population group being tested. Since my study performed an intergroup analysis comparing oxygen costs, I included the relevant data necessary for my analysis from my collaborators' studies with their permission. This collaboration between three similar studies which facilitated an intergroup analysis provides a more comprehensive, complete analysis of the effect of a side handrail support on oxygen costs during the CST.

3.2 Participants

Fifteen young healthy participants (5 males, 10 females) volunteered to take part in this study. From the collaborating studies 10 older healthy participants (3 males, 7 females) and 7 cardiac patients (7 males, 0 females) were recruited. On average, the young healthy participants had a mean (±SD) age of 23.4 ± 3.3 years, the older healthy participants had a mean age of 36.4 ± 6.1 years and the cardiac patients had a mean age of 60.3 ± 11.8 years.

The majority of the young healthy participants were recruited from a student population based at the University of Chester, Cheshire. The older healthy participants were recruited from a south Asian population based in Cheshire. All of the healthy participants were recruited on a voluntary basis and were adjudged to be healthy if they met the following inclusion criteria: were aged between 18 to ≤ 45 years for males, aged between 18 to ≤ 55 years for females, had no symptoms of or known presence of heart disease, and had no major cardiovascular disease risk factors. The inclusion criteria the participants had to meet were based on the risk stratification criteria published by the ACSM (2009). Before exercising, all healthy participants were given a participant information sheet (Appendix A), completed a consent form (Appendix B) and a health screening questionnaire (Appendix C).

The cardiac patients who volunteered for this study were recruited from the cardiac rehabilitation exercise classes that take place at the University of Chester. To participate in the study the cardiac patients had to meet the following inclusion criteria: they had to have attended at least three weeks of exercise classes in a cardiac rehabilitation programme, they had a blood pressure within their normal range for exercising, they had no limiting symptoms at the time of testing, they had

no ill effects in the week prior to testing and had no musculoskeletal problems that would affect their mobility. Before exercising, all cardiac participants were given a participant information sheet (Appendix D) and completed a consent form (Appendix E).

To ensure patient confidentiality, all participants were allocated a testing number. This number system was used in place of participant names throughout the study in order to maintain privacy of data.

3.3 Ethical Approval

Ethical approval for the study was granted by the University of Chester Ethics Committee (Appendix F) and the Lancaster NHS Ethics Committee (Appendix G). As the intergroup analysis included information from both healthy individuals and cardiac patient groups, ethical approval from the NHS ethics committee approving the cardiac patient group for the study of my colleague Amy Fairhurst was also documented in the appendices.

3.4 Study Design

This study was designed to investigate the effects a side handrail support had on oxygen uptake in young healthy individuals, older healthy individuals and in patients with cardiac disease. To do this, the study followed a repeated measures design. Participants performed a CST both with and without handrail support on either two or three occasions. The younger healthy participants completed three test protocols; performing the CST hands free, holding onto a side handrail with one

hand and holding onto a side handrail with two hands. Due to time limitations, the older healthy participants and cardiac patients completed two CSTs; hands free and holding onto a side handrail with one hand. The order the participants completed the testing protocols was randomised by using a ‘numbers out of a hat’ system, this was done on the day of the first testing session. Healthy participants then had the option of completing the exercise tests in a single day or over multiple testing days. The participants who performed multiple exercise tests in a single day were given a minimum of 30 minutes rest between each of the testing sessions to allow the heart rate to return to a resting level. In this recovery time participants were given the chance to relax and eat a light snack if required. The cardiac patients performed just one exercise test at a time and testing sessions were separated by a period of at least one week.

All the testing of the healthy participants took place within a classroom laboratory located at the University of Chester. The testing of the cardiac patients took place in a university gym hall at the University of Chester. The temperature of the laboratory and gym hall remained similar throughout the testing period. Prior to the start of the first exercise test each participant was introduced to the RPE scale and given the chance to familiarise themselves with wearing the gas analysis face mask. Standardised instructions of the RPE scale were also given to each participant. The starting exercise point of the CST is set at a very low tempo, so this first stage of the test was used as a familiarisation period for each participant. A flow chart describing the study design is shown in Figure 3.1.

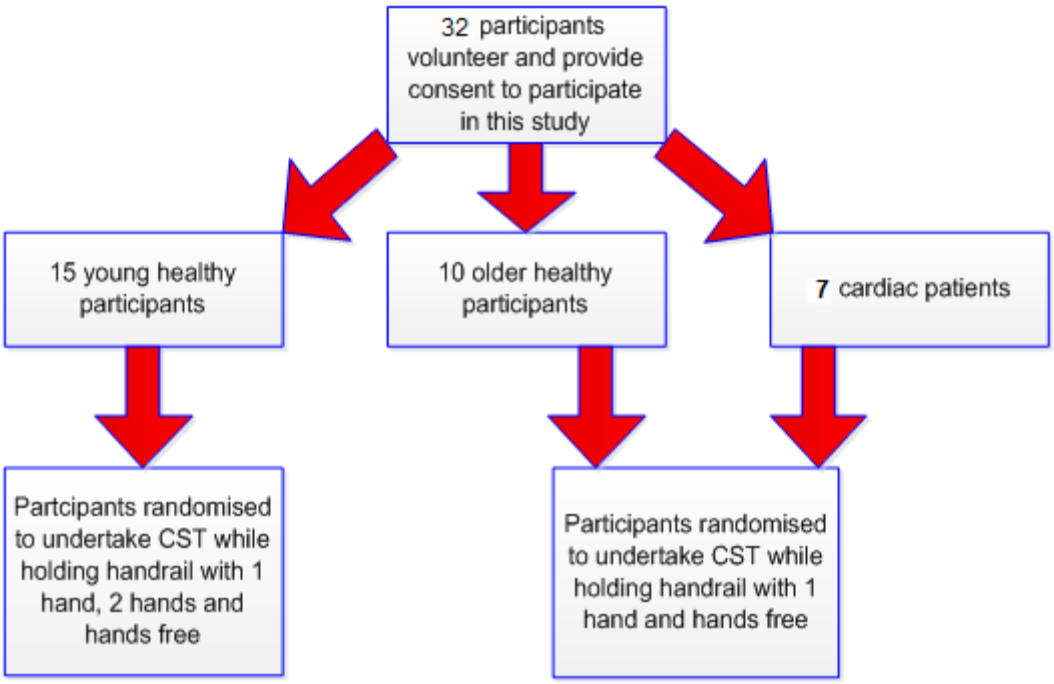


Figure 3.1. Flow chart of the study design

3.5 Equipment and Measurements

Prior to the participants taking the exercise test, each individual's height, weight, blood pressure and resting heart rate were calculated. Height was measured using a wall stadiometer (Seca, Germany) and weight was measured using calibrated weighing scales (Seca, Germany). For both height and weight measurements, participants were asked to remove their footwear. Height was calculated to the nearest centimetre and weight was measured to the nearest 0.1kg. Blood pressure was recorded manually using an adult blood pressure cuff (Welch Allyn, USA) and stethoscope. Blood pressure was measured when the participants were seated and relaxed. Heart rate (HR) was measured using a Polar T31 HR monitor (Polar, Finland). The HR monitor was worn by the participant around the chest and HR was monitored by the researcher using the accompanying HR watch.

The CST compact disc (Sykes, 2010), an RPE scale (Borgs 6-20 scale), a 30cm CST box and an adjustable Reebok step were used to carry out the step test. The handrails used were two cycle ergometers (Monark Ergomedic 818E, Sweden) with adjustable handlebars. A photograph displaying how the equipment was set up for exercise testing is shown in Appendix H. Gas analysis was measured using a portable online breath by breath analyser (Cortex Metalyzer 3B, Germany). This gas analyser is an accurate and reliable tool for measuring an individual's gas exchange measurements (Meyer, Georg, Becker and Kindermann, 2001). Forty five minutes prior to the start of each exercise test session, the gas analyser was switched on to allow the analyser time to 'warm up'. The gas analyser was calibrated at the start of each testing day by the project supervisor or researcher. A 3 litre syringe was used to calibrate the air volume, and gas volume was calibrated using pre measured gas canisters containing 17.02% O_2, 4.98% CO_2 and a balance of N_2. The temperature of the room was also recorded.

3.6 Test Procedure

3.6.1 Healthy Participants

On arrival to the study laboratory, each participant was seated, given a participant information sheet, a pre exercise health screening questionnaire and a study consent form. The health screening questionnaire and consent form were completed and signed by each participant, and countersigned by the study researcher.

Once the forms had been completed, the participants had their height and weight measured using a wall stadiometer and weighing scales. Participants were fitted with a heart rate monitor worn around the chest for the duration of the testing. After the participants were suitably relaxed, a resting heart rate was recorded and blood pressure taken. Blood pressure was measured manually using an adult blood pressure cuff and stethoscope. All the measurements were recorded on a data collection sheet (Appendix I) and entered into the computer software programme.

At the start of each test, participants were given standardised instructions on the use of Borg's 6-20 rating of perceived exertion (RPE) scale (Borg, 1998). Verbal instructions were used to explain: the meaning of RPE, the top and bottom anchoring points of the scale, and the physical, muscular, and cardiorespiratory sensations the participant should be focusing on when using the scale. The RPE scale was positioned in front of the participant and was in view of the participant at all times during the exercise test.

Maximal heart rate for each participant was calculated so a prediction of 80% of heart rate maximum (HRmax) could be used as a test end point. Maximal heart rate was estimated using the equation 220 minus the participant's age. Following the pre-test measurements, participants were fitted with a suitably sized gas analysis face mask and given time to familiarise themselves with the wearing of the mask. After all pre-test measurements had been taken, and the participant was ready to begin the exercise test, the participant was then asked to stand behind the step.

The height of the step used during testing was dependent on the participant's age, physical ability and their current physical activity level. The height of the step varied from 6 inches to 12 inches in height and could be altered for each individual

participant. The aim was to select a step height that would allow each participant to complete at least 3 stages of the CST. This was in accordance with guidelines given in the ASSIST CST manual (2010). In general, the participants who were younger and more active used the 10 and 12 inch step height and the participants who were older and less active used the 6 and 8 inch step height. Professional judgement and advice given by the research supervisor was also used to select the appropriate step height.

