



*Cycling***CANADA***Cyclisme*

Physiological Assessment Guide

Coaches' Reference

DRAFT on 29 May, 2014



TABLE OF CONTENTS

Introduction	3
Mean Maximal Power Curves: The Foundation	3
What assessments do we recommend for Talent Identification?	5
A general comment about anthropometric measures	5
What assessments do we recommend for development level endurance riders?.....	6
What assessments do we recommend for development level sprint and BMX riders?	7
What assessments do we recommend for elite level endurance riders?	9
What assessments do we recommend for elite level sprint and BMX riders?	10
Special Case: What long-term questions are we considering, to better support coaching practice?	12
What should a rider expect when they go into a lab for testing?.....	13
Key Contacts and Resources	13
References	14



Introduction

Cycling Canada has developed a number of physiological assessment protocols that riders and coaches can access across the country, either in the field, with a coach, or in designated lab locations. The purpose of this is to make sure the assessment service protocols are consistent. This way you can do an assessment at any of the locations and get comparable data, and that we can help put the data in perspective through comparison with results from other riders we have tested.

We appreciate that there are numerous assessments that can be done on cyclists, and also realize that **NONE** of them provide a “Single Best Answer”. Each protocol has its benefits and limitations and there is no one protocol that can give us all of the answers. We have selected assessment protocols that give us a wide range of information that is applicable to training, and that can be used to monitor changes in fitness. Furthermore, we have selected assessment protocols that have lots of normative data (for comparisons) and that are scientifically validated to being correlated to key performance outcomes (or why do the test?). We have also aimed for a progression in the assessments, with protocols that can be done easily in the field or short lab visits at first, building up to specific protocols that depend on lab-based equipment and technicians for those riders aiming at the upcoming Olympics or Paralympics.

The complete protocols are written up in a separate document, which provides full instructions to coaches, physiologists, and lab technicians on how to run the tests. The purpose of this “Coaches’ Reference” document is to put those protocols into context.

Mean Maximal Power Curves: The Foundation

Accessibility of power meter data has never been better. There are a variety of affordable devices out there that can now provide coaches and athletes with accurate and reliable data for almost any cycling discipline. This access to power data means that cyclists are in a unique position among all other athletes in general; they can get near lab-quality data from everyday training sessions.

The aggregate of an athlete’s **highest average power outputs from 1 second to well over 4 hours** is called the **mean maximal power (MMP) curve**. Using the mean maximal power curve to describe an athlete allows us to:

- Have a broader physiological continuum from peak power to anaerobic to aerobic domain for each athlete, rather than focusing on a handful of data points in one “zone”
- Interpolate *between* points, so we don’t need all tests to be the exact same over time in order to generate comparable data
- Test for changes in fitness far more frequently than could be done with conventional tests, because training and *racing* becomes testing as this data is fitted to the curve

First, this type of testing also allows the coach/athlete to suggest events that may suit each rider best; the shape of the mean maximal power curve helps us determine how to make the most of their physiological strengths. Second, this data (the individual curve) can also identify an athlete’s physiological weaknesses, which may also need to be addressed (“if” the weakness is, indeed, a performance gap for success in their event). This data will become the “common language” that will enable comparison of athletes from the earliest days of their cycling careers, to athletes who have reached the Olympic podium. It will enable more consistent and more frequent



