A Test to Assess Aerobic and Anaerobic Parameters During Maximal Exercise in Young Girls

Kerry McGawley  
Mid Sweden University

Erwan Leclair  
University of Lille

Jeanne Dekerle and Helen Carter  
University of Brighton

Craig A. Williams  
University of Exeter

The Wingate cycle test (WAnT) is a 30-s test commonly used to estimate anaerobic work capacity (AWC). However, the test may be too short to fully deplete anaerobic energy reserves. We hypothesized that a 90-s all-out isokinetic test (ISO_90) would be valid to assess both aerobic and anaerobic capacities in young females. Eight girls (11.9 ± 0.5 y) performed an exhaustive incremental test, a WAnT and an ISO_90. Peak VO$_2$ attained during the ISO_90 was significantly greater than VO$_2$peak. Mean power, end power, fatigue index, total work done and AWC were not significantly different between the WAnT and after 30 s of the 90-s test (i.e., ISO_30). However, 95% limits of agreement showed large variations between the two tests when comparing all anaerobic parameters. It is concluded that an ISO-90 may be a useful test to assess aerobic capacity in young girls. However, since the anaerobic parameters derived from the ISO_30 did not agree with those derived from a traditional WAnT, the validity of using an ISO_90 to assess anaerobic performance and capacity within this population group remains unconfirmed.

Aerobic capacity reflects the maximal rate of oxygen uptake at the muscle cells and is expressed via the widely accepted “gold standard” measurement of VO$_2$max. Since a plateau in oxygen uptake (VO$_2$), which is traditionally considered necessary
for the achievement of a true VO₂max (33), occurs in less than 40% of children during the final stages of an incremental exercise test (1,28) the term “VO₂max” is more commonly termed “VO₂peak” in pediatric exercise science. Despite this common lack of a plateau in VO₂, VO₂peak values obtained at the end of an incremental test have been shown to provide a valid indication of aerobic capacity in children (27), regardless of sex (1).

Anaerobic capacity represents the upper limit to energy production from anaerobic glycolysis and alactic pathways. The direct quantification of anaerobic adenosine triphosphate (ATP) yield is only possible via sophisticated, expensive and/or invasive technologies such as magnetic resonance spectroscopy (³¹P-NMR) or muscle biopsy techniques. While ³¹P-NMR equipment is expensive and therefore scarce, direct muscle biopsy sampling is generally unjustified in child population groups. To overcome the problems associated with calculating ATP production, per se, it has been common to measure external mechanical power and subsequently estimate an anaerobic work capacity (AWC) from the total work done (19). The most conventional test to estimate AWC is the Wingate Anaerobic Test (WAnT). The WAnT is a 30-s maximal cycling test usually performed on a friction-braked ergometer, where mean power (MP) is assumed to reflect the rate of combined anaerobic energy conversion (21). Due to the simplicity, noninvasiveness and reliability of the WAnT (4,26), the test has been particularly popular within pediatric research groups (2,6,7,13,21).

While the reproducibility of the WAnT appears acceptable, the validity of AWC estimates derived from the test are disputed. For example, although information for children does not currently appear available, research using adults has suggested that 30 s is insufficient to fully deplete anaerobic energy reserves (25,32). Medbø and Tabata (25) used cycling exercise to exhaustion to support earlier data from exhaustive treadmill running (24) and concluded from both studies that a test of anaerobic capacity should prescribe 2–3 min of exhaustive exercise. Furthermore, Withers et al. (39) found a significantly greater muscle lactate concentration and oxygen deficit in adult males following 60 s and 90 s of maximal cycling on an air-braked ergometer, compared with 30 s. While it is noted that anaerobic power relative to body size is lower in children compared with adults (15,16), and that children’s WAnT test data correlate well (-0.7 < r > 0.7) with performances of anaerobic tasks such as high-intensity running, speed-skating and swimming (4), it remains possible that exhaustive cycling tests lasting longer than 30 s are necessary to ensure a valid assessment of AWC in children. Despite this, maximal tests lasting > 30 s have not currently been compared with the WAnT within child populations.