When the participant was undertaking the CST when holding the handrails, the height of the handrails was adjusted according to each individuals preference. In this study, the handrails used were the adjustable handlebars from a Monark cycle ergometer. Each participant was then asked to take a couple of steps onto and then off the step while holding on to the handrails. This was used to check if the height of the handrails was both comfortable and suitable. Any alterations to handrail height were then made at this time. The participants undertaking the test with a handrail were told to grip the handrails lightly for support and to avoid gripping tightly during the test. Participants who performed the test without the use of handrail support were advised that they could perform the test with either an active or a passive arm swing. This was in accordance with the findings by Elliot et al (2008). Appendices J, K and L show how the participant would perform the CST with no hands, with one hand holding onto the handrail and with two hands holding onto the handrails. Once all the pre-test procedures had been completed and the participant was happy with the handrail height then the CST could commence.

When the participant was ready to exercise, the gas analyser was connected to the gas mask worn by the participant. The participant was told to listen to the CD instructions and to keep pace with the metronomic beat on the CD track. As this

started, the gas analyser was then switched on to record the data. Every metronome beat heard on the CD recording corresponded to one foot step. The CST had five incremental stepping stages that could last up to a maximum of 10 minutes in total. The stepping rates for each stage in the CST increased every two minutes by a beat of five steps per minute. The starting stepping rate was set at a rate of 15 steps per minute. At each two minute stage the participant's heart rate and RPE was noted and recorded on a data collection sheet (Appendix I). The test continued in this manner until an appropriate end point was reached.

The exercise test was terminated if the participant:

- Managed to complete all five stages of the CST
- Appeared to be stressed and indicated that they wanted to stop
- Reached their target heart rate point of 80% HRmax
- Recorded an RPE value ≥ 15
- Showed any signs of dizziness or over-tiredness
- Was unable to keep up with the metronomic beat

In some cases if the participants recorded a heart rate above 80% HRmax, the test was allowed to continue as long as the participant appeared in good health and recorded an RPE less than 14. Table 3.2 shows the 5 stages of the CST and the oxygen cost estimates for varying step heights and step speeds. The full CST protocol can be found in Appendix M.

On completion or termination of the exercise test, the gas analysis recording was stopped and the participant was allowed to remove the face mask. The participant was provided with a glass of cool water and instructed to keep moving their feet slowly to gradually cool down. Once the participant was seated and their

heart rate returned to normal, the researcher asked some general questions in relation to the test they had just completed. If the participant was completing multiple tests in a single day, the participants were then given at least a 30 minute rest between testing sessions to allow their heart rate return to a resting level. Participants who reported no ill feelings, had completed all of the exercise tests and who were deemed fit to leave, were thanked for their time.

Table 3.2 Oxygen cost and MET estimate values at various step heights and step speeds of the CST

CST Stage	1		2		3		4		5	
Stepping Rate (Steps/min)	15		20		25		30		35	
Step Height	$\dot{V}O_2$	METs	$\dot{V}O_2$	METs	$\dot{V}O_2$	METs	$\dot{V}O_2$	METs	$\dot{V}O_2$	METs
6 inch	11	3.1	14	4.0	18	5.1	21	6.0	25	7.1
8 inch	12	3.4	17	4.9	21	6.0	26	7.4	29	8.3
10 inch	14	4.0	19	5.4	24	6.9	28	8.0	33	9.4
12 inch	16	4.6	21	6.0	27	7.7	32	9.1	37	10.6

3.6.2 Cardiac Patients

Upon arrival to the cardiac rehabilitation class, each cardiac patient was risk assessed by a member of the cardiac rehabilitation staff. The patient had their blood pressure recorded, they were then monitored for any limiting symptoms at the time of testing and were asked if they had no ill effects in the previous week. If the patient was deemed safe to proceed with testing, they were then asked to read a participant information sheet and complete a consent form.

The participant then had their height and weight recorded and were fitted with a heart rate monitor around their chest. Standardised instructions on the use of Borg's 6-20 RPE scale were given to each participant. Following the pre-test measurements, participants were fitted with a suitably sized gas analysis face mask and given time to familiarise themselves with the feeling of wearing the mask. After all pre-test measurements had been taken and the participant was ready to begin the exercise test, the participant was then asked to stand behind the step.

The lowest step height of six inches was chosen as the stepping height for all of the cardiac patients. This height was chosen, so the cardiac patients would be able to complete at least three stages of the CST. Once all the pre-test procedures had been completed and the participant was happy with the handrail height then the CST could commence. The gas analyser was connected to the gas mask worn by the participant and the CD track was started.

At each two minute stage, the participant's heart rate and RPE were noted and recorded on a data collection sheet. The test continued in this manner until an appropriate end point was reached. The target heart rate end point used for each participant was determined by their individual exercising target rate set in their cardiac rehabilitation class. The test termination points were slightly different from those used for the healthy participants, as a higher risk population group was being tested

The exercise test was terminated if the cardiac patient:

- Managed to complete all 5 stages of the CST
- Appeared to be stressed and indicated that they wanted to stop
- Reached their target heart rate point

- Recorded an RPE value ≥ 14
- Showed any signs of dizziness or over-tiredness
- Was unable to keep up with the metronomic beat
- Recorded a respiratory exchange ratio (RER) value ≥ 1.0

On completion or termination of the exercise test, the gas analysis recording was stopped and the participant was allowed to remove the face mask. The participant was instructed to keep moving their feet slowly to gradually cool down. Once the participants heart rate returned to normal, the researcher asked some general questions in relation to the test they had just completed. Participants who reported no ill feelings and who were deemed fit to leave were thanked for their time and could return to their cardiac rehabilitation exercise class.

3.7 Data Collected

Data collected from the gas analyser during the test included O_2 uptake ($ml \cdot kg^{-1} \cdot min^{-1}$), respiratory exchange ratio (RER) and metabolic equivalents (METs). Oxygen uptake was averaged over 30 second periods and recorded until the termination of the test. Heart rate and RPE were also recorded during the CST.

3.8 Statistical Analysis

All statistical analyses were performed using Statistical Package for Social Science (SPSS) version 18.0 for Windows (SPSS Inc., Chicago, USA) with a statistical significance set at p-value 0.05.

The data collected in this study was ratio level data, except for RPE which was treated as interval level data. In order to determine if the set of data was normally distributed, a test for normality was conducted on each testing variable. As the sample size for this study was less than 100, the Shapiro-Wilk test was consulted in order to determine if the data was normally distributed. Under each testing condition, the p-value was greater than 0.05 and so met the assumption for being normally distributed.

Oxygen uptake, METs, heart rate and RPE were compared between each group (Young healthy, old healthy and cardiac patients) and between each testing condition (no hands, 1 hand holding and 2 hands holding) at each stage of the CST. As the testing variables met the condition for being normally distributed, a fully repeated measures ANOVA was carried out. Before the parametric analysis was conducted, the data had to meet the assumption of sphericity. If the data met the assumption of sphericity ($p > 0.05$) then the statistical analysis under 'sphericity assumed' was referred to. If the data did not meet the assumption of sphericity ($p < 0.05$) then then the statistical analysis under 'Greenhouse-Geisser' was referred to. In the event that there were significant differences between the data, post-hoc analyses were carried out using multiple paired t-tests. As multiple tests were conducted at the same time, a Bonferroni adjustment was used in order to reduce the risk of a type 1 error.

Chapter 4

Results

The main aim of this study was to perform an intergroup analysis to investigate if handrail use significantly altered $\dot{V}O_2$ values between the testing groups undertaking the CST. In order for an intergroup analysis to be performed, the data collected from the study collaborators testing groups (middle aged Asian population and cardiac rehabilitation population) was included alongside my current findings from younger healthy individuals. Although some of the data has already been published by the collaborators in their personal studies, it was important to include the collaborators data in this study so that a comparative analysis could be made about handrail support across the three varying population groups. All of the data in this study that represents the other two population groups is presented with the permission of Amy Fairhurst and Jerry Ikkattumannil. In order for a comparative analysis to be conducted between the groups, it was important to first examine each group individually. Although the individual analyses of the other two collaborators studies may appear similar to my individual analyses of the other two groups, I maintain a focus on oxygen costs and the comparison between the results of the three groups is addressed in the discussion section.

4.1 Basic Demographic Data

In total, 36 participants were included in this intergroup analysis study. Sixteen young healthy participants (6 males, 10 females) volunteered to take part in this study. From the collaborating studies 10 older healthy participants (3 males, 7

females) and 7 cardiac patients enrolled in a phase III cardiac rehabilitation exercise programme (7 males, 0 females) were recruited. One of the young healthy participants dropped out of the study due to time constraints; therefore, 15 young healthy participants completed the exercise testing (5 male, 10 female). Descriptive statistics of the participants is shown in Table 4.1. All of the study participants were able to complete at least three stages of the CST protocol. Five healthy young participants were able to complete all five stages of the CST. None of the healthy older participants were able to complete all five stages of the CST. Only one cardiac patient managed to complete four stages of the CST but for statistical reasons this stage was not included in the final analysis for the cardiac patient group. During exercise testing there were no participants who presented with any problematic events.

Table 4.1 Demographic Data of the Participants

	Young Healthy (n=15)	Old Healthy (n=10)	Cardiac Patients (n=10)
Sex	5 male, 10 female	3 male, 7 female	7 male, 0 female
Age (years)	23.4 ± 3.3	36.4 ± 6.1	60.3 ± 11.8
BMI	24.2 ± 2.7	25.3 ± 3.0	25.8 ± 3.7
Height (cm)	165.9 ± 9.4	165.9 ± 10.5	174.6 ± 4.1
Weight (Kg)	67.0 ± 11.6	69.9 ± 12.7	78.3 ± 9.6
Step Height (inches)	10.1 ± 1.9	7.2 ± 1.0	6.0 ± 0

4.2 Was There an Order Effect?

In this study it would be expected that there would be no significant differences to oxygen uptake during the completion of the CST, no matter what order the testing conditions were conducted. To examine if there was an order effect, a fully repeated measures ANOVA was carried out to examine if the randomisation

method which was used in this study had any significant effect on $\dot{V}O_2$ results between trials in each of the three study groups. A summary table showing the trial order in the three testing groups at each stage of the CST can be viewed in Table 4.2. There was found to be no significant differences in oxygen uptake at each stage of the CST between the testing trials in the younger healthy participants ($p = 0.413$), older healthy participants ($p= 0.986$) and cardiac patients ($p = 0.170$). From these results, it can be stated that there was no order effect with the participants used in this study.

Table 4.2 Mean VO_2 values ($ml \cdot kg^{-1} \cdot min^{-1}$) elicited during each of the study trials in the three testing groups at each stage of the CST.

