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AEROBIC ENERGY CONTRIBUTION TO MAXIMAL EXERCISE IN CHILDREN

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Abstract. The aerobic energy contribution to a 30-s Wingate Anaerobic Test ($WAnT_{30\ s}$) was examined in 18 boys and 18 girls aged 10-12 years. Participants completed an incremental test to volitional exhaustion to determine peak oxygen uptake (VO_2) and a $WAnT_{30\ s}$ on two separate occasions on a cycle ergometer (Monark 834E). VO_2 during the tests was monitored breath-by-breath using an on-line gas analysis system (SensorMedics). $WAnT_{30\ s}$ VO_2 amounted to 67% and 73% of peak VO_2 in boys and girls, respectively. By assuming extreme mechanical efficiency (ME) values of 15% and 35%, the aerobic contributions to the $WAnT_{30\ s}$ in boys and girls were between 16% and 45%. Peak VO_2 and $WAnT_{30\ s}$ power were higher in boys than in girls but there was no sex difference in the aerobic energy contribution to the $WAnT_{30\ s}$ for the same assumed ME. The magnitude of the aerobic energy contribution to the $WAnT_{30\ s}$ reflected plausibly a swift oxygen uptake response to maximal intensity exercise and perhaps a reduced reliance on non-oxidative metabolism in boys and girls.

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Key words: Oxidative metabolism - Wingate Anaerobic Test

Introduction

In adults, it has been established that during maximal intensity exercise such as that in the Wingate Anaerobic Test (WAnT), there is energy contribution from oxidative metabolism to the work accomplished [12,18]. This is to be expected since during incremental exercise to volitional exhaustion to determine peak oxygen uptake, there is anaerobic energy supplementation, as shown by the high blood lactate concentration, normally three to six times the values at rest, at the end of the test [4]. Previous studies on the aerobic contribution to the WAnT are

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few in number, have concentrated on male adults, and most studies are based on small sample sizes. Notably scarce are data on females and there are apparently no comparative data on boys and girls in the same study.

The quantification of aerobic contribution to maximal exercise performance is difficult because the mechanical efficiency (ME) during a non-steady state exercise task remains speculative [3]. Nevertheless extreme ME values for cycling [11] have been proposed to provide a general scope of the estimated values [20]. A trawl of the literature on mechanical efficiency of aerobic and anaerobic cycling revealed that an optimistic view of mechanical efficiency during maximal cycling exercise is 35% whereas a pessimistic value is 15% [6].

In adults, assumptions about oxygen uptake lag time [19], the size and role of the stored oxygen stores [14], all of which are difficult to verify, when taken into account also affect the estimation of aerobic contribution. The situation about the role and size of stored oxygen stores in young people is even less secure although the oxygen uptake response to high intensity exercise is swifter in children than in adults [8]. Invariably, however, the magnitude of the aerobic contribution to high intensity exercise is reliant on the assumed mechanical efficiency for the group being examined.

A number of methods have been used to estimate the extent of aerobic contribution during high intensity exercise. The most straightforward method is to measure baseline oxygen uptake and during the high intensity exercise. The net oxygen uptake i.e. exercise minus baseline is then computed. Using this method, Hebestreit *et al.* [8] reported that the net oxygen uptake during a 30 s WAnT was 45% higher in 10-year-old boys compared to 22-year-old men. Others have expressed the oxygen uptake during a 30 s WAnT in relation to peak oxygen uptake [17], where in 7-15 year old boys, this amounted to 60-70% of peak oxygen uptake, with the percentage decreasing with age.

It is also possible to estimate relative aerobic and anaerobic contribution to cycling exercise by (a) assuming a fixed mechanical efficiency (13, 20 and 25%) [13] or an extreme range of mechanical efficiency (e.g. 15-25%) [20] and (b) using a conversion of 1 litre of oxygen consumed to be equivalent to 21 KJ (assuming 100% carbohydrate metabolism), the net oxygen uptake during the WAnT, expressed in KJ of work done is used to compute the aerobic contribution. Using this method to estimate aerobic contribution during 30s WAnT in adults, researchers have reported that the results lie between 13-28% [12], 9-19% [13], 16-24% [9] and 10-17% [20].

