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SHORT REPORT

The effect of an active arm action on heart rate and predicted VO_{2max} during the Chester step test

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Summary This study examined whether the predictive outcomes of the Chester step test (CST) would be influenced by arm dynamics. Participants completed the CST on two separate occasions, once using active arms and once using passive arms. Results revealed that when compared to the passive arm protocol, the use of active arms led to a mean increase in heart rate of approximately 7 beats per minute across all of the incremental stages. However, this increase had little impact upon predicted VO_{2max}. Consequently, these results indicate that when performing the CST, participants are able to adopt an arm action that is compatible with personal preference.

Introduction

The Chester step test (CST)[1,2] is a sub-maximal, multi-stage step test that has been adopted throughout the world by fire brigades and health authorities to assess aerobic fitness.[2] Founded upon the assumption that, during work of light to moderately heavy intensity, heart rate (HR) and O_2 consumption possess a linear relationship, the CST utilises exercising HR to predict aerobic power (VO_{2max}).[3] Specifically, HR values are recorded at various intensities throughout the test until 80% HR_{max} is obtained, after which a line of best fit is applied and extrapolated to HR_{max}. From this, predicted VO_{2max} is calculated. Although the CST supporting documentation provides instruction as to the correct stepping action, no such information is provided with regard to arm dynamics. Hence, with no specific direction, it would appear that participants of the test are able to select an arm action that is congruent with individual preference. From experience, the authors have observed that the majority of participants adopt one of two distinct approaches, active or passive. The active arm action involves sagittal-plane flexion/extension at the shoulder, accompanied by sagittal-plane flexion/extension at the elbow. This is synchronised with the opposing leg movement. With the static approach, the participant's arms are fully extended along the midaxillary line; when stepping there is minimal movement at the shoulder or elbow.

As the CST relies on HR to predict VO_{2max}, assessment outcomes may be sensitive to any factor

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that influences HR. Obviously stepping rate impacts upon this. However, active arms may place an additional demand upon the cardio-respiratory system. Conceivably, when compared to the adoption of static arms, an active arm action may increase energy expenditure, provoking an elevation of HR. This could produce a comparatively lower estimation of VO_{2max}. Therefore, this study will examine whether or not the adoption of an active arm action will influence the predicted VO_{2max}.

Materials and methods

Participants

A convenient sample of 25 healthy individuals (10 males, 15 females; 23.0 ± 6.5 year; 1.71 ± 0.07 m; 66.7 ± 10.4 kg) voluntarily participated in this study with informed consent. All those involved were students attending a University College in the north of England. Prior to any testing, ethics approval was obtained and participants were screened for cardiovascular and pulmonary disease and orthopaedic problems through the administration of the PAR-Q [4] pre-participation screening questionnaire.

Experimental design

The experimental conditions required the completion of the CST once utilising an active arm action and once with arms passive. These were counterbalanced and participants were randomly allocated to each condition. Participants were asked to attend the laboratory at a predetermined time. This was maintained for both trials and tests were completed one week apart. Before the first trial commenced, a brief pre-test session was conducted, the purpose of which was to obtain informed consent and physical activity readiness; this required the completion of the PAR-Q. Maximal heart rate was predicted from the formula 220 − age, after which 80% was calculated. Polar heart rate monitors were used to measure HR. Borg's 15-point rating scale was then introduced.[5] Participants were informed that the CST was to be terminated if their target HR (predicted 80% HR_{max}) had been obtained, or an RPE value of '14' was expressed.

Once the introductory procedures had been completed, a series of familiarisation tasks were administered. First, the correct stepping action was demonstrated after which 30 s of practice was undertaken. Second, because localised muscular fatigue can influence the outcome of the CST, participants were shown how to change their leading leg. Thirty-second practice was provided. Next, the active arm action was demonstrated along with a verbal instruction. In this study the action was thus.

When placing the lead leg on to the step, the opposite arm should be flexed at the shoulder until the elbow passes the sternum; approximately 40° past the mid-axial line. This was to be accompanied with elbow flexion of approximately 90°. Simultaneously, the alternate arm was to be extended at the shoulder until the elbow passed the lumbar region; this was approximately 40° past the mid-axial line. This was to be accompanied by full elbow extension. The arm sequence was repeated four times during each stepping action, two with the upward stepping sequence and two with the downward sequence.

After this demonstration, participants practised the action for 1 min, after which a 2 min rest period was provided. To maintain consistency, the above procedure was followed for both conditions but, when completing the passive condition, participants were to refrain from moving their arms. Once the rest period had expired the test protocol began with HR and RPE being recorded at completion of each two min stage. Stage 1 commenced at 15 steps per minute, with each successive stage increasing by five steps per minute, up to a maximum of five stages. Upon completion of both trials, HR data were entered into the CST computerised prediction program and VO_{2max} was calculated.

Statistical analysis

Results for HR and predicted VO_{2max} are presented as sample mean and standard deviation. Differences between means are presented first in the raw unit, then as an effect size (ES).[6,7] We show the precision of our estimates of outcome statistics as 90% confidence limits, which define the likely range of the true value in the population from which we drew our sample.[8] The smallest practically important change in HR and predicted VO_{2max} was assumed to be an ES of 0.2, with the full scale of effect descriptors being trivial (0—0.2), small (0.2—0.6), moderate (0.6—1.2), large (1.2—2.0) and very large (2.0—4.0).