In addition to the increased validity of anaerobic assessment, 90-s tests used with both children and adults have elicited a peak VO₂ that is comparable with the VO₂peak measured during a conventional incremental ramp test (38,39). As such, it could be hypothesized that a 90-s test would be a valid and effective short-duration test to assess both VO₂peak and anaerobic performance parameters. A short, simple protocol that is inclusive of both aerobic and anaerobic assessment would be advantageous to testing children in applied settings due to the reduced time requirements of completing only one test. This may present an attractive option to teachers, coaches and practitioners and may subsequently increase the information and data available within pediatric groups.
Maximal cycle tests with children have to date employed only boys (11,18) or a mixture of boys and girls (38). Since sex-related differences in anaerobic characteristics and performance may occur in children as young as 10 y (31) it is important that female-only groups are also studied. This will allow for an increase in the scientific knowledge associated with girls’ physiology and ensure that exercise and training prescription within this population are based on appropriate evidence. It is possible that a friction-braked ergometer would not be appropriate for use with young children performing 90 s of all-out exercise due to the resistances for peak power (PP) and MP being too high for the cadence to be maintained, particularly toward the end of the test (21). Instead, an isokinetic ergometer has been suggested as more appropriate (14,38). To this end, the aim of the current study was to investigate whether a 90-s all-out isokinetic test (ISO_90) may be used to assess both VO_{2peak} and anaerobic parameters in young girls. It was hypothesized that: (i) performance parameters (i.e., MP, end power [EP], fatigue index [FI] and total work done [TWD]) would be similar after 30 s in both the traditional WAnT and the all-out isokinetic test (ISO_30); (ii) AWC (measured in J) would be greater at the end of the ISO_90 compared with the WAnT and the ISO_30; (iii) VO_{2peak} would be attained during the ISO_90 but not the WAnT.

**Methods**

**Participants and Experimental Design**

Eight healthy, active girls (mean ± SD: age 11.9 ± 0.5 y; body mass 40.8 ± 8.8 kg; stature 150 ± 8 cm) were recruited to participate in the current study. The participants and their parents gave written informed assent and consent following an explanation of the experimental procedures and the associated risks and benefits of participation. The experimental procedures were approved by the University of Brighton ethics committee.

Participants were required to complete three exercise tests: an incremental ramp test to exhaustion to determine VO_{2peak}, a WAnT and an ISO_90 test. Participants were instructed to arrive at the laboratory rested and in a fully VO_{2peak} hydrated state and were also asked to avoid strenuous exercise in the 24 hr preceding each testing session. For each participant, tests took place at the same time of day (± 2 hr) to minimize the effects of diurnal biological variation (12). The three tests were each separated by at least two days and were completed within one week for all participants, with the WAnT and the ISO_90 performed in a random order.

**Equipment**

The incremental test was performed on an electrically-braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The WAnT was completed on a modified cycle ergometer (Monark Ergomedic 620, Varberg, Sweden) fitted with power measuring cranks (SRM; Schoberer Rad Messtechnik, Julick, Germany). The ISO_90 was performed on an isokinetic cycle ergometer (SRM; Schoberer Rad Messtechnik, Julick, Germany), where cadence and torque applied at the crank was measured continuously at 200 Hz. Before each testing session the SRM power meter
was calibrated according to the manufacturer’s recommended procedure (22). Seat and handlebar heights were kept constant between ergometers for each participant.

Pulmonary gas exchange was determined breath-by-breath during each of the three tests using standard algorithms, allowing for the time delay between gas concentration and volume signals (5). Ventilatory expired gases were obtained using a Hans Rudolph mouthpiece (with nose-clip) connected to a breath-by-breath respiratory gas analysis system (Jaeger Oxycon Pro, Höchberg, Germany), which was calibrated using a known mixture of gases before each test. Respiratory gas exchange variables (VO2, VCO2 and VE) were displayed for each breath and were subsequently interpolated to provide 1-s values.

Fingertip capillary blood samples (~25 μL) were collected in capillary tubes and subsequently analyzed for plasma lactate concentration ([La-]) using an automated analyzer (YSI 2300, Yellow Springs, Ohio, USA). Heart rate (HR) was monitored every 5 s using a telemetric HR monitor (Sports Tester, Polar Electro Oy, Kempele, Finland).

