ESTABLISHING MAXIMAL OXYGEN UPTAKE IN YOUNG PEOPLE DURING A RAMP CYCLE TEST TO EXHAUSTION

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1.1 INTRODUCTION

Maximum oxygen uptake (VO_{2\text{max}}) is recognized as the best single measure of aerobic fitness, although the most appropriate methods to assess and interpret VO_{2\text{max}} in young people remain controversial (Armstrong and Welsman 1994). As only ~20-40% of children performing exercise to exhaustion display a plateau in their VO_{2} response to exercise (Armstrong et al. 1995; Rowland 1993), the term ‘peak VO_{2}’ (VO_{2\text{peak}}) has been adopted. Consequently, paediatric researchers rely on subjective indicators of intense effort (e.g. facial flushing, sweating, unsteady gait, hyperpnoea) supported by secondary ‘objective’ criteria (e.g. respiratory exchange ratio [RER], blood lactate and heart rate values) to verify a ‘maximal’ response.

A ramp based cycling protocol is becoming a popular method for determining VO_{2\text{max}} both in healthy and diseased children (e.g. Barker et al. 2008; Stevens et al. 2009). However, it remains to be established whether the highest VO_{2} attained during ramp cycling exercise reflects a ‘true’ VO_{2\text{max}}, as determined from supra-maximal exercise testing. Moreover, a recent study has questioned the validity of using secondary criteria during ramp exercise, as RER, heart rate and blood lactate criteria can underestimate VO_{2\text{max}} by 30-40%, or falsely reject a valid VO_{2\text{max}} measure (Poole et al. 2008). As large inter-individual variations in RER (0.95-1.15), heart rate (185-215 beats·min^{-1}) and blood lactate (3-12 mM) are present in children at VO_{2\text{max}} (Armstrong and Welsman 1994), it is plausible that the utility of secondary criteria are equally inappropriate in young people.

The aims of this study were to test the following hypotheses: 1) that using secondary criteria can result in the acceptance of a ‘sub-maximal’ VO_{2\text{max}} during ramp cycling exercise in children; and 2) that the highest VO_{2} recorded during a ramp
cycling exercise in children is comparable to the highest VO$_2$ achieved during supra-
maximal testing, thus satisfying the plateau requirement for a ‘true’ VO$_{2\text{max}}$.

1.2 METHODS

1.2.1 Experimental Design

Thirteen 9-10 y old children (8 boys, 5 girls) completed two tests to exhaustion within
a single day on an electronically braked cycle ergometer (Lode, Groningen, Netherlands). The first test consisted of a ramp exercise test to exhaustion to determine
their VO$_2$ max using a ramp rate of 10 W·min$^{-1}$. Following a recovery period consisting
of 10 min cycling at 10 W and 5 min rest, the participants completed a supra-maximal
bout to exhaustion with the intensity set to 105% of the peak power achieved during
the ramp test. Oxygen uptake (EX671, Morgan Medical, Kent, UK) was determined
every 15 s and a finger tip capillary blood was analysed for lactate concentration
following the ramp test (YSI 2300, Yellow Springs, Ohio, USA).

1.2.2 Criteria for establishing VO$_2$ max

A plateau in the VO$_2$ profile during the ramp test was identified by examining the
profile of the residuals against a linear regression extrapolated from the ‘linear’ portion
of the response to end exercise. The secondary criteria used to verify a ‘maximal’ VO$_2$
were an RER of 1.00, a heart rate of 195 beats·min$^{-1}$ and within 85% of age predicted
maximum (220-age), and a blood lactate concentration of ≥ 6 mM (Armstrong and
Welsman 1994; Dencker et al. 2007; Leger 1996; Rowland 1993).

1.2.3 Statistical analysis

Boys’ and girls’ data were grouped ($n=13$) to form a single data set for analysis. Paired
samples t-tests examined mean differences between outcome variables with the
Bonferroni correction applied for multiple comparisons. Limits of agreement analyses
were used to establish the mean bias and 95% confidence limits between the ramp and
supra-maximal test responses. The alpha level was set at 0.05.

1.3 RESULTS
Four participants had a VO₂ plateau at exhaustion, whereas seven showed a linear and two showed an accelerated response. At exhaustion the mean RER was 1.11 [SD 0.06, range 0.99-1.20]. A single boy failed to reach the RER criterion. In the 12 participants that satisfied this criterion, the VO₂ recorded at an RER of 1.00 (1.293 L·min⁻¹ [SD 0.265]) significantly underestimated the VO₂ recorded at exhaustion (1.681 L·min⁻¹ [SD 0.295], P=0.002), representing 77% of the latter.

Mean heart rate at exhaustion was 202 beats·min⁻¹ [SD 7, range 191-214]. All children satisfied the 85% of their age predicted maximum criterion (equivalent to ~ 179 beats·min⁻¹). Three children failed to reach the 195 beats·min⁻¹ criterion, despite a clear plateau in VO₂ at exhaustion in 2 of these participants. In the participants that satisfied the heart rate criteria, the VO₂ recorded at 85% of their age predicted maximum (1.345 L·min⁻¹ [SD 0.228]) and at 195 beats·min⁻¹ (1.556 L·min⁻¹ [0.265]) significantly underestimated the VO₂ recorded at exhaustion (1.690 L·min⁻¹ [SD 0.284] and 1.721 [SD 0.318] respectively; P<0.002), representing 80% and 90% of the latter.

Mean blood lactate following ramp exercise was 6.7 mM [SD 2.1, range 4.2-12.1]. Six children (4 boys, 2 girls) satisfied the blood lactate criterion of ≥ 6 mM. Of the 7 participants who had a blood lactate < 6 mM, 2 had a plateau in their VO₂ profile.

Supra-maximal testing yielded a VO₂ peak that was not significantly different from the ramp test (1.615 L·min⁻¹ [SD 0.307] vs. 1.690 L·min⁻¹ [SD 0.284], P=0.090, respectively), despite exercising at a higher power output (127 vs. 120 W). The limits of agreement for the VO₂ peak achieved during supra-maximal and ramp exercise found a mean bias of -0.075 L·min⁻¹, which corresponds to ~ 4% of the initial ramp test VO₂ peak score (95% confidence limits: -0.263 to 0.112 L·min⁻¹ or -16 to 6%).

1.4 CONCLUSION

The main findings from the current study are that during ramp cycling exercise in a group of healthy 9-10 year old children: 1) a plateau in the VO₂ profile at exhaustion is an infrequent phenomenon, occurring in ~ 30% of children; 2) adherence to commonly used secondary criteria to validate a maximal effort in young people can result in either a ‘sub-maximal’ VO₂ max or a rejection of a participant’s VO₂ max score despite a plateau being evident; and 3) supra-maximal testing at 105% of the power output achieved during ramp exercise did not increase the VO₂ peak achieved compared to the ramp test, thus suggesting the achievement of a ‘true’ VO₂ max during the initial ramp test.

Collectively these results provide a basis for paediatric researchers to abandon the use of secondary criteria to validate a ‘maximal’ VO₂. Rather, as supra-maximal testing elicits a VO₂ peak similar to the ramp protocol, thus satisfying the plateau criterion despite only been present in 30% of the initial ramp responses, it is recommended that the use of such tests should be adopted as the appropriate method of confirming a ‘true’ VO₂ max in healthy young people.
1.5 NOTE

At the time of writing the full version of this paper is in press in the British Journal of Sports Medicine, but published on-line (doi:10.1136/bjsm.2009.063180), and this extended abstract is reproduced here with permission from the BMJ Publishing Group.

1.6 REFERENCES