Results

Heart rate

The mean ± S.D. for both conditions during Stages 1—3 of the CST are displayed in Fig. 1. The differences in HR between conditions during Stages 1—3

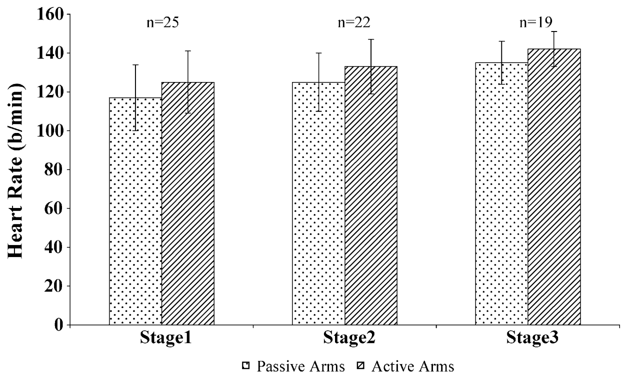

Figure 1 The mean heart rate for both conditions during Stages 1—3 of the CST.

of the CST are presented in Fig. 2. These figures show a consistent effect of an active arm action on heart rate of approximately 7 beats per minute, although the 90% confidence intervals suggest the true effect across the stages could be in the range of an increase of 5 to 10 beats per minute (Fig. 2). Expressing the results as ES, there was an increase for each successive stage of the CST: Stage 1 (0.44 ES; 90% confidence 0.27 to 0.6 ES), Stage 2 (0.52 ES; 90% confidence 0.37 to 0.68 ES) Stage 3 (0.63 ES; 90% confidence 0.39 to 0.88 ES).

Predicted VO_{2max}

The mean ± S.D. predicted VO_{2max} for the active and passive arm actions were 47.7 ± 6.5 and 48.4 ± 6.3 mL kg^{-1} min^{-1}, respectively. The mean difference between conditions (active minus passive) was −0.7 mL kg^{-1} min^{-1} although the 90% confidence interval suggests this value could be −2.8 mL kg^{-1} min^{-1} to 1.5 mL kg^{-1} min^{-1}. The size of this difference as an ES is −0.1 (−0.4 to 0.2).

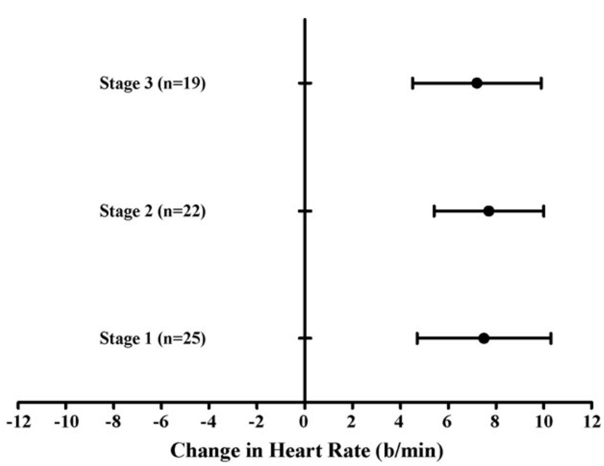

Figure 2 The mean effect of an active arm action on heart rate during stages 1—3 of the CST. The control condition involved participants not using their arms. Bars define the 90% confidence interval.

Discussion

The results of the present investigation show that there was a small effect of an active arm action on HR at Stages 1—3. At these stages an active arm action increased mean HR by approximately 7 beats per minute. Given the direction of this difference, the most plausible explanation is the effect of a greater active muscle mass in the active arm condition, thereby requiring a higher cardiac output and ultimately higher HR. However, this difference is within the normal test-retest variation of the CST.[9,10]

Importantly, despite the increases in HR, this did not have a significant impact upon mean VO_{2max}. Results revealed that, when an active arm action was used, there was a slight reduction in mean predicted VO_{2max} (−0.7 mL kg^{-1} min^{-1}). However, the 90% confidence interval indicates that predicted VO_{2max} could be reduced by as much as 2.8 mL kg^{-1} min^{-1} or increased by 1.5 mL kg^{-1} min^{-1}. Nevertheless, these effects are again within the normal test-retest variation.[9,10] Regarding the fact that for some individuals an active arm action appears to increase VO_{2max} prediction, it would appear that the use of the arms may improve movement economy. However, the positive direction of HR responses suggest that active arms did increase energy expenditure. Hence it is more likely that the differences in predicted VO_{2max} were also as a result of normal test-retest variation. The results of the current investigation do appear to be within the normal reliability limits. Therefore, it can be concluded that arm dynamics do not significantly impact upon predicted VO_{2max}. We therefore suggest that participants can select an arm action based upon personal preference.

Practical implications

- Individuals performing the Chester step test can select either static or dynamic arm actions without affecting predicted maximal aerobic power.
- Those administering the Chester step test should inform participants that arm action can be based on personal preference.
- It is unclear whether or not the current results are applicable to other step tests.

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