CHANGES IN 6-MINUTE WALK TEST DISTANCE AND HEART RATE WALKING SPEED INDEX FOLLOWING A CARDIOVASCULAR PREVENTION AND REHABILITATION PROGRAMME

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Abstract

Introduction: Improvements in the 6-minute walk test (6MWT) distance is a key outcome measure following a cardiovascular prevention and rehabilitation programme (CPRP). In the absence of a practice test, reporting metres scored in isolation lacks reliability as walking performance has been shown to be influenced by the test-retest learning effects. Therefore, we employed a more robust evaluation using the heart rate walking speed index (HRWSI) to determine if the improvement in 6MWT distance following a CPRP is related to a true physiological adaptation.

Methods: 39 patients (21 female), mean age 68.2 ± 9.8 years attended a 12 week MyAction CPRP. All were assessed using the 6MWT on the initial and end of programme (EOP) assessment. Heart rate (HR), rating of perceived exertion (RPE) and the HRWSI were measured. HRWSI was calculated by dividing HR by the walking speed (meters per minute) multiplied by 10 to describe heart beats per 10 metres walked.

Results: Following the MyAction CPRP there was a 40 metre (17%) improvement in the 6MWT distance (95% CI 18.8-50 p=<0.001) with a subsequent reduction in the HRWSI (-2.7 + IQR -0.59 to 0 95% CI -0.4-0.8 p<0.001). There was a non-significant change in peak HR (-0.4 bpm 95% CI -1.8-2.6 *p*=0.69) and RPE (0 95% CI 0-1 p= 0.4) between the initial and EOP assessments.

Conclusions: The use of the HRWSI provides transparency on the physiological adaptations following a CPRP and can also be used to help patients recognise the benefits of exercise training. For example, the average patient increased his/her 6MWT distance by 40 metres and decreased their HRWSI by 2.7, which translates in a saving of 3 heart beats for every 100 metres walked or 45 heart beats for every mile walked.

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In the absence of a practice test, reporting metres scored in isolation lacks reliability as walking performance has been shown to be influenced by the test-retest learning effects.

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Given the title the abstract should report on functional limitations profile?

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Something about HRWSI being more robust and presenting the physiological adaptations gains and leaving out the performance gains from motivation and learning……

Consider making this how many heart beats saved for a mile – more powerful key message.

Consider adding a recommendation for the future……. i.e. should this measure be employed more widely?

Introduction

Cardiovascular prevention and rehabilitation programmes (CPRP) are an evidence-based intervention, which reduces cardiovascular mortality, hospital readmissions and it improves quality of life (Anderson et al 2015). Traditionally, exercise training has been the 'glue' to most CPRP as gains in cardiorespiratory fitness have been associated with several positive health outcomes (Dorn et al 1999, Myers et al 2002, Kodama et al 2009). Furthermore, formal evaluations of cardiorespiratory fitness are core to most national and international guidelines (BACPR 2007, Piepoli et al 2014). The choice of cardiorespiratory fitness test is dependent on cost, operator experience, space, time and the participant's comorbidities and baseline fitness levels. In many countries maximal exercise testing is performed using open-circuit spirometry whilst exercising on a treadmill or cycle ergometer (Guazzi et al 2012). Whilst open-circuit spirometry is considered as the gold standard, typically this type of exercise test is normally performed at baseline and is rarely used to measure changes in cardiorespiratory fitness over time.

As an alternative, the Association of Chartered Physiotherapists in Cardiac Rehabilitation recommend using a functional capacity test, such as a walk test or step test, as a more practical, cost effective means of assessing cardiorespiratory fitness following a CPRP (ACPICR 2015). Walk tests such as the incremental shuttle walk test and the 6-minute walk test (6MWT) typically report changes in distance achieved; whereas step tests (Chester Step test) report changes in terms of predicted oxygen uptake (Holland et al 2014 and Sykes 1998). Both these types of functional capacity tests have been used extensively in patients at high risk of cardiovascular disease and in those with established vascular disease (Connolly et al 2017, Grove et al 2017). However, due to the progressive nature of the incremental shuttle walk test and the Chester Step test they are more suited to patients with higher baseline cardiorespiratory levels. For patients with a low functional capacity the self-paced 6MWT is more appropriate and closely resembles submaximal effort, which is related to daily living activities.

