

# Incremental exercise test with measurement of blood lactate on a cycle ergometer

## Test Protocol Document

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# Objective

To measure the physiological response as a function of exercise intensity using blood lactate on a cycle ergometer.

# Traceability

<b>Protocol Name</b>	<b>Date (yyyy-mm)</b>	<b>Changes Made</b>	<b>Changes Made by</b>
<b>Cycling Incremental Exercise Test with Measurement of Blood Lactate</b>	2025-04	Version 1 – Creation of SOP	Jalena Bertagnolli, Jérémie Chase, Stacey Hutton, Laura Isherwood, Kevin Iwasa-Madge, Chris Pignanelli, Kelly Quipp
<b>Cycling Incremental Exercise Test with Measurement of Blood Lactate</b>	2025-08	Reviewed by:	Jem Arnold Erik Groves Andy Hung Liz Johnson Hilkka Kontro Myriam Paquette
<b>Incremental Exercise Test with Measurement of Blood Lactate on a Cycle Ergometer</b>	2025-09	Version 1 edits made from reviewers' suggestions	Jalena Bertagnolli, Jérémie Chase, Stacey Hutton, Laura Isherwood, Chris Pignanelli

# Preparatory Work

The following subsections contain preparatory work that the practitioner and athlete can do at least one day prior or in the morning of testing.

## Laboratory

- Ensure the following conditions are met and the equipment is in working order:
  - Room temperature 18-23°C
  - Relative humidity less than 70%
  - Standardize whether music and/or a fan will be used during the test
  - Cycle ergometer is maintained, and calibrated as per manufacturer recommendations and institutional guidelines
  - Lactate analyzer calibration as per manufacturer recommendations and institutional guidelines

## Technician

- Blood sampling may fall under a controlled act within the province of practice. As such, phlebotomy certification and/or medical delegation may be required in your province.
  - The test administrator must be well trained to collect blood samples to obtain valid and reliable data while minimizing the risks associated with blood sampling.
  - See '[CAPILLARY BLOOD SAMPLING EXECUTION](#)' in the appendix for guidelines to collect capillary blood samples.

## Schedule

- The test should be scheduled to occur after the athlete has had time to recover from a heavy training block, competition, recent illness and/or recent travel to best reflect an athlete's current fitness.
- For longitudinal monitoring, fatigue leading into the testing session and time of day should be standardized as best as possible.

## Protocol Design

- Table 1 has recommendations for key variables for the incremental exercise test based on the caliber of the athlete using the tier system provided by McKay and colleagues<sup>1</sup>. Refer to the [appendix](#) for further information and justification of these recommendations.
- The initial power output, stage duration, and increase in power output per stage should be determined in advance. To provide adequate resolution for determining thresholds while minimizing test duration, the following targets are recommended:
  - 6-7 steps with lactate spanning baseline up to ~6mM
  - 2-3 steps with lactate at baseline levels (less than ~2mM)

- Other key metrics that should be considered include:
  - Cycling cadence
  - Blood sampling location
  - Test termination criteria
- If applicable, review and use athlete's prior test results as a guide.

Apart from eliminating excessive submaximal stages and starting at a higher power output, protocol design should remain consistent between tests if results are to be compared over time for an individual. If changes to the protocol are required, consider timing where continuity is less crucial e.g. at the start of a new Olympic/Paralympic cycle.

Table 1: Recommended Protocol for Canadian Olympic and Paralympic Athletes

<b>Protocol Variable</b>	<b>Recommendation</b>
<b>Stage Duration</b>	Between 3 and 5 minutes
<b>Initial Stage</b>	<ul style="list-style-type: none"> <li>• Female Cyclist (Tier 5/4): 100-150 W</li> <li>• Male Cyclist (Tier 5/4): 120-200 W</li> <li>• Female Non-Cyclist (Tier 5/4/3/2): 50-100 W</li> <li>• Male Non-Cyclist (Tier 5/4/3/2): 75-150 W</li> </ul>
<b>Stage Size</b>	<ul style="list-style-type: none"> <li>• Female Cyclist (Tier 5/4): 25-30 W</li> <li>• Male Cyclist (Tier 5/4): 30-40 W</li> <li>• Female Non-Cyclist (Tier 5/4/3/2): 20-25 W</li> <li>• Male Cyclist (Tier 5/4): 25-30 W</li> </ul>
<b>Breaks</b>	None - Continuous
<b>Cycling Cadence</b>	<ul style="list-style-type: none"> <li>• Between 80 and 100 revolutions per minute (RPM)               <ul style="list-style-type: none"> <li>○ Athlete preference within range, but must be steady, without sudden drops or surges</li> </ul> </li> </ul>
<b>Test Termination</b>	<ul style="list-style-type: none"> <li>• Submaximal: Intensity exceeding the second lactate threshold (i.e., blood lactate &gt; 6 mM), RPE between 5-9 (CR10) or 15-18 (Borg 6-20)</li> <li>• Maximal: Volitional fatigue, cadence cannot be maintained above 70 RPM, RPE of 9-10 (CR10) or 19-20 (Borg 6-20).</li> </ul>
<b>Blood Sampling Site</b>	Consistent site of either fingertip or earlobe

## Athlete

### *Instructions for athlete*

- Day(s) before testing:
  - Avoid high-intensity, long-duration, and/or unaccustomed exercise at least 48 hours prior
  - Abstain from alcohol for at least 24 hours prior
- Day of testing:
  - Do not arrive to the testing if sick, injured, or have recently (less than 24 hours) consumed alcohol
  - Wear comfortable, moisture-wicking clothing and suitable athletic shoes, or if normally used, clipless pedals and shoes
  - Consume any usual supplements and/or medications
  - Consume an easily digestible meal, avoiding high-fat foods. A meal of high carbohydrates, moderate protein, and low fat is recommended
  - Arrive to the testing well-hydrated, ensuring at least 1-2 cups of fluids consumed 2-3 hours prior to the test

### *Medical Clearance and Informed Consent*

- Confirm the athlete is medically cleared to perform the test.
- Review the athlete's medical history, including any para-relevant considerations, which may impact protocol decision-making and test results.
- Explain the purpose of the test to the athlete and what will be expected of them.
- Ensure the athlete has consented to participate in the testing and, if applicable, the sharing of their data with coaches and other practitioners.

