AEROBIC AND ANAEROBIC PERFORMANCES OF BOYS

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Abstract: The purpose of the study was to compare the aerobic performance [peak $V0_2$] of boys with their anaerobic performance [Wingate Anaerobic Test (WAnT)]. Twenty-four boys (10.1±0.3 yrs; 32.9±4.1 kg), all of whom were adjudged as Tanner stage 1 for sexual maturity status, participated in the study. Peak $V0_2$ was determined using a discontinuous, incremental protocol on a cycle ergometer. During a separate test session, the exercise $V0_2$ during the WAnT, was determined. Twenty-second data were extracted from the single 30-second test for comparison. Mean peak $V0_2$ was 1.97±0.24 $l.min^{-1}$. Mean 1-second peak power [PP] was 269±45 W, and as expected, mean power over 20 seconds [MP_{20s}] was higher than mean power over 30 seconds [MP_{30s}] (212±37 vs. 192±33 W, $p<0.05$). Significant correlations were established between peak $V0_2$ and peak power ($r = 0.43$, $p<0.05$); MP_{20s} ($r=0.48$, $p<0.05$); and [MP_{30s} ($r= 0.51$, $p<0.05$). However, when partial correlations were run between peak $V0_2$, and PP and MP, respectively, controlling for body mass, the resultant correlations coefficients became non-significant ($0.25<r<0.39$, $p>0.05$). Subjects attained 61 ± 9% and 69± 9% ($p<0.05$) of peak $V0_2$ over 20 seconds and over 30 seconds of the WAnT, respectively. The observed correlations may reflect the aerobic contribution to the WAnT. The study confirms that in young boys, the aerobic contribution over a predominantly anaerobic test is quite substantial, therefore the 20s test may be more appropriate.

Introduction

During high intensity exercise, such as those performed during cycling in the Wingate Anaerobic Test (WAnT), there is energy contribution from oxidative metabolism to the work accomplished (Bar-Or, 1987; Chia, Armstrong and Childs, 1997). Previous on the aerobic contribution to the WAnT, have been few in number and are limited by a number of factors:- subject samples have been small (usually less than 10); only adults have been studied; and the results are based on a 30-second duration Wingate test ($WAnT_{30second}$). Even fewer studies have addressed the issue of aerobic contribution to very intense exercise, in relation to peak $\dot{V}O_2$. In apparently the only reported study, Van Praagh, Bedu, Falgairette, Fellman and Coudert (1991), reported that the oxygen uptake over $WAnT_{30\ second}$ amounted to 60-70% of peak $\dot{V}O_2$ in seven- and 15-year old boys. It is hypothesised that the oxygen uptake over an abbreviated WAnT would be significantly lower than over a 30-second WAnT. Therefore, the purpose of the study was to examine the extent of aerobic contributions over 20- and 30-seconds of the WAnT, in relation to peak aerobic function, in a cohort of prepubertal boys.

Methods

Subjects

Twenty-four young boys were recruited for the study. All subjects consented to participate in the study and had parental and school consent. Subjects were assessed by an experienced resident nurse for general health and sexual maturity (Tanner indices; Tanner, 1962).

Equipment

A Monark model 814*E* cycle ergometer that was specially modified for testing young children was used to assess the anaerobic fitness of the children. The determination of anaerobic performance required the young subject to pedal all-out for a conventional 30-seconds (i.e.$WAnT_{30\ second}$). Recent innovations in computer software technology allow data over 20 seconds (i.e. $WAnT_{20\ second}$) to be extracted from a single 30-second exercise effort. Details of power calculations in the WAnTs (e.g. choice of integration time periods, adjustment for flywheel inertia and system inertia) have been discussed elsewhere (e.g. Chia *et al*, 1997). An isokinetic cycle ergometer (Biodex Medical Lower Body Cycle) with settings for a constant power mode was used to elicit peak $\dot{V}O_2$ in the children. An automated respiratory mass spectrometer (Airspec QP 9000), with an analysis response time of 20 milliseconds was used to determine the breath-by-breath oxygen consumption during $WAnT_{20\ second}$ and $WAnT_{30\ second}$, as well as during the maximal cycle ergometer test that was used to elicit peak $\dot{V}O_2$.