The 6MWT originated from the 12-minute walk test and was designed to measure the functional capacity in patients with respiratory disease (Butland 1982, Macgavin et al 1976). Since its introduction, it has been used in patients with various types of cardiovascular disease (Bellet et al 2012, Dunn et al 2015). The main aim of the 6MWT is for the individual to walk as far as possible back and forth or around a 30-metre track at their own pace and they are able to stop and rest as required (Holland et al 2014). The 6MWT correlates well with symptom-limited exercise testing (r=0.56 to 0.93), physical function subscales of the SF-36 (r = 0.624) and it is responsive to measuring change (60.43m 95% CI 54.57 to 66.30 m) following a CPRP (Guyatt et al 1985, Faggiano et al 1997, Hamilton and Haennel 2000, Bellet et al 2012). However, in the absence of a practice test, the 6MWT can overestimate the change in walk distance due to the learning effect following an exercise intervention by as much as 2 to 8% (Bellet et al 2012). Therefore, an 8% improvement could potentially be as much as 24 metres in patients achieving >300 metres on the 6MWT. In order to eliminate the learning affect, Buckley et al (2010) have recommended applying the heart rate walking speed index (HRWSI) to tease out the physiological adaptations from other reasons for improvements in walk distance. The HRWSI is the ratio between heart rate (HR) at given walking speed (meters per minute) multiplied by 10 to describe heart beats per 10 metres walked. The HRWSI has been used in post-MI and coronary revascularization patients during the incremental shuttle walk test following a cardiac rehabilitation programme (Buckley et al 2010). However to date, it has not been used to assess the physiological adaptations during the 6MWT in patients at high risk of cardiovascular disease (CVD) and in patients with established atherosclerotic disease including acute coronary syndrome, cerebral vascular disease and peripheral artery disease. Therefore the primary aim of this study is to assess the changes in 6MWT distance and HRWSI in patients attending the Westminster community MyAction CPRP.

Research design

This was a service evaluation study designed to establish a change in walking distance on the 6MWT, HRWSI, HR, and rating of perceived exertion (RPE) following the Westminster MyAction CPRP. The MyAction programme is an innovative nurse-lead multidisciplinary community-based CPRP, which provides integrated care to those with established cardiovascular disease as well as those identified to be at high multifactorial risk (QRisk2> 15%) through the NHS Health Checks programme. The MyAction programme was founded on the principles of the successful EUROACTION cluster randomised-controlled trial (Wood et al 2008). Data were collected on patients who attended their initial and end of programme assessment at the Imperial College NHS Healthcare Trust between September 2009 and October 2015.

Methods and methodology

Patients attended an initial assessment (IA) and an end of programme assessment (EOP) after 12 weeks of a once weekly exercise and educational session. At IA, patients were assessed by a Cardiac Specialist Nurse, Dietitain and an Exercise Specialist. During the assessments the patients were interviewed about their medical history, smoking habits, dietary habits using the Mediterranean diet score and their physical activity behaviours using a 7-day physical activity diary and their physical function using a subscale of SF-36 questionnaire. As part of the assessment, objective measures were taken including: carbon monoxide testing, basic anthropometric measurements (body mass index (BMI), weight and waist circumference) medical history, blood pressure, lipid and glucose profiles, and a functional capacity test. The functional capacity test included the Chester Step test for patients with higher predicted baseline fitness levels or the 6MWT for patients who were predicted to have a low functional capacity. The choice of test was determined from the patient's subjective responses to the physical function subscale of SF-36 questionnaire. This study will only focus on the results of the 6MWT.

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6-minute walk test

Before each 6MWT the patients were asked to refrain from eating, smoking or drinking caffeinated drinks for at least 2 hours before their assessment and they were instructed to take all prescribed medication as normal. The patients were also asked not to take part any moderate or vigorous exercise for 24 hours prior to 6MWT to ensure a consistent baseline activity levels. The patients were fitted with a HR monitor and the Borg 6-20 RPE scale was explained and 'anchored' (Borg 1998). RPE is a validated subjective tool that is used to estimate the patient's global perception of effort. The instructions given to the patients was to focus on overall exertion and not exertion of a particular body part. Before commencing the 6MWT the patients rested, had their blood pressure and HR measured and they were instructed on the protocol described in box 1. Figure 1 presents the 6MWT. Due to limited clinic space the 6MWT course was 10 metres long. During the 6MWT the patient's HR and RPE score were recorded at each minute. HRWSI was calculated by dividing HR by the walking speed (meters per minute) multiplied by 10 to describe heart beats per 10 metres walked.