In the absence of comparative data on the aerobic contribution to maximal intensity cycling exercise in boys and girls, the study purpose was to examine the aerobic contribution to a $WAnT_{30\ s}$ by taking extreme assumed mechanical efficiency values for cycling to be 15 and 35%, and expressing the oxygen uptake during the $WAnT_{30\ s}$ in relation to peak VO_2 in a group of boys and girls.

Materials and Methods

Participants: Participants were 36 healthy and physically active boys and girls from a primary school in Singapore. Participants had not been previously involved in any form of sports or exercise training. All participants gave informed consent to be part of the study. Institutional ethical clearance for the study was also obtained.

Habituation sessions: All participants were habituated to the laboratory and test procedures that involved sub-maximal and maximal intensity cycle ergometer exercise. These involved two sessions held within seven days before the actual testing sessions. In the first session, participants were habituated to cycling at a constant pedal cadence with increments in load every two minutes for a 2-3 stages while breathing through a mouthpiece. In the second session, participants completed an abbreviated WAnT while breathing through a mouthpiece.

Experiment design: Participants reported to the laboratory on two separate occasions in the morning within a two-week period. On the first occasion, participants completed a peak VO_2 test and on the second occasion, baseline oxygen uptake over three minutes and oxygen uptake over a $WAnT_{30\ s}$ were collected. The testing sessions for boys and girls were held separately.

Determination of peak VO_2: Participants performed a continuous incremental exercise test on a calibrated cycle ergometer (Monark *834E*) to volitional exhaustion to determine. Applied resistance was increased every two minutes until participants could not maintain the required pedal cadence. Heart rate was monitored throughout the cycle test using a short distance telemetric system (Polar Advantage). Participants breathed through a mouthpiece with a low-resistance valve, which allowed for the analysis of expired air. Oxygen uptake during the cycle test was measured breath-by-breath using an on-line gas analyser (Sensormedics) with breaths averaged over 15 s. Peak VO_2 was taken as the highest VO_2 recorded during the final stage of the test, when heart rate was at least 95% of the predicted maximum heart rate for the participant and the respiratory exchange ratio was greater than 1.10.

Monitoring base line oxygen uptake and oxygen uptake in Wingate Anaerobic Test: Prior to the test, participants sat on a chair and the baseline oxygen uptake, measured breath-by-breath and averaged over 15-s time periods was collected for three minutes by asking participants to put on a nose-clip and breathe through a mouthpiece. The same mouthpiece and nose-clip method was used to collect the oxygen uptake during the $WAnT_{30\ s}$

Wingate Anaerobic Test: Participants completed a $WAnT_{30\ s}$ following a standardised warm-up, which included four minutes of constant pedal at 70 revolutions per minute (rpm) that was interspersed with three maximal sprints of 2-3 s at an applied resistance set at 0.74N/kg body mass. This was followed by two minutes of static stretching for the groin, hamstrings and quadriceps.

Toe-clips were used to fasten the feet to the pedals and the seat height and handlebars were adjusted to suit the participants. The test was initiated from a rolling start at 70 rpm, at minimal applied force (with the weight basket supported) following a count down of “3,2,1, go”. On the word “Go”, data collection was activated and participants were verbally encouraged to pedal as fast as could, while remaining seated till they were told to stop.

Peak power, the highest power, integrated over 1-second time periods and mean power, the average power attained in the $WAnT_{30\ s}$ corrected for the inertia of the ergometer were the variables of interest. The correction procedures for inertia of the flywheel and internal resistance of the ergometer are described in detail elsewhere [5].

Computation of aerobic contribution to $WAnT_{30\ s}$: Two methods were used to estimate the aerobic energy contribution to the $WAnT_{30\ s.}$ The first method expressed the net oxygen uptake rate during the $WAnT_{30\ s}$ as a percentage of peak VO_2 [17]. The rate of net oxygen uptake was obtained by taking the WAnT VO_2 rate minus the baseline VO_2 rate. The second method used was to convert the net oxygen uptake during the $WAnT_{30\ s}$ to work units (i.e. joules) using the conversion factor of 20.92 KJ/L of oxygen, assuming 100% carbohydrate metabolism, [9], since the respiratory exchange ratio for a $WAnT_{30\ s}$ is 0.99 [15]. By assuming extreme gross mechanical efficiency values of 15 and 35%, the aerobic contribution to the test is given by the $WAnT_{30\ s}$ VO_2, expressed in work units, divided by the total work done in the $WAnT_{30\ s}$ expressed in percentage terms [9].