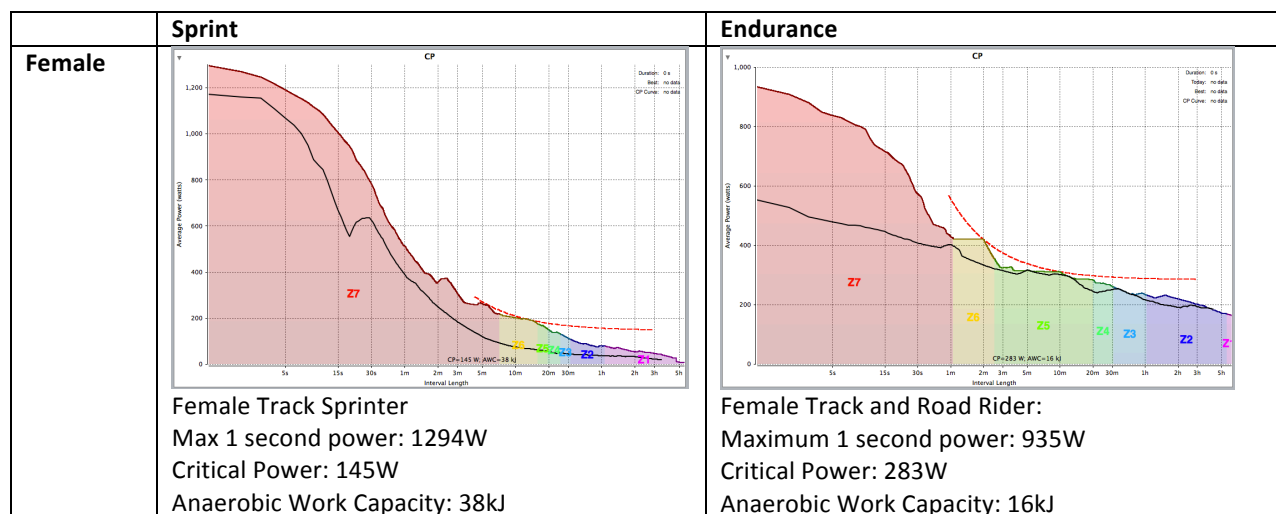
Athlete Testing and Monitoring Guide: Coaches' Reference

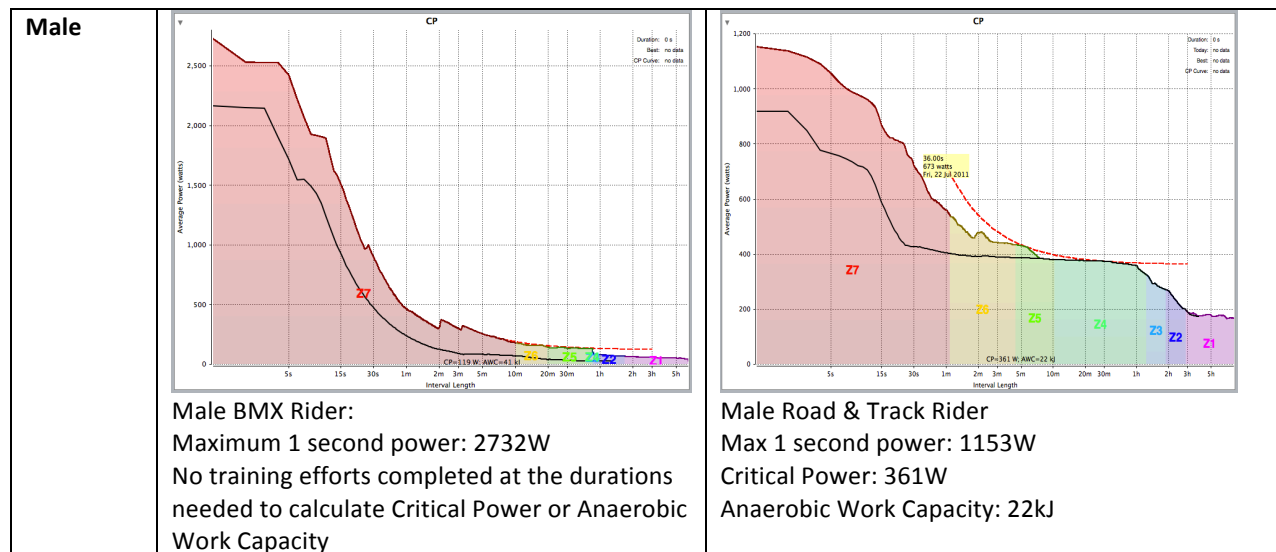
longitudinal tracking of fitness, to help us understand the variety of pathways that ultimately lead to elite performance. As a consequence, it is the foundation of Cycling Canada's current test protocols. For the interested coach, please see the attached applied coaching specific review on this concept by Vanhatalo et al. (IJSP 2011)ⁱ.