Conduct of the Wingate Anaerobic Test

All subjects completed a WAnT on a calibrated Monark cycle ergometer where the seat-saddle height was individually adjusted for each subject. The bike was equipped with toe-clips which helped to secure the subject's feet to the pedals. The test preceded with a standardised warm-up that consisted of four minutes of constant pedalling at 60 rpm against a minimal force, interspersed with three all-out intensity sprints of 3-5s at the test applied force. Subjects were then taken through a two-minute series of standardised stretches for the quadriceps and hamstring group of muscles. The WAnT commenced from a rolling start at 60 rpm and the subjects were verbally encouraged to cycle as fast as they could against an applied force that was set equivalent to 0.74 $N \bullet kg$ body $mass^{-1}$ (7.5% of body mass). Inertia-adjusted 1s peak power (PP) and mean power over 30s of the test (MP) were derived from the WAnT. The procedure for the direct determination of flywheel inertia and the computational formulae for inertia-adjusted power have been previously described (e.g. Chia *et al*, 1997).

Determination of peak $\dot{V}O_2$

An isokinetic cycle ergometer with settings for a constant power mode was used for the determination of peak $\dot{V}O_2$. The constant power mode was selected that allowed for two minute incremental exercise intensity stages to be programmed and the pedal revolutions kept unaltered at 50 per minute. This constant power mode ensured that for each subject, the same power output programmed for each stage was elicited. An all-out discontinuous progressive protocol, was used for the determination of peak $\dot{V}O_2$. A standardised warm up preceded each test session. This involved a three minute pedal at a constant exercise intensity of 30W. That was followed by a set of static stretches for the quadriceps, groin and the hamstrings. Thereafter, the test commenced, with the subject exercising at an initial exercise intensity of 50W for two minutes, followed by incremental two minute stages of 20W, interjected by a minute's rest. The procedure was followed until the subject was unable to maintain the required 50 rpm pedal cadence despite strong verbal encouragement by the research team members. Throughout the test stages, ventilation and respiratory gases were monitored breath-by-breath, and the data were averaged over 30s time intervals. The criteria for attainment of peak $\dot{V}O_2$ were set in accordance to the children-specific guidelines recommended by Armstrong and Welsman, (1994). These are:

* Failure to maintain constant pedal rate of 50 rpm in spite of continual verbal encouragement. Signs of intense effort (hyperpnoea, facial flushing, sweating).
* Peak heart rate has levelled off prior to the final exercise intensity at a value at least 95 % of maximal heart rate as predicted by age.
* A respiratory exchange ratio of at least 1.0.

Expired air analyses

During the WAnT and peak $\dot{V}O_2$ test, expired exercise air samples were collected using the breath-by-breath technique, using a respiratory mass spectrometry automated system (Airspec QP 9000). The system had an eight-channel high speed multi-gas analyser system with an overall response time of 20 milliseconds. For the WAnTs, the $\dot{V}O_2$ values were obtained by the summation of the individual breaths. In the peak $\dot{V}O_2$ tests, the $\dot{V}O_2$ values for each of the two minute incremental stages, were obtained by averaging the breaths over 30s time intervals. Baseline oxygen uptake values were obtained by the summation of breaths over one minute.

Blood lactate sampling

Capillary blood samples using the finger-stick method (Autoclix® Boehringer) were obtained from the left thumb of the subjects. In the case of the WAnT, a sample was obtained post-warm-up and two minutes after the completion of the 30-scond test. In the case of the peak $\dot{V}O_2$, a sample was obtained immediately after each two minute stage. The samples were later assayed for whole blood lactate values, using an automated and self-calibrating lactate analyser (YSI 2300 Stat Plus). The analyser self-calibrated with a known concentration of lactate, every eight samples and the calibration was checked regularly (i.e. at the beginning of each test series) against commercially prepared standards of verified concentration.

Statistical analyses

Checks for normality in the distribution and homogeneity of variance of the data sets using Sharpiro-Wilks and Levene statistical tests, respectively were carried out. Descriptive statistics were used to describe the physical and physiological characteristics of the subjects. Pearson product moment correlations were used to identify the strength of associations between aerobic and anaerobic function indices. Partial correlations were also computed where appropriate. Statistical significance was set priori at $p<0.05$.

