Pediatric Exercise Science, 1997, **9**, 80-89

The Assessment of Children's Anaerobic Performance Using Modifications of the Wingate Anaerobic Test

Michael Chia, Neil Armstrong, and David Childs

Twenty-five girls and 25 boys (mean age 9.7 ± 0.3 years) each completed a 20- and 30-s Wingate Anaerobic Test (WAnT). Oxygen uptake during the WAnTs, and postexercise blood lactate samples were obtained. Inertia and load-adjusted power variables were higher (18.6–20.1% for peak, and 6.7–7.5% for mean power outputs, $p < .05$) than the unadjusted values for both the 20- and 30-s WAnTs. The adjusted peak power values were higher (7.7–11.6%, $p < .05$) in both WAnTs when integrated over 1-s than over 5-s time periods. The aerobic contributions to the tests were lower ($p < .05$) in the 20-s WAnT (13.7–35.7%) than in the 30-s WAnT (17.7–44.3%) for assumed mechanical efficiencies of 13% and 30%. Postexercise blood lactate concentration after the WAnTs peaked by 2 min. No gender differences ($p > .05$) in anaerobic performances or peak blood lactate values were detected.

The 30-s Wingate Anaerobic Test (WAnT) (5), supervised on a cycle ergometer has been widely used to assess the anaerobic performance of both adults and children (7, 19). The choice of the 30-second duration of the test was based on an earlier cycle test described by Cumming (11) and also on the findings of Margaria et al. (17) that 30 s was adequate to run adolescents and adults to exhaustion on the treadmill. A main consideration in selecting the 30-s duration, however, was based on pilot observations that some subjects were unable to complete longer all-out intensity cycle tests (6). Importantly, what works appropriately for adolescents and adults does not necessarily apply to young children, and the problems associated with the assessment of children's anaerobic performance are well documented (4, 9).

As young children have faster oxygen uptake kinetics during high intensity exercise than do adults (1), a 30-s test with children is likely to include a significant contribution from aerobic metabolism. Indeed, pilot work with 9-year old prepubertal children in our laboratory (27) showed an aerobic energy contribution to a 30-s WAnT ranging from 23% to 41% at assumed mechanical efficiencies of 15% and 25%, respectively. These findings suggest that, as a measure of anaerobic performance, a shorter WAnT may be more appropriate with young children. It has

Michael Chia, Neil Armstrong, and David Childs are with the Children's Health & Exercise Research Centre, School of Education, University of Exeter, Heavitree Road, Exeter, EX1 2LU, United Kingdom.

been advocated that a 15- to 20-s supramaximal exercise bout would be more specific of anaerobic metabolism and would be easier to perform than 30- and 40-s tests (25).

By convention, the key WAnT variables assessed during the test include peak power output (the highest mechanical power, averaged over 5-s intervals) and mean power output (the average power output over the entire 30-s period). Recent developments in computer technology allow for the power variables to be computed over 1-s period average instead of the conventional 5-s period average. However, the comparison of WAnT power variables integrated over both the 1- and 5-s time periods, during the same performance in young children, does not appear to have been elucidated. Most studies with the WAnT report on the power variables without any adjustment for the work done in overcoming the inertia of the flywheel and the internal resistance of the cycle ergometer in spite of its recognition (16, 21). Therefore, the actual power outputs are likely to be underestimated, as shown in a study of fit adults (16). However, no similar investigation appears to have been conducted with young children.

Blood lactate values after a WAnT are usually sampled 3–5 min following the exercise, principally based on the identification of peak blood lactate values in adults, following incremental maximal exercise (22, 23). Fujitsuka et al. (13), however, have recommended a statistically derived time of 7.65 min, after 1 min of all-out intensity exercise for identifying the peak blood lactate value in adults. Given that the change in lactate is rapid, the timing of blood draw for the identification of the peak value is critical (10). In young children, the time to a post-WAnT peak blood lactate value is not apparent, although many investigators continue to adhere to a 3-min (12) or 5-min (18) postexercise blood draw.