Exercise intervention

The patients attended a community or hospital-based supervised circuit training session once per week for up to 12 weeks and they were encouraged to take part in a home exercise programme or an exercise DVD two –three times per week. The supervised circuit consisted of a 15 minute warm-up, 20-24 minutes of circuit interval training comprised of aerobic and low-intensity resistance exercises and a 10 minute cool-down. For some patients the circuit interval training programme consisted of chair-based or supported exercise stations. During the training programme, the patients exercised at an intensity range of between 40 and 60% of their age predicted HR reserve max and/or at an RPE of 11 to 13, as recommended by the ACPICR (2015) guidelines. Over the 12 weeks, the exercise programme was progressed on the basis of increasing the duration of time spent on the aerobic exercise stations and decreasing the time spent on the resistance exercise stations until 20-24 minutes of continuous aerobic exercise was achieved. In addition, at the end of each exercise session, the patients attended a 45-minute weekly educational workshop on CVD risk factor modification, smoking cessation, cardio-protective medication, stress management, benefits of physical activity, food labelling and the Mediterranean diet.

Statistical methods

All data was assessed for parametric assumptions prior to statistical analysis using Stata version 13.0. Parametric data are expressed as mean ± standard deviation (sd) and non-parametric data are expressed as median ± interquartile range (IQR). The Wilcoxon signed rank test are conducted on the 6MWT distance and RPE, Paired *t* tests for HR and the Sign rank test are conducted on the HRWSI. A sub-group analysis was carried out, which compares the 6MWT distance, HRWSI, HR and RPE between those at high risk and in patients with CVD.

Results:

A total of 1810 patients attended an IA and EOP assessment over a 6 year period. Out of the 1810 patients, 45 patients were identified as having a low predicted baseline fitness level and they took part in the 6MWT. From the 45 patients, 2 patients were excluded from the analysis due to missing HR data on the 6MWT and 4 patients were excluded due to changes in their beta-blocker dose following their IA. The final analysis included 39 patients (21 female), mean age 68.2 ± 9.8 years (range 48 to 93 years) who attended a 12 week Westminster MyAction programme (mean 11 exercise sessions range 8-14). Out of the 39 patients, 18 patients were stratified as high multifactorial risk (26.9% ± 7.1 risk score) and 21 had established CVD. In addition, 95% of the patients presented with one or more co-morbidities (range 0-5). Demographics are presented in table 1.

Changes in 6-minute walk test distance

At the EOP assessment, the median 6MWT distance had increased by 40 metres + IQR 0-70 metres (95% CI 18.8-50 p=<0.001) following the MyAction programme (table 2). The median distance achieved was slightly greater in those who had established CVD when compared to the patients at high multi-factorial risk, although this was not significant (p=0.8) figure 2.

Changes in heart rate walking speed index

In support of an increase in the 6MWT distance the HRWSI had significantly decreased by -2.7 + IQR -5.8 to 0 (95%_CI -3.5,-0.4 p<0.001) at the EOP assessment (table 2). In a sub-group analysis there were no significant differences in the decrease in the HRWSI between patients at high risk and in patients with established CVD (p=0.8).

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Changes in heart rate

The overall peak HR response was similar between the IA and EOP assessment 6MWTs (-0.4 bpm 95% CI -1.8-2.6 *p*=0.69) (table 2). In a subgroup analysis, the high risk patients decreased their exercise HR from 104.4±14 beats/min to 102.6±13 beats/min at EOP assessment (-1.7 95% CI -0.7-4.2 p=0.15) and patients with CVD had a slight increase in their exercise HR response from 94.1±17 beats/min to 94.8±17 beats/min (0.7 95% CI -4.4-3 p=0.69) at EOP assessment. The change in HR response between the two groups was non-significant (p=0.05)

Changes in rating of perceived exertion

Overall RPE did not significantly change and the median score was 0 + IQR 0 to 1 (95% CI 0-1 p= 0.4) (table 2). In a subgroup analysis, the median RPE score was 0 + IQR 0-2 and 0 + IQR -1-2 respectively for patients at high risk and patients with CVD. There were no significant differences between the two groups (p=0.2)