**Incremental Ramp Test**

After one minute of baseline expired-air collection and a 3-min warm-up of cycling at 20 W, power output was increased by 15 W×min⁻¹. The first stage of the incremental test was programmed at either 35 W or 50 W, depending on the body mass and stature of the participant. Participants were asked to maintain a pedaling frequency of 70 rev×min⁻¹ and were required to remain seated throughout the test. Strong verbal encouragement was provided, particularly toward the latter stages of the test. The test ended at the point of volitional exhaustion or when the pedaling frequency dropped by >5 rev×min⁻¹ on a second occasion and a rating of perceived exertion was recorded using the 10-point children’s effort rating table (CERT) devised by Lamb (23). Three minutes after the end of the test a fingertip blood sample was collected and immediately analyzed for [La-]. The highest 10-s average of the second-by-second VO2 data characterized VO2peak. Attainment of a valid VO2peak was confirmed by the incidence of a HR ≥ 95% of age-predicted maximum (i.e., 220–age) and/or a respiratory exchange ratio (RER) > 1.06 (30).

**Maximal Cycle Tests**

For both the WAnT and the ISO_90 a familiarization protocol was completed one hour before the experimental test, which consisted of three maximal 10-s sprints (14). The main sprint tests commenced following one minute of baseline expired-air collection and a three-minute warm-up at 70rev×min⁻¹ against minimal resistance (for the WAnT the weight-basket was supported by the experimenter; for the ISO_90 the resistance was 20 W). Three seconds before the end of the warm-up a “3-2-1” countdown was given and participants began a maximal effort on the word “go”. For the WAnT the resistance was applied at 0.075 kg·kg body mass⁻¹ (3.1 ± 0.7 kg) and for the ISO_90 the flywheel was accelerated to the preset cadence (imposed by the SRM system) of 71 ± 0 rev×min⁻¹. For both tests participants were instructed to cycle as hard and as quickly as possible throughout the entire test and remain seated at all times. Standardized verbal encouragement was provided throughout the tests. Three minutes after the end of each sprint a blood sample was collected.
and immediately analyzed for [La\textsuperscript{−}]. A change in [La\textsuperscript{−}] from preexercise to 3-min postexercise (Δ[La\textsuperscript{−}]) was calculated for each test using the following equation:

\[ Δ[La^-] = Post-exercise [La^-] − Baseline [La^-] \] (eq. 1)

**Aerobic and Anaerobic Contributions**

The accumulated oxygen deficit (AOD) method was used to calculate the aerobic and anaerobic contributions to the two sprints, as described previously (17,24). Using the submaximal VO\textsubscript{2}-power output relationships from individual incremental ramp tests, the oxygen cost for the power output produced throughout each sprint was estimated at one-second intervals for each participant. The actual VO\textsubscript{2} measured second-by-second during the sprints was subtracted from the estimated oxygen cost to calculate an AOD. The aerobic contribution to each sprint was equivalent to the oxygen uptake relative to the oxygen cost (expressed as a %) and the remainder of the energetic requirement (i.e., the AOD) reflected the estimated anaerobic contribution. The AWC was expressed in J as a proportion of TWD according to the relative anaerobic contribution.

**Data Analysis**

The PP was calculated as the highest 5-s average power output, MP as the average power output for the entire sprint and EP as the average power output over the final 5 s. The FI was calculated using the following equation:

\[ FI (%) = 100 × [(PP-EP)/PP] \] (eq. 2)

Data are reported as mean ± SD. The requirements of the Shapiro Wilks and Levene tests were met for normality and homogeneity of variance, respectively, for all variables. Differences between parameters derived from the incremental test, the WAnT and the ISO_90 were evaluated using a one-way ANOVA with repeated measures. Paired t tests were used to compare WAnT and ISO_90 data and the bias ± 95% limits of agreement (LoA) between test measurements were evaluated using Bland-Altman calculations (8). Statistical significance was accepted at the \( p < .05 \) level.

**Results**

**Incremental Ramp Test**

All of the girls reached 95% of their age-predicted maximum HR and/or exceeded the RER criterion for attaining a valid VO\textsubscript{2}peak, with a peak RER of 1.10 ± 0.05. The CERT score at the end of the test was 9 ± 1 (with individual scores ranging from 8, “Very hard”, to 10, “So hard I’m going to stop”). Physiological data from the incremental ramp test (VO\textsubscript{2}, RER, HR and [La\textsuperscript{−}]) are displayed in Table 1.