# Equipment

The number of athletes tested and practitioners available will determine the actual number of equipment and resources. Below are the key equipment and resources that are needed to execute the testing. Please refer to accompanying excel file with equipment details used across Canadian Institutions as well as reliability and validity data, as applicable. If using equipment not found in the excel file, it is relevant to determine if the alternative equipment is valid and/or reliable to the degree that is needed, which will depend on the purpose of conducting the test.

## Equipment Checklist

- Body mass scale
- Calibrated cycling ergometer
- Lactate Analyzer
- Phlebotomy supplies and bandages
- Chest strap heart rate monitor
- Device to view and record heart rate (e.g., phone, iPad, personal computer, bike computer)
- Spare batteries for lactate analyzer and heart rate monitor
- Borg Category Ratio-10 (CR-10) or 6-20 Rating of Perceived Exertion (RPE 6-20) Scale
- Portable fan
- Weather station or equivalent to measure temperature, relative humidity, atmospheric pressure
- Stopwatch
- Tape measure, level and plum bob for bike set up

# Procedures

## Pre-Test Preparation

1. Measure body mass
  - Remove shoes
  - Wear only the clothing for exercise
  - If applicable, account for weight of prostheses or mobility aids
  - Record to nearest 0.1kg
2. Collect contextual data
  - Travel in the last seven days
  - Recent sickness or injury
  - Relevant supplement and/or medication information that may influence exercise data
3. Record environmental conditions: temperature, relative humidity, atmospheric pressure
4. Provide heart rate monitor chest strap to athlete
  - Moisten electrodes on strap with water or electrode gel
  - Adjust strap length so it fits to the individual, but is still comfortable
  - Consider positioning receiver so its display is visible to test administrator, but not the athlete
5. Wrap the handlebar with non-porous material to ensure blood does not get onto the handle (saran wrap, blue pad, dental dam, etc.)
6. Adjust cycle ergometer to fit athlete
  - General guidelines include:
    - slight bend in knee when pedal is at lowest point in the crank cycle
    - knee over pedal spindle when pedal is furthest forward in crank cycle
  - Record ergometer settings (See the [bike fitting diagram](#) within the appendix):
    - Crank length
    - Saddle height
    - Saddle setback
    - Handlebar height
    - Handlebar reach
    - Pedals used (i.e., platform, toe clips, or clipless)
7. Prior to the warm-up period, the practitioner can provide an overview of the test if the athlete is unfamiliar with it. Include the following details
  - Test Overview: Initial power output, stage duration, stage size, and end-test criteria
  - Instructions for when/how a blood sample is to be acquired
  - How to use RPE scale (See the [Appendix](#) for instructions)
  - Maintain steady cadence within target RPM
  - Minimize postural changes
  - Minimize talking during the test
8. Have the athlete begin their warm-up for a suggested time of 10 minutes.

Unless otherwise dictated by the sport or athlete, instruct the athlete to pedal at an intensity that does not exceed the starting power output. See the [appendix](#) for more information.

- Confirm appropriateness of predetermined starting load.
  - If no previous history to suggest otherwise, use the following as a guideline:
    - Heart rate of approximately 120bpm or <65% of heart rate max
    - RPE should be “light” (2 if using the CR-10 and 11 if using RPE 6-20)
9. Measure pre-test blood lactate concentration
- Clean the area with alcohol swab → wipe with clean gauze pad → puncture the skin with lancet → wipe first drop of blood with gauze pad → create a drop of blood → collect blood droplet with lactate analyzer.
  - If less than 2mM, proceed with the test
  - If greater than 2mM, reduce the power output by 1 full stage for 3-to-5 minutes
    - Re-measure blood lactate
    - If concentration decreased below 2mM, consider starting test at a lower intensity than initially planned
    - If concentration does not decrease, athlete’s baseline may be higher than 2mM and planned starting intensity is appropriate
10. If applicable, zero-offset the power meter

## Test Execution

A schematic overview of the test execution for each stage can be found in Figure 1 below.

1. Allow athlete to start pedaling with little or negligible resistance
2. Start the initial power output when they are close to target cadence
3. At the end of each minute, use a visual average of the last 15-seconds to record heart rate
  - Option to use software to record cadence and heart rate for review afterwards
4. In the last 30 seconds of the stage, perform the following:
  - Record cadence
  - Rating of perceived exertion
  - Prepare to acquire a blood sample just prior to the end of the stage
    - If previous puncture exists, try to obtain a blood sample without excessively squeezing. Otherwise create a new puncture in a different site
5. Acquire blood sample in last 10 seconds of the stage
6. Increase workload when step duration is met with no breaks between stages
7. Make note of data validity concerns (e.g., late blood sample, talking, low blood volume, test strip touching skin, fluctuating cadence, changes in athlete posture, etc.)
8. Repeat the above procedural steps until end-test criteria is met. If conducting the test until volitional fatigue, record the following at task failure:
  - Peak RPE
  - Peak heart rate
  - Power output at last full completed stage

- Power output and time into failed stage
- Reason(s) for ending the test
- Peak lactate (if required)