For coaches who are used to working with Functional Threshold Power (FTP), this approach will be very convenient. FTP is defined as a quasi-steady state power that can be held for approximately 60 minutesⁱⁱ. Rather than have athletes do a 60 minute maximal effort, most coaches simply use 95% of the average power from a 20 minute test as a simple, but robust estimation of an athlete's 60 minute MMP (i.e. FTP). In reality, 95% of 20 minute MMP is the *average* relationship between those two values. As with any average, there will always be some variation around the mean for any given individual. With these new protocols, the raw data from the 20' tests can be included in the broader MMP curve, which simply allows for a more individualized extrapolation to find FTP. The 95% approach can still be used in the absence of other good data, but as coaches build up profiles over time for each athlete, better individualization of training zones should lead to improved training prescription and ultimately, better athlete development.

There are a variety of tools available for looking at power data (e.g. GoldenCheetah, WKO+, TrainingPeaks online, Strava, etc.) and they all provide some sort of MMP curve. GoldenCheetah and the new WKO+ (when released) both automatically do some modeling of the MMP data. Regardless of the software that a coach prefers to use, it is important that files are easy to share among coaches and athletes. If the files are easily shared, then each person can use the software of their choice. Cloud storage solutions such as DropBox can be helpful for this, and can ensure that an athlete's complete training history travels with them throughout their career.

Examples of different mean maximal power (MMP) curves are shown below, to show the difference between the shape as well as some of the key variables for different types of male and female cyclists. These curves change shape for each rider as they train and compete.





What assessments do we recommend for Talent Identification?

Understanding the *biological* age of an athlete is fundamental to the evaluation of any test results. Certain anthropometric measures help us to evaluate the level of physical maturity of an athlete, with the primary one being peak height velocity (PHV) ⁱⁱⁱ. Where possible, a historical annual or quarterly record of height for each individual should be provided for athletes under 20 years of age. In addition to height, body mass should be recorded in order to contextualize the power outputs from the on-bike testing, and to get power to weight ratios.

The bike tests that are included in the national Talent ID program include the 6-second sprint test (6S), and the 4-minute time trial effort that forms part of the AIS Power Profile test. The purpose of the 6S test is to get an indication of peak muscle power. The 4MT is designed to estimate an athlete's endurance capacity. These two tests give considerable insight about an athlete's power-duration curve across a range of durations that are relevant to cycling events, in a time effective manner. These tests are recommended for talent identification of all cyclists, including sprint and endurance athletes.

Summary of tests recommended:

- Standing height (cm)
- Body mass (kg)
- Quadriceps girth (cm)
- 6-second sprint test to obtain peak 1-second power (Watts)
- 4-minute time trial test (for peak 4-minute power, in Watts)

A general comment about anthropometric measures



“... asking an individual (sport participant) to engage in a process that could lead to poor physical and psychological health for the sake of possibly enhancing sport performance is more a question of ethics than (sport) science.” – From *Eating Disorders in Sport*, p 65^{iv}.

Depending on the cycling event, body mass can have important implications for performance. However, it is our responsibility to ensure that an athlete's focus is not unduly centred on body mass, at the expense of their mental health and physical performance. It is critical that anthropometric testing and discussions around body composition are taken very seriously, considering the increased incidence of disordered eating among athletes in general, but particularly with females^{vi}.

Therefore, the primary goal of gathering anthropometric measures is to obtain an accurate weight for any 'relative power' calculations (i.e. power to weight), and to track body composition over time, so that associations can be made between body mass and composition with performance. If an athlete is in the process of working on changing his or her body composition, the measures suggested here are designed to help make sure that any weight lost comes from fat, not from muscle (unless muscle loss is the goal). The focus is on **performance**, and muscle is the key variable we look at here. The skinfold measures contribute to the muscle mass calculation, and can be used over time to track changes in fat mass as well, without the amount of error that exists within percent body fat measures.

