British Journal of
CARDIAC
NURSING

Chester Step Test in patients with cardiovascular disease: Practical applications in a cardiovascular prevention and rehabilitation setting

Tim Grove

Author details can be found at the end of this article

Correspondence to:
Tim.Grove@brunel.ac.uk

Abstract

The Chester Step Test is a low-cost, sub-maximal exercise test, which is commonly used in the assessment of cardiorespiratory fitness in a cardiovascular prevention and rehabilitation setting. This review discusses the practical applications of the Chester Step Test in the context of its validity, reliability and predictability in measuring cardiorespiratory fitness. The Chester Step Test has been compared to the 'gold standard' treadmill test for validity. There was a strong correlation (r=0.92) between predicted VO_2 values in the test and actual measurements from the treadmill test. In addition, the Chester Step Test has good reliability, which eliminates the need for a practice test. Furthermore, the Chester Step Test can provide valuable information on the patient's exercise tolerance to specific levels of sub-maximal stress, risk stratification, and physical activity/exercise prescription.

Key words: Cardiovascular prevention and rehabilitation; Chester Step Test; Functional capacity test; Sub-maximal exercise test

Submitted 24 June 2019; accepted following double blind peer review: 10 October 2019

Introduction

Aerobic training forms the glue of most cardiovascular prevention and rehabilitation programmes. It is usually commenced during the early phases of rehabilitation and continued into the long-term maintenance phase (Association of Chartered Physiotherapists in Cardiac Rehabilitation (ACPICR), 2015; British Association for Cardiovascular Prevention and Rehabilitation (BACPR), 2017).

In clinical practice, functional capacity tests are commonly used to assess the following:

- Changes in cardiorespiratory fitness between baseline and follow-up
- Tolerance to specific levels of sub-maximal stress
- Cardiopulmonary responses to incremental physical effort.

These provide important information for cardiac risk stratification and physical activity counselling (ACPICR, 2015). Traditionally, cardiorespiratory fitness is measured during a maximal exercise test that employs a graduated incremental protocol on a treadmill or cycle ergometer. Such tests are normally conducted in a laboratory that is equipped to measure gas fractions (VO_2, ventilatory threshold, etc), blood lactate, and electrocardiogram responses. Most cardiovascular prevention and rehabilitation programmes do not have access to laboratory-based exercise tests as they require expensive equipment and highly trained operators to carry them out.

To overcome these limiting factors, the Chester Step Test was devised for use in a wide variety of scenarios, and easily adapted for use in Cardiovascular prevention and rehabilitation programmess. The latest version, CST2, has a bespoke cardiovascular prevention and rehabilitation programme Edition (Sykes, 2019). The test is inexpensive, easy to administer, portable, and provides a valid measure of cardiorespiratory fitness in patients with cardiovascular disease (Grove et al, 2017). Therefore, the purpose of this article is to review the evidence surrounding the practical applications of the Chester Step Test as a valid and reliable instrument in measuring cardiorespiratory fitness in a cardiovascular prevention and rehabilitation programme.

How to cite this article: Grove T. Chester Step Test in patients with cardiovascular disease: Practical applications in a cardiovascular prevention and rehabilitation setting. British Journal of Cardiac Nursing. 2020;15(1):1–9. https://doi.org/10.12968.bjca.2019.0064

What is the Chester Step Test?

The Chester Step Test is a multi-stage, sub-maximal test, which requires the patient to step on and off a box-step at a predetermined rate, set by a metronome beat played from an audio player or digital software (Sykes, 2010; 2018). There are four choices of step height in the CST2 cardiovascular prevention and rehabilitation programme edition (10 cm, 15 cm, 20 cm and 25 cm), and the choice of height used is determined by the patient's current physical activity habits. The test commences at a very slow stepping rate (15 steps/minute) and gradually progresses by 5 steps/minute at each stage (**Figure 1**). There are five stages in total, with each stage lasting for 2 minutes (**Table 1**).