	Young Healthy VO_2			Old Healthy VO_2		Cardiac Patients VO_2	
CST Stage	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 1	Trial 2
1	14.3 ± 2.7	14.5 ± 3.2	14.7 ± 3.4	11.2 ± 1.3	11.1 ± 0.8	11.1 ± 1.9	11.8 ± 2.1
2	16.6 ± 2.9	17.2 ± 3.6	17.7 ± 4.1	13.4 ± 1.4	13.6 ± 1.2	13.0 ± 1.1	13.8 ± 2.5
3	20.0 ± 4.1	19.8 ± 3.7	20.1 ± 4.0	15.4 ± 1.9	15.6 ± 1.8	15.4 ± 2.5	16.3 ± 2.3
4	26.1 ± 4.9	25.3 ± 3.5	26.6 ± 5.4	18.9 ± 2.2	19.1 ± 1.6	-	-
5	31.5 ± 4.9	32.7 ± 3.3	33.5 ± 5.2	-	-	-	-

4.3 Comparison of Oxygen Uptake Values between Testing Groups

The main aim of this study was to perform an intergroup analysis to investigate if handrail use significantly altered $\dot{V}O_2$ values between the testing groups undertaking the CST. A summary table of the $\dot{V}O_2$ values in $ml \cdot kg^{-1} \cdot min^{-1}$ (±SD) recorded at each stage of the CST can be viewed in Table 4.3. In all participant groups, a fully repeated measures ANOVA was used to examine if there were any significant differences in $\dot{V}O_2$ between handrail holding and no handrail holding at each stage of the CST. The data comparing $\dot{V}O_2$ between the testing

conditions in the older healthy participant group was given by the study collaborator Jerry Ikkattumannil and adapted to fit the aim of this intergroup analysis. The data comparing $\dot{V}O_2$ between the testing conditions in the cardiac rehabilitation participant group was given by the study collaborator Amy Fairhurst and adapted to fit the purpose of this intergroup analysis.

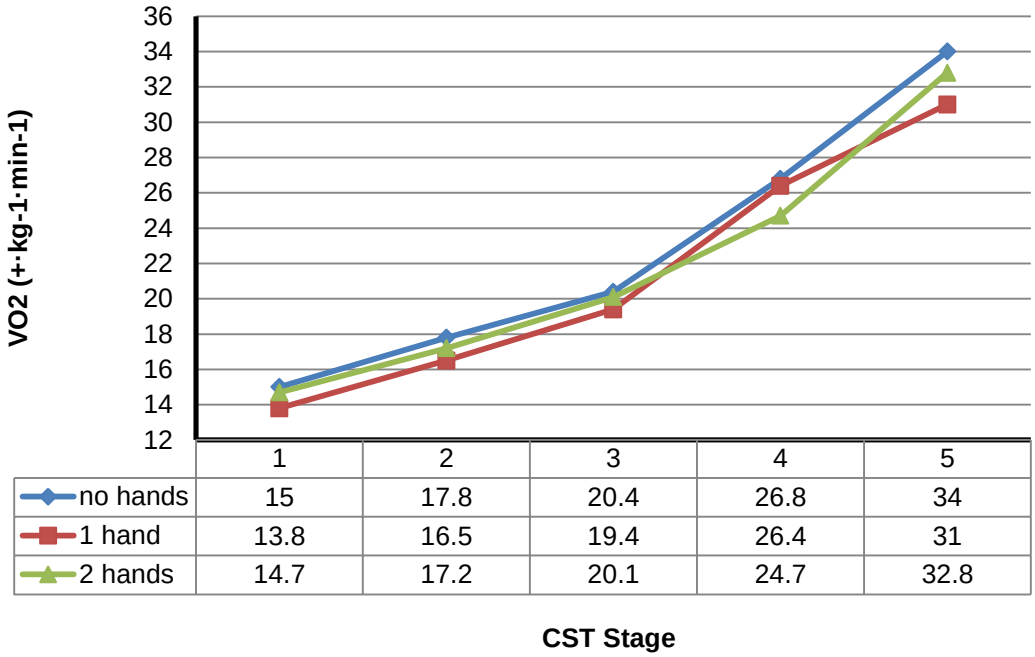
Table 4.3 Mean VO_2 values ($ml \cdot kg^{-1} \cdot min^{-1}$) (±SD) recorded at each stage of the CST in the three participant groups.

	Young Healthy VO_2			Older Healthy VO_2		Cardiac Patients VO_2	
CST Stage	No hands	1 Hand	2 Hands	No Hands	1 Hand	No Hands	1 Hand
1	15.0 ± 3.7	13.8 ± 2.2	14.7 ± 3.1	11.2 ± 1.3	11.2 ± 0.9	11.8 ± 2.1	11.1 ± 1.9
2	17.8 ± 4.0	16.5 ± 3.0	17.2 ± 3.7	13.6 ± 1.5	13.4 ± 1.3	13.9 ± 2.4	12.9 ± 1.2
3	20.4 ± 3.9	19.4 ± 3.7	20.1 ± 4.1	15.5 ± 1.9	15.4 ± 1.9	16.2 ± 2.4	15.4 ± 2.4
4	26.8 ± 4.7	26.4 ± 4.8	24.7 ± 4.3	18.9 ± 1.8	19.1 ± 2.4	-	-
5	34.0 ± 4.0	31.0 ± 5.0	32.8 ± 4.3	-	-	-	-

4.3.1 Comparison of Oxygen Uptake Values in Young Healthy Participants

As $\dot{V}O_2$ is ratio level data and was found to be normally distributed in the young healthy participant sample, a fully repeated measures ANOVA was performed. The fully repeated measures ANOVA revealed that there was no significant difference ($p = 0.158$) in $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) values between holding the handrails with two hands, one hand or no hands. There was also no significant difference ($p = 0.337$) in the interaction effect between handrail holding at each stage of the CST. This is illustrated clearly in Figure 4.1 which demonstrates the mean $\dot{V}O_2$ values recorded between the three testing conditions at each stage of the CST. As the conditions for meeting the null hypothesis cannot be rejected, it can be stated that there is no significant difference in oxygen costs at each stage of the CST when

holding a side handrail with one hand, two hands and hands free in younger healthy individuals.



	1	2	3	4	5
no hands	15	17.8	20.4	26.8	34
1 hand	13.8	16.5	19.4	26.4	31
2 hands	14.7	17.2	20.1	24.7	32.8

Figure 4.1 Mean VO_2 values ($ml \cdot kg^{-1} \cdot min^{-1}$) recorded between the three testing conditions at each stage of the CST in young healthy individuals

4.3.2 Comparison of Oxygen Uptake Values in Older Healthy Participants

In the older healthy participant group the data was deemed to be normally distributed and met all the assumptions for ratio level data. There was found to be no significant difference ($p = 0.495$) in $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) values when holding the handrail with one hand or no hands during the CST. There was also no significant difference ($p = 0.560$) in the interaction effect between the testing condition and CST stage. This indicates that there was no significant difference in the $\dot{V}O_2$ values recorded at each stage of the CST between holding the handrail with one hand or with no hands (as shown in Figure 4.2). As the conditions for meeting the null

hypothesis cannot be rejected, it can be stated that there is no significant difference in $\dot{V}O_2$ values at each stage of the CST when holding a side handrail with one hand and hands free in older healthy individuals.

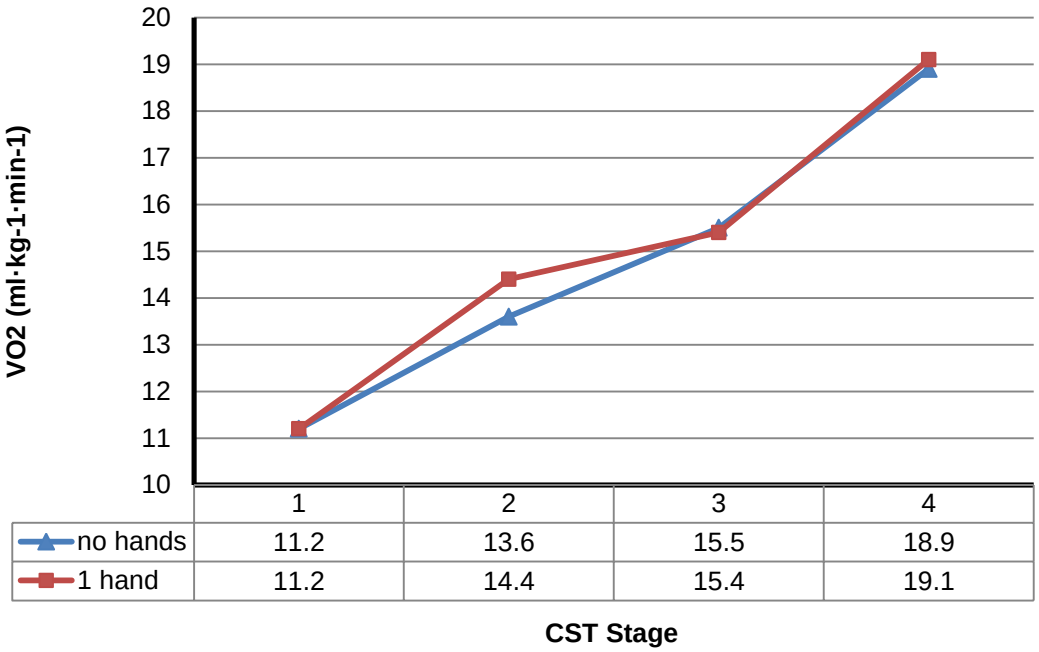


Figure 4.2 Mean VO_2 values ($ml \cdot kg^{-1} \cdot min^{-1}$) recorded between holding the handrail with one and hands free at each stage of the CST in older healthy individuals

4.3.3 Comparison of Oxygen Uptake Values in Cardiac Patients

In the cardiac patient group, the data was deemed to be normally distributed and met all the assumptions for ratio level data. There was found to be no significant difference ($p = 0.139$) in $\dot{V}O_2$ values between holding the handrail with one hand or with no hands during the CST. This is illustrated in Figure 4.3.There was also no significant difference ($p = 0.924$) in the interaction effect between the testing condition and CST stage. This signifies that there were no differences in the $\dot{V}O_2$ values recorded at each stage of the CST between holding the handrail with one

hand or no hands. As the conditions for meeting the null hypothesis cannot be rejected, it can be stated that there is no significant difference in $\dot{V}O_2$ values at each stage of the CST when holding a side handrail with one hand and hands free in cardiac patients.