In the light of these uncertainties, this study was designed to explore the effects of modifications of the conventional WAnT on the performance of young children. Specifically, the purposes of the project were to investigate (a) the power outputs adjusted for, and unadjusted for, the inertia of the flywheel and system resistance of the cycle ergometer; (b) to examine the power outputs integrated over 1- and 5-s time periods; (c) to study the performance in WAnTs of 20- and 30-s durations; (d) to compute the relative aerobic contributions to the 20- and 30-s tests; and (e) to investigate the time to peak blood lactate concentration, following both the 20- and 30-s WAnTs.

Method

Subjects

Fifty (25 boys and 25 girls) young children, with personal, parental, and school consent, were recruited for the study. Stature, body mass, triceps and subscapular skinfolds, and secondary sexual characteristics (24) of the children were assessed by a resident nurse.

Cycle Ergometer Modifications

The Monark (Model 814 E) cycle ergometer was modified to yield high-precision data that could be selectively integrated over 1-s or 5-s time periods. Pedal revolutions were measured with a voltage generator attached to the flywheel.

Determination of Flywheel Inertia

The flywheel was suspended horizontally by means of three parallel supporting wires. The length (l) of the wire, weight (w) of the flywheel, and the radius (r) of the flywheel were determined.

The period (t) of oscillation from angular displacement was derived from observations of 15, 30, 50, 100, 180, 190, and 200 oscillations. Natural angular frequency is given by $(wr^2/Il)^{1/2}/2\pi$, and the period of oscillation is given by $2\pi \cdot (Il/wr^2)^{1/2}$, where I is the inertia of the flywheel. By substituting in the known variables, the inertia of the flywheel (I) was calculated to be 0.92 kg · m².

Test Procedures

The same modified Monark cycle ergometer (Model 814 E) was used to compare the subjects' performance in both the 20-s and 30-s WAnTs. The ergometer was calibrated for pedal velocity and applied resistance, in accordance to the manufacturer's instructions prior to each test series. All subjects were familiarized with the test protocol. The order of the two WAnTs was randomized and supervised one week apart. The resistance was set equivalent to 0.075 kp (0.74 N) · kg^{-1} body mass (5). A standardized warm-up, which consisted of 4 min of steady-state pedaling at 60 revolutions per minute (rpm), interspersed with three 2- to 3-s periods of all-out cycle sprints at the test resistance, together with static stretches for the quadriceps and hamstrings, preceded each WAnT.

One minute of post-warm-up oxygen uptake was computed using a calibrated and automated on-line mass spectrometer (Airspec QP 9000) while the subject was seated passively on the cycle ergometer. The WAnT commenced from a "rolling start" at 60 rpm against minimal resistance (with the weight-basket lifted). When a constant pedal rate of 60 rpm was achieved, a countdown of "3–2–1–go!" was given. On the word *go*, with simultaneous effect, data capture for the WAnT, and the oxygen uptake captured breath-by-breath were initiated.

Subjects were encouraged to avoid pacing and to sustain their supramaximal efforts throughout the test. The power outputs generated were computed over both 1- and 5-s time periods.

Computation of Power Outputs

The respective power variables were computed based on the following formulae:

$$\text{unadjusted power output } (P_{unadj}) = \omega \cdot T_r,$$

$$\text{adjusted power output } (P_{adj + int.\ res.}) = \omega(T_i + T_r) = \omega[I(d\omega)/dt) + L_{plus9\%}r),$$

where ω is the angular velocity and $d\omega/dt$ is the angular acceleration of the flywheel; T_r is the resistive torque given by the product of $L_{plus9\%}$ and r; $L_{plus9\%}$ is the applied resistance plus the frictional loss in overcoming the internal resistance of the ergometer (21, 28); r is the radius of the flywheel; T_i is the inertial torque, which is given by the product of inertia (flywheel inertia plus sprocket and crank inertia) and angular acceleration of the flywheel. The flywheel inertia was calculated as described above and the inertia of the sprocket and chain was assumed to be 0.0111 kg · m² (20).

Aerobic Contribution to High-Intensity Exercise Tests

The percentage of energy supply from oxidative metabolism toward work accomplished in the 20- and 30-s WAnTs was computed by expressing net (exercise minus post-warm-up) oxygen uptake values during the WAnTs in kilojoules as a percentage of total work accomplished during the WAnTs, taking into account assumed mechanical efficiency (ME) values of 13% (15) and 30% (9). The relative aerobic contributions to power output in the WAnTs were computed using each of these extreme values to illustrate the potential scope of the aerobic contribution.