Discussion

The aim of this study was to assess the changes in 6MWT distance, HRWSI, HR and RPE following the Westminster MyAction CPRP. The results demonstrated that walking performance on the 6MWT had significantly increased by 40 metres + IQR 0-70 metres at the EOP assessment (95% CI 18.8-50 p=<0.001). In a sub-group analysis, patients with established CVD achieved a greater improvement in their median distance when compared to patients at high risk (40 metres vs 35 metres), although this was not statistically significant (p=0.8). Overall, 72% (*n*=28) of the patients had increased their 6MWT distance (range 10 to 265 metres), 15% (*n*=6) had remained the same and 13% (*n*=5) had a decrease in their 6MWT distance (-10 to -80 metres) following the MyAction programme. However, the overall median change in distance of 40 metres is less than the 60.43 metres that has been previously reported in a recent meta-analysis (Bellet et al 2012). These differences are probably due to the fact that the present study reported on the median change in distance and the 6MWT course length was set at 10 metres. According to guidelines the standard course length should be at least 30 metres (Crapo et al 2002, Holland et al 2014); however, due to limited clinic space a shorter course length of 10 metres was used at the initial and EOP assessments. Therefore, it should be noted that on average patients walk 49.5 metres less on a 10 metre course when compared to a 30 metre course (Beekman et al 2013). In addition, many other factors might have also influenced the distance that was achieved during the 6MWT and these include: age, body mass, gender, additional co-morbidities, stride length, motivation, and the test-retest learning effect (Crapo et al 2002, Beekman et al 2013, Garyfallia et al 2013). The following will discuss the factors relating to motivation and the test-retest learning effect.

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Motivation can be influenced internally by the patient (i.e. patient remembering their pre-test distance and trying to do better on their post-test) or externally through encouragement from the tester. In order to minimise the internal factors, patients were only reminded of their IA 6MWT distance once they had completed their EOP 6MWT. For external motivation, standardised encouragement from the test administrator was given every two minutes such as “you are doing well” and “keep it up”. Encouragement can increase the mean walking distance by 30.5 metres compared to no encouragement (Guyatt et al 1984)**.**

With regards to the test-retest learning effect this can be reduced by performing a practice test. However, in the present study it was not possible to conduct a practice test due to time constraints and the extra burden that would have been placed on the patients if they had to attend additional assessments on different days. In light of the current evidence, Hamilton and Haennel (2000) and Bellet et al (2012) have reported a 2-8% improvement following a practice test and Guyatt et al (1984) have observed a plateau in the performance on the 6MWT following 3 consecutive tests. Therefore, it could be argued that a 22 metre (8%) improvement in the present study could be accounted for by the learning effect. Nonetheless, to contest this argument the HRWSI was applied to measure the physiological adaptations following the MyAction programme. The HRWSI is the ratio between HR at given walking speed (meters per minute) multiplied by 10 to describe heart beats per 10 metres walked (Buckley et al 2010). In the present study the HRWSI decreased by 2.7 + IQR -0.59 to 0 (95% CI -0.4-0.8 $p<0.001$). These findings translate into a saving of 3 heart beats for every 100 metres walked or 45 heart beats for every mile walked. Moreover, for patients who lie within the interquartile range the saving could be as much 6 heart beats for every 100 metres walked or 90 heart beats for every mile walked. These findings are similar to Buckley et al’s (2010) study, who observed a saving of 4 heart beats for every 100 metres walked or 60 heart beats for every mile walked in patients taking part in the incremental shuttle walk test following a cardiac rehabilitation programme.

The reduction in HR at a given workload is a classical training adaptation, which reflects an improvement in cardiac efficiency. Such improvements can reduce the rate pressure product, myocardial ischaemia and the risk of arrhythmias (Malfatto et al 1996, May et al 1984). The magnitude that is associated with the reduction in submaximal HR response is dependent on the exercise training intensity and volume. This was demonstrated by a 7–14 bpm reduction in submaximal HR response in 140 patients with an abdominal aortic aneurysm following a high exercise volume (1,999 ± 1,030 kcal/week energy expenditure) and a high intensity (98.8% of HR training zone) exercise training programme (Myers et al 2014). In addition, lower intensity exercise training programmes (40-70% of predicted HR reserve max) can also provoke a 4-7 bpm reduction in submaximal HR response following a training intervention in those at high risk of CVD and with established vascular disease (Grove et al 2017).

In support of the reduction in both HRWSI and HR responses, RPE was used to assess the overall global perception of effort during the 6MWT. The use of RPE is widely accepted as a valid and reliable method for assessing exercise intensity as it correlates well with HR, oxygen uptake and the lactate threshold (Chen et al 2002). At the EOP assessment RPE did not significantly change despite an increase in walking distance (0 95% CI 0-1 $p=0.4$). This clearly demonstrates that patients at the EOP assessment are able to accomplish a greater workload with a similar perception of exertion and physiological demand.