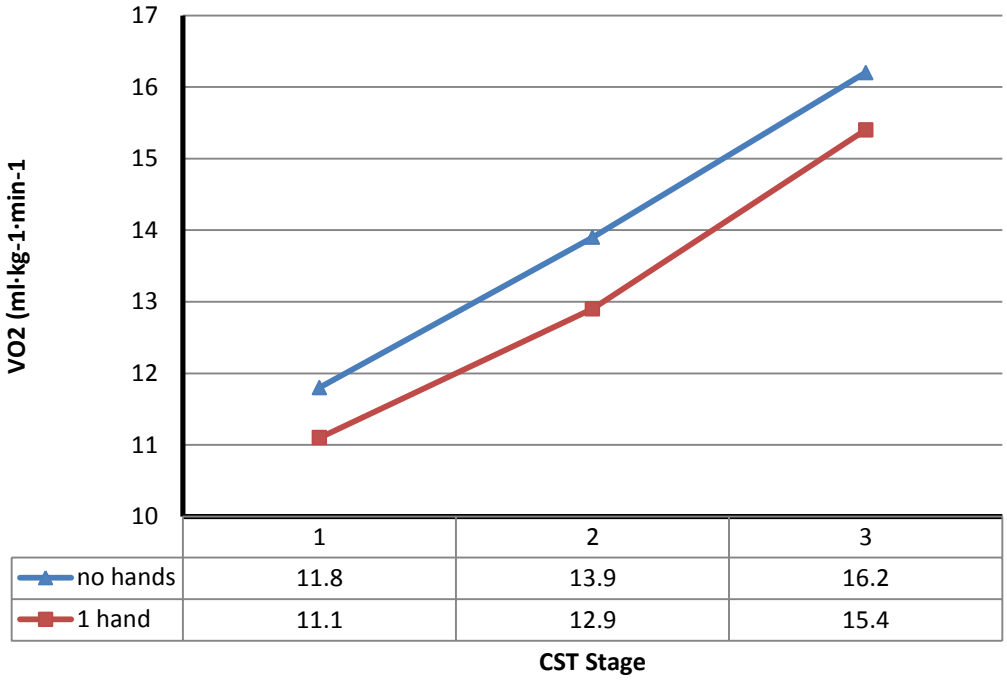


Figure 4.3 Mean VO_2 values ($ml \cdot kg^{-1} \cdot min^{-1}$) recorded between holding the handrail with one and hands free at each stage of the CST in cardiac patients

4.4 Comparison of MET Values between Testing Conditions

A summary table of the MET values (±SD) recorded at each stage of the CST in the three testing groups can be viewed in Table 4.4. In all participant groups, a fully repeated measures ANOVA was used to examine if there were any significant differences in METs values between handrail holding and no handrail holding at each stage of the CST. The data comparing METs between the testing conditions in the older healthy participant group was given by the study collaborator Jerry

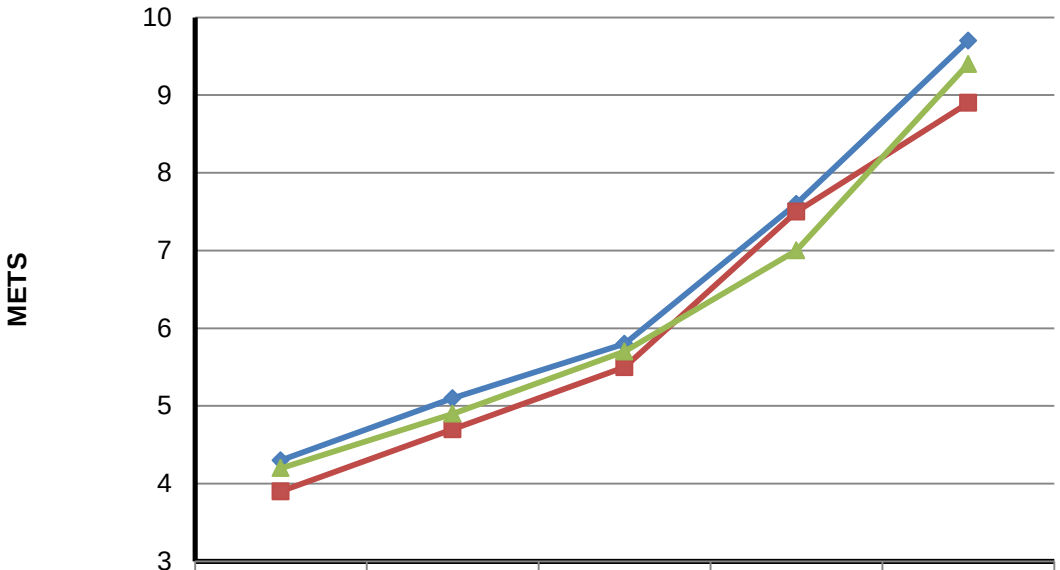
Ikkattumannil and adapted to fit the aim of this intergroup analysis. The data comparing METs between the testing conditions in the cardiac rehabilitation participant group was given by the study collaborator Amy Fairhurst and adapted to fit the purpose of this intergroup analysis.

Table 4.4 Mean MET values (±SD) recorded at each stage of the CST in the three participant groups

	Young Healthy METs			Older Healthy METs		Cardiac Patients METs	
CST Stage	No hands	1 Hand	2 Hands	No Hands	1 Hand	No Hands	1 Hand
1	4.3 ± 1.0	3.9 ± 0.6	4.2 ± 0.9	3.2 ± 0.4	3.2 ± 0.3	3.4 ± 0.6	3.2 ± 0.5
2	5.1 ± 1.1	4.7 ± 0.9	4.9 ± 1.1	3.9 ± 0.4	3.8 ± 0.4	4.0 ± 0.7	3.8 ± 0.5
3	5.8 ± 1.1	5.5 ± 1.1	5.7 ± 1.2	4.4 ± 0.5	4.4 ± 0.5	4.6 ± 0.7	4.4 ± 0.7
4	7.6 ± 1.3	7.5 ± 1.4	7.0 ± 1.2	5.4 ± 0.5	5.5 ± 0.7	-	-
5	9.7 ± 1.1	8.9 ± 1.4	9.4 ± 1.3	-	-	-	-

4.4.1 Comparison of METs in Young Healthy Participants

As METs are ratio level data and the data was normally distributed in the young healthy participant sample, a fully repeated measures ANOVA was performed. The fully repeated measures ANOVA revealed that there was no significant difference ($p = 0.145$) in MET values between holding the handrails with two hands, one hand or no hands. There was also no significant difference ($p = 0.345$) in the interaction effect between handrail holding at each stage of the CST. This is illustrated clearly in Figure 4.4. It can be stated that there is no significant difference in MET values recorded at each stage of the CST when holding a side handrail with one hand, two hands and hands free in younger healthy individuals.



	1	2	3	4	5
no hands	4.3	5.1	5.8	7.6	9.7
1 hand	3.9	4.7	5.5	7.5	8.9
2 hands	4.2	4.9	5.7	7	9.4

CST Stage

Figure 4.4 Mean MET values recorded between the three testing conditions at each stage of the CST in young healthy individuals

4.4.2 Comparison of METs in Older Healthy Participants

In the older healthy participant group, the data was deemed to be normally distributed and met all the assumptions for ratio level data. In this testing group there was found to be no significant difference ($p = 0.508$) in MET values between holding the handrail with one hand or with no hands during the CST. There was also no significant difference ($p = 0.617$) in the interaction effect between the testing condition and CST stage. This indicates that there were no differences in the MET values recorded at each stage of the CST between holding the handrail with one hand or no hands. This can be viewed in Figure 4.5.

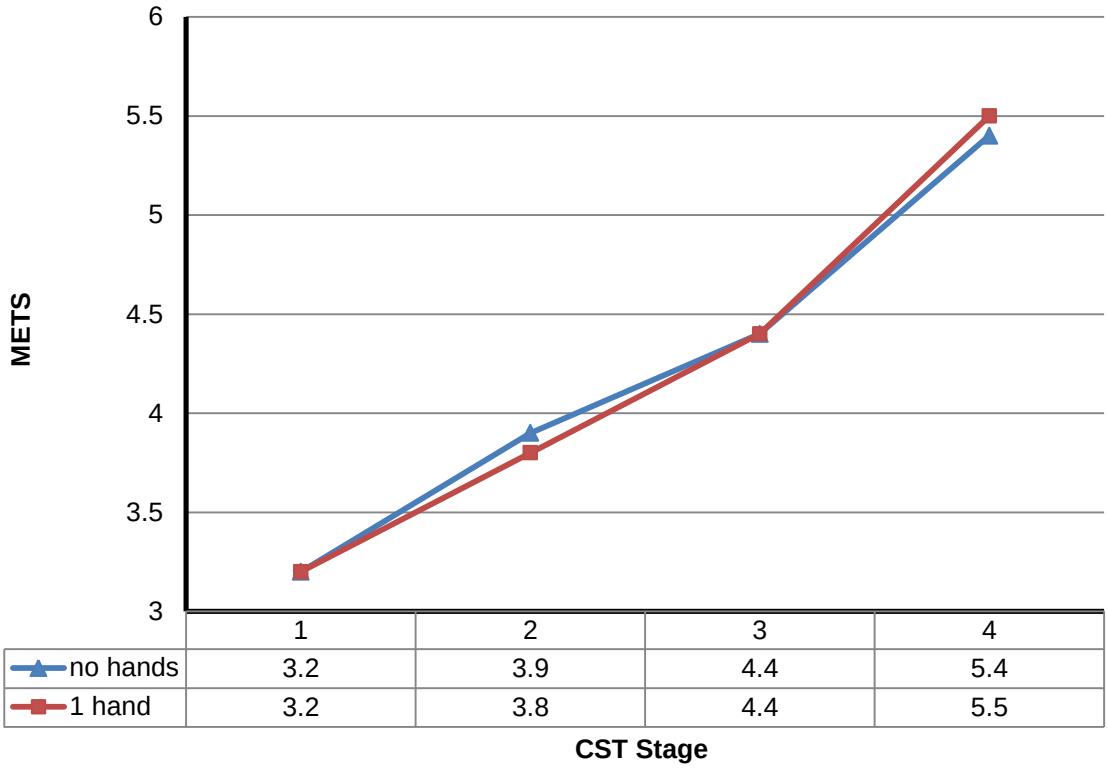


Figure 4.5 Mean MET values recorded between holding the handrail with one and hands free at each stage of the CST in older healthy individuals

4.4.3 Comparison of METs in Cardiac Patients

In the cardiac patient group there was found to be no statistically significant difference ($p = 0.171$) in MET values between holding the handrail with one hand or with no hands during the CST (shown in Figure 4.6). There was also no significant difference ($p = 0.899$) in the interaction effect between the testing condition and CST stage. This indicates that there were no differences in the MET values recorded at each stage of the CST between holding the handrail with one hand or no hands in the cardiac patient group.