Serial Capillary Blood Sampling

Postexercise capillary blood samples were obtained while the subject recovered passively on the ergometer, and sampled serially at 30-s intervals up to 3 min. The samples were assayed as whole blood lactate values using an automated and self-calibrating lactate analyzer (YSI 2300 Stat Plus).

Treatment of Data

Descriptive statistics were computed, and performance in the WAnTs was analyzed statistically using repeated measures ANOVA. The level of statistical significance was set at $p < .05$.

Results

The physical and anthropometric characteristics of the young subjects are depicted in Table 1. All boys and 20 girls were judged to be Tanner Stage 1 for sexual maturity. One girl was assessed as Tanner Stage 3 for pubic hair and Tanner Stage 2 for breast development. The other four girls were either Tanner Stage 1 for pubic hair and Tanner Stage 2 for breast development or vice versa. The descriptive statistics of the WAnT performances are shown in Table 2.

The power variables (computed over 1-s intervals) adjusted for the inertia of the flywheel and the internal resistance of the ergometer, were significantly different from the unadjusted values. There were no gender differences between the

Table 1 Physical and Anthropometric Characteristics of the Subjects

Variable	Boys (n = 25)	Girls (n = 25)
Age (years)	9.7 ± 0.3	9.7 ± 0.3
Stature (m)	1.35 ± 0.05	1.34 ± 0.05
Body mass (kg)	31.0 ± 4.8	31.1 ± 7.4
Sum of skinfolds (mm)	17.7 ± 7.8	22.1 ± 10.7
Maturity status (Tanner indices)	100% Tanner Stage 1	80% Tanner Stage 1

Note. Values are $M \pm SD$. The gender differences in the means are not significant ($p > .05$).

Table 2 Adjusted Versus Unadjusted 20- and 30-s WAnT Peak and Mean Power Outputs, Computed Over 1-s Time Periods

Variable	Adjusted value	Unadjusted value
	20-s WAnT	
Boys		
Peak power (W)	205.0 ± 45.9	171.5 ± 33.2
Mean power (W)	164.7 ± 39.3	153.6 ± 32.2
Girls		
Peak power (W)	202.5 ± 61.3	168.8 ± 46.5
Mean power (W)	163.2 ± 43.5	151.8 ± 39.4
	30-s WAnT	
Boys		
Peak power (W)	201.8 ± 42.5	168.0 ± 33.7
Mean power (W)	151.3 ± 31.7	141.7 ± 27.7
Girls		
Peak power (W)	197.8 ± 54.3	166.8 ± 44.9
Mean power (W)	153.7 ± 38.2	141.1 ± 35.3

Note. Values are $M \pm SD$. WAnT = Wingate Anaerobic Test. The differences in the means between the anadjusted and adjusted power values are significant ($p < .05$).

adjusted and unadjusted power variables. The adjusted peak and mean power outputs over 1-s and 5-s periods are presented in Table 3.

The adjusted peak power and mean power values were significantly higher when they were integrated over the 1-s period interval than over the conventional 5-s period integration interval. However, the difference in the adjusted mean power values in the 30-s WAnT for boys, did not achieve statistical significance. In both boys and girls, the adjusted peak power values, computed over the 1-s time period, were not significantly different in the 20-s or 30-s WAnTs. There were no gender differences for the adjusted power variables computed over 1- and 5-s time periods. The percentage of aerobic contributions to the 20- and 30-s WAnTs are presented in Table 4.

