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Reliability of a high-intensity cycling capacity test

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ABSTRACT

Objectives: To assess the reliability of the $CCT_{110\%}$, a high-intensity cycling capacity test performed to exhaustion.
Design: 27 recreationally active participants (age 23 ± 4 y; height 1.79 ± 0.06 m; body mass 78.0 ± 8.8 kg; Powermax 306 ± 49 W) performed the $CCT_{110\%}$ on two occasions.
Methods: Performance measures determined from the $CCT_{110\%}$ were time to exhaustion (TTE) and total work done (TWD). Blood pH, lactate, bicarbonate and base excess were determined before exercise, immediately after exercise, and 5 min after exercise. Exercise capacity data were analysed using intra-class correlations (ICC), systematic bias ratio, ratio limits of agreement, coefficient of variation (CV) and *t*-tests. Blood variables were analysed using repeated measures ANOVA and Tukey tests for post hoc comparisons.
Results: TTE (mean ± SD: 134 ± 20 s and 135 ± 20 s, $P = 0.75$) and TWD (42.2 ± 10.3 kJ and 42.2 ± 9.8 kJ, $P = 0.97$) were not different between trials. The ICC between trials was $r = 0.88$ for TTE and $r = 0.94$ for TWD, with the CV being 4.43% for TTE and 4.94% for TWD. There were no between trial differences in blood markers at any time point except immediately post-exercise pH (7.246 ± 0.041 vs. 7.269 ± 0.064, $P = 0.004$).
Conclusions: The $CCT_{110\%}$ is a reliable exercise protocol that can be used for nutritional interventions designed to affect intracellular and extracellular pH changes. Although blood pH was significantly different between trials immediately post-exercise, the absolute differences are much smaller than those expected to be seen using nutritional interventions intended to alter extracellular pH during exercise.

1. Introduction

Buffering agents are commonly used to enhance exercise performance and capacity (for reviews see[1,2]). Few studies have reported on the reliability of the exercise test employed while investigating the effects of nutritional supplementation on increased buffering capacity, which may have contributed to equivocal results. An appropriate exercise test to investigate the effects of increased buffering capacity should be of sufficient intensity to result in a large accumulation of H^+, and therefore be limited by increasing muscle acidosis. Furthermore, it is of vital importance that a test is reliable in order to interpret the meaningfulness of the data.[3]

Investigations into the effect of buffering agents on exercise performance and capacity require multiple repetitions of a protocol, with and without supplementation, in order to determine any improvements following supplementation. Therefore, the exercise test employed should be reliable to determine whether differences are due to the nutritional intervention or are simply due to the natural variation of the test. The reliability of a protocol is a reflection of the consistency of the data when the measurements are taken on multiple occasions under identical conditions.[4] However, there will always be a degree of measurement error due to a variety of factors including circadian variation, instrumentation failure, and participant and experimenter error.[5] Atkinson and Nevill[3] have suggested, therefore, that reliability is the amount of measurement error deemed acceptable for the effective practical use of an analysis system.

The $CCT_{110\%}$ is a high-intensity cycling capacity test performed at 110% of previously determined Powermax (W_{max}), designed[6] to last between 120 and 240 s, an exercise duration when anaerobic energy sources can contribute up to 60% of the total energy requirement.[7] Therefore, the high-intensity nature of the test would be expected to incur a large accumulation of intracellular, and subsequently extracellular H^+, leading to an early cessation of exercise due to increasing acidosis. Indeed, Hill et al.[6] showed that TWD was increased by 13.0% alongside a 58.8% increase in muscle carnosine following four weeks of β-alanine supplementation; when supplementation was extended to ten weeks,

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carnosine was increased by 80% and TWD by 16%. Similarly, Sale et al.[8] recently confirmed the effect of β-alanine supplementation on high intensity exercise capacity using the $CCT_{110\%}$, with TWD increased by 14.6% following 4 weeks supplementation. They also reported a further, yet non-significant, increase of 4.3% in TWD following acute supplementation with sodium bicarbonate following β-alanine supplementation. The results of Hill et al.[6] and Sale et al.[8] suggest the $CCT_{110\%}$ to be an appropriate tool for the investigation of dietary interventions designed to manipulate changes in pH during exercise.

The aim of this study was to examine the reliability of the $CCT_{110\%}$ as a high-intensity cycling capacity test. Further, due to the high association between lactate and H^+ production,[9] the reliability of blood lactate concentration was measured alongside several other blood markers. We hypothesised that the $CCT_{110\%}$ would be a highly repeatable and appropriate model that can be utilised to examine the effects of dietary interventions designed to manipulate changes in pH during exercise.

2. Methods

Twenty seven recreationally active males (age 23 ± 4 y; height 1.79 ± 0.06 m; body mass 78.0 ± 8.8 kg; W_{max} 306 ± 49 W) volunteered and gave their written informed consent to participate in this study. The study was first approved by the institution's Ethics Review Committee.