During the test, heart rate and rating of perceived exertion (on the Borg (1998) ratings of perceived exertion scale) are checked and recorded every 1 minute, and the stepping rate is increased every 2 minutes. The test continues in a progressive manner until the patient reaches 70% of their age-predicted heart rate reserve maximum (the calculation for which

Figure 1. The Chester Step Test, performed by Tim Grove

Table 1. The five stages of the Chester Step Test and the predicted oxygen costs (VO_2/Metabolic equivalents (METs)) for varying step heights (cm) and stepping rates (steps/min) (American College of Sports Medicine, 2017).

Stage	I	II	III	IV	V
Stepping rate	15	20	25	30	35
VO_2 (ml/kg/min)/ METs					
10 cm step	10/2.9	12/3.5	14/4.1	17/4.8	19/5.4
15 cm step	12/3.4	15/4.2	18/5.0	20/5.8	23/6.6
20 cm step	14/3.9	17/4.9	20/5.8	24/6.8	27/7.8
25 cm step	15/4.4	20/5.6	23/6.7	27/7.8	32/9.0

Box 1. Absolute and relative contraindications to exercise testing adapted from ACSM (2017)

Absolute contraindications

Acute myocardial infarction within 2 days

Ongoing unstable angina

Uncontrolled cardiac arrhythmia with haemodynamic compromise

Active endocarditis

Symptomatic severe aortic stenosis

Decompensated heart failure

Acute pulmonary embolism, pulmonary infarction or deep vein thrombosis

Acute myocarditis or pericarditis

Acute aortic dissection

Physical disability that precludes safe and adequate testing

Relative contraindications

Known obstructive left main coronary artery stenosis

Moderate-to-severe aortic stenosis with uncertain relationship to symptoms

Tachyarrhythmias with uncontrolled ventricular rate

Acquired, advanced, or complete heart block

Recent stroke or transient ischaemia attack

Mental impairment with limited ability to cooperate

Resting hypertension with systolic >200 mmHg or diastolic >110 mmHg

Uncorrected medical conditions, such as significant anaemia, important electrolyte imbalance, and hyperthyroidism

Box 2. Example of the heart rate reserve maximum calculation (BACPR, 2018)

206-(0.7x age)-resting heart rate x 0.7 (70%) + resting heart rate

206 -(0.7 x age (70yrs) = 157

157- RHR (60 bpm) = 97

97 x 0.7 (70%) = 68

68 + RHR (60bpm) = 128bpm

If the patient is on a beta-blocker or another heart rate limiting medication, such as Ivabradine, a further 30 bpm should be subtracted from the age-predicted heart rate maximum (reference). An example is given below:

206-(0.7x age)- 30bpm (beta-blocker) - resting heart rate x 0.7 (70%) + resting heart rate

206 -(0.7 x age (70yrs) – 30bpm (beta-blocker = 127

127- RHR (60 bpm) = 67

67 x 0.7 (70%) = 47

47 + RHR (60bpm) = 107bpm

can be seen in **Box 2**) and/or reports a score of 14 on the perceived exertion scale. The prediction of maximal oxygen uptake (VO_2 max) is based on the assumption that heart rate and work rate track in a linear fashion with VO_2 consumption, which will be discussed in the next section (American College of Sports Medicine (ACSM), 2017).

Patient preparation for the Chester Step Test

The BACPR (2017) recommends that an assessment of functional capacity should take place within 10 working days of receipt of a referral to a cardiovascular prevention and rehabilitation programme. Before commencing a functional capacity test such as the Chester Step Test, the patient should be screened for any contraindications to exercise (**Box 1**). In addition, the patient should:

- Refrain from eating or drinking any caffeine-based foods or drinks for at least 2 hours before the test
- Not eat a heavy meal before the test
- Not smoked for 2 hours before the test
- Refrained from vigorous exercise in the 24 hours before the test
- Taken all medication as normal
- Be wearing loose, comfortable clothing

As part of the assessment, the patient should have their resting blood pressure, resting heart rate and functional limitations checked. Following the screening process, a heart rate monitor should be fitted and the Borg (1998) ratings of perceived exertion chart explained. The ratings of the perceived exertion scale should be displayed at all times in front of the patient who is taking part in the test. Following the example in **Box 2**, 70% of the patient's heart reserve maximum should be calculated.