**Maximal Cycle Tests**

Physiological data for the two maximal cycle tests are also displayed in Table 1. The peak VO\textsubscript{2} (L·min\textsuperscript{−1}) was attained after 20 ± 6 s and 60 ± 17 s during the WAnT.
Assessing Aerobic and Anaerobic Parameters in Young Girls

Despite a tendency for peak VO\textsubscript{2} to be higher in the ISO\textsubscript{90} compared with the WAnT, differences were not significant \((p > .05)\). Bland-Altman calculations showed a bias ± 95% LoA of 0.09 ± 0.31 L·min\(^{-1}\) (a 4 ± 14% change in the mean) between the two tests. There was no significant difference \((p > .05)\) between the peak VO\textsubscript{2} attained during the WAnT and VO\textsubscript{2peak} measured during the incremental ramp test and there was a bias ± 95% LoA of 0.09 ± 0.36 L·min\(^{-1}\) (a 5 ± 18% change in the mean) between the two measures. The peak VO\textsubscript{2} attained during the ISO\textsubscript{90} test was significantly greater than VO\textsubscript{2peak} \((p < .05)\) and there was a bias ± 95% LoA of 0.19 ± 0.28 L·min\(^{-1}\) (a 9 ± 14% change in the mean) between the two measures. Peak [La\textsuperscript{-}] and Δ[La\textsuperscript{-}] measured after the two maximal cycle tests were not different from the peak [La\textsuperscript{-}] and Δ[La\textsuperscript{-}] measured after the incremental test \((p > .05)\). While the peak [La\textsuperscript{-}] and Δ[La\textsuperscript{-}] values tended to be higher for the ISO\textsubscript{90} compared with the WAnT, these differences were not significant \((p > .05)\).

Figure 1 shows typical power output profiles for the two maximal cycle tests and group performance data for the two tests are displayed in Table 2. Data from the 90-s test is reported after 30 s (ISO\textsubscript{30}) and at the end of the 90-s period (ISO\textsubscript{90}). The PP for the two tests did not differ significantly \((p > .05)\). While MP, EP, FI and TWD were not significantly different between the WAnT and ISO\textsubscript{30} \((p > .05)\), MP and EP were lower for ISO\textsubscript{90} compared with WAnT and ISO\textsubscript{30} \((p < .005)\) and FI and TWD were greater for ISO\textsubscript{90} compared with WAnT and ISO\textsubscript{30} \((p < .01)\). The estimated anaerobic contribution expressed in J was not significantly different between the three tests \((p > .05)\). As such, the anaerobic contribution expressed as a % of TWD was lower in the ISO\textsubscript{90} compared with the WAnT and ISO\textsubscript{30} \((p < .005)\). The bias ± 95% LoA for comparisons between the WAnT, ISO\textsubscript{30} and ISO\textsubscript{90} are presented in Table 3.

**Discussion**

In support of the first hypothesis, the current study has shown that MP, EP, FI and TWD were not significantly different following a WAnT or after 30 s within an ISO\textsubscript{90} test (i.e., at ISO\textsubscript{30}). However, MP and EP were significantly reduced, while
FI and TWD were significantly increased, at the end of the ISO_90. Contrary to the second hypothesis AWC, reflected by the anaerobic contribution (measured in J), was not higher at the end of the ISO_90 compared with the W AnT or the ISO_30. This finding appears to be due to methodological limitations, which will be discussed in more detail later within this section. The final hypothesis was not supported as the peak VO2 attained during the ISO_90 was higher than the VO2peak measured during the exhaustive incremental ramp test, whereas the peak VO2 attained during the WAnT yielded a similar value to the VO2peak. Despite some unexpected results, the current study shows that an ISO_90 may be used to assess aerobic capacity in young girls. However, the low level of agreement identified between WAnT and ISO_30 parameters suggest that the two tests should not be used interchangeably to assess anaerobic capacity and performance within this population.