Participants attended the laboratory on four separate occasions at the same time of day to ensure results were not affected by circadian variation. The first trial consisted of an incremental cycling test to exhaustion to determine individual W_{max}. The remaining three sessions (one habituation and two main trials) were for the completion of the main $CCT_{110\%}$ trials. All trials were separated by 48 h. Prior to the main trials, participants abstained from alcohol, caffeine and strenuous exercise and completed a food record for the 24 h period prior to the initial trial, which was subsequently replicated prior to the second main trial. Participants consumed a standardised breakfast (3 slices toast with jam) 4 h prior to the commencement of exercise and were allowed to drink water ad libitum throughout the day. Arterialised finger-prick blood samples were taken immediately pre-, immediately post- and 5-min post-exercise. Blood samples were analysed for lactate (Lactate Pro, Arkray, Japan), pH, haemoglobin (Hb) and blood gases (Radiometer ABL 400, UK). Blood bicarbonate was calculated from PCO_2 and pH values according to the Henderson–Hasselbalch equation and base excess was calculated according to $((1 - 0.014[Hb]) \times ([HCO_3^-] - 24 + (1.43[Hb] + 7.7)(pH - 7.4)))$.

Participants performed a graded cycle capacity test to exhaustion on a cycle ergometer (Lode Excalibur, Lode B.V., Germany) to determine individual W_{max}. Individual set up of the bike (saddle and handlebar height and length) was determined prior to the initial W_{max} trial and was maintained for all subsequent $CCT_{110\%}$ trials. Exercise commenced at a self-selected power between 100 and 150 W, and was increased by 6 W every 15 s (ramp rate of 24 W min^{-1}) until participants reached volitional exhaustion. Participants pedalled at a constant, self-selected pedal cadence (mean ± SD = 87 ± 8 rev min^{-1}, median = 90 rev min^{-1}, range = 75–100 rev min^{-1}) and were given verbal encouragement throughout. Volitional exhaustion was deemed to have occurred when participants dropped 20 rev min^{-1} below their self-selected pedal cadence, at which point they were instructed to stop pedalling. The maximum power output averaged over the final two stages was defined as an individual's W_{max}.

All trials of the cycling capacity test at 110% of W_{max} were performed on a cycle ergometer (Lode Excalibur, Lode B.V., Germany).

Table 1
Absolute and relative reliability measures of the $CCT_{110\%}$.

	TTE	TWD
Trial 1	134 ± 20 s	42.2 ± 10.3 kJ
Trial 2	135 ± 20 s	42.2 ± 9.8 kJ
Trial 1 (In)	4.89 ± 0.15	3.71 ± 0.27
Trial 2 (In)	4.90 ± 0.15	3.71 ± 0.26
Systematic bias	1.005	1.003
×/÷ Ratio LoA	1.156	1.176
CoV (%)	4.43	4.94
ICC (CI)	0.884 (0.761–0.945)	0.939 (0.931–0.986)
t-Test	$p = 0.745$	$p = 0.970$
Variation LoA	135: 117, 157	42.2: 36.0, 49.8
Variation CoV	135: 129.0, 141.0	42.2: 40.1, 44.3

A five min cycling warm up was performed at 100 W followed by a 2 min period of stretching. Each participant's $CCT_{110\%}$ was incremented over the first 30 s which corresponded to 80% W_{max} during the first 15 s, 95% W_{max} over the second 15 s followed by 110% W_{max} until volitional exhaustion. Participants pedalled at a constant, self-selected pedal cadence and were given verbal encouragement throughout. Volitional exhaustion was deemed to have occurred when participants dropped 20 rev min^{-1} below their self-selected pedal cadence, at which point they were instructed to stop pedalling. Time to exhaustion (TTE, s) and total work done (TWD, kJ) were recorded as the outcome measures for all tests. No feedback was provided to the participants regarding their performance until all trials had been completed.

All data are presented as mean ± 1 SD, unless stated otherwise. Exercise capacity data were analysed using intra-class correlations (ICC, 2 way fixed, repeated measures, absolute model),[5] systematic bias ratio, ratio limits of agreement (LoA),[10] coefficient of variation (CV) and *t*-tests. Blood variables were analysed using repeated measures ANOVA and Tukey tests were used for post hoc analyses. Effect sizes were calculated using Cohen's *d*.[11] Statistical significance was accepted at $p \leq 0.05$.

3. Results

TTE ($p = 0.75$; 134 ± 20 s and 135 ± 20 s, $d = 0.05$) and TWD ($p = 0.97$; 42.2 ± 10.3 kJ and 42.2 ± 9.8 kJ, $d = 0.00$) were not different between trials (Table 1). Following confirmation of heteroscedasticity, ratio systematic bias and limits of agreement were determined and are presented in Table 1. The intra-class correlation between trials was $r = 0.88$ for TTE and $r = 0.94$ for TWD, with the CV being 4.43% for TTE and 4.94% for TWD.

Baseline blood pH, bicarbonate and base excess were similar between both trials (Table 2). In both trials, pH, bicarbonate and base excess were significantly reduced from baseline immediately post exercise and following 5 min of recovery ($p \leq 0.001$). Only immediately post-exercise pH was significantly different between trials ($p \leq 0.001$; Table 2)

Blood lactate was not significantly different between trials at baseline, and was significantly increased from baseline immediately post exercise and following 5 min of recovery in all trials ($p \leq 0.001$), with no between trial differences.

4. Discussion

The aim of this study was to determine the reliability of a high-intensity cycling capacity test. The $CCT_{110\%}$ was designed to provide a high-intensity cycling test with an expected TTE between 120 and 240 s. Main trial times of 134 ± 20 s and 135 ± 20 s lie within the expected timeframe of the test, with no significant differences between trials. The reliability of the $CCT_{110\%}$ was demonstrated by the ratio bias for TTE and TWD being close to 1, narrow agreement ratios