As mentioned, the step height of the test should be set based on the patient's current physical activity level and functional limitations. For example, if a patient engages in regular bouts of brisk walking and they are able to climb several flights of stairs, then a step height of 20 or 25 cm can be used. However, for patients who are inactive and are only able to climb one flight of stairs, a lower step height of 10 or 15 cm should be used. The step height should be set at a level that allows the patient to achieve at least three stages as this will increase the accuracy in predicting cardiorespiratory fitness (Buckley et al, 2004).

The test should be administered in a well-ventilated room, with an air temperature set between 20 °C and 22 °C (ACSM, 2018). The room should also be quiet, with plenty of space to allow the patient to step up and down on the step. The test should be explained to the patient verbally and they should be allowed to practise stepping up and down on the box step for at least 1 minute in time to the metronome beat. The patient should step with an upright posture, making sure the whole foot makes contact with the step. The patient may change their lead stepping leg every so often during the test. The test commences when the patient and test operator are ready.

Cardiorespiratory fitness in cardiac disease

Cardiorespiratory fitness is defined as a person's ability to take up and use oxygen during physical work. With this concept in mind, measuring oxygen uptake is often mistaken as simply a marker of lung and heart function. However, these two organs act as transport systems that deliver oxygenated blood to skeletal muscles (McArdle et al, 2009). Therefore, measuring oxygen uptake provides important information on the working relationship between the heart, lungs and the skeletal muscles in using oxygen at the mitochondrial

Box 3. Description of metabolic equivalents

Metabolic equivalents (METs) define the levels of physical activity as multiples of the resting energy cost in a seated position at rest. One MET at rest is equal to an oxygen consumption of approximately 3.5 ml per kilogram of body weight per minute. Walking 1 mile in 15 minutes (4 miles per hour (mph)) is equivalent to 5 METs or five times the energy cost of rest, whereas jogging 1 mile in 10 minutes (6 mph) is equivalent to 10 METs.

level (McArdle et al, 2009). Measurements of oxygen uptake are sometimes referred to as VO_2 max, VO_2 peak, MET max or MET peak. A true VO_2 peak or MET peak test in the context of cardiac disease is when a patient performs a symptom-limited exercise test, whereas a VO_2 max or MET max exercise test is where an individual exercises to their absolute limit. METs are described in **Box 3**.

Because of the sub-maximal nature of the Chester Step Test, VO_2 max/MET max is predicted using the 'line of best fit.' The line of best fit involves drawing a line through the sub-maximal heart rate responses recorded at the end of each stage on the test, up to a level that equals the patient's age-estimated HR maximum (220 – age). At this point, a vertical line is dropped down to the x axis of the graph, which represents the estimated VO_2 max/MET max.

The validity of the Chester Step Test has been studied in both health and cardiovascular disease. Sykes and Roberts (2004) carried out the test in 68 apparently heathy subjects, with a wide age range (18–52 years old). Their study demonstrated a strong correlation between the test with direct measurements of VO_2 max on a treadmill ergometer (r=0.92, P<0.001) with a standard error of estimate of 3.9 ml/kg/minute (Sykes and Roberts, 2004). In patients stratified at high multifactorial risk of cardiovascular disease, Grove et al (2012) found a moderate correlation (r=0.59, p<0.03) between maximal treadmill testing time and predicted VO_2 max on the test in 14 male patients (mean age 68±4.2 years). In support of these findings, Reed et al (2019) demonstrated a moderate-to-high correlation (r=0.69, p <0.001) between the test and direct measurements of VO_2 peak on a treadmill in 34 patients with established cardiovascular disease. However, in their study, the Chester Step Test overestimated VO_2 peak, as the mean bias and 95% limits of agreement was 4.1 $mL.kg^{-1}.minute^{-1}$.