For the extreme ME values of 13% and 30%, both boys and girls, had a lower aerobic contribution to the 20-s WAnT than to the 30-s WAnT. There were no gender differences in the aerobic contributions to the 20- and 30-s cycle test. Peak whole blood lactate was achieved by 2 min postexercise. Blood lactate values at 2 min were significantly higher than the values at 3 min post-WAnTs. There were no gender differences in peak blood lactate values for either the 20- or 30-s WAnTs. The spread of 2-min post-30-s WAnT blood lactate values was 2.0–8.1 mmol · L^{-1} (SD = 1.4) and 1.8–5.6 mmol · L^{-1} (SD = 0.9) for the girls and boys, respectively. The corresponding values for the post 20-s WAnT blood lactate values were 2.1–5.5 mmol · L^{-1} (SD = 1.1) and 1.6–4.9 mmol · L^{-1} (SD = 1.0). Figure 1 shows the time to peak blood lactate values following the 20- and 30-s WAnTs.

Table 3 Adjusted Peak and Mean Power Outputs Integrated Over 1- and 5-s Time Periods

Variable	1-s integration interval	5-s integration interval
	20-s WAnT	
Boys		
Absolute peak power (W)	205.0 ± 45.9	183.7 ± 48.3
Absolute mean power (W)	164.7 ± 39.3	162.3 ± 41.3
Girls		
Absolute peak power (W)	202.5 ± 61.3	181.5 ± 51.1
Absolute mean power (W)	163.2 ± 43.5	161.8 ± 42.1
	30-s WAnT	
Boys		
Absolute peak power (W)	201.8 ± 42.5	184.5 ± 45.3
Absolute mean power (W)	151.3 ± 31.7[a]	145.4 ± 41.9[a]
Girls		
Absolute peak power (W)	197.8 ± 54.3	183.7 ± 53.1
Absolute mean power IW)	153.7 ± 38.2	149.8 ± 37.8

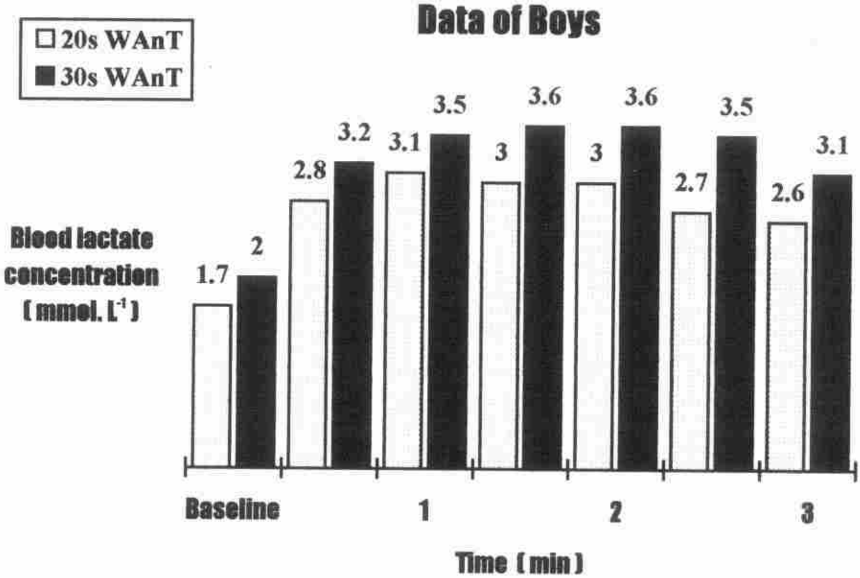
Note. Values are $M \pm SD$. WAnT = Wingate Anaerobic Test. All the differences in the means between the power variables integrated over 1- and 5-s time periods are significant ($p < .05$) with one exception as indicated. There were no gender differences in the power variables integrated over 1- and 5-s time periods.

[a] $p > .05$.

Table 4 Percentage of Aerobic Contributions to the 20- and 30-s WAnTs, Adopting Assumed Net Efficiency Values of 13% and 30%

Mechanical efficiency (%)	% aerobic contribution to 20-s WAnT	% aerobic contribution to 30-s WAnT
Boys		
13	15.5 ± 5.9	19.2 ± 5.9
30	35.7 ± 13.6	44.3 ± 13.6
Girls		
13	13.7 ± 5.1	17.7 ± 6.6
30	31.5 ± 11.7	40.7 ± 15.2

Note. Values are $M \pm SD$. WAnT = Wingate Anaerobic Test. All the differences in the means between the percentage of aerobic contributions to the 20- and 30-s tests are significant ($p < .05$). There were no gender differences in the percentage of aerobic contributions to the 20- and 30-s tests, for similar assumed mechanical efficiency values.