Results

Normality in distribution and homogeneity of variance

Statistical tests of normality in the data sets used in the analyses revealed that there were normality of distribution (Sharpiro-Wilks test statistic, $p>0.05$) and homogeneity of variance (Levene test statistic, $p>0.05$).

Subject characteristics

The anthropometric and descriptive statistics of the subjects are depicted in Table 1. All of the boys were adjudged as Tanner stage 1 for sexual maturity, based on their pubic hair and genitalia development.

Table 1

Anthropometric and descriptive characteristics of the subjects. Data are means±SD

Variable	Boys (N = 24)
Age [y]	10.1 ± 0.3
Stature [m]	1.37 ± 0.05
Body mass [kg]	32.9 ± 4.1
Maturity status [Tanner indices]	100% Tanner stage 1

Cycle ergometer-based peak oxygen uptake (peak $\dot{V}O_2$) values

The cycle ergometer-based peak $\dot{V}O_2$ values were determined breath-by-breath and averaged over 30s time periods, to derive the oxygen uptake for each of the 2 min incremental stages. Data of the boys with the supporting exercise-responses at peak $\dot{V}O_2$ are summarised in Table 2.

Table 2

Exercise responses at peak $\dot{V}O_2$ (unless stated otherwise). Data are means±SD

Variable	Boys
Absolute peak $\dot{V}O_2$ [L•min^{-1}]	1.97 ± 0.24
Relative peak $\dot{V}O_2$ [mL•kg^{-1}•min^{-1}]	60 ± 7
RER (respiratory exchange ratio) at peak $\dot{V}O_2$	1.02 ± 0.05
Max HR at peak $\dot{V}O_2$ [beats•min^{-1}]	193 ± 11
VE (ventilation) at peak $\dot{V}O_2$ [L•min^{-1}]	65.70 ± 11.54
Post- peak $\dot{V}O_2$ BL [mM•L^{-1}]	6.6 ± 1.8

The anaerobic performances of the boys over 20 seconds and over 30 seconds of the WAnT are summarised in Table 3. Twenty-second data were extracted from a single $WAnT_{30\ second}$. All the power variables were adjusted to account for the flywheel inertia and were computed over 1s periods.

Table 3

1s PP, MP and fatigue index in $WAnT_{20\ second}$ and $WAnT_{30\ second}$. Data are means±SD

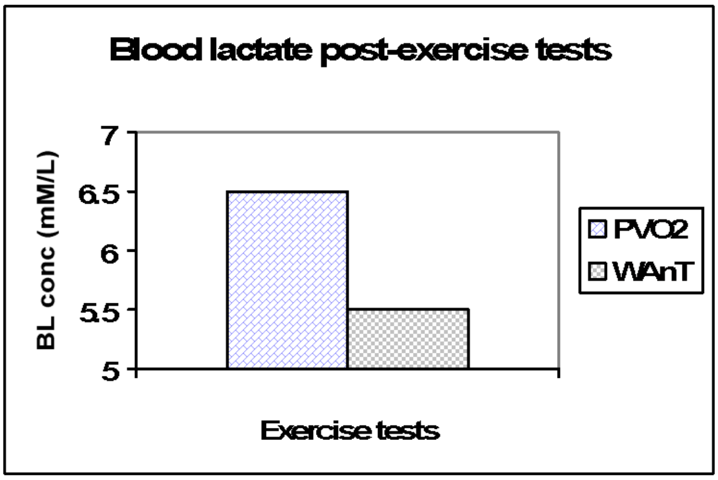
Variable	$WAnT_{20\ second}$	$WAnT_{30\ second}$
PP [W]	269 ± 45	269 ± 45
PP•kg^{-1} BM [W•kg^{-1}]	8.3 ± 1.2	8.3 ± 1.2
MP [W]	212 ± 37 *	192 ± 33 *
MP•kg^{-1} BM [W•kg^{-1}]	6.5 ± 1.0 *	5.9 ± 1.0 *
∗ Fatigue index [%]	35 ± 10 *	45 ± 9 *

Values are means ± SD. *denotes that the differences in the means are significant at $p < 0.05$. ∗ Fatigue index is given by the difference between peak and end power, expressed as % of peak power output.