Reliability of the Chester Step Test

According to Buckley et al (2004), the test–retest reliability is far more encouraging than its validity, as there is little inter-trial bias (0.8 ml/kg/min) between two trials that were carried out 5–7 days apart. In addition, the bias at 95% of the limits of agreement between the two tests was 0.8 (3.7 ml/kg/minute), which was insignificant (Buckley et al, 2004). In support of these findings, Sykes and Roberts (2004) reported a 0.7 ml/kg/minute difference between repeated measures on the Chester Step Test and the limits of agreement was within 4.5 ml/kg/minute of the original predicted measurement. Therefore, the Chester Step Test has good repeatability, as the work-rate is set externally by a standardised metronome beat.

Assessing changes in cardiorespiratory fitness

Improvements in cardiorespiratory fitness can be reported as the following: sub-maximal VO_2/METs, predicted VO_2/MET max, or the amount of time spent on the Chester Step Test. Such changes in cardiorespiratory fitness have been previously reported by Sandercock et al (2013), who conducted a study across UK cardiovascular prevention and rehabilitation programmes that included 950 patients. In their study, cardiorespiratory fitness increased by a mean of 0.52 METs across: the incremental shuttle walk test, the 6-minute walk test, the incremental bike test, and the treadmill test, following an 8-week cardiovascular prevention and rehabilitation programme. However, the Sandercock et al (2013) study did not include the Chester Step Test. Therefore, a retrospective analysis of programme data that uses the Chester Step Test was conducted (Imperial NHS Trust Cardiac Health and Rehabilitation Programme, *data on file*). In this analysis of 626 patients with cardiac disease, the mean improvement in sub-maximal METs and MET max on the Chester Step Test was 0.46 and 0.76 METs respectively, following an 8-week cardiovascular prevention and rehabilitation programmes. These findings are comparable to the Sandercock et al (2013) study.

To improve the sensitivity of the Chester Step Test in detecting a change in cardiorespiratory fitness, the heart rate response at each stage of the test can be compared between baseline and follow-up. If the heart rate response has declined at the follow-up assessment, a true physiological adaptation has taken place. In support of this notion, Grove et al, 2017 demonstrated that, on average, sub-maximal heart rate responses decrease by 4–7 beats per minute at each stage of the test, following a 12-week cardiovascular prevention and rehabilitation programme. These findings were observed in 169 patients who were either at high risk of cardiovascular disease or had established vascular disease. A reduction in the sub-maximal heart rate response is a classical physiological training adaptation. It is suggestive of an adjustment in the autonomic balance between parasympathetic and sympathetic nervous activity, resulting in the ability of the myocardium to accomplish a similar cardiac output at a lower myocardial oxygen demand (Ehsani et al, 1982; Malfatto et al, 1996; Myers et al, 2014; Grove et al, 2017) However, it should be noted that comparing the heart rate responses between baseline and follow-up tests is only valid as long as the patient has not started or up-titrated their dose of medications that affect heart rate (such as beta blockers) following their initial Chester Step Test. In cases where the patient has been prescribed heart rate-limiting medication or had their dose up-titrated following initial assessment, changes in ratings of perceived exertion can be used as a marker to assess changes in cardiorespiratory fitness.

What are the limitations of the Chester Step Test in measuring cardiorespiratory fitness?

The Chester Step Test is not without its limitations. According to Buckley et al (2004), the test can overestimate the VO_2 max/MET max by as much as 11%, or underestimate it by up to 19%. One of the main sources of error is in using age-predicted heart rate max formulas. Such formulas can potentially over or underestimate an individual's actual maximal heart rate by 6-12 beats per minute (Robergs and Landwehr, 2002). For example, a 40-year-old male's age-predicted heart rate max is 180 beats per minute (220 –40 years). If the standard error of estimate of 10 beats per minute is applied, the patient's age-predicted max heart rate will lie between 170 beats per minute and 190 beats per minute. Therefore, this error of estimate will influence the line of best fit when predicting VO_2 max/MET max.