Statistical analysis: Data were collected and stored in computer using the Windows software Statistical Package for Social Science (SPSS 11.0). Descriptive statistics were generated for the variables of interest. Differences between boys and girls were analysed using one-way analysis of variance (OW-ANOVA). The level of significance was set at $p<0.05$.

Results

Participant characteristics: The participant characteristics of the 18 boys and 18 girls are presented in Table 1.

Table 1
Participant characteristics and exercise performances of boys and girls

Variable	Boys (n=18)	Girls (n=18)
Age (y)	11.3±0.2	12.1±0.2*
Stature (m)	1.42±0.05	1.36±0.06*
Body mass (kg)	35.9±4.1	33.5±7.6
Absolute peak VO_2 ($l \cdot min^{-1}$)	1.59±0.24	1.44±0.21*
Relative peak VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	53±7	45±6*
RER (respiratory exchange ratio) at peak VO_2	1.02±0.05	1.02±0.07
Max HR at peak VO_2 ($beats \cdot min^{-1}$)	193±11	197±11*
VE (ventilation) at peak ($l \cdot min^{-1}$)	65.70±11.5	50.42±8.82*
PP (peak power) (W)	269±45	220±58*
$PP \cdot kg^{-1}$ BM ($W \cdot kg^{-1}$)	8.3±1.2	6.9±1.2*
MP (mean power) (W)	192±33	168±41*
$MP \cdot kg^{-1}$ BM ($W \cdot kg^{-1}$)	5.9±1.0	5.3±0.8*

Values are means±SD.
*denotes difference is significant at p<0.05

Based on their age, standing height and body mass, the boys and girls had similar characteristics.

Exercise performances of the participants: With reference to Table 1, information is presented about the exercise characteristics at peak VO_2 and the power generated in the $WAnT_{30\ s}$ of the boys and girls. In essence boys had greater peak VO_2 and $WAnT_{30\ s}$ power than girls.

Oxygen uptake during $WAnT_{30\ s}$: Over the $WAnT_{30\ s}$ oxygen uptake in girls amounted to 73±10% of peak VO_2 while in boys the values were 67±9%. There was an absence of sex difference in the relative oxygen uptake percentage.

By assuming extreme gross mechanical efficiency (ME) values of 15% and 35%, the aerobic energy contribution to the $WAnT_{30\ s}$ of boys and girls are shown in Fig. 1. In essence the values range from 16% to 45%. There was also the absence of any sex difference in the percentage aerobic contribution to the $WAnT_{30\ s}$ for similar assumed ME values.

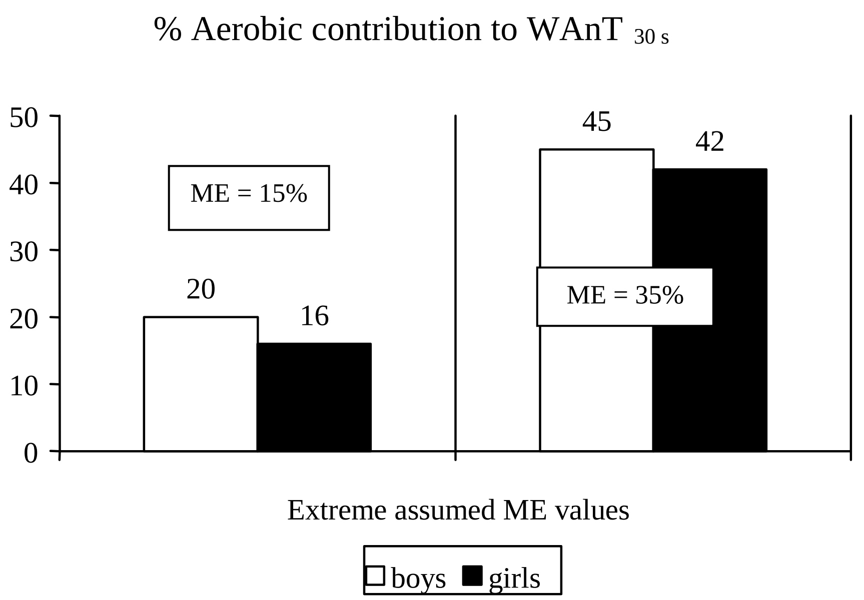

Fig. 1
Percentage aerobic energy contribution to $WAnT_{30\ s}$ in boys and girls for assumed extreme ME values of 15% and 35%. Values are mean. No sex difference was detected for the same assumed ME.