Table 2 Performance Data (Mean ± SD) for the WAnT, After 30 s of the 90-s Cycle Test (ISO_30) and at the End of the 90-s Cycle Test (ISO_90)

<table>
<thead>
<tr>
<th></th>
<th>WAnT</th>
<th>ISO_30</th>
<th>ISO_90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power (W)</td>
<td>340 ± 105</td>
<td>-</td>
<td>306 ± 47</td>
</tr>
<tr>
<td>Mean Power (W)</td>
<td>271 ± 80 **</td>
<td>252 ± 51 **</td>
<td>179 ± 37</td>
</tr>
<tr>
<td>End Power (W)</td>
<td>201 ± 65 **</td>
<td>200 ± 55 **</td>
<td>127 ± 31</td>
</tr>
<tr>
<td>Fatigue Index (%)</td>
<td>41 ± 8 *</td>
<td>36 ± 9 **</td>
<td>58 ± 9</td>
</tr>
<tr>
<td>Total Work Done (J)</td>
<td>8131 ± 2402 **</td>
<td>7564 ± 1534 **</td>
<td>15984 ± 3308</td>
</tr>
<tr>
<td>Anaerobic contribution (J)</td>
<td>4531 ± 2139</td>
<td>4370 ± 1675</td>
<td>3876 ± 2921</td>
</tr>
<tr>
<td>Anaerobic contribution (%)</td>
<td>54 ± 11 **</td>
<td>55 ± 12 **</td>
<td>23 ± 11</td>
</tr>
</tbody>
</table>

Significantly different from ISO_90: * P < 0.01; ** P < 0.005

Figure 1 — Typical power output profiles from the WAnT and the ISO_90 test.
Table 3  Bland-Altman Bias ± 95% Limits of Agreement, Expressed as an Absolute Change in the Mean (Upper Row) and as a % of the Change in the Mean (Lower Row), for Comparisons Between the WAnT, After 30 s of the 90-s Cycle Test (ISO_30) and at the End of the 90-s Cycle Test (ISO_90)

<table>
<thead>
<tr>
<th></th>
<th>WAnT vs ISO_30</th>
<th>WAnT vs ISO_90</th>
<th>ISO_30 vs ISO_90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power (W)</td>
<td>-</td>
<td>-34 ± 175</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-7% ± 47%</td>
<td>-</td>
</tr>
<tr>
<td>Mean Power (W)</td>
<td>-19 ± 103</td>
<td>-92 ± 103</td>
<td>-73 ± 37</td>
</tr>
<tr>
<td></td>
<td>-5% ± 35%</td>
<td>-39% ± 28%</td>
<td>-34% ± 13%</td>
</tr>
<tr>
<td>End Power (W)</td>
<td>-1 ± 56</td>
<td>-73 ± 92</td>
<td>-73 ± 76</td>
</tr>
<tr>
<td></td>
<td>0% ± 25%</td>
<td>-43% ± 34%</td>
<td>-43% ± 36%</td>
</tr>
<tr>
<td>Fatigue Index (%)</td>
<td>-5 ± 17</td>
<td>18 ± 25</td>
<td>23 ± 19</td>
</tr>
<tr>
<td></td>
<td>-15% ± 45%</td>
<td>36% ± 52%</td>
<td>50% ± 46%</td>
</tr>
<tr>
<td>Total Work Done (J)</td>
<td>-568 ± 3094</td>
<td>7582 ± 3976</td>
<td>8150 ± 3678</td>
</tr>
<tr>
<td></td>
<td>-5% ± 35%</td>
<td>65% ± 30%</td>
<td>70% ± 12%</td>
</tr>
<tr>
<td>Anaerobic contribution (J)</td>
<td>-161 ± 2501</td>
<td>-655 ± 3822</td>
<td>-494 ± 3209</td>
</tr>
<tr>
<td></td>
<td>-1% ± 61%</td>
<td>-73% ± 378%</td>
<td>-93% ± 471%</td>
</tr>
</tbody>
</table>