Table 2. Actual versus predicted VO_2 on each stage on a 20 cm height Chester Step Test in a student aged 37 years

Stage	Step rate (min)	Predicted VO_2 m/kg/min	Actual VO_2 m/kg/min	Difference
1	15	12	11.9	–0.1
2	20	17	16.1	–0.9
3	25	21	18.9	–2.1
4	30	25	23.8	–1.2
5	35	29	31.8	+2.8

Table 3. Actual versus predicted VO_2 on each stage on a 25 cm height Chester Step Test in 4 students aged 21 years, 34 years, 36 years and 37 years

Stage	Step rate (min)	Predicted VO_2 ml/kg/min	Actual mean/range VO_2 ml/kg/min	Difference VO_2 ml/kg/min
1	15	15.4	15.6 (15–16)	+0.2
2	20	19.6	18.8 (17–21)	–0.8
3	25	23.5	23.1 (22–24)	–0.4
4	30	27.3	31 (24 – 29)	+3.7
5	35	31.5	36 (36)*	+4.5

**One student reached stage 5*

The second limitation is the estimation of the oxygen uptake on each stage of the test. In order to calculate the VO_2/METs on each stage of the test at different step heights, a standard regression formula is used (ACSM, 2017). Reports have shown that this formula is accurate for stepping rates between 12–30 steps/minute (ACSM, 2017). To assess the accuracy of the stepping formula, a laboratory experiment was carried out on five students, which involved measuring the direct oxygen uptake using a Cortex Metamax 3b at each stage of the test. The Cortex Metamax is a portable spiroergometer that analyses the functionality of an individual's lungs, heart and metabolism at rest and during exercise by measuring each breath. During each experiment, VO_2 was measured over 2 minutes and an average was taken over the last 10 seconds at each stage of the test. All five students gave their informed consent and took part in the Chester Step Test at box step heights of 20 and 25 cm. One student took part in the test at a step height of 20 cm and four students took part at 25 cm. The results of this experiment are reported in Tables 2 and 3, compared to the predicted VO_2/METs from standard metabolic calculations. From the experiment it was found that, on a 25 cm step height, the stepping formula underestimates VO_2/METs at stages 1, 4 and 5, and overestimates VO_2/METs at stages 2 and 3. On a 20 cm step height, the stepping formula overestimates VO_2/METs at stages 1, 2, 3 and 4, and it underestimates VO_2/METs at stage 5. Despite the marginal differences between actual and predicted VO_2/METs, it should be noted that the results of this experiment represent a small sample of apparently healthy young adults and they might not necessarily apply to an older population with cardiovascular disease.

Can the Chester Step Test be used to risk-stratify patients with cardiovascular disease ?

Risk stratification is a process that predicts an individual's risk in terms of their future prognosis and determines an appropriate exercise intensity and level of supervision during an exercise programme (American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR), 2013). The AACVPR (2013) provides details on the risk stratification criteria. The criteria assign an individual to a low, moderate or high-risk category based on the pumping capacity of the heart (left ventricular function), residual ischaemia, ventricular arrhythmias and exercise capacity. With reference to exercise capacity, patients are considered to be at low risk if they have a maximal functional capacity of at least 7 METs, and at high risk if they have a functional capacity of 5 METs or less. Therefore, patients who are able to achieve 5 METs on the Chester Step Test at a 70% of their predicted heart rate reserve maximum and who report a rating of perceived exertion of 14 or less could be stratified as low risk as long as they fulfil the other criteria outlined in the low-risk category. This assumption is based on the fact that their maximal functional capacity has been predicted at 7.1 METs. However, if the patient experienced chest pain at 5 METs on the Chester Step Test they would be deemed as high risk, and they would require a lower exercise intensity and a closer level of supervision during cardiovascular prevention and rehabilitation programme exercise sessions.