Discussion

The main result of the study was that aerobic energy contribution to the $WAnT_{30\ s}$ whether it was expressed as a percentage of peak VO_2 or expressed in work units, taking into account assumed extreme ME values, was not negligible. Over the $WAnT_{30\ s}$ oxygen uptake amounted to 67% and 73% of peak VO_2 in boys and girls, respectively. This is in agreement to the range of 60-70% of peak VO_2 reported Van Praagh *et al.* [17] during a $WAnT_{30\ s}$ albeit in 101 European boys aged between seven and 15 years.

Results of the study showed that boys had greater peak VO_2 than girls whether it was in litres per minute or millilitres per kilogram body mass per minute. This is in agreement with the findings Armstrong and Welsman [2]. They reported that 10 year old prepubertal boys had 13.3% higher body mass-related peak VO_2 (51 vs. 45ml/kg/min) albeit, elicited from an incremental treadmill protocol.

Despite the boys having a higher peak $VO_{2,}$ there was no sex difference in the aerobic contribution to the $WAnT_{30\ s}$ when the WAnT VO_2 was expressed in relation to peak VO_2 (i.e. 67±9% vs. 73±10%; $p>0.05$). This suggested that boys and girls responded similarly in extent to oxidative metabolism in meeting the energy demands of the $WAnT_{30\ s}$ and also that aerobic fitness did not affect the extent of aerobic contribution to maximal exercise.

It is very difficult to establish the gross mechanical efficiency of maximal intensity exercise like that in the $WAnT_{30\ s}$ but by taking on an optimistic view and a pessimistic view of the ME during maximal intensity cycling exercise, it is likely that differences in individual gross efficiencies could be accommodated. By taking extreme assumed ME values of 15% and 35% [6], it was found that the aerobic contribution to the $WAnT_{30\ s}$ ranged from 16% (ME=15%) to 45% (ME=35%) in boys and girls (Fig. 1). The range of values is higher than the 9.4% reported by Kavanagh and Jacobs [13] for five men and is also higher than the 10% (ME=15%) and 17% (ME=25%), reported by Williams [20] for women physical education students. It appears that during the $WAnT_{30\ s}$ children resorted more to oxidative metabolism than adults to meet the energy demands of the $WAnT_{30\ s.}$ This does not however, necessarily indicate a deficiency in children's capability to generate power from non-oxidative metabolism: instead, it may reflect a reduced reliance on non-oxidative metabolism to meet the demands of maximal exercise. This is buttressed by the result that oxygen uptake in the $WAnT_{30\ s}$ amounted to up to 73% of peak VO_2, explained possibly by the fact that children demonstrate a swifter oxygen uptake response than adults to maximal intensity exercise [1,21].

Power generated in the $WAnT_{30\ s}$ was greater in boys and in girls, despite similar body mass in girls and boys. PP and MP in W/kg body mass were 20% and

11% greater in boys than in girls. These results compare favourably with the 16% higher MP, expressed in ratio to body mass in prepubertal boys than in prepubertal girls, [7]. Even though evidence of a sex difference in $WAnT_{30\ s}$ power prior to sexual maturation in children is equivocal [2] the present results are supportive of a sex difference in $WAnT_{30\ s}$ power prior to puberty.

Conclusion

Results showed that aerobic energy contribution to a $WAnT_{30\ s}$ in boys and girls was not negligible. When expressed in relation to peak VO_2, the net oxygen uptake during a $WAnT_{30\ s}$ amounted to 67% in boys and 73% in girls. Conversely, by taking extreme assumed ME values of 15% and 35%, the aerobic energy contribution to a $WAnT_{30\ s}$ was between 16% and 45% in the boys and girls. Despite higher peak VO_2 values in boys than in girls, the aerobic energy contribution to the $WAnT_{30\ s}$ in boys and girls was not significantly different. A swifter oxygen uptake response to maximal intensity exercise and less reliance on non-oxidative metabolism in children are plausible explanations for the extent of aerobic energy contribution to the $WAnT_{30\ s}$.

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