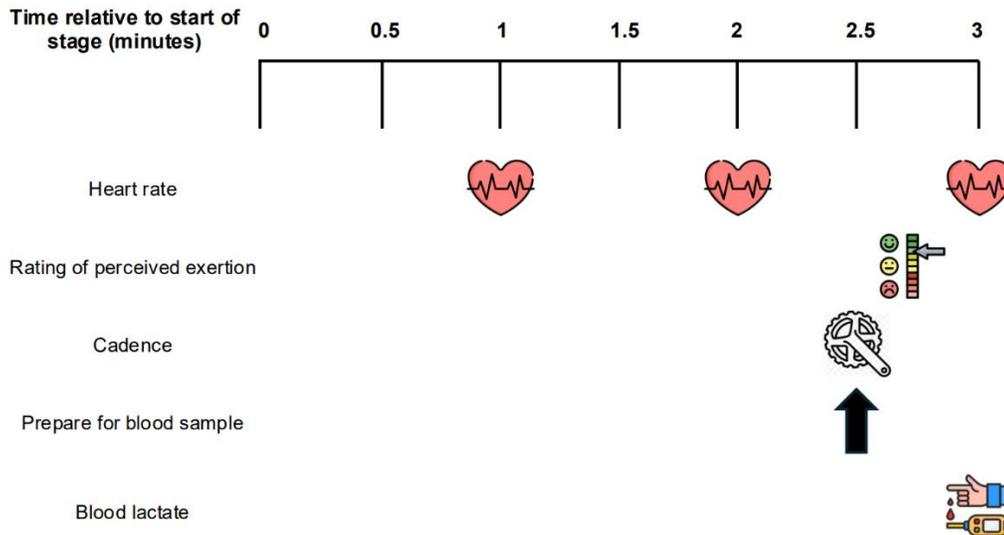


Figure 1. Schematic representation of data acquisition during a single exercise stage.

### Post-Test

- Allow athlete to recover actively at a self-selected intensity until heart rate has returned to baseline level
- If lactate clearance data is desired, standardize an active or passive protocol and obtain a blood lactate at 1, 3, and 5 minutes after exercise
- If applicable, wipe away any blood on athlete and clean their skin
- Apply bandage(s) to puncture sites
- Remove handlebar covering, clean handlebar and anything that contacted blood with 10% bleach solution or equivalent. Clean the bike frame, seat and other surfaces with soap and water.



## Data Validity and Technical Concerns

During the data collection period, data validity and technical concerns are possible. This section provides suggestions on how the practitioner can document and/or mitigate some of these concerns.

### *Insufficient blood volume in test strip*

- Do not add blood to the same test strip
- Immediately take a second measurement using a different test strip and analyzer, even if athlete is already in subsequent stage. Document this within the data collection sheet.

### *Blood collected late*

- Record time blood is collected
- If taken within 30-sec of target, report as usual
- If > 30-sec late, measurement cannot be used as a data point for the stage, however, it may be used to help interpret test results.

### *Unexpected blood lactate value*

- Even with proper blood collection technique, occasional measurements can be made that are suspiciously high/low, or the analyzer displays an error. Record the result but immediately take a second measurement and record the time of the 2<sup>nd</sup> sample.
- If values continue to be unexpected, consider any of the following that could be possible explanations:
  - Test strips were not properly stored or handled
  - Violation of manufacturer operating specifications for temperature, humidity, and hematocrit ranges
  - An error with analyzer itself (e.g. analyzer was not properly codded to Edge lactate strip)
  - Athlete related factors like hypohydration, glycogen depleted and/or overreaching

### *Fluctuating heart rate*

- In the first minutes, it is not unusual for heart rate to fluctuate, however, on average it should fluctuate within 5 bpm range in the stage's final minute (e.g., 140-145bpm)
- If changes greater than 5 bpm are seen during the test, take steps to mitigate potential causes that include postural changes, fluctuations in cadence, talking, and anxiety associated with blood collection
- Record average heart rate seen prior to fluctuation if it is believed to be more reflective of athlete's response to power output than that seen in the last 15-sec of stage

### *Accuracy of targeted power output*

- Electromagnetically braked cycle ergometers allow for constant power outputs by adjusting resistance depending on the cadence, but there is a lag in this adjustment
- Changes in cadence must be gradual and relatively smooth for the actual power output to match that which is targeted

- Consider restricting athletes from standing to limit drop/surges in cadence

*Deviations from standardization*

- Care must be taken to compare test results longitudinally for an athlete in the following situations:
  - Change in cycle ergometer and/or lactate analyzer
  - Degree of athlete fatigue from recent training, competition, and/or travel
  - Changes in athlete medication, diet and/or supplementation (See [Appendix](#) for these considerations)
  - In the case of athlete illness/inebriation, test results are invalid and should not be included in the database for analysis
  - Different testing location elevation (i.e., atmospheric pressure changes)
  - Temperature and relative humidity fall outside recommended ranges
  - Inconsistent use of fans
  - Inconsistent use of music in maximal tests

