Determining Anaerobic Power and Capacity: The Wingate Cycle Ergometer Test

The Wingate cycle ergometer test represents the most popular test to assess anaerobic capacity. Developed at the Wingate Institute in Israel in the 1970s, test scores can reliably determine peak anaerobic power and anaerobic fatigue.

THE TEST

A mechanically braked bicycle ergometer serves as the testing device. After warming up (3 to 5 min), the subject begins pedaling as fast as possible, without resistance. Within 3 seconds, a fixed resistance is applied to the flywheel; the subject continues to pedal “all out” for 30 seconds. An electrical or mechanical counter continuously records flywheel revolutions in 5-second intervals. Total work during the 30 seconds computes in joules and power computes as joules · s$^{-1}$, or watts.

RESISTANCE

Flywheel resistance equals 0.075 kg per kg body mass. For a 70-kg person, the flywheel resistance would equal 5.25 kg (70 kg × 0.075). Resistance often increases to 0.10 kg per kg body mass or higher (up to 0.12 kg) when testing power- and sprint-type athletes. The Wingate test was originally designed using the Swedish Monarch cycle ergometer. The unit of resistance was the former standard Swedish unit of force called the kilopond. Measurement of the kilopond (kp) was a cleverly engineered system comprised of a basket containing a weight representing the braking force applied to the flywheel, equal to the weight of the basket and its contents. The standard corresponded to the weight of a 1 kg mass; hence, 1 kp has come to represent 1 kg. The proper unit of force when using the Monarch bike should be kp·m · min$^{-1}$, not kg·m · min$^{-1}$. When Sweden joined the European Union, they switched to the SI unit of force, the Newton (N). [One kp corresponds to the force exerted by Earth's gravity (9.80665 m · s$^{-2}$) on 1 kilogram of mass; thus, one kilogram-force equals 9.80665 Newtons (N).]

TEST SCORES

- **Peak power output (PP)**—The highest power output, observed during the first 5-second exercise interval, indicates the energy-generating capacity of the immediate energy system (intramuscular high-energy phosphates ATP and PCr). PP, expressed in watts (1 W = 6.12 kp·m · min$^{-1}$), computes as Force in Newtons (kp resistance × acceleration due to gravity) × Distance (number of revolutions × distance per revolution) ÷ Time in minutes (5 s = 0.0833 min).
- **Relative peak power output (RPP)**—Peak power output (W) relative to body mass: PP ÷ Body mass (kg).
- **Anaerobic fatigue (AF)**—Percentage decline in power output during the test; AF is thought to represent the total capacity to produce ATP via the immediate and short-term energy systems. AF computes as (Highest 5-second PP - Lowest 5-second PP) ÷ Highest 5-second PP × 100.
- **Anaerobic work (AW)**—Total work accomplished in watts for duration of the test (30 s).
EXAMPLE
A male weighing 73.3 kg performs the Wingate test on a Monark cycle ergometer (6.0 m traveled per pedal revolution) with an applied resistance (force) of 5.5 kp (73.3·kg body mass × 0.075 = 5.497, rounded to 5.5 kg); pedal revolutions for each 5-second interval equal 12, 10, 8, 7, 6, and 5 (48 total revolutions in 30 s).

CALCULATIONS
1. Peak power output
   \[ PP = \text{Force} \times \text{Distance} \div \text{Time} \]
   \[ = (5.5 \text{ kp} \times 9.8 \text{ m} \cdot \text{s}^{-2}) \times (12 \text{ rev} \times 6 \text{ m/rev}) \div 5 \text{ s} \]
   \[ = 776.8 \text{ kg} \cdot \text{m} \cdot \text{s}^{-3} \]
   \[ = 776.8 \text{ N} \cdot \text{m} \cdot \text{s}^{-2} \]
   \[ = 776.8 \text{ W} \]

2. Relative peak power output
   \[ RPP = PP \div \text{Body mass, kg} \]
   \[ = 776.8 \text{ W} \div 73.3 \text{ kg} \]
   \[ = 10.6 \text{ W} \cdot \text{kg}^{-1} \]

3. Anaerobic fatigue
   \[ AF = \left( \frac{\text{Highest PP} - \text{Lowest PP}}{\text{Highest PP}} \right) \times 100 \]
   \[ \text{Highest PP} = \text{Force} \times \text{Distance} \div \text{Time} = (5.5 \text{ kp} \times 9.8 \text{ m} \cdot \text{s}^{-2}) \times (12 \text{ rev} \times 6 \text{ m}) \div 0.0833 \text{ min} \]
   \[ = 4753.9 \text{ kp} \cdot \text{m} \cdot \text{min}^{-1}, \text{ or } 776.8 \text{ W} \]
   \[ \text{Lowest PP} = \text{Force} \times \text{Distance} \div \text{Time} = (5.5 \text{ kp} \times 9.8 \text{ m} \cdot \text{s}^{-2}) \times (5 \text{ rev} \times 6 \text{ m}) \div 0.0833 \text{ min} \]
   \[ = 1980.8 \text{ kp} \cdot \text{m} \cdot \text{min}^{-1}, \text{ or } 323.7 \text{ W} \]
   \[ AF = \frac{776.8 \text{ W} - 323.7 \text{ W}}{776.8 \text{ W}} \times 100 \]
   \[ = 58.3\% \]

4. Anaerobic work
   \[ AW = \text{Force} \times \text{Total Distance (in 30 s)} \]
   \[ = (5.5 \text{ kg} \times 9.8 \text{ m} \cdot \text{s}^{-2}) \times [(12 \text{ rev} + 10 \text{ rev} + 8 \text{ rev} + 7 \text{ rev} + 6 \text{ rev} + 5 \text{ rev}) \times 6 \text{ m}] \]
   \[ = 15,523 \text{ joules}, \text{ or } 15.5 \text{ kJ} \]

### Subject #1:
- \[ PP = \quad \text{Rank} = \quad \% \]
- \[ RPP = \quad \text{Rank} = \quad \% \]
- \[ AF = \quad \% \]

### Subject #2:
- \[ PP = \quad \text{Rank} = \quad \% \]
- \[ RPP = \quad \text{Rank} = \quad \% \]
- \[ AF = \quad \% \]

### Subject #3:
- \[ PP = \quad \text{Rank} = \quad \% \]
- \[ RPP = \quad \text{Rank} = \quad \% \]
- \[ AF = \quad \% \]