Chester Step Test results and exercise counselling

The following case study describes how the results of the Chester Step Test can be used to guide physical activity advice. A 62-year-old male was referred to a cardiovascular prevention and rehabilitation programme following an anterior segment elevation myocardial infarction and primary percutaneous coronary intervention with one drug-eluting sent to the left anterior descending artery. The patient took part in the Chester Step Test 7 days after their cardiac event and achieved 5.8 METs, with a predicted maximal capacity of 8.3 METs. The patient had a good ejection fraction (55%) and no residual ischaemia or arrhythmias. Based on these findings, the patient was risk-stratified as low and he could safely exercise at a MET level between 4.2 METs and 5.8 METs, which was equal to 40–70% of his heart rate reserve achieved on the test. Based on these results, the Ainsworth Compendium of Physical Activities (Ainsworth et al, 2011) was used to prescribe activities. The compendium includes over 500 activities and their associated MET values. The patient started with physical activities of around 4.2 METs such as lawn and garden raking (4

METs) and walking at 3.5 miles per hour on a level surface (4.3 METs). An individual exercise prescription was given, which formed part of a cardiovascular prevention and rehabilitation programme circuit. These exercises included stationary cycling 51–89 watts (4.8 METs), 20 steps/minute on a 15 cm box step (4.2 METs) and 10 shuttles on a 10 m shuttle walk course (3.9 METs).

The main focus of the physical activity advice was to increase duration of activity first before intensity. Once the patient could achieve 20–30 minutes of continuous exercise, the intensity was increased to 5.8 METs. These activities included lawn mowing (5.5 METs), walking 2.9–3.5 miles per hour uphill at 1–5% grade (5.3 METs), stationary cycling 90–100 watts (5.3 METs), 30 steps/minute on a 15-cm box step, and 11–12 shuttles on a 10 m shuttle walk course (5.6–6.1 METs). It should be noted that before each exercise session, the patient warmed up for 15 minutes and after each session, they cooled down for 10 minutes. This is consistent with current guidelines (ACPICR, 2015).

Key Points

- The Chester Step Test is commonly used in the assessment of cardiorespiratory fitness in a cardiovascular prevention and rehabilitation setting
- The test is a valid and reliable assessment tool in predicting maximal cardiorespiratory fitness
- The test can be used to assess changes in cardiorespiratory fitness over time, and provide information for risk stratification, physical activity advice and exercise prescription.

CPD Reflective Questions

1. What type of functional capacity tests are commonly used in a cardiovascular prevention and rehabilitation setting?
2. What are the two main outcome measures reported on the Chester Step Test?
3. What is the purpose of performing a Chester Step Test in a cardiovascular prevention and rehabilitation setting?
4. What three variables can be used in order to assess the changes in cardiorespiratory fitness following a cardiovascular prevention and rehabilitation programme?

Conclusion

The Chester Step Test is a low-cost, practical, sub-maximal test, which is used in the assessment of cardiorespiratory fitness in patients who attend a cardiovascular prevention and rehabilitation programme. This review has highlighted that the validity of the Chester Step Test correlates well with both VO_2 and METs. However, it is prudent to be critical when interpreting the validity of the test, as additional research is required in patients with established cardiovascular disease. Moreover, when assessing the repeatability of the test in measuring changes in cardiorespiratory fitness, it is also important to assess the physiological adaptations associated with exercise training. The physiological adaptations can be assessed by observing a reduction in the heart rate response at each stage of the test.

With reference to prescribing a physical activity and exercise programme, the Chester Step Test provides valuable information for setting walking speeds, work rates on cycle ergometers and deciding on different types of domestic/occupational activities, such as mowing the lawn. In addition, the results of the test can used to help risk-stratify patients, which will help determine an appropriate exercise intensity and level of supervision during a cardiovascular prevention and rehabilitation programme exercise class. In conclusion, future research into the clinical application of the Chester Step Test will help shape our practice in assessing cardiorespiratory fitness in patients who attend a cardiovascular prevention and rehabilitation programme.

Author details

Brunel University London, College of Health and Life Sciences, Department of Clinical Sciences, UK

Conflict of interest

The author has no conflicts of interest to declare.

Acknowledgements

The author would like to acknowledge Professor Kevin Sykes, developer of the Chester Step Test.

References

American College of Sports Medicine. Guidelines for exercise testing and prescription. 10th edn. Lippincott Williams and Wilkins; 2017.