Data Presentation

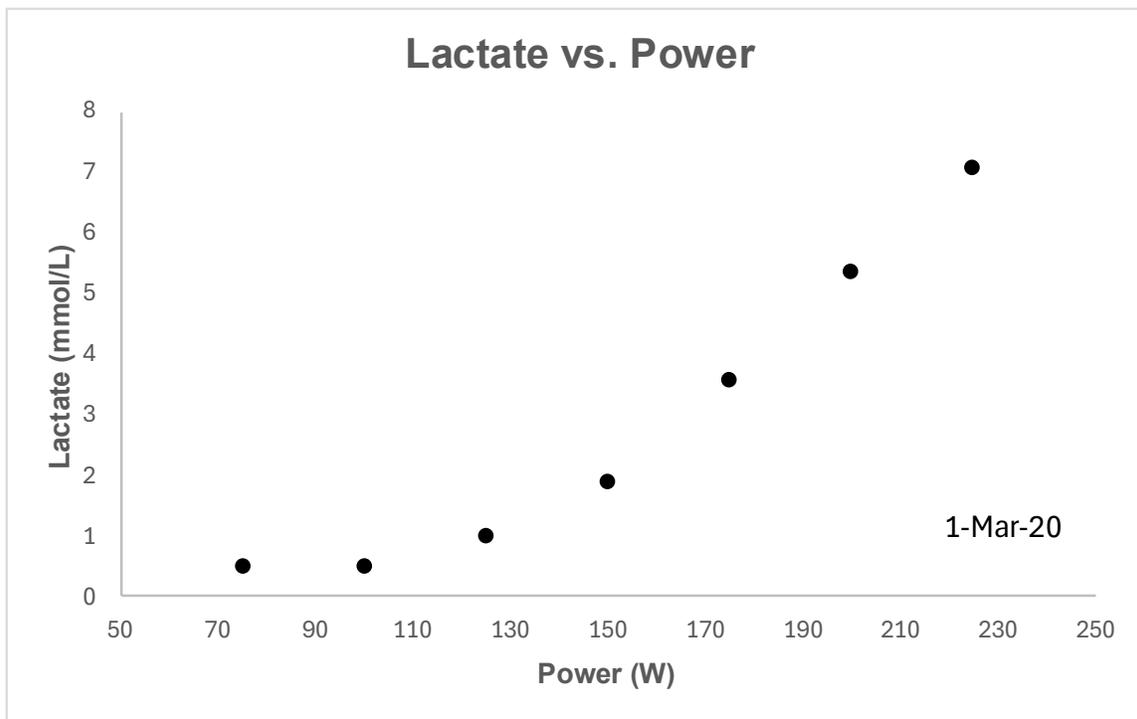


Figure 3. Example blood lactate vs. power graph. Data taken from sample data sheet in Figure 2.

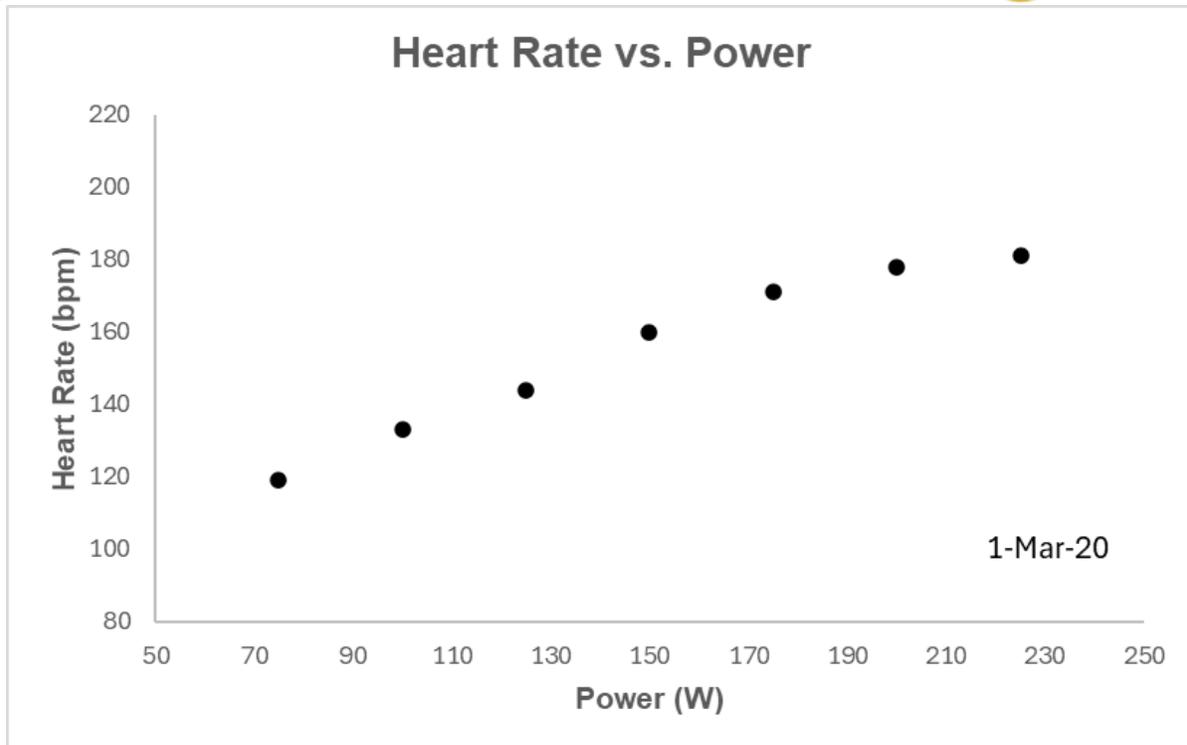


Figure 4. Example heart rate vs. power graph. Data taken from sample data sheet in Figure 2.

### Data Interpretation

Interpreting data from an incremental test requires careful consideration of the various factors influencing the physiological responses to the incremental exercise test. In conjunction with other metrics collected during this test and/or other performance tests, the acquisition of blood lactate can be used to identify exercise thresholds with two common applications:

1. Individualize training zones
2. Monitor training adaptations across months-to-years.

Both applications require a practitioner to select exercise thresholds. This process is complex and can vary based on the athlete, coach, and/or sport philosophy. In addition, exercise thresholds are influenced by the exercise protocol, the definition used, and/or identification methods. A full description of the various methods used to calculate the thresholds is out of the scope of this document. For more information please refer to recent reviews on these topics<sup>2,3</sup>.