Limitations

Despite the positive outcomes of the present study, it is important to acknowledge the main study limitations. The first limitation is related to the data, which was collected from clinical practice with no control group and it needs to be verified in a randomised prospective study design. The second limitation is related to HR, which was recorded on the database as peak rather than the average during the 6MWT. The third limitation relates to medication compliance, which was only assessed subjectively and not objectively. Therefore, poor compliance with heart rate limiting medication such as beta blockade therapy could alter the HR response during the 6MWT. The fourth limitation relates to extrinsic variables such as room temperature was not controlled, which could potentially influence the HR response during the 6MWT. Future research is needed to control for these variables and to detect whether a change in the HRWSI translates into a minimal clinically important difference.

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In the above is there anything about clinically important differences? Maybe the suggestion would be made that this is a further research question to detect the MICD

Conclusion

The results of this study demonstrated that the Westminster MyAction CPRP is an effective intervention for improving 6MWT distance, HRWSI and physical function in patients at high risk of CVD and in patients with established vascular disease. Following the programme there was a 14% improvement in the 6MWT distance with a subsequent 2.7 + IQR -0.58 to 0 reduction in the HRWSI. The use of the HRWSI provides transparency on the physiological adaptations following a CPRP and can also be used to help patients recognise the benefits of exercise training. For example, the average patient increased his/her median 6MWT distance by 40 metres and decreased their HRWSI, which translates in a saving of 3 heart beats for every 100 metres walked or 45 heart beats for every mile walked. These findings are consistent with previous studies.

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Box 1. 6-minute walk test protocol

Two cones were set out 9 metres apart, which allowed for a 0.5 metre turn at each end giving a total distance of 10 metres. Chairs were placed at either end of the course. The patients were instructed to cover as much distance as possible within 6 minutes by walking back and forth around the course pivoting 180^0 at each cone. The test administrator demonstrated by walking one lap around the course and pivoting around the cones. During the 6MWT patients were able to rest when needed and recommence when they felt able to. Patients were able to take part in the test using a walking aid. Standardised verbal encouragement was given to the patients every 2 minutes. HR and RPE were recorded each minute during the test. After 6 minutes patients were instructed to stop and the total distance achieved was recorded.

Figure 1. 6-minute walk test

Table 1. Patient demographics

Demographics	Summary
Age, mean ± SD (yr)	68.2 ± 9.8
Gender (n % male)	18 (46%)
Ethnicity (n % Caucasian)	20 (51%)
BMI, mean ± SD ($kg.m^{-2}$)	31±6.2
Waist, mean ± SD (cm)	104±13.6
No. exercise sessions mean (range)	11± (range 8-14)
Diagnosis on referral *n* (%)	
Acute coronary syndrome	7 (18)
Angina	7 (18)
CVA/TIA	2 (5)
Heart failure	1 (3)
Peripheral artery disease	3 (8)
Valve disease	1 (3)
High risk	18 (46)
Co-morbidities *n* (%)	
Asthma/COPD	6 (15)
Cancer	7 (18)
Chronic back pain	12 (31)
CVA/TIA	2 (5)
Diabetes	9 (23)
Previous cardiac events	10 (26)
Atrial septal defect	1 (3)
Rheumatoid/osteoarthritis	15 (38)
Osteoporosis	4 (10)
Obesity (>30 $kg.m^{-2}$)	18 (46)
Medications *n* (%)	
Anti-platelets	20 (51)
Ace inhibitors/ARB	17 (44)
Beta-blockers	14 (36)
Calcium Channel Blockers	8 (21)
Diuretics	8 (21)
Statins/Ezetimibe	23 (59)
Antianginal/Nitrates	5 (13)
Anti-coagulant	2 (5)
Sulfonylureas/Biguanide/Human log	9 (23)

Table 2. Changes in 6MWT distance, HRWSI, HR and RPE

Variable	Initial Assessment	End of programme assessment	95% Confidence interval	P value
6-minute walk test (median +IQR) (metres)	280 (220 to 370)	350 (270 to 430)	18.8-50	0.001
Peak heart rate (mean + SD)	98.8 (16.9)	98.4 (16.1)	-1.8-2.6	0.69
Heart rate walking speed index (median +IQR)	19.4 (16 to 27)	16.8 (15 to 20)	0.4-0.8	0.001
Rating of perceived exertion (median +IQR)	12 (11 to 13.5)	13 (11 to 13)	0-1	0.4

Figure 2. Differences in 6MWT distance in high risk patients and with CVD