ISAK standards should be used for all anthropometric tests, and only certified ISAK practitioners should conduct the testing. Intra-tester technical error of measurement should be reported for all measures.

What assessments do we recommend for development level endurance riders?

“Development” level riders includes anyone who is taking riding seriously, working with a coach, and aiming to get onto the Elite National Team to perform at the Olympic or Paralympic Games. They may or may not currently be part of the identified National Development Team pool of athletes.

At this stage, we encourage coaches to gather data as often as possible from the field, according to the list below; these data points form the mean maximal power curve. Using this single reference point throughout an athlete's cycling career provides significant insight into the rate of progression that athletes follow. Power meters provide the best information for physiology, and are becoming more and more affordable. Lab testing, if available, can be helpful every 6-12 months, particularly for reliable measures of anthropometry and for the Australian Institute of Sport (AIS) Power Profile Test, which is a series of maximal efforts at progressively longer durations, from one second through to 30 minutes. This lab-based test has been shown to be ecologically valid when compared to data obtained in racing^v. Use of only power output (and the time for which it can be sustained) maximizes testing accessibility, which is advantageous because it supports testing of athletes in a variety of locations and situations. Anyone conducting the testing should be able to prove the accuracy of their power meter or bike ergometer when submitting test results to the national program.

Anthropometric measures for this group are meant to be relatively basic; the primary goal being to obtain an accurate weight for any 'relative power' calculations (i.e. power to weight ratio), and to get a snapshot of an athlete's current body composition. Coaches should keep the aforementioned comments about anthropometry firmly in mind if planning these tests. Where appropriate, seated and standing height should be measured with young development athletes to ensure that training is appropriate for that athlete's level of physical maturation.



Baseline concussion testing using the SCAT3 should be done on all riders in this category, so that any potential concussions can be either diagnosed or ruled out as quickly as possible. It is worth asking riders if they ever feel limited by their breathing when they train or race – if they do, ask them to follow up with their doctor by asking to be tested for exercise-induced asthma or bronchoconstriction.

Finally, it may be advisable to begin more detailed athlete monitoring at this stage, depending on the competitive level of the rider and resource availability. Athletes at this level should engage in regular, thorough logging of their training as the first stage of this process. If an athlete is sufficiently advanced that a personal power meter is justified, this is the next most important part of an athlete monitoring program. When these building blocks are in place, adding measures such as hydration monitoring or basic morning heart rate testing can be employed. Hydration monitoring, although it requires specialized hardware and personnel, could be included for the purpose of athlete education rather than being a regular part of training.

Summary of core tests recommended:

- Standing height (cm)
- Body mass (kg)
- Quadriceps girth (cm)
- Mean maximal powers (either from field data or from the AIS Power Profile Test):
 - 1"
 - 30"
 - 4'
 - 10'
 - 20' (from FTP testing, if done) or 30'
- Baseline SCAT3 Concussion test (done in the off-season if possible)

Summary of optional tests:

- Bi-acromial distance (cm) (for Frontal Surface Area calculation)
- Thigh volume (cm³)
- Fat Free Mass (kg)
- Coefficient of aerodynamic drag (CdA)
- Draft ratio (for team pursuit, team sprint, and/or team time trial – this is a team specific measure)
- Maximum Lactate Steady State (if you have access to reliable lactate testing and can do 2 days of testing in a row)
- Pulmonary function "Flow-Volume Loop" (especially if they report trouble breathing during hard efforts)
- Daily Monitoring
 - Training Logs
 - Power Meter Data
 - Morning Resting Heart Rate
- Hydration testing (USG)

What assessments do we recommend for development level sprint and BMX riders?



At the development level, maximal 1-second and 5-second powers, are key on-bike measures for BMX, with the addition of maximal 30 second and maximal 1 minute powers added for track sprinters. There are now affordable power meters that work on Track and BMX bikes, so this data is easier to get than it used to be. With track sprint and BMX events often being decided by multiple sprint efforts rather than a single one, it is important to get a picture of an athlete's resistance to fatigue over several sprints. The Australian Institute of Sport's Repeated Sprint Ability test is extremely useful for evaluating this, although it is best to do this test using some type of ergometer, rather than in the field. This test is 6 x 3 second efforts (3 seconds on, 27 seconds rest), looking at how an athlete fatigues during repeated sprint efforts.