# Appendix

## Preamble

Incremental exercise testing is widely used in both research and applied settings to assess physiological responses to progressively increasing exercise intensity. One biomarker measured during these tests is blood lactate. As exercise intensity increases during an incremental exercise test, lactate accumulation follows a predictable pattern. At lower intensities, lactate production is minimal and well-matched by clearance, maintaining near-resting levels. However, as the workload rises, a point is reached where lactate production surpasses clearance, leading to an exponential increase in blood lactate levels.

The blood lactate response as a function of exercise intensity has been used historically to provide insight into exercise intensity prescription, overall exercise capacity, and as a predictor of endurance performance. With the advancement in technology, portable blood lactate analyzers now exist and are commonly performed in settings beyond the laboratory. Nonetheless, nuances exist for the equipment use, protocol selection, protocol collection, and data interpretation of the blood lactate responses to increasing exercise intensity, which emphasizes the importance of understanding key factors to consider when conducting this test across different locations, environments, and athletes in Canada.

## Laboratory Set-up

How the laboratory is set-up will depend on how many athletes are being tested at one time, the exercise mode, and staff availability. Other considerations include excessive talking during the test, the implementation of music and fans, as these both may affect exercise performance and physiological variables like heart rate<sup>4-7</sup>.

Ensure an emergency activation plan is in place for each testing location and practitioners have appropriate relevant training including first aid/CPR and blood collection practices.

## Protocol Selection

If possible, it is important to determine the protocol of each athlete prior to the testing date. The chosen protocol will depend on, but not limited to body size, age, fitness status, experience, previous test results, and the primary purpose of conducting the test. Furthermore, it is important to understand how changing specific protocol variables can affect the blood lactate response to exercise testing. The consequences of changing key protocol variables will be summarized below. In special cases, each of the parameters must be adapted consistently. If any parameter is changed, it should be clearly documented for historical tracking purposes.

## Warm-Up

When performed, the warm-up intensity should not exceed the initial power output of the test to minimize lactate accumulation. It also provides an opportunity for the following:

- Familiarize athlete to starting power output
- Confirm that heart rate and cadence signals are being received
- Check appropriateness of bike fit
- Check heart rate and RPE for appropriateness of starting load

A higher intensity warm-up (i.e., priming exercise) may be desired by the sport or athlete; however, this runs the risk of having an elevated blood lactate value above baseline values prior to testing<sup>8,9</sup>. If a high intensity warm-up is performed, ensure the power output and duration are recorded as well as sufficient recovery time is given for blood lactate to approach near baseline concentrations.

## Stage Duration

One of the more crucial factors is the stage length, which is known to affect the blood lactate responses, power output at specific lactate markers, and peak power outputs at volitional exhaustion<sup>10,11</sup>. While the power output at the 'first' lactate threshold is less affected by stage duration, the power output at the 'second' lactate threshold is very sensitive to the stage duration. As a rule of thumb, the greater difference in stage duration (e.g., 3 versus 10 minute), the greater the discrepancy in power output at the second lactate threshold<sup>10-12</sup>. Interestingly, heart rate differs very little with different stage durations (3-10 minutes) resulting in minimal practical differences on prescribed HR training zones<sup>11</sup>. Considering the balance between testing efficiency, cost, and other constraints, stage durations between 3-to-5 minutes is recommended.

Practitioners may want to consider longer stages within that range if they suspect athletes have slower lactate kinetics (e.g., non-elite and/or 'fast-twitched' athletes), or if they just want to minimize the risk of overestimating the power output associated with metabolic thresholds. Otherwise, 3 minutes is sufficient to provide a snapshot of the physiological response across a wide range of intensities while minimizing test length.

## Increase in Power Output per Stage

Beyond determining the stage duration, it is also important to consider the increase in power output per stage. The size of power output is relevant, as too large of an increase in power output may reduce the ability to confidently provide power outputs at distinct blood lactate anchors (e.g., absolute concentrations or lactate threshold values) and too small of an increase may needlessly fatigue athletes and potentially underestimate peak wattage in a maximal test. If you are working with an athlete without previous data, it is best to be cautious and use the low-end of the recommended values (i.e., 20W for female, 25W for male).

## Blood Sampling Site

It is well accepted that blood lactate values can differ between vascular compartments (i.e., arterial-capillary-venous blood), location of sampling (e.g., inactive vs active limbs), and/or fraction of blood (e.g., plasma vs whole blood)<sup>13,14</sup>. Typically, in a high-performance setting, it is more common to measure capillary blood from the earlobe or the finger. The capillary bed that is sampled will be influenced depending on the sport and/or exercise modality, however, the location site is relevant as blood lactate levels are typically higher in the finger versus the ear<sup>15</sup>. There are pros and cons associated with each collection site, but because it is easier to collect blood from the fingertip on cycle ergometers and, as such, less likely to result in errors, we recommend this location be used when possible.

Collection Site	Pros	Cons
<b>Earlobe</b>	<ul style="list-style-type: none"> <li>• Less painful</li> <li>• Often a more appropriate site for certain para-athletes (e.g., arm amputees)</li> <li>• Does not interfere with athlete's grip on handlebars</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult to collect blood from</li> <li>• Earrings can interfere with collection</li> <li>• Upper-body movement can heighten the chance of test strip or capillary tube contacting athlete's skin</li> </ul>
<b>Fingertip</b>	<ul style="list-style-type: none"> <li>• Easier to collect blood drop from. Minimal movement of finger, even at peak exercise</li> </ul>	<ul style="list-style-type: none"> <li>• More painful</li> <li>• Athlete's hand may need to be moved from their preferred position on handlebars during blood collection</li> </ul>

## Cadence

It is known that altering the cadence across a wide range of power outputs can alter the physiological response to an incremental exercise test due in part to differences in the energetic cost required to move the exercising limbs<sup>16</sup>. The blood lactate response may also be affected in a non-linear function of cadence<sup>16,17</sup>.