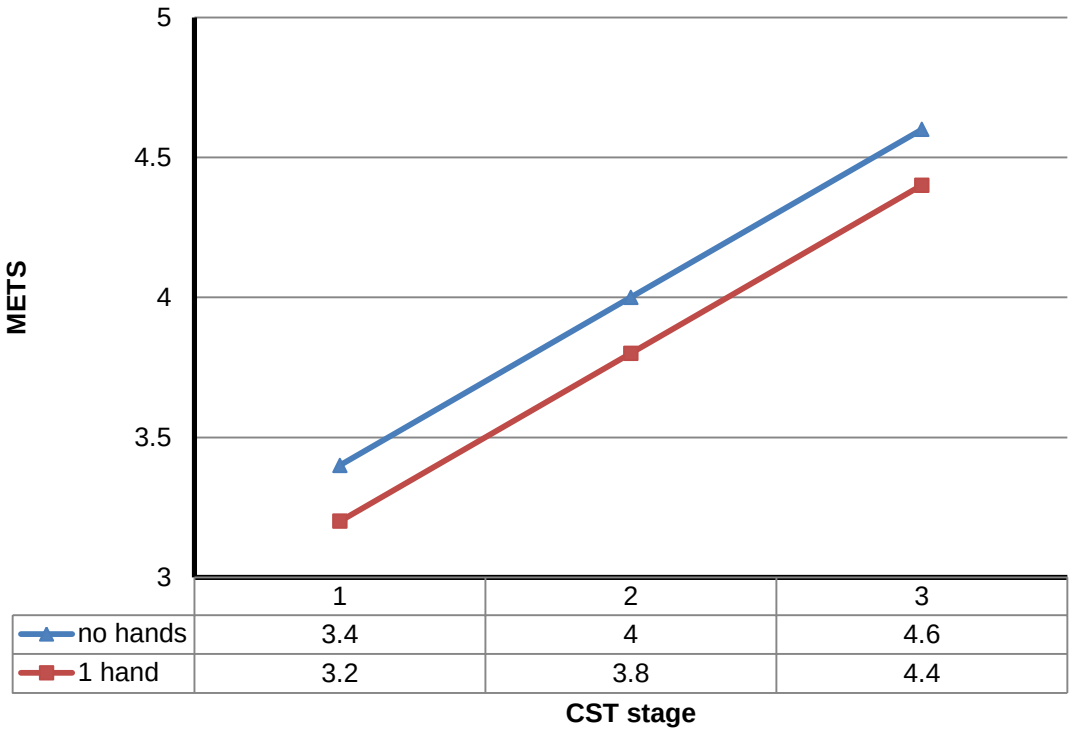


Figure 4.6 Mean MET values recorded between holding the handrail with one and hands free at each stage of the CST in cardiac patients

4.5 Comparison of Heart Rate and Rate of Perceived Exertion

A summary table of HR values (±SD) recorded at each stage of the CST in the three testing groups can be viewed in Table 4.5. The data comparing HR between the testing conditions in the older healthy participant group was given by the study collaborator Jerry Ikkattumannil and adapted to fit the aim of this intergroup analysis. The data comparing HR between the testing conditions in the cardiac rehabilitation participant group was given by the study collaborator Amy Fairhurst and adapted to fit the purpose of this intergroup analysis.

In the younger healthy individuals, there was found to be no significant difference ($p = 0.193$) in HR (bpm) values between holding the handrails with two

hands, one hand or no hands at each stage of the CST. When HR was compared between holding a handrail with one hand and no handrail holding in the older healthy participant group the p-value was 0.028. As the p-value was less than 0.05, it indicated that there was a significant difference in HR values between holding a handrail with one hand and no hands during the CST. To discover where the differences lay, multiple paired t-tests were conducted with a Bonferroni adjustment value set at p = 0.0125. However, at each stage of the CST the p-value for HR was greater than the Bonferroni adjusted p-value of 0.0125. It can be concluded that there was no significant difference in HR values between holding the handrails with one hand and no hands at each stage of the CST in older healthy individuals. In the cardiac patient participant group, there was also no statistically significant differences (p = 0.184) in HR values between holding the handrails with one and no hands at each stage of the CST.

Table 4.5 Mean heart rate values (beats per minute) (±SD) recorded at each stage of the CST in the three participant groups

	Young Healthy HR			Older Healthy HR		Cardiac Patients HR	
CST Stage	No hands	1 Hand	2 Hands	No Hands	1 Hand	No Hands	1 Hand
1	115.5 ± 16.6	115.9 ± 13.5	114.3 ± 17.6	113.1 ± 12.2	108.6 ± 8.6	84.0 ± 12.1	81.9 ± 9.3
2	128.8 ± 16.9	127.6 ± 17.0	126.5 ± 19.1	125.7 ± 12.8	119.6 ± 11.4	90.6 ± 10.7	87.4 ± 10.3
3	144.2 ± 17.7	140.7 ± 17.7	140.2 ± 18.1	140.1 ± 14.1	135.8 ± 13.9	98.4 ± 10.8	94.6 ± 10.8
4	164.2 ± 12.1	161.4 ± 18.3	155.8 ± 17.9	159.6 ± 11.9	157.3 ± 12.0	-	-
5	179.6 ± 9.8	178.2 ± 10.7	172.0 ± 12.5	-	-	-	-

A summary table of RPE values (±SD) recorded at each stage of the CST in the three testing groups can be viewed in Table 4.6. The data comparing RPE

between the testing conditions in the older healthy participant group was given by the study collaborator Jerry Ikkattumannil and adapted to fit the aim of this intergroup analysis. The data comparing RPE between the testing conditions in the cardiac rehabilitation participant group was given by the study collaborator Amy Fairhurst and adapted to fit the purpose of this intergroup analysis.

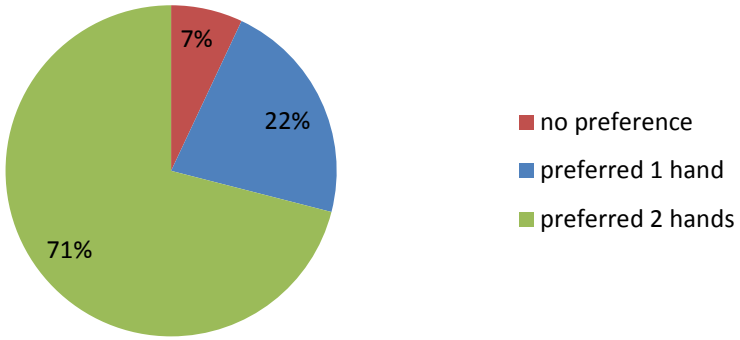
Normal distribution of the RPE data was not achieved in the healthy participant groups at all four stages of the CST; however, as there is no equivalent non-parametric test and normality was achieved at most of the stages, a fully repeated measures ANOVA was used to determine if there were any significant differences in RPE between handrail holding and no handrail holding at each stage of the CST in the younger and older healthy participant groups. In the young healthy participant group, there were no significant differences ($p = 0.522$) in RPE values between holding the handrails with two hands, one hand or no hands at each stage of the CST. In the older healthy participant group, there were no significant differences ($p = 0.541$) in RPE values between holding a handrail with one hand or no hands in the first four stages of the CST. In the cardiac patient group there were no statistically significant differences ($p = 0.419$) in RPE values between holding the handrails with one hand and no hands in the first three stages of the CST.

Table 4.6 Mean RPE values (±SD) recorded at each stage of the CST in the three participant groups

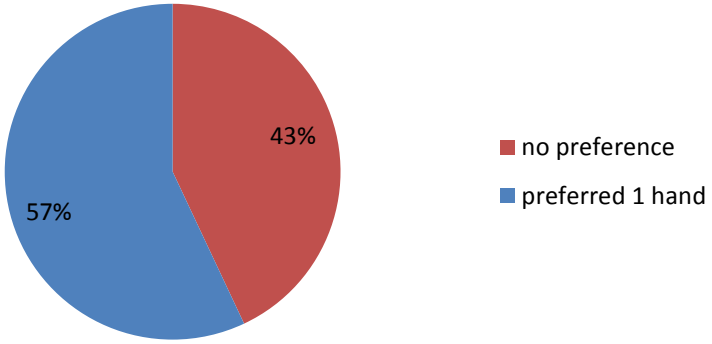
	Young Healthy RPE			Older Healthy RPE		Cardiac Patients RPE	
CST Stage	No hands	1 Hand	2 Hands	No Hands	1 Hand	No Hands	1 Hand
1	7.8 ± 1.4	7.7 ± 1.6	8.1 ± 1.4	7.5 ± 1.4	7.7 ± 2.1	9.0 ± 1.2	8.3 ± 2.0
2	10.3 ± 2.3	10.0 ± 2.3	10.3 ± 2.3	11.2 ± 2.2	10.4 ± 2.1	10.6 ± 1.5	10.3 ± 2.1
3	12.6 ± 2.6	12.3 ± 2.7	12.4 ± 3.0	13.7 ± 2.6	13.3 ± 2.3	12.1 ± 1.3	11.6 ± 1.9
4	14.6 ± 2.0*	14.3 ± 2.0	13.8 ± 1.9	15.4 ± 2.0	15.0 ± 2.0	-	-
5	15.4 ± 1.3	15.2 ± 1.1	15.0 ± 1.4	-	-	-	-

4.6 Preference of Tests

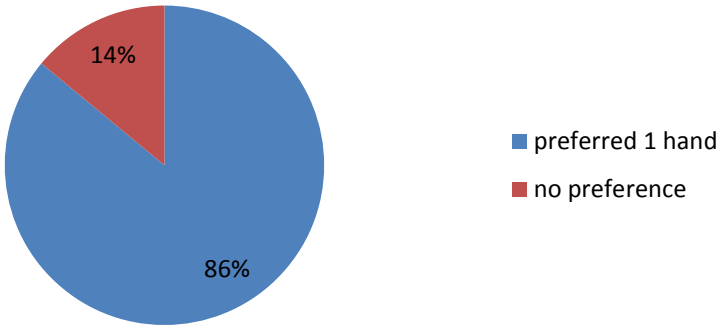
Patient preference was determined by the response to informal questions asked by the study researcher at the end of exercise testing. In the healthy young participant group, 10 individuals preferred the CST holding on to a handrail with two hands, three of the individuals preferred the CST holding on to a handrail with one hand and only one of the participants had no preference how they performed the test. In the healthy older participant group, four participants stated that they preferred the CST holding on to a handrail with one hand while three of the participants stated that they had no preference how they performed the test. In the cardiac patient group, six of the participants preferred the CST holding on to a handrail with one hand while only one participant had no preference in testing protocols. Figure 4.7 illustrates the test preference in the three participant groups.