Much of the work of moving from the development level to the elite level is done in the gym. Peak rate of force development (RFD), and peak concentric force, measured on a force platform is an excellent way to track changes in force production off of the bike. This obviously requires specialized equipment, so it may not be available to athletes that do not train at a national centre or Canadian Sport Institute. This testing can still be done with specialized, lower-cost devices that use accelerometers or position transducers to calculate force (e.g. Myotest; Tendo) in cases where force plates are not available in the training environment.

Body composition can change dramatically in sprint-type riders as they mature and train seriously in the gym. Standing height, body weight, thigh volume, and fat free mass are good indicators of what types of changes are taking place, and how they tie in with performance on the track and in the gym.

Baseline concussion testing using the SCAT3 should be done on all riders in this category, so that any potential concussions can be either diagnosed or ruled out as quickly as possible. It is worth asking riders if they ever feel limited by their breathing when they train or race – if they do, ask them to follow up with their doctor by asking to be tested for exercise-induced asthma or bronchoconstriction. It does affect sprint riders, even though their events are short.

Summary of core tests recommended:

- Standing height (cm)
- Body mass (kg)
- Quadriceps girth (cm)
- Mean maximal powers (either from field data or from the AIS Power Profile Test):
 - 1"
 - 5"
 - 30"
 - 1' (for Track Sprint)
- Repeated Sprint Ability (AIS 6x3" sprint test)
- Rate of Force Development (using force plate, accelerometry)
- Maximal Concentric Force (using force plate, accelerometry)
- Baseline SCAT3 Concussion test (done in the off-season if possible)

Summary of optional tests:

- Thigh volume (cm³)
- Fat Free Mass (kg)



- Pulmonary function “Flow-Volume Loop”
- Hydration testing (USG)
- Daily Monitoring
 - Training Logs
 - Power Meter Data
 - Morning Resting Heart Rate

What assessments do we recommend for elite level endurance riders?

The tests recommended for elite endurance riders are the same as the core and optional tests recommended for development endurance riders – with additional variables measured. All tests for athletes at this level are designed to help understand the physiology, biomechanics and other variables that underpin the Mean Maximal Power curve and ultimately, performance. For instance, respiratory gas analysis can be added to the 4-minute test within the AIS Power Profile test, to look at maximal oxygen uptake (VO_{2max}). An additional submaximal protocol (e.g. a short time after completing the power profile testing) can be used to assess cycling efficiency and VO_2 kinetics. Cardiac output testing can also be used to look specifically at changes in cardiac function with training. In keeping with the theme of understanding the physiological components of an individual's oxygen delivery system, hemoglobin (Hb) mass testing is also recommended annually, but potentially more frequently when altitude training is a part of an athlete's yearly training plan.

Team physicians have categorically rejected the notion that blood screening is effective or advisable, as recent research does not support the use of blood tests^{vi} or ECG^{vii} in a screening context for athletes. Therefore, it must be understood that the intention is not to use blood testing to screen otherwise asymptomatic athletes out of training or competition. In that context, athletes in this group could still have a routine blood test done every 6-12 months for the purpose of establishing individual baseline values for key parameters *under the guidance of the team physician*. Rather than relying on normative data when interpreting test results, the objective is to establish these baseline ranges under various states of training stress to enable better interpretation of results in the event of illness or unexplained underperformance. The recommended blood monitoring tests include a Complete Blood Count (CBC), as well as serum ferritin and soluble transferrin receptor to establish iron status. Vitamin D deficiency has been linked with impaired performance and health^{viii}, and is prevalent in people living in the northern hemisphere. Subject to budgetary constraints, it is advisable to get a baseline Vitamin D screen at the point in the year where Vitamin D stores are lowest, in order to inform supplementation recommendations.