If an athlete does not compete or regularly train with the exercise modality chosen, it is recommended they maintain a consistent between 80-100 RPM throughout the exercise test. Athletes whose sport uses the exercise modality or is frequently training with said exercise, practitioners may permit a self-selected cadence. It is important to note individual's self-selected cadence can vary widely during submaximal stages (e.g., approximately 60-100 revolutions per minute<sup>18</sup>). Whether using a fixed cadence or self-selected cadence, recording the cadence of each test stage is recommended.

## Test Termination

Completing steps to volitional fatigue can provide additional insight into physiological response to increasing exercise intensity, however, there are instances when practitioners may opt to terminate the test at a submaximal level, usually once the athlete's data clearly suggests they have surpassed a sustainable intensity. For most practitioners, this occurs when the athlete's blood lactate concentration

exceeds 6 mM, but the athlete's RPE and heart rate is often used to help refine this determination. Notably, if the test is terminated at a submaximal criterion, certain models to calculate lactate thresholds are not possible.

Test Type	Termination Criteria	Pros	Cons
<b>Submaximal</b>	<ul style="list-style-type: none"> <li>• Blood lactate exceeding 6 mM</li> <li>• RPE of 5-9 (CR10) or 15-18 (Borg 6-20)</li> </ul>	<ul style="list-style-type: none"> <li>• Less time consuming</li> <li>• Less fatiguing</li> <li>• Reduced impact on training and other performance tests</li> </ul>	<ul style="list-style-type: none"> <li>• Unable to calculate thresholds that require maximal data</li> <li>• Peak power output unknown</li> <li>• Greater possibility of misinterpreting cause of rightward shift in blood lactate curves</li> </ul>
<b>Maximal</b>	<ul style="list-style-type: none"> <li>• Voluntarily stops exercising</li> <li>• Inability to keep cadence above 70 RPM</li> <li>• RPE of 9-10 (CR10) or 19-20 (Borg 6-20)</li> </ul>	<ul style="list-style-type: none"> <li>• Allows for calculation of greater number of threshold variants (e.g., modified Dmax)</li> <li>• Provides insight into athlete's peak performance</li> </ul>	<ul style="list-style-type: none"> <li>• More fatiguing</li> <li>• Greater impact on training and other performance tests</li> </ul>

### Capillary Blood Sampling Execution

This section outlines the procedural steps for obtaining a capillary blood sample from the finger or ear lobe using a retractable lancet. It includes necessary safety precautions to minimize risks for both the practitioner and the individual receiving the puncture. In most cases, individuals will be performing this procedure in conjunction with exercise to monitor physiological responses.

#### *Materials Required*

- Alcohol wipes (70% isopropyl alcohol)
- Single use sterile retractable lancet
- Clean gauze pads
- Single-use nitrile or vinyl gloves
- Eye protection
- Blood collection device (e.g., capillary tube, microcuvette, or test strip)
- Adhesive bandage
- Sharps container
- Waste basket
- Biohazard bag (if local regulations mandate its use for non-sharp materials soiled with small amounts of blood)
- Hand sanitizer or soap and water
- Duplicate sets of materials if more than one athlete is being tested simultaneously

### *Safety Precautions*

- Ensure hands are sanitized before and after the procedure
- Wear disposable gloves throughout the procedure
- Eye protection is recommended as re-opening a puncture site may cause blood to spray
- Dispose of used lancet immediately into a sharps container
- Avoid direct contact with blood and properly dispose of single-use materials immediately after their use (check your local regulations – materials contaminated with small amounts of blood may or may not require biohazard disposal)
- Use a new, sterile lancet for everyone to prevent cross-contamination
- Ensure a stable and clean working environment
- If two individuals are having blood samples taken simultaneously, ensure that each has a separate set of equipment, and that no materials or equipment are shared between them
- If gloves touch non-clean items (e.g., surfaces that were not disinfected or personal belongings), they should be cleaned with hand sanitizer if not visibly soiled, or discarded and replaced with new gloves before proceeding with additional collections

### *Procedural Steps*

- Explain the procedure to the individual and obtain verbal consent
- Clean hands and don personal protective equipment (disposable, nitrile or vinyl gloves and eye protection)
- Ensure all materials are within reach and that separate sets are available if two individuals are being tested simultaneously
- Select an appropriate puncture site
  - **Finger puncture:** central fleshy portion of the middle or ring finger, slightly off-centre, and perpendicular to the grooves in the fingerprint if a bladed lancet is used
  - **Ear lobe puncture:** Use the lower part of the ear lobe, avoiding cartilage
- Clean the selected site with an alcohol wipe and allow it to air dry
- Wipe the site with clean gauze
- Position the individual's hand below heart level or, if using the ear lobe, ensure the head is held steady
- Remove the sterility cap from the single-use retractable lancet and select an appropriate depth setting (a deeper setting is often preferred if repeated samples from the same puncture is desired, or if the athlete has calloused fingers)
- Place the lancet firmly against the selected site, pointed away from one's face, and activate the device to create a small puncture
- Gently apply a pulse of pressure around the puncture site (without squeezing directly) to encourage blood flow. If blood does not easily begin to pool upon a light squeeze, repeat the above steps on a different location on the same finger, another finger, or earlobe position
- Wipe away the first drop of blood with clean gauze to remove potential contaminants like sweat

- Collect the required amount of blood using the appropriate collection device while avoiding touching the skin
- Apply clean gauze to the puncture site and ask the individual to apply light pressure
- For subsequent blood samples, repeat the steps above, starting at cleaning the site with alcohol – a new puncture may or may not be needed
- When no further blood samples are needed, apply adhesive bandage(s) to puncture site(s)
- Dispose of all single-use materials appropriately, if not already done so directly after use
- Disinfect work surfaces and reusable items following manufacturer’s instructions for contact time – if items were visibly soiled, be sure to clean them prior to disinfection
- Remove gloves and discard them properly
- Clean hands thoroughly with soap and water or, if not visibly soiled, hand sanitizer
- Record any necessary information related to the blood sample collection if adverse responses are suspected