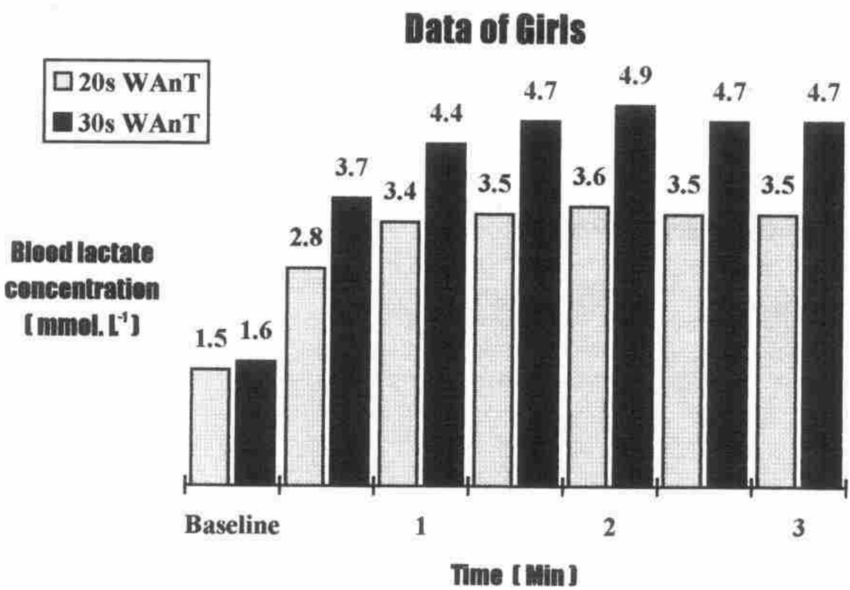


Figure 1 — Blood lactate concentration values following 20- and 30-s Wingate Anaerobic Tests (WAnTs). For clarity of illustration, only mean values are shown. There were no gender differences in peak blood lactate values for either the 20- or 30-s WAnTs.

Discussion

This study confirms that the inertial and internal resistance factors of the cycle ergometer affect the computation of the peak and mean power outputs in both the 20-s and 30-s WAnTs. The unadjusted peak power values were 83.3–84.3% of the adjusted values while the unadjusted mean power values were 93.0–93.8% of the adjusted values. The present results are in accord with the findings of Lakomy and Wootton (16), whose subjects were 9 male and 9 female physical education students. Their results showed that the underestimation in peak power outputs was 33–51%, for normal loads, when no account was made for the inertia of the flywheel.

However Lakomy and Wootton (16) employed a series of 6-s all-out sprints, and a range of resistances (0.5–11.3 $N \cdot kg^{-1}$ body mass) to generate their data rather than a 20-s or 30-s WAnT, using a resistance equivalent to 0.74 $N \cdot kg^{-1}$ body mass, as was the case in the current study. Unlike the present study, Lakomy and Wootton (16) ignored the 8–9% added-on value to the applied resistance (21, 28) which is attributed to the internal resistance (frictional losses to the drive train, pedal cranks, and sprockets) of the cycle ergometer. Although appropriate adjustments have been advocated (16, 21, 28), the issue has been largely ignored in studies involving children. The present findings indicate that both the flywheel inertia and the internal resistance of the ergometer should be accounted for if an accurate quantification of children's performance in the WAnT is required.

The choice of the integration time periods in the computation of the power variables in the WAnTs is important, especially when peak power output is the variable of focus. In the present study, the 1-s peak power outputs were greater than the 5-s values. Adopting the 1-s integration interval as the preferred choice instead of the conventional 5-s integration interval is likely to make the WAnT more sensitive and discriminatory to small alterations in peak anaerobic power. However, we suggest that in future reports, WAnT variables integrated over both 1- and 5-s time periods should be cited to allow a comparison with the extant literature. When comparing the relative performances of the children in the 20-s and 30-s WAnTs, peak power outputs were unaffected.