Healthy young participant group



Healthy older participant group



Cardiac patient participant group

Figure 4.7 Graphs indicating participant test preference

Chapter 5
Discussion

5.1 Overview

The aim of this study was to perform an intergroup analysis to investigate what the effects a side handrail support had on oxygen uptake during the CST on younger healthy individuals, older healthy individuals and on cardiac patients who participated in a cardiac rehabilitation programme. In accordance with the findings by Barnett (2010), the current study found that handrail support had no statistically significant effect on oxygen uptake values when individuals performed the CST. Results from the current study provide encouraging support for the use of a side handrail support during the CST when testing both healthy individuals and for cardiac patients in a cardiac rehabilitation setting.

5.2 Effect of Handrail Support on Oxygen Uptake

The results from this current study show that holding onto a side handrail during the CST did not significantly alter $\dot{V}O_2$ values at each stage of the test in healthy younger individuals, healthy older individuals and in patients with cardiac disease. In the younger healthy participant group however, holding onto a side handrail with two hands and with one hand did appear to slightly underestimate $\dot{V}O_2$ values by ~ 1 - 2 ml·kg^{-1}·min^{-1}at each stage of the test in comparison to hands free, although this was deemed to be not statistically significant ($p = 0.158$). Similarly, in the cardiac patient group, holding onto a side handrail with one hand appeared to

underestimate $\dot{V}O_2$ values by ~ 0.7-1.0 ml·kg^{-1}·min^{-1} at each stage of the test. Again, this was deemed to be not statistically significantly different ($p = 0.139$).

As the study produced by Barnett (2010) was similar in design to this current study, a comparison between the two studies was possible. The results from this current study are also in agreement with the study by Barnett (2010) who found no significant differences in $\dot{V}O_2$ values when individuals performed the CST with a front handrail support and then with hands free. This current study has furthered the previous findings by Barnett (2010) that front handrail use was beneficial in a young, healthy population and has included supporting evidence for the use of a side handrail support in a healthy older sample group as well as a sample group of cardiac patients attending cardiac rehabilitation classes. Furthermore, the addition of a side handrail support, in comparison to a front handrail support used by Barnett (2010), opens up further possibilities for the use of a handrail support to be used in clinical practice because it has no discernible effect on oxygen costs.

Contrary to this studies current findings, Berling et al (2006), Christman et al (2000) and Haskell et al (1982) found that handrail holding did have a significant effect on the physiological responses elicited during exercise testing. Findings from these previous studies found that continuous handrail support underestimated both oxygen uptake and HR during submaximal exercise. It was noted that greater reductions in oxygen uptake and HR were observed when the handrail support was gripped tighter in comparison to hands being lightly rested on a handrail support. These studies concluded that there was a relationship between the level of handrail support and the physiological responses when performing submaximal exercise. These studies however, examined the effect of handrail holding in treadmill exercise

testing and exercising on a strairmaster exercise machine and so cannot be directly compared with this current study which examined the effect of handrail support in the CST.

Barnett (2010) stated that a sharing of the workload between the upper and lower limbs may be the reason for similar oxygen uptake costs between handrail support and no handrail support during the CST. Unlike treadmill exercise, which requires an increased workload to overcome gravity, box stepping is able to share the workload between the upper and lower limbs as there is no alteration in the workload required to overcome gravity (Barnett, 2010). This sharing of the workload between arm and leg muscles became more notable in the later stages of the CST, when some individuals started to use the handrail support for stepping assistance and not just as an aid to help their balance. During the treadmill exercise, individuals can lift themselves up using the handrail support; this may decrease the overall workload as their lower limbs might not keep up with the motorised treadmill speed. This same principal is not applicable in the CST however, as individuals are still required to step onto and then off, the stepping box, with a shared upper and lower body workload so the test can continue.

5.3 Effect of Handrail Support on Other Physiological Variables

Other physiological variables that compared handrail holding and no handrail holding were METs, HR and RPE. The findings from this study showed that handrail support did not significantly alter MET values at any stage of the CST in the three testing groups. Similar to the findings for $\dot{V}O_2$, in the younger healthy participant group, holding onto a side handrail with two hands and with one hand did appear to

slightly underestimate MET values by ~ 0.1 - 0.8 METs at each stage of the test in comparison to hands free. Similarly, with the cardiac patient group, holding onto a side handrail with one hand appeared to underestimate MET values by ~ 0.2 METs at each stage of the test. However, both of these findings were deemed to be not significantly different ($p = 0.145$ & $p = 0.171$).

Handrail support was also found to have no significent effects on HR and RPE values in all of the three testing groups. Only at stage four of the CST in the young healthy participant group, was a statistically significant difference found ($p = 0.008$) in RPE values between holding the handrail with two hands and no handrail holding. These findings also agreed with those found by Barnett (2010). Again, the sharing of the workload between the upper and lower limbs may account for the similar physiological responses between handrail support and no handrail support during the CST.

5.4 Test Preference

The majority of the participants in this intergroup analysis study preferred the CST when handrail holding was allowed, compared to the test being performed hands free. In the young healthy participant group, 93% of the individuals stated that they preferred the test when handrail holding was allowed with either one or two hands in comparison to the hands free test. In the older healthy participant group, 57% of the individuals preferred the test when handrail holding was allowed with one hand in comparison to hands free. In the cardiac patient participant group, 86% of the individuals preferred the test when handrail holding was allowed with one hand in comparison to hands free. Participants stated, that the reasons they felt the test was

‘easier’ with handrail support in comparison to hands free was that, it helped them with their balance, it helped them with support at the higher test stages of the CST, and it also made them feel more secure. The findings from this study have shown that handrail support did not significantly alter physiological and subjective responses to exercise. The fact that individuals found the test ‘easier’ to perform with a side handrail indicated that a handrail was able to provide greater support and balance for some individuals without altering changes to $\dot{V}O_2$, HR, MET and RPE.

5.5 The Benefits of Handrail Support

As previously stated, the CST is a valuable mode of exercise testing for a large number of individuals as it is a submaximal test and reflects movements used in daily life. However, a problem of the CST was its suitability for individuals with poor balance, a lack of mobility or pains in the knees (BACR, 2009). As many individuals entering cardiac rehabilitation are elderly these physical limitations might apply to them. Work produced by Hinman, Bennell, Metcalf and Crossley (2002) found that individuals suffering from knee osteoarthritis had poorer balance levels in comparison to a group of age matched controls. Additionally, the ACSM guidelines (2010) suggest that individuals with osteoarthritis should try and avoid modes of exercise testing which are too painful on their joints.

The current study has now provided evidence that could allow the CST to be expanded to include more patient groups e.g. those with osteoarthritis or those with poor balance. The majority of participants in the study found that handrail support helped them with their balance, helped them with support at the higher test stages of the CST, and it gave them a sense of security. The addition of a side handrail to the

CST could increase the confidence levels of some individuals, and could also offer physically impaired individuals the chance to undertake the CST as an exercise testing protocol. This would be especially beneficial to all cardiac rehabilitation programmes across the United Kingdom as the CST is a widely used exercise testing protocol.

The addition of a side handrail support to the CST may also be a more suitable exercise testing alternative to cardiac rehabilitation programmes that use other exercise testing protocols, e.g. the six minute walk test or the incremental shuttle walk test. These exercise tests require a greater area of free space, can have a lack of accuracy and can be more prone to an increase in falls and injury. The addition of a handrail could also allow the test operator to take an individuals blood pressure more easily, if this was needed. As the CST is a very practical, inexpensive and reliable exercise test, the addition of handrail support to the CST could allow the test to be more widely considered as an exercise testing protocol in a cardiac rehabilitation setting.

5.6 Limitations of the Study

All data collection techniques used in this study were correctly adhered to. This avoided any potential discrepancies in the final results, however this study was not without its limitations. The participant numbers in this study were relatively small and might have affected the statistical power of the results. A larger sample size could have improved the reliability and validity of the results but due to a restricted timescale set for testing the participants, the sample size had to be limited. Additionally, no female patients took part in the cardiac participant group. During the

recruitment of cardiac patients for the study, many female patients felt apprehensive and uncomfortable with the thought of wearing the gas analysis mask and so declined to participate in the study.

To measure predicted maximum HR in the participants, the equation 220 minus the individuals age was used. The use of this equation to predict maximum HR has been questioned as it is not an exact science (Tanaka, Monahan and Seals, 2001), it is however still commonly used in research studies involving submaximal testing (Buckley et al, 2004; Sykes & Roberts, 2004; and Barnett, 2010). Some of the cardiac patients used in this study were on beta-blocker medications while others were not. As no study to date has yet been published on the effects of patients participating in the CST with beta blockers, the equation 220 minus the individuals age minus a further 30 (for the effect of beta-blockers) was used to estimate maximum HR in patients prescribed beta-blockers.

Another problem encountered in this study was the variation in the number of completed CST stages among the different testing groups. In the young healthy participant group, analysis was provided over all five testing stages, in the older healthy participant group, analysis was provided over four testing stages and in the cardiac patient group, only the first three stages were included in the final analysis. The step height was individually adjusted to enable the participants to complete as many testing stages, but it was not always physically possible for every participant to complete all five CST stages. Our results however, are in accordance with the CST manual which recommends that only three stages need to be completed in order for the results of the test to be valid.

The testing of the healthy participants and the cardiac patients were undertaken in two different rooms of the university. For safety reasons, the cardiac patients were tested in a gym hall next to the cardiac rehabilitation class. This was done so that if any problematic event occurred during testing, then appropriately trained personel and equipment would be readily on hand for support. As a result of this, the two testing environments were slightly different, as the healthy participants were tested in the research laboratory. A great effort to keep testing conditions standard throughout was attempted.