*Potential Hazards and Risk Mitigation*

<b>Hazard</b>	<b>Risk</b>	<b>Mitigation Strategy</b>
<b>Needle stick injury</b>	Blood borne infections	Use retractable lancets and dispose of immediately in a sharp container.
<b>Infection</b>	Contaminated site	Clean blood sampling site prior to puncture Use sterile, single-use lancets Clean/disinfect work surfaces and reusable items Cover puncture site with bandage
<b>Extreme pain or discomfort during the procedure</b>	Improper puncture location and excessive squeezing	Puncture fleshy part of middle/ring fingertip and ear lobe. If possible, avoid puncturing dominant hand. Apply light pressure.
<b>Pain or discomfort after the procedure</b>	Bruising from puncturing the same area or squeezing the finger or earlobe too hard	Avoid puncturing the same area multiple times. Warm the hand or earlobe with cream, heat pad, or submerge in warm water prior to testing.
<b>Syncopal symptoms such as feeling faint, dizziness, nausea, pale skin</b>	Could lead to fainting that can result in injury or vomiting	Have the individual laydown, feet up if possible. Provide juice or an alternative supplement with sugar. Monitor individual until symptoms subside.
<b>Cross-contamination</b>	Shared materials between individuals or touching material not related to acquisition of blood sampling	Use separate sets of equipment for each person and prevent contact between materials. Change gloves and clean area if necessary.

## Athlete Preparations

Below are additional considerations to prepare the athletes to perform the test. These are best case scenarios; however, it is possible some factors cannot be controlled, which emphasizes the importance of documentation within the data recording sheet.

### *Nutrition considerations*

Data interpretation from the incremental exercise test can be impacted by nutrition in several ways. Three main considerations include carbohydrate availability, hydration status, and ergogenic supplements.

Blood lactate concentration is sensitive to carbohydrate availability. Diets low in carbohydrate intake may reduce the blood concentration at rest<sup>19</sup> and for a given power output<sup>20,21</sup>. As a result, this can give an interpretation of a rightward shift in the blood lactate curve relative to a well-fueled state. Mitigation strategies include consistent fueling/carbohydrate intake surrounding testing sessions. Sport demands may require different recommended intakes, consider consulting with a sport dietitian.<sup>22</sup>

A loss in body water, known as being hypohydrated, can, but not always include a decrease in blood volume<sup>23</sup>. Consequences of being hypohydrated can include an increased blood lactate concentrations or heart rate at a given power output and impaired exercise performance. If an athlete is suspected to be hypohydrated on the day of testing, consider advising the athlete to consume water (5-10mL/kg body mass) approximately 2-4 hours prior to the test<sup>24</sup>.

Lastly, supplements recognized by the IOC as ergogenic<sup>25</sup> such as caffeine, creatine, nitrates and buffering agents (e.g., beta-alanine, sodium bicarbonate) may also impact blood lactate concentration or exercise performance, ultimately affecting the interpretation of test results. As such, recording supplement intake on the day of testing is advised.

### *Test Description for Athletes*

Today, you'll be completing an incremental exercise test, which is designed to measure how your body responds to increasing levels of effort. The test will start at a low intensity, and every few minutes, the difficulty will gradually increase. During the test, we will be measuring your blood lactate levels by taking small blood samples from your fingertip (or earlobe). This helps us understand how your body is producing and clearing lactate, a substance that builds up when you exercise harder. We will also be recording your heart rate and your rating of perceived exertion (RPE) or how hard you perceive the exercise.

This test is important because it can give us insights into your fitness level, endurance capacity, and how your body handles intense exercise. The results can help guide training programs, improve performance, and even monitor progress over time. The test will continue until 6mM blood lactate or to

a point where you can no longer maintain the effort. It's important to try your best, but you can stop at any time if needed.

### *Scale to Quantify Rating of Perceived Exertion (RPE)*

Different methods exist to quantify how someone perceives the intensity of exercise. Two popular scales include the Borg category-ratio 10 (Borg CR-10) and the Borg 6-20 rating of perceived exertion (Borg 6-20 RPE). Below are instructions that are from the creator of the scales.

Regardless of scale used, ensure it is a validated tool with consistent wording. If you are working with visually impaired individuals, verbalize three anchors during each stage (e.g., Very light – Light – Moderate) and have the athlete chose which anchor best matches their perceived exertion. For the subsequent stage, start one anchor below the chosen one and repeat the sequence again.

### Instructions for using the Borg CR-10 Scale

**Instruction.** Use this rating scale to report how strong your perception is. It can be exertion, pain or something else. First look at the words on the scale, and then the numbers. Of these ten (10) or "Extremely strong", "Maximal" is a very important intensity level. This is the most intense perception or feeling you have ever had.

If your experience or feeling is "Very weak", you should select "1", if it is "Moderate", select "3". Note that "Moderate" is "3" and thus weaker than "Medium", "Mean" or "Middle". If the experience is "Strong" or "Heavy" (it feels "Difficult") select "5". Note that "Strong" is about half of "Maximal". If your feeling is "Very strong", select a number from 6 to 8. If your perception or feeling is stronger than "10", - "Extremely strong", "Maximal" – you can use a larger number, e.g. 12 or still higher (that's why "Absolute maximum" is marked with a dot "•").

It's very important that you report what you actually experience or feel, not what you think you should report. Be as spontaneous and honest as possible and try to avoid under- or overestimating. Look at the words and then select a number.