Post-exercise lactate profiles

Following both aerobic and anaerobic function tests, the spread of peak blood lactate values was considerable. This is depicted in Figure 1.

Figure 1
Peak blood lactate values immediately post-peak $\dot{V}O_2$ determination and at 2 min post-$WAnT_{30\ second}$.



Associations between aerobic and anaerobic function

In both $WAnT_{20\ second}$ and $WAnT_{30\ second}$, MP was correlated with peak $\dot{V}O_2$ for the boys (r=0.51 for $WAnT_{30\ second}$ and r=0.48 for $WAnT_{20\ second}$, both $p<0.05$). The corresponding strength of association between peak $\dot{V}O_2$ and PP was described as r=0.43 ($p<0.05$). However, when partial correlations between peak aerobic and anaerobic function indices (PP and MP), controlling for body mass, were run, the resultant correlation coefficients for boys (i.e.$0.25<r<0.39$; $p>0.05$) were non-significant.

Percent of peak $\dot{V}O_2$ attained during $WAnT_{20\ second}$ and $WAnT_{30\ second}$

Over 20- and 30-second of the WAnT, the boys attained 61±9% and 69± 9% ($p<0.05$), respectively, of their absolute peak $\dot{V}O_2$ values. The calculations were based on averaging the exercise breaths over 20- and 30s time periods and expressing them as a percentage of the peak $\dot{V}O_2$.

Discussion

Studies on the exercise performances of young people lag behind those adults; consequently less is known about the exercising child. Few studies have jointly addressed both aerobic and anaerobic performances of young people in the same study. This study showed that young people were able to complete both maximal (peak $\dot{V}O_2$) and supramaximal (WAnT) tests without incident.

Subject cohort differences and test protocol differences across studies preclude any direct comparisons in the boys' aerobic and anaerobic performances. However, their performances, including post-exercise lactate profiles, are apparently consistent with those reported in the extant literature for subjects in their age group and maturity category (Bar-Or, 1983; Armstrong and Welsman, 1997).

In this study, significant correlations were established between PP and peak $\dot{V}O_2$ (r=0.43), and also between MP and peak $\dot{V}O_2$ (r=0.48-0.51). However when the effect of body mass was statistically adjusted for, the partial correlations between peak $\dot{V}O_2$, and PP and MP (i.e.

$0.25<r<0.39$; $p>0.05$) became non-significant. This result offers some credence to the argument that body mass accounts for a significant amount of the variance in aerobic and anaerobic performance.

WAnT $\dot{V}O_2$, over 20- and 30 seconds, amounted to 61 to 69% of the subjects' peak $\dot{V}O_2$ values. This is in accord with the percentage values reported by Van Praagh *et al* (1991), albeit by 101 boys aged between 7 and 15 years. This can be explained by the increasing role played by oxidative metabolism towards energy regeneration during the latter stages of the WAnT. It has been argued that young people have a swifter oxygen uptake in response to high intensity exercise compared to adults (Barstow, 1994), and this may account for the higher oxygen uptake in the boys during the 30-second test compared to the 20-second test.
The fact that there is some oxygen (aerobic) contribution to an “anaerobic” exercise test such as the WAnT is to be expected, since the energy systems work in concert with each other. The response to a high intensity exercise stimulus is therefore, an integrated one as the energy systems are not mutually exclusive of each other. Moreover, even in aerobic test such as the peak $\dot{V}O_2$ test, there is also some anaerobic contribution to the test, as evidenced by the substantial blood lactate concentration immediately after the maximal effort test.

What is important is the extent of “aerobic” contribution that is acceptable for an “anaerobic” test and how much “anaerobic” contribution is acceptable for an “aerobic” test? The answer to the question is of course dependent on the research question at hand and the characteristics of the subject cohort being tested. In this study where the subjects are boys, it appears that the 20-second WAnT is more tenable and the more appropriate “anaerobic” test, than the 30-second WAnT.

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