Anaerobic Parameters

Given the difficulties associated with direct measurements of anaerobic energy turnover, it has become common practice to assess external mechanical power in laboratories using the WAnT. For a 90-s all-out test to be considered a valid alternative to the WAnT, the traditional power parameters derived from the two tests needed to be compared. Findings from the current study have shown that MP measured during the WAnT (i.e., 271 ± 80 W), which is comparable to previously recorded values of 226–275 W for females aged 10–13 y (35), was not different from the MP (i.e., 252 ± 51 W) measured after 30 s of the ISO_90 (i.e., ISO_30). This suggests that MP derived from a WAnT may be replicated over the first 30 s of a 90-s all-out test with young girls using isokinetic cycle ergometry. The EP, FI and TWD data for ISO_30 provide further support for the use of an ISO_90 test as an alternative to the WAnT, whereby the values at 30 s were not significantly different between the two tests. Collectively these data seem to provide evidence that the girls did not pace themselves during the ISO_90 test, which may have been a potential limitation of this longer test. Despite these findings, however, the large 95% LoA calculated between the WAnT and the ISO_30 for the performance parameters (highlighted in Table 3) suggest that the two tests may not be used interchangeably. For example, if WAnT MP were to be estimated from the ISO_30 MP, the 95% LoA suggest that an under-estimation of as much as 122 W, or an over-estimation of as much as 84 W, could occur. This level of inaccuracy is obviously too large to provide a valid estimate from one test to another.
In addition to MP, EP, FI and TWD measures, PP was also derived from the WAnT and the ISO_90 test. While PP reflects the ability of the active muscles to produce a high mechanical power output in a short period of time, it is not a measure of AWC. Instead it may be a useful marker of pacing and/or a lack of all-out, maximal effort. In the current study, no significant difference was identified between the PP values measured during the WAnT or the ISO-90 test, which indicates no discernible differences in all-out effort. However, the bias ± 95% LoA (-34 ± 175 W) again suggests that the value measured during WAnT may not be used interchangeably with that measured during the ISO_90 test. The inconsistencies in the two measures may be partly explained by the use of different cycle ergometers. For example, Williams et al. (36) have shown that the typical error in PP for Monark and isokinetic ergometers is 27 W (a variation of ~10%) when boys and girls aged 9 y completed 20-s cycle sprints. In addition, different cadences used between tests in the current study (due to isokinetic and free-cadence protocols) may have led to discrepant PP results. This has previously been shown by Williams et al. (37), whereby different cadences during maximal cycle sprints led to significantly different maximal power output values. It is also worth noting that PP during all-out exercise has been reported to exhibit low reliability (4), so more extensive familiarization with equipment and the exercise task may have been necessary for obtaining more reliable PP data. Further research is also required to validate this parameter with children.

Anaerobic Work Capacity

Although MP sustained during a WAnT has been proposed to reflect anaerobic performance (21), it has since been shown with adult participants via AOD and muscle biopsy methods that exercise tests lasting 60–150 s impose a more severe anaerobic demand than 30-s tests (24,25,39). As such, the ISO_90 was expected to elicit a greater AWC (measured as the anaerobic contribution in J) compared with the WAnT and ISO_30. However, the absolute anaerobic contributions did not differ between the three measures. In fact, although not significantly different, there was a tendency for less total energy to be produced anaerobically during the ISO_90 compared with the WAnT and ISO_30. This was due to the VO2 during the final 60 s of the ISO_90 being greater than the estimated O2 demand for some individuals, which reflects a methodological flaw in AOD-derived AWC estimates. The validity of AOD assumptions have been questioned previously (3,20,40), with the assumed linear increase in VO2 for work performed above the VO2peak receiving criticism. Indeed, data from the current study would concur with this limitation of the method and the validity of calculating energy demand at intensities above VO2peak by extrapolating beyond VO2peak. The significantly lower relative anaerobic contribution (expressed as a % of TWD) to the ISO_90 compared with the WAnT and ISO-30 was an artifact of a significantly greater TWD and no difference in the AWC, so interpretation of this parameter should be treated with similar caution.