Following both of the WAnTs, serial blood sampling at 30-s intervals up to 3 min, revealed that peak blood lactate values were attained by 2-min postexercise rather than the conventional 3–5 min used by many investigators. In boys, the blood lactate concentration values at 3 min were 86% and 87% of the values at 2 min postexercise following the 30- and 20-s WAnTs, respectively. For the same tests in girls, the values at 3 min were 96% and 97%, respectively, of the blood lactate concentration values at 2 min post exercise. The spread of blood lactate values, following both WAnTs was considerable, an observation that is in accord with the literature (3). This emphasizes the need for care in the interpretation of children's postexercise blood lactate values and the requirement to state the time of blood sampling, particularly when comparisons across studies are made.

The percentage of aerobic contributions to the cycle tests were significantly higher in the 30-s than in the 20-s tests. The values in the current study were higher than the 9.4% reported by Kavanagh and Jacobs (15) in their study of 5 adult men during a 30-s WAnT. It appears, therefore, that during supramaximal exercise, children resort more to oxidative pathways to meet the energy requirement than do adults (8, 14). This does not, however, necessarily indicate a deficiency in children's ability to generate anaerobic energy; instead, it may reflect a reduced reliance on anaerobic metabolism to meet the energy demands of exercise. Van Praagh et al. (26), for instance, showed that in young boys between 7 and 15 years of age, the oxygen uptake ($\dot{V}O_2$) during a 30-s high-intensity exercise task is between 60 and 70% of peak oxygen uptake values.

No gender differences were detected in the WAnT performances, post-WAnT blood lactate concentration values, or the net oxygen consumption during the WAnTs. The results of the current study therefore support Bar-Or's (5) view that prior to puberty, gender differences in anaerobic performance, as assessed by the WAnT, are statistically nonsignificant. The current finding of no gender difference in the WAnT performance among young children is of interest in light of our recent findings (2), which demonstrated that 10-year-old prepubertal boys had 13.3% higher body-mass-related treadmill-determined peak $\dot{V}O_2$ values than similarly aged prepubertal girls (51 vs. 45 $ml \cdot kg^{-1} \cdot min^{-1}$). The reasons why a gender difference exists in aerobic power, but not in anaerobic performance, as assessed using the WAnT, are not readily apparent.

Based on the present findings, we recommend that future studies that employ the 30-s WAnT with young children report the power variables, adjusted for the flywheel inertia and system resistance of the ergometer; that the power variables should be integrated over both 1- and 5-s time periods; and that the 20-s data should also be reported. It is important to report the time of blood sampling with young children, and peak blood lactate values appear to occur within 2 min of completing a WAnT.

References

1. Armon, Y., D.M. Cooper, R. Flores, S. Zanconato, and T.J. Barsto. Oxygen uptake dynamics during high-intensity exercise in children and adults. *J. Appl. Physiol.*, 70:841-848, 1991.
2. Armstrong, N., B. J. Kirby, A.M. McManus, and J. Welsman. Aerobic fitness of prepubertal children. *Ann. Hum. Biol.* 22:427-441, 1995.
3. Armstrong, N., and J. Welsman. Assessment and interpretation of aerobic fitness in children and adolescents. *Exerc. Sports Sci. Rev.* 22:435-476, 1994.
4. Armstrong, N., and J. Welsman. *Young People and Physical Activity.* Oxford: Oxford University Press, 1997.
5. Bar-Or, O. *Pediatric Sports Medicine for the Practitioner.* New York: Springer-Verlag, 1983.
6. Bar-Or, O. The Wingate anaerobic test: An update on methodology, reliability and validity. *Sports Med.* 4:381-394, 1987.
7. Bar-Or, O. Children: Lower anaerobic power, testing, puberty, and carryover to adulthood. In: *Future Directions in Exercise and Sports Science Research,* J.S. Skinner (Ed.). Champaign, IL: Human Kinetics, 1989, pp. 231-243.
8. Bar-Or, O. The young athlete: Some physiological considerations. *J. Sports Sci.* 13:S31-S33, 1995.
9. Bar-Or, O. Anaerobic performance. In: *Measurement in Pediatric Exercise Science,* D. Docherty (Ed.). Champaign, IL: Human Kinetics, 1996, pp. 161-182.
10. Bishop, P., and M. Martino. Blood lactate measurement in recovery as an adjunct to training. *Sports Med.* 16:5-13, 1993.
11. Cumming, G.R. Correlation of athletic performance and aerobic power in 12–17 year-old children with bone age, calf muscle, total body potassium, heart volume and two indices of anaerobic power. In: *Pediatric Work Physiology,* O. Bar-Or (Ed.). Netanya, Israel: Wingate Institute, 1974, pp. 109-134.