**When rating exertion** give a number that corresponds to how hard and strenuous you perceive the work to be. The perception of exertion is mainly felt as strain and fatigue in your muscles and as breathlessness or any aches.

- 0 "Nothing at all", means that you don't feel any exertion whatsoever, no muscle fatigue, no breathlessness or difficulties breathing.
- 1 "Very weak" means a very light exertion. As taking a shorter walk at your own pace.
- 3 "Moderate" is somewhat but not especially hard. It feels good and not difficult to go on.
- 5 "Strong". The work is hard and tiring, but continuing isn't terribly difficult. The effort and exertion is about half as intense as "Maximal".
- 7 "Very strong" is really very strenuous. You can still go on, but you really have to push yourself and you are very tired.
- 10 "Extremely strong – Maximal" is an extremely strenuous level. For most people this is the most strenuous exertion they have ever experienced previously in their lives.
- Is "Absolute maximum" for example "12" or even somewhat more.

Any questions?

Borg CR10 scale®  
© G. Borg, 1998, 2007  
English

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"
11		
↖		
●	Absolute maximum	Highest possible

Borg CR10 Scale®  
© Gunnar Borg, 1982, 1998, 2004  
English

<b>Rien du tout</b>	<b>0</b>	<b>Nothing at all</b>
<b>légère</b> À peine perceptible	<b>0.5</b>	<b>Extremely weak</b> Just noticeable
<b>Très faible</b>	<b>1</b>	<b>Very weak</b>
<b>Faible</b> Légère	<b>2</b>	<b>Weak</b> Light
<b>Modérée</b>	<b>3</b>	<b>Moderate</b>
	<b>4</b>	
<b>Forte</b> Lourde	<b>5</b>	<b>Strong</b> Heavy
	<b>6</b>	
<b>Très forte</b>	<b>7</b>	<b>Very strong</b>
	<b>8</b>	
	<b>9</b>	
<b>Extrêmement forte</b> <<Maximale >>	<b>10</b>	<b>Extremely strong</b> "Maximal"
	<b>•</b>	

Modified to collate French and English, utilizing Borg 1982 numbering with Borg 2004 wording.  
Borg CR10 Scale (1982, 1998, 2004)

## Instructions for using the Borg 6-20 RPE Scale

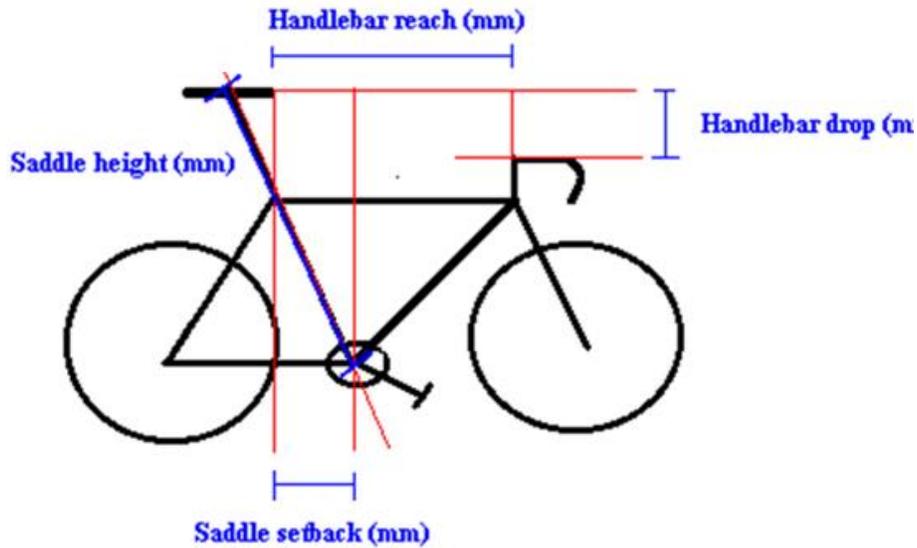
### Borg RPE Scale®

Use this scale to tell how strenuous and tiring the work feels to you. The exertion is mainly felt as fatigue in your muscles and as breathlessness or possibly aches. When the exercise is hard it also becomes difficult to talk. It is your own feeling of exertion that is important. Don't underestimate it, but don't overestimate it either. For common exercise, such as cycling, running or walking, 11-15 is a good level. For strength and high-intensity interval training (HIIT), 15-19 is good. If you are sick follow your doctor's advice. Look at the scale and the descriptions and then choose a number. Use whatever numbers you want, even numbers between the descriptions.

<b>6</b>	<b>No exertion at all</b>	No muscle fatigue, breathlessness or difficulty in breathing.
<b>7</b>	<b>Extremely light</b>	Very, very light.
<b>8</b>		
<b>9</b>	<b>Very light</b>	Like walking slowly for a short while. Very easy to talk.
<b>10</b>		
<b>11</b>	<b>Light</b>	Like a light exercise at your own pace.
<b>12</b>	<b>Moderate</b>	
<b>13</b>	<b>Somewhat hard</b>	Fairly strenuous and breathless. Not so easy to talk.
<b>14</b>		
<b>15</b>	<b>Hard</b>	Heavy and strenuous. An upper limit for fitness training, as when running or walking fast.
<b>16</b>		
<b>17</b>	<b>Very hard</b>	Very strenuous. You are very tired and breathless. Very difficult to talk.
<b>18</b>		
<b>19</b>	<b>Extremely hard</b>	The most strenuous effort you have ever experienced.
<b>20</b>	<b>Maximal exertion</b>	Maximal heaviness.

Borg RPE Scale®  
Ratings (R) of Perceived (P) Exertion (E).  
© Gunnar Borg, 1970, 1998, 2017  
English

## Bike Fitting Diagram



Saddle height is typically measured from the middle of the bottom bracket to the top of the saddle where the saddle has a width of 80mm.

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