The handrails used in this study were from the handlebars of a cycle ergometer (See appendix H). Adjustable handrails were chosen to enable participants to change the height of the handles if it was required. A cycle ergometer with adjustable handrails is not always readily available but, it would not be too difficult to improvise a similar set of adjustable handrails to be used in any future cardiac rehabilitation setting.

5.7 Recommendations for future research

- Performing the test again with greater numbers of participants in each testing group would be beneficial as a larger sample size would provide greater statistical reliability and could reduce any anomalous results.

- Getting female cardiac patients to participate in the study would also allow a gender comparison between the cardiac testing groups.

- A comparison study between the healthy older group and the cardiac patient group using two handed support might be of interest, as in our current tests these two groups performed the CST with only one handed support and with no hands.

5.8 Conclusion

In conclusion, the results from this intergroup analysis study provide encouraging support to the use of a handrail support during the CST, when exercise testing both healthy individuals and cardiac patients in a cardiac rehabilitation setting. Holding a side handrail did slightly underestimate oxygen uptake values in healthy individuals and cardiac patients, however, this difference was not deemed to be statistically significant ($p < 0.05$). In addition, handrail support was also found to have no significant effect on other physiological variables during the CST such as HR, METs and RPE.

The American College of Sports Medicine exercise testing guidelines suggest that handrail support may be required for exercise testing in older adults as they have reduced balance, decreased muscular strength, poor neuromuscular co-ordination and fear (ACSM, 2009). Currently, handrails have not been used when individuals undertake the CST in a clinical setting. The addition of a side handrail to the CST, however could increase an individuals confidence level, give some individuals more balance and could also offer physically impaired individuals the chance to undertake the CST as an exercise testing protocol. From the evidence gathered in this study, a side handrail support would not only enhance the CST, but be beneficial to many of the cardiac rehabilitation programmes and clinical practices

across the United Kingdom as it would allow a wider range of individuals to undertake the CST as an exercise testing protocol.

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Appendix A – Healthy Participant Information Sheet

Participant information sheet

What is the effect of holding a side handrail support on oxygen uptake values during the completion of the Chester Step Test?

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
The aim of this study is to evaluate the physiological effects which occur when a side handrail is held with one hand, two hands and hands free during the completion of the Chester Step Test. The Chester Step Test is a submaximal, multistage, fitness test, which measures heart rate and rate of perceived exertion continuously during exercise to provide a simple, yet effective way to assess an individual's aerobic capacity.

The aim is to transfer this work to cardiac patients. Exercise testing guidelines suggest that handrail support may be required for exercise testing in older adults because of reduced balance, decreased muscular strength, poor neuromuscular co-ordination and fear. This study would help to provide a complete picture on handrail use during the Chester Step Test, which may offer some individuals a safer alternative during exercise testing.

Why have I been chosen?
You have been chosen because you are a healthy adult.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will attend two separate testing sessions which will take place over a period of about 1 week. The first session will involve a familiarisation session where you will get the chance to wear the ventilatory gas mask and get accustomed to the Chester Step Test procedure and Rate of Perceived Exertion scale. After you have become familiarised with the test

procedure you will then be asked to perform one of three different Chester Step Test protocols. In a randomised order, you will perform a Chester Step Test 'hands free', a Chester Step Test whilst holding a side hand rail with two hands and a Chester Step Test whilst holding a side hand rail with one hand. The next testing session will involve you completing the remaining two Chester Step Test protocols. These test sessions will last no longer than 60 minutes. No-one will be identifiable in the final report.

What are the possible disadvantages and risks of taking part?
For most people physical activity should not pose any problem or hazard. There is a slight risk that performing the Chester Step Test may reveal a weakness that may lead to injury or illness. You may feel slightly distressed or discomforted while performing the test. To try and overcome initial distress of performing the test, a familiarisation session will be held in which you will get the chance to wear the ventilatory gas mask and ask any questions related to the test.

What are the possible benefits of taking part?
By taking part, you will be able to discover your predicted maximal aerobic fitness level. This measurement can be used to provide more individualised and effective work out schedules. In addition you will be contributing to the development of an exercise test which may offer cardiac and elderly patients a safer alternative during exercise testing.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?
The research is conducted as part of a MSc in Cardiovascular Rehabilitation within the Department of Clinical Sciences at the University of Chester. The study is organised with supervision from the department, by Graham Reid, an MSc student.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Graham Reid. [redacted]@chester.ac.uk.

Thank you for your interest in this research

<u>Appendix B</u> – Healthy Participant Consent Form

What is the effect of holding a side handrail support on oxygen uptake values during the completion of the Chester Step Test?

Name of Researcher: Graham Reid

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐
3. I agree to take part in the above study. ☐

_____	_____	_____
Name of Participant	Date	Signature

_____	_____	_____
Researcher	Date	Signature

<u>Appendix C</u> – Healthy Participant Health Screening Questionnaire

University of Chester

Pre-test Questionnaire

What is the effect of holding a side handrail support on oxygen uptake values during the completion of the Chester Step Test?

Name:_____ Test date:_____

Contact number:_____ Date of birth:_____

Signature of Lead Researcher:_____

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor? YES/NO
2. Do you feel pain in the chest when you perform physical activity? YES/NO
3. In the past month, have you had chest pain when you were not performing physical activity? YES/NO
4. Do you lose your balance because of dizziness *or* do you ever lose consciousness? YES/NO
5. Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity? YES/NO
6. Is your doctor currently prescribing drugs for your blood pressure or heart condition? YES/NO
7. Are you pregnant, or have you been pregnant in the last six months? YES/NO
8. Have you injured your hip, knee or ankle joint in the last six months? YES/NO
9. Do you know of any other reason why you should not participate in physical activity? YES/NO

If so please state:_____

Appendix D – Cardiac Patient Participant Information Sheet

Participant information sheet

What are the physiological effects of holding a handrail during a Chester Step Test in Cardiac Rehabilitation patients?

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

Exercise testing guidelines suggest that handrail support may be required for exercise testing in and older adult population due to; a reduced balance, decreased muscular strength, poor neuromuscular co-ordination and fear. This study may provide a complete picture on handrail use during the Chester Step Test, which may offer some individuals a safer alternative during exercise testing

Therefore the research is being undertaken on cardiac rehabilitation patients. The aim of the study is to evaluate the physiological effects, which occur when a handrail is held with; one hand and hands free during the completion of the Chester Step Test.

Why have I been chosen?

You have been chosen to participate in the research study because you are currently enrolled in a cardiovascular rehabilitation programme.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to

take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your care in any way.

What will happen to me if I take part?

You will attend two separate testing sessions. On the first session you will be given an opportunity to familiarize yourself with the equipment; the ventilatory gas mask and become accustomed with the Chester Step Test Protocol and the Rating of Perceived Exertion (RPE) scale. Following this the first test will be completed. The session will last up to an hour.

The 2 test days will require you to perform 2 different Chester Step Test protocols. In a randomised order, you will perform the Chester Step Test 'hands free,' and a Chester Step Test whilst holding the handrail with 1 hand.

These 2 testing session will last no longer than 1 hour. Your data will not be identifiable in the final report or throughout the testing procedure.

What are the possible disadvantages and risks of taking part?

As the Chester Step Test is a sub-maximal test the risk on injury is relatively low. You may feel slightly distressed or discomforted while performing the test as a result of the ventilatory gas mask. Therefore to try and prevent such problems, a familiarisation session will be held in which you will have the opportunity to wear the ventilatory gas mask and ask any questions related to the test.

What are the possible benefits of taking part?

By taking part, you will be contributing to the development of an exercise test, which may offer other cardiac and also elderly patients a safer alternative during exercise testing

What if something goes wrong?

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?

The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?

The research is conducted as part of an MSc in Cardiovascular Rehabilitation within the Department of Clinical Sciences at the University of Chester. The study is organised with supervision from the department, by Amy Fairhurst, an MSc student.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Email : [redacted]*@chester.ac.uk.*

Telephone : [redacted]

Thank you for your interest in this research.

<u>Appendix E</u> – Cardiac Patient Participant Consent Form

Title of Project: What are the physiological effects of holding a hand rail during a Chester Step Test in Cardiac Rehabilitation patients.

Name of Researcher: Amy Fairhurst

Please initial box

2. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

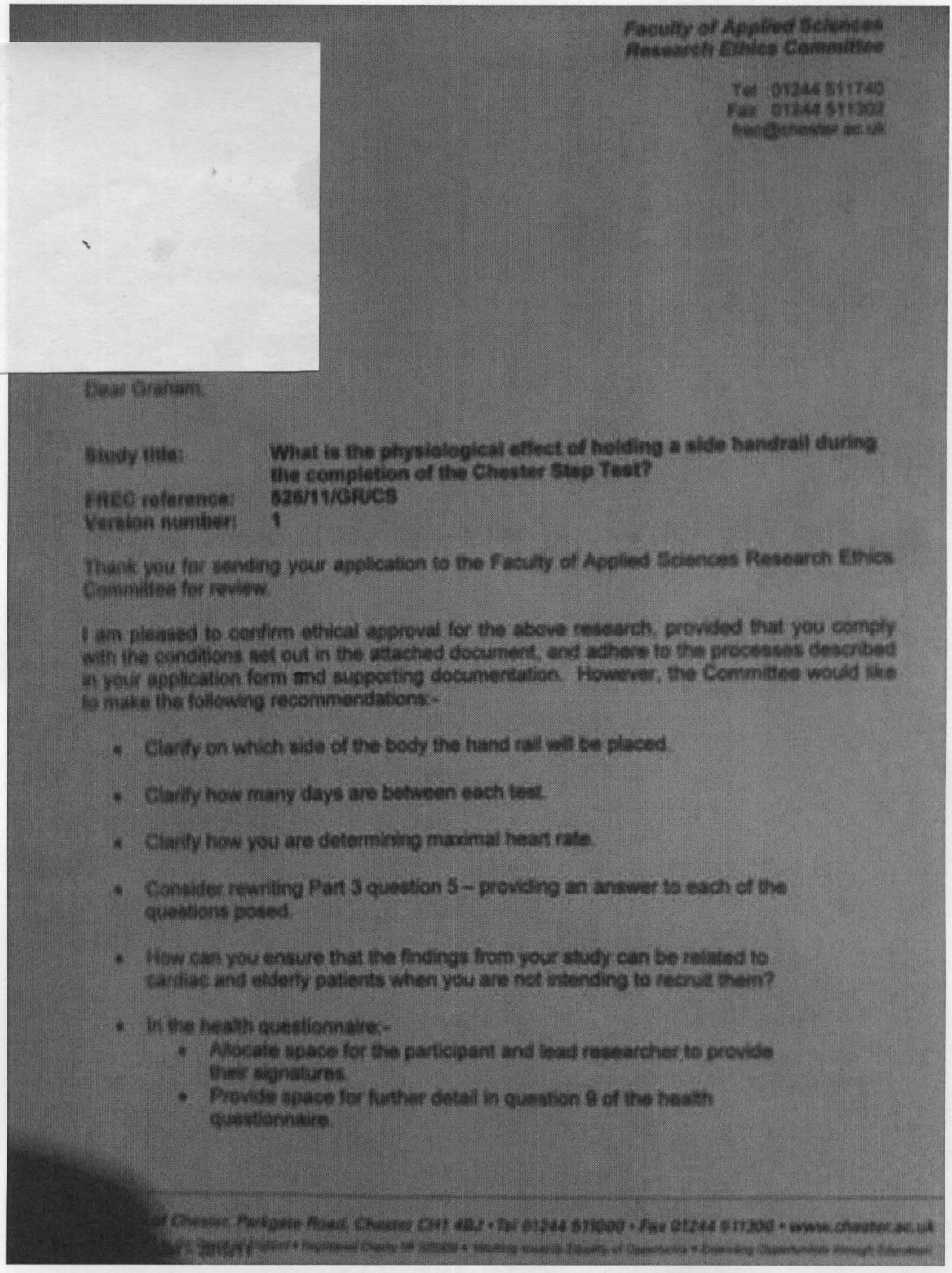
3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my care or legal rights being affected. ☐