12. Duche, P., G. Falgairette, M. Bedu, N. Fellman, G. Lac, A. Robert, and J. Coudert. Longitudinal approach of bioenergetic profile in boys before and during puberty. In: *Pediatric Work Physiology,* J. Coudert and E. Van Praagh (Eds.). Paris: Mason, 1992, pp. 43-46.
13. Fujitsuka, N., T. Yamamoto, T. Ohkuwa, M. Saito, and M. Muramura. Peak blood lactate after short periods of treadmill running. *Eur. J Appl. Physiol.* 48:289-296, 1982.
14. Hebestreit, H., K.-I. Minura, and O. Bar-Or. Recovery of muscle power after high intensity short-term exercise: comparing boys to men. *J. Appl. Physiol.* 74:2875-2880, 1994.
15. Kavanagh, M.F., and I. Jacobs. Breath-by-breath oxygen consumption during performance of the Wingate Test. *Can. J. Sports Sci.* 13:91-93, 1988.
16. Lakomy, H.K.A., and S. Wootton. Discrimination of rapid changes in pedal frequency. *J. Physiol.* 316:1, 1984.
17. Margaria, R., D. Oliva, P.E. di Prampero, and P. Cerretelli. Energy utilisation in intermittent exercise of supramaximal intensity. *J. Appl. Physiol.* 26:752-756, 1969.
18. Mero, A. Blood lactate production and recovery from anaerobic exercise in trained and untrained boys. *Eur. J. Appl. Physiol.* 57:660-666, 1988.
19. Mercier, B., J. Mercier, P. Grainer, D. Le Gallais, and C.H. Prefaut. Maximal anaerobic power: Relationship to anthropometric characteristics during growth. *Int. J. Sports Med.* 13:21-26, 1992.
20. Monger, L.S., A. Allchom, and J. Doust. An automated bicycle ergometer system for the measurement of Wingate Test indices with allowance for inertial and accelerative influences. *J. Sports Sci.* 7:77-78, 1993.
21. Pirnay, F., and J.M. Crielaard. Mesure de la puissance anaerobic alactique [Measure of anaerobic alactic power]. *Med. de Sports* 53:13-16, 1979.
22. Rieu, M., A. Duvallet, L. Scharapan, L. Thieulart, and A. Ferry. Blood lactate accumulation in intermittent supramaximal exercise. *Eur. J. Appl. Physiol.* 57:235-245, 1988.
23. Stegmann, H., W. Kindermann, and M. Schnabel. Lactate kinetics and individual anaerobic threshold. *Int. J. Sports Med.* 2:160-165, 1981.
24. Tanner, J.M. *Growth at Adolescence.* Oxford: Blackwell, 1962.
25. Vandewalle, H., G. Peres, and H. Monad. Standard anaerobic exercise tests. *Sports Med.* 4:268-289, 1987.
26. Van Praagh, E., M. Bedu, G. Falgairette, N. Fellman, and J. Coudert. Oxygen uptake during a 30s supramaximal exercise in 7- to 15-year-old boys. In: *Children and Exercise: Pediatric Work Physiology XV*, R. Frenkl, and I. Szmodis (Eds). Budapest: National Institute for Health Promotion, 1991, pp. 281-287.
27. Williams, C.A. *Anaerobic Performance of Prepubescent and Adolescent Children.* Unpublished doctoral dissertation, University of Exeter, United Kingdom, 1995.
28. Winter, E.M. Cycle ergometry and maximal intensity exercise. *Sports Med.* 11:351-357, 1991.

Acknowledgments

We gratefully acknowledge the advice of Prof. Peter Preece and Dr. Francis Chiu, and the assistance of Sue Vooght, Juliet Mosney, Richard Winsley, and Mark De Ste Croix with the data collection.