Other non-hematological tests that can be done as part of an annual baseline medical examination include lung function evaluation and a sleep questionnaire, and additional evaluation should be done when athlete expresses specific concerns in these areas. As with any of the health-related evaluations listed here, the team physician will provide follow-up.

A torque profile test can be done to analyze the pedal stroke for any egregious biomechanical issues and to correlate with longitudinal changes in cycling efficiency. Bike position should be optimized at this level for both aerodynamics and power output, through the National Team. In addition to the training monitoring protocols outlined for development level riders, two additional items are included for this group. Psychological response to training can be monitored with a questionnaire such as the Hooper-MacKinnon or the Daily Analysis of Life



Demands of Athletes (DALDA). Resting heart rate variability (HRV) can also be a useful measure for understanding the response to training when used in conjunction with training logs and power meter data.

Summary of core tests recommended:

- Standing height (cm)
- Body mass (kg)
- Quadriceps girth (cm)
- Coefficient of aerodynamic drag (CdA)
- Mean maximal powers (either from field data or from the AIS Power Profile Test):
 - 1"
 - 30"
 - 4'
 - 10'
 - 20' (from FTP testing, if done) or 30'
- Maximum Lactate Steady State
- Baseline SCAT3 Concussion test (done in the off-season if possible)
- ASSQ Sleep Questionnaire
- Daily Monitoring
 - Training Logs
 - Power Meter Data
 - Questionnaire data (Hooper & MacKinnon / DALDA)
 - Heart Rate Variability

Summary of optional tests:

- Bi-acromial distance (cm) (for Frontal Surface Area calculation)
- Thigh volume (cm³)
- Fat Free Mass (kg)
- Draft ratio (for team pursuit, team sprint, and/or team time trial)
- Pulmonary function "Flow-Volume Loop"
- VO_{2max}
- VO₂ kinetics
- Cycling efficiency
- Cardiac output
- Torque profile – pedal stroke analysis
- Medically supervised blood monitoring, including:
 - CBC
 - Ferritin and Soluble Transferrin Receptor
- Hb mass (Hemoglobin mass protocol/technique to measure red blood cells: annual baseline, and more frequently if engaging in altitude/hypoxic training)
- HEC (hypoxic response – only for athletes engaging in altitude/hypoxic training)
- Hydration testing (USG)

What assessments do we recommend for elite level sprint and BMX riders?



Again, the tests for elite riders build upon those done for development level sprint athletes, to ensure that we build a full history of a rider's progression throughout their career with comparable data. In addition, elite sprint athletes should use the same recommendations for medical monitoring as those outlined for elite endurance athletes. Where indicated, baseline and post-exercise lung function should be tested to make sure that there are no undetected issues with breathing. A sleep questionnaire should be performed annually, and whenever a rider reports a problem with sleep, to be followed up by one of the National Team Doctors.

At the elite level, a deeper understanding of the individual responses to different training phases in preparation for competition is important. We can add SRM ergometer-based assessments to track the transfer of strength and power in the gym onto the bike and then into power at high cadence, using two tests that hold a rider steady at a designated cadence. These are not included in the list of development level tests simply because of the limited availability of SRM ergometers across Canada – if there is one available, these tests are worth doing. To further understand the transfer of strength and power from the gym to the bike, it is advisable to compare peak torque and rate of torque development while pedaling with the gym-based equivalent tests mentioned earlier. The torque profile of the entire pedal stroke can be evaluated simultaneously, which can highlight biomechanical deficiencies. Performance can also be optimized by understanding the relationship between peak power and pedaling rate (cadence) for an individual, through making more informed decisions about gear selection in training and racing.

Bike position and/or clothing should be optimized at this level for both aerodynamics and power output, through the National Team. Psychological response to training can be monitored with a questionnaire such as the Hooper-MacKinnon or the Daily Analysis of Life Demands of Athletes (DALDA).