ACSM's Health/Fitness Facility Standards and Guidelines, 5th edn. Champaign (IL): Human Kinetics; 2018

American Association of Cardiovascular and Pulmonary Rehabilitation. Guidelines for cardiac rehabilitation and secondary prevention programs. 6th edn. Champaign (IL): Human Kinetics; 2013.

Ainsworth BE, Haskell WL, Herrmann SD et al. Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011;43(8):1575–1581.

Association of Chartered Physiotherapists in Cardiac Rehabilitation. ACPICR standards for physical activity and exercise in the cardiac population. 2015. http://acpicr.com/publications (accessed February 2019)

British Association for Cardiovascular Prevention and Rehabilitation. BACPR standards and core components for cardiovascular disease prevention and rehabilitation. 2017. http://www.bacpr.com/resources/8BZ_BACPR_Standards_and_Core_Components_2017.pdf (accessed February 2019).

British Association for Cardiovascular Prevention and Rehabilitation. Exercise Instructor Course Manual. 4th edn (Version 5, 2018)

Borg G. Borg's perceived exertion and pain scales. Leads: Human Kinetics; 1998.

Buckley JP, Sim J, Eston RG, Hession R, Fox R. Reliability and validity of measures taken during the Chester step test to predict aerobic power and to prescribe aerobic exercise. Br J Sports Med. 2004;38(2):197–205. https://doi.org/10.1136/bjsm.2003.005389

Ehsani AA, Martin WH, 3rd, Heath GW, Coyle EF. Cardiac effects of prolonged and intense exercise training in patients with coronary artery disease. Am J. 1982;50(2):246–254. https://doi.org/10.1016/0002-9149(82)90173-4

Grove TP, Jones JL, Clements S-J, Connolly SB. The validity and responsiveness of the Chester step test in predicting and measuring the changes in aerobic fitness in comparison with vo2 max treadmill testing in patients at high multifactorial risk of cardiovascular disease. Presented at BACPR Annual Conference, Edinburgh, Scotland, 2012.

Grove TP, Jones JL, Connolly SB. Cardiorespiratory fitness, oxygen pulse and heart rate response following the MyAction programme. Br J Cardiol. 2017;24:25–29. https://doi.org/10.5837/bjc.2017.006

Malfatto G, Facchini M, Bragato R et al. Short and long term effects of exercise training on the tonic autonomic modulation of heart rate variability after myocardial infarction. Eur Heart J. 1996;17(4):532–538. https://doi.org/10.1093/oxfordjournals.eurheartj.a014905

McArdle WD, Katch FL, Katch VL. Exercise physiology: nutrition, energy and human performance. 7th revised international edn. London: Lippincott Williams and Wilkins; 2009.

Myers J, McElrath M, Jaffe A et al. A randomized trial of exercise training in abdominal aortic aneurysm disease. Med Sci Sports Exerc. 2014;46(1):2–9. https://doi.org/10.1249/MSS.0b013e3182a088b8

Reed JL, Cotie LM, Cole C et al. Submaximal exercise testing in cardiovascular rehabilitation settings (BEST study). Front. Physiol. 2019;10:1517. Doi:

Robergs RA, Landwehr R. The surprising history of the “HRmax=220-age” equation. J Ex Physiol. 2002;5(2):1–10.

Sandercock GR, Cardoso F, Almodhy M, Pepera G. Cardiorespiratory fitness changes in patients receiving comprehensive outpatient cardiac rehabilitation in the UK: a multicentre study. Heart. 2013;99(11):785–790. https://doi.org/10.1136/heartjnl-2012-303055

Sykes K. Chester Step Test: resource pack (Version 4). Cartwright Fitness, Cheshire, 2010.

Sykes K. Chester Step Test. Occ Med. 2018;68(1):70–71. https://doi/org/10.1093/occmed/kqx180

Sykes K. Chester Step Test 2 CST2 cardiac edition. Cheshire: Cartwright Fitness; 2019. https://www.chesterstep.com/register (accessed 16 November 2019)

Sykes K, Roberts A. The Chester Step test – a simple yet effective tool for the prediction of aerobic capacity. Physiotherapy. 2004;90(4):183–188. https://doi.org/10.1016/j.physio.2004.03.008