Despite the limitations of the AOD method, it is possible that higher absolute and relative anaerobic contributions to all-out 30- versus 90-s exercise truly exists among young girls and that this population group responds differently to maximal cycling compared with the adult males previously investigated (24,25,39). That is, a child’s anaerobic capacity may be more rapidly exhausted and a 30-s maximal test may be more suitable than tests lasting 60–150 s for assessing AWC. The peak [La]...
values reported in the current study, which were similar to those reported previously for females aged 12.5 y (35), do not necessarily support this notion though. That is, although not significantly different, peak [La\(^-\)] tended to be higher following the ISO_90 compared with the WAnT. More specifically, peak [La\(^-\)] was higher for six out of the eight participants following the ISO_90 compared with the WAnT (\(p < .05\)). Despite these observations, it is recognized that [La\(^-\)] is not a direct marker of muscle metabolism and should not be interpreted as a direct representation of anaerobic glycolysis, especially in children where the physiological mechanisms associated with blood lactate accumulation are still not entirely clear (35). It is also important to note the longer duration between the start of the 90-s test and the point of blood sampling (i.e., 4.5 min) compared with the WAnT (i.e., 3.5 min), which may have allowed greater diffusion of lactate from the muscle to the blood and could give a false impression of greater anaerobic glycolysis. Therefore, further research using more direct methods for measuring the anaerobic contribution to maximal exercise are required to determine whether a 30- or a 90-s all-out test is more appropriate with young girls.

**Aerobic Parameters**

It is believed that valid measures of VO\(_{2}\)\(_{\text{peak}}\) were derived from the incremental ramp test to exhaustion in the current study, since all participants attained 95% of their age-predicted maximum HR and/or an RER > 1.06 and showed signs of maximal physical effort, with CERT scores of 9 ± 1 (on a 1–10 scale). Furthermore, the peak [La\(^-\)] and \(\Delta[La^-]\) values measured during the incremental ramp test were not different from those measured during the WAnT and the ISO_90 protocols. Despite meeting these criteria, peak VO\(_2\) was significantly greater than VO\(_{2}\)\(_{\text{peak}}\) for all participants during the ISO_90, and for five of the eight participants during the WAnT. This is in contrast to work with adults and adolescents aged ~14 y, whereby peak VO\(_2\) attained during a 90-s all-out isokinetic cycling remained either lower than (9,11) or similar to (38) VO\(_{2}\)\(_{\max}\) or VO\(_{2}\)\(_{\text{peak}}\). The attainment of VO\(_{2}\)\(_{\max}\) during a 90-s test has been identified in well-trained adult cyclists and winter-sport athletes (29,39), but a 90-s test has not previously produced VO\(_2\) values greater than those measured during a traditional incremental test to exhaustion.

Although familiarization to the testing procedures was carried out before the incremental test, and that criteria for attaining VO\(_2\)\(_{\text{peak}}\) were met, it seems that higher VO\(_2\) values were nevertheless achievable. While reasons for the higher peak VO\(_2\) in the ISO_90 are unclear, a possible explanation is that a learning effect may have been associated with exhaustive cycling, as the incremental test was always completed before the two sprint tests. Given these unexpected and currently unexplainable findings, it is also important to consider the inherent variability of maximal aerobic power testing in children, which may be as high as 4.6% (34). Given that the peak VO\(_2\) during the ISO_90 in the current study was 9.6% higher than VO\(_2\)\(_{\text{peak}}\), a combination of participant and test variation may have led to the significant difference between the two values.

**Summary**

The WAnT is a simple performance test that has been the traditional method for assessing anaerobic characteristics for over 20 years and is an accepted measurement
tool within the field of applied exercise physiology. This is despite questions raised over the physiological validity of the test, at least in adult groups, whereby longer-duration tests may elicit higher anaerobic contributions to exercise. The advantages of using a WAnT that have been outlined by Carey and Richardson (10), which include continuous power assessment, power adjustment based on fatigue as the test progresses and analysis of gas measurements in a stationary subject, can also be obtained from a 90-s all-out test. However, the question of whether valid measures of specific anaerobic parameters can be derived from a 90-s test still requires further investigation.

The present study has shown that a 90-s all-out isokinetic cycle test is able to elicit maximal VO\textsubscript{2} values within a group of young females. While there were no differences identified between group mean data for anaerobic performance and capacity measures, the low level of agreement between tests suggest that an ISO\textsubscript{90} does not provide measurements of anaerobic power that are interchangeable with those derived from a WAnT. The wide LoA may be due to inherent differences in the two tests, the small sample size used within the current study and/or insufficient experience in cycle ergometry exercise among the participants. Further research is required to eliminate these possibilities, with more replication required for female groups across 30-s and 90-s all out cycle sprints.

References