4. I agree to take part in the above study. ☐

4. I understand that data collected during the study may be looked at by individuals from regulatory authorities or from the NHS Trust where it is relevant to my taking part in this research. I give permission for these individuals to have access to this information

_____	_____	_____
Name of Participant	Date	Signature
_____	_____	_____
Researcher	Date	Signature

Appendix F – University of Chester Ethics Committee Approval Form



Faculty of Applied Sciences
Research Ethics Committee

Tel 01244 511740
Fax 01244 511302
frec@chester.ac.uk

Dear Graham,

Study title: **What is the physiological effect of holding a side handrail during the completion of the Chester Step Test?**
FREC reference: **526/11/GRUCS**
Version number: **1**

Thank you for sending your application to the Faculty of Applied Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation. However, the Committee would like to make the following recommendations:-

- Clarify on which side of the body the hand rail will be placed.
- Clarify how many days are between each test.
- Clarify how you are determining maximal heart rate.
- Consider rewriting Part 3 question 5 – providing an answer to each of the questions posed.
- How can you ensure that the findings from your study can be related to cardiac and elderly patients when you are not intending to recruit them?
- In the health questionnaire:-
  - Allocate space for the participant and lead researcher to provide their signatures.
  - Provide space for further detail in question 9 of the health questionnaire.

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- Re-write Appendix 5, inviting the participants to take part in the study and make reference to the Participant Information Sheet.

- In the Participant Information Sheet:-
    - Delete the first sentence of the third paragraph and provide a brief definition of the Chester Step Test.
    - In paragraph 5, provide a definition of a healthy adult.
    - In paragraph 7, provide a time frame in which the four exercise sessions are intending to take place (i.e. over a week).
    - In paragraph 10, include detail about the predication of the participant's maximal aerobic fitness level.

- The risk assessment form requires a signature from the relevant laboratory technician to ensure consent for the use of equipment.

- Consider repeating the handrail or the non-handrail test to determine the reliability.

- Consider using a better technique for the randomisation of each test.

- Consider measuring blood lactate responses during each Chester Step test.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	March 2011
Appendix 1 – List of References	1	March 2011
Appendix 2 – C.V. for Lead Researcher	1	March 2011
Appendix 3 – Chester Step Test Protocol	1	March 2011
Appendix 4 – Health Screening Questionnaire	1	March 2011
Appendix 5 – Recruitment Email to Participants	1	March 2011
Appendix 6 – Recruitment Poster	1	March 2011
Appendix 7 – Participant Information Sheet	1	March 2011
Appendix 8 – Participant Consent Form	1	March 2011
Appendix 9 – Chester Step Test Data Collection Sheet	1	March 2011
Appendix 10 – Borg's Rate of Perceived Exertion Scale	1	March 2011
Appendix 11 – Risk Assessment Form	1	March 2011

With the Committee's best wishes for the success of this project.

Yours sincerely,

Simon Alford
Chair, Faculty Research Ethics Committee

Appendix G – Lancaster NHS Ethics Committee Approval Form

NHS
National Research Ethics Service
NRES Committee North West - Lancaster
Barlow House
3rd Floor
4 Minshull Street
Manchester
M1 3DZ

Telephone: 0161 625 7818
Facsimile: 0161 237 9427

Dear Miss Fairhurst

Study title: **What is the physiological effect of holding a handrail during the completion of the Chester Step Test, in cardiac rehabilitation patients?**

REC reference: **11/NW/0360**

The Research Ethics Committee reviewed the above application at the meeting held on 09 June 2011. Thank you for attending to discuss the study.

Ethical opinion

The Chair welcomed you to the REC and thanked you for attending to discuss the study.

You confirmed that patients would be identified by you and by the head of the rehabilitation programme.

The Committee asked what is additional for participants in the study and you confirmed that the mask is additional. You told the Committee that participants would have a familiarisation process. Their first appointment would be to ensure that they are familiar with the step and the mask. The Committee asked whether they are additional visits and you confirmed that they are but that they will be on the day they have their programme, and they will be asked to come earlier or to stay later. If they cannot come on normal days another day can be arranged.

The Committee asked why the sample size of 20 has been chosen given the statistician's recommendation for 743. You explained that this is due to time limits.

The Committee asked for a number of changes to the paperwork as outlined below.

The Committee asked what is being recorded and you said that you are not recording anything the patients say. The recording refers to the metronome for the step test.

You clarified for the Committee that you hope the intervention will be half an hour but will be up to an hour.

The members of the Committee present gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting

documentation, subject to the conditions specified below.

Ethical review of research sites

NHS Sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Other conditions specified by the REC

a. the Committee would like to see the Participant Information Sheet revised to
   i) include a telephone number for further contact as well as the email address. It should not be a personal number
   ii) change "will not affect you" in the last line of "Do I have to take part?" to "will not affect your care…"
   iii) change "the session will last approximately 30 minutes" to "the session will last up to an hour" in "What will happen to me..?"

b. the Committee would like to see the Consent Form revised to include the standard clause "I understand that data collected during the study may be looked at by individuals from regulatory authorities or from the NHS Trust where it is relevant to my taking part in this research. I give permission for these individuals to have access to this information"

It is responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. Confirmation should also be provided to host organisations together with relevant documentation

<u>Appendix H</u> – Photo displaying how the equipment was set up for exercise testing

Appendix I – Data Collection Sheet

CHESTER STEP TEST

_____ Age_____ Patient Consent Obtained Y / N Check List Completed Y / N

ure Explained Y/N Resting HR_____ Rhythm_____

g BP_____ Beta Blockers Y / N

nts

_____

lcted HR max: age (-30 if BB))	80%HR max: Step height 15 / 20 / 25cm	Other Test end point if indicated:

L	MINS	Step rate	HR	RPE	Symptoms / comments			
	1	15						
	2							
	3	20						
	4							
	5	25						
	6							
	7	30						
	8							
	9	35						
	10							

UTE RECOVERY HEART RATE:_____

TEST SUMMARY: Completed stages: Total minutes: METS achieved:

for stopping (select appropriate reason/s)

Unable to maintain required speed

Achieved end point heart rate (specify value)

Rating of perceived exertion of 15

Chest pain

Marked shortness of breath

Leg fatigue

Other (please specify)

ponse Normal / Abnormal BP Response Normal / Abnormal / Not assessed

4

Appendix J – Photo displaying how the participant would perform the CST with no hands

Appendix K – Photo displaying how the participant would perform the CST with one hand

Appendix L – Photo displaying how the participant would perform the CST with two hands

Appendix M – Full Chester Step Test Protocol

1. Ensure that:
   a) there are no medical contraindications to performing the Test
   b) the test environment is suitable
   c) you have selected the appropriate step height
   d) the 'Rating of Perceived Exertion' Chart is clearly visible for the participant
   e) the participant 'warms-up' with some gentle limbering and stretching movements
2. Enter the participant's name and age on the appropriate CST Graphical Data sheet, then calculate their Maximum Heart Rate (220-Age) and 80% Max. Heart Rate. Enter these values at the top of the Data sheet and draw two horizontal lines on the graph to illustrate these values.
3. Fit the heart rate monitor. If you are using a telemetric model, attach the watch receiver to the clipboard along with the CST Graphical Data sheet so that you, as the tester, can monitor the participant's heart rate throughout the test.
4. Inform the participant briefly what they will be required to do - demonstrating the stepping technique (Initially a rate of 15 steps/min). Emphasise that the whole foot should be firmly placed on the step and the leg should be fully straightened when stepping up. Inform the participant that they may change the lead leg, if they so wish, at the beginning of a new stepping rate. explain that the first stepping rate is very slow and controlled - and they should attempt to keep to the correct rhythm throughout the test as the tempo increases.
5. Turn on the cassette tape and ask the participant to listen to the instructions and then to commence stepping at the appropriate time and step rate. Give further encouragement to keep in time with the stepping rhythm.
6. After the first 2 minutes of stepping Level 1, you will be asked to check heart rate and perceived exertion. Please ensure that you keep a regular check on heart rate throughout the Test and that you record a mean stable value over the last few seconds of each Level. This will help eliminate ant erroneous fluctuations that might occasionally - and unexpectedly - occur. The participant should then indicate their Exertion Level - as a number, from the RPE Chart provided (See back cover for RPE scale). Record the Heart Rate and Rating of Perceived Exertion (RPE) on the CST Data sheet
7. Providing the heart rate is below 80% Max. HR and the RPE below 14, the subject should continue stepping at Level II - a slightly faster rate.
8. Record the heart rate and RPE at the end of Level II.
9. Providing the heart rate is below 80% Max. HR and the RPE is below 14, ask the subject to continue stepping at Level III - a slightly faster rate.
10. Continue the test in this manner until either the target heart rate of 80% Max. HR is reached or the participant reports an RPE of 14
11. Ensure that the subject cools down with some gentle limbering and stretching exercises.