Summary of core tests recommended:

- Standing height (cm)
- Body mass (kg)
- Quadriceps girth (cm)
- Mean maximal powers (either from field data or from the AIS Power Profile Test):
 - 1"
 - 5"
 - 30"
 - 1' (for Track Sprint)
- Isokinetic Maximal Power tests (High and Low Cadence)
- Power-Pedaling Rate Relationship
- Repeated Sprint Ability (AIS 6x3" sprint test)
- Peak Rate of Force Development (from force plate)
- Maximal Concentric Force (from force plate)
- Baseline SCAT3 Concussion test (done in the off-season if possible)
- Coefficient of aerodynamic drag (CdA) (particularly for Track Sprinters)
- Daily Monitoring
 - Training Logs
 - Power Meter Data
 - Questionnaire data (Hooper & MacKinnon / DALDA)
 - Heart Rate Variability

Summary of optional tests:



- ISAK Level 1 body composition profile
- Thigh volume (cm³)
- Fat Free Mass (kg)
- Pulmonary function “Flow-Volume Loop”
- VO_{2max} (from 4' test)
- Torque profile – pedal stroke analysis
- Draft ratio (for Team Sprint riders)
- Hydration testing (USG)
- Medically supervised blood monitoring, including:
 - CBC
 - Ferritin and Soluble Transferrin Receptor
- For altitude exposure only:
 - HEC (hypoxic response)
 - Hb mass

Special Case: What long-term questions are we considering, to better support coaching practice?

There are some tests listed as 'optional' for the various athlete groups that may be of limited use for a single athlete in the short term. The rationale for their inclusion is that, while there is strong scientific evidence that these variables are important for performance, it may still be unclear how large a role they play, or how trainable they are. Furthermore, we cannot rely on the assumption that the group mean response from a research study will apply to the individual athletes who are aiming for a very limited number of podium positions. By understanding the factors contributing to these variable responses, we can make better training decisions in the future.

One example is VO_{2max} for sprint cyclists. Although the power generated at VO_{2max} is much more correlated with performance outcomes, aerobic fitness clearly plays a role for sprint events, but it is unclear what the minimum level of aerobic fitness is for elite performance in these sprint events. Through annual or bi-annual monitoring of these types of variables, we are seeking to better understand these relationships for the benefit of all of our athletes. In this example, we can collect the evidence we need to objectively guide coaching decisions about how best to spend time, particularly for development athletes.

A second example is VO₂ kinetics for endurance athletes. Essentially, VO₂ kinetics is a measure of the responsiveness of the aerobic system to changes in workload. Since cycling by nature is almost never done at a steady pace, a highly responsive aerobic system is critical. The paper by Burnley and Jones (2007)^{ix} shows how important VO₂ kinetics are in performance, and while there is strong cross-sectional evidence to suggest that elite athletes have faster kinetics than recreational athletes, sufficient evidence does not yet exist to show the specific training interventions that can truly enhance this attribute. Tracking this variable over time, with the other information we will have at our disposal, will allow us to understand how this variable can better inform coaches' decisions about the training of their athletes.



What should a rider expect when they go into a lab for testing?

Going into a lab can be unnerving, even when a rider has done it often. They should expect to be greeted when they arrive, to get clear instructions about what they will be doing and where they should go, and to have any questions answered clearly. If they are unsure about what they are being told to do, ask for clarification. They should expect to be treated in a professional and respectful manner at all testing sessions.

During the assessment process, they can expect to have the other people in the lab respect the effort they're giving, and to give them as much quiet and space as they need to focus. We limit the number of people who are allowed to attend an assessment session for exactly this reason.

After the assessments are finished, they can expect to be given a written copy of your results before they leave the lab. It takes some time to crunch the data and put it into the report document, but within 15 to 30 minutes (by the time they've cooled down and gotten changed) they should be able to walk out with a copy of at least the basic information. **THIS IS THE RIDER'S DATA, AND WE TREAT IT AS CONFIDENTIAL.** Unless specified otherwise by the rider, the data will be given to them, to you (the coach), the relevant National Coach, and the Cycling Canada IST Manager who looks at it for quality control of the assessment service. It's up to the rider who else they share it with.

Key Contacts and Resources

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