

Protocol for Determination of VO₂max using Wattbike and Douglas Bag

By the end of this practical session and continued practice you should be able to:

- ✓ Determine Maximal Oxygen Uptake (VO₂max) and Maximal Heart Rate (HRMax) using a cycle ergometer test.

Equipment HR monitor, Douglas bag, stopwatch, mouthpiece & valve, nose-clip, breathing tube, Wattbike, Servomex gas analyser, dry gas meter and vacuum, Borg RPE scale.

Aim: The aim of this test is to collect the final 30-60s of expired air during a maximal incremental cycle ergometer test.

Background

Maximal oxygen consumption, or VO₂ max, is the maximum volume of oxygen that an individual can take up and utilise as measured during incremental exercise. VO₂ max is the gold standard assessment of aerobic fitness and this parameter is an important determinant of endurance performance. VO₂ max is expressed in an absolute value (L·min⁻¹) or relative to body weight (ml·kg·min⁻¹).

VO₂ max is determined during an incremental exercise test to volitional exhaustion, whereby expired air is collected and analysed. The test can be performed on several ergometers, such as the treadmill, cycle ergometer, and rowing ergometer. This protocol describes a VO₂ max test conducted on a cycle ergometer.

The precise details of the test will vary with regard to the participant's fitness, activity level and exercise background. A suitable test will be selected for the participant in order to meet the criteria required for an accurate VO₂ max test.

VO₂max determination criteria

To ensure the test result is accurate, the following criteria should be considered:

- The test should be designed to last between 8 – 15 minutes to ensure exhaustion is due to cardiovascular fatigue;
- A plateau in the oxygen uptake/intensity relationship should be observed;
- A respiratory exchange ratio (RER) of **1.15** or above on a cycle ergometer;
- A final heart rate within 10 bpm of the age-related heart rate maximum;
- A 19-20 reading on the rate of perceived exertion (RPE) on the Borg Scale or equivalent.

A VO₂ max test will also allow determination of other parameters such as maximum heart rate, maximum pulmonary ventilation volume (VE) and maximum rate of carbon dioxide production (VCO₂).

General protocol

The general format of a VO₂ max test is described below. At all times, the participant will be supervised by the practitioner.

- The participant will complete an appropriate low intensity warm up on the cycle ergometer for a minimum of 4 minutes. This intensity should be lower than that of the initial test workload. Allowing a short duration warm up on the cycle ergometer prior to the commencement of the test will allow the opportunity for any adjustments to be made to the set up position of the ergometer.
- The test begins at a low intensity power output and increases progressively throughout the test until the participant reaches volitional exhaustion.
- The increase in intensity will be achieved through adapting the power output on the cycle ergometer.
- The increments and duration of intensity will be determined by the practitioner on an individual basis and must take into account the participants age, gender, activity history, current activity levels (see section below on selecting starting cadence).
- The test will continue until the participant reaches volitional fatigue. On the cycle ergometer, this will be identified by the participant stopping cycling and/or signalling the practitioner. The practitioner may end the test if the participants cycling cadence drops 10 rpm or more below that of their self-selected cycling cadence.
- A sample of at least 30s of expired air must be collected at the final workload.
- When the test has finished, the mouthpiece is removed from the participant and the external resistive load will be removed from the cycle ergometer. This should be reduced to a resistive load equivalent to or lower than the warm up intensity. The participant will be instructed continue cycling at this intensity at a reduced cadence to cool down on the cycle ergometer for a minimum of 5 minutes. After this point, the participant may get off the cycle ergometer whenever they are recovered.

Protocol design

VO₂ Max decreases with age and physical inactivity, and also males tend to have a higher VO₂ Max than females. As a result, the initial workload and increments in intensity will vary as a result of age, gender and training status. The participant's current fitness and activity levels will be discussed to assist the practitioner in developing the testing protocol that it is appropriate for that individual and also ensures achievement of the VO₂ Max determination criteria.

Selecting the correct power output

- You must select a power profile that will result in the participant reaching volitional fatigue 8-15 minutes after the start of the test.
- Power is adjusted by instructing the participant to keep to a set cadence, and then increasing the air resistance on the side of the wattbike. Starting at a resistance level of 1 and increasing by 1 each minute.
- If the participant completes level 10 and has not yet fatigued, instruct them to increase cadence by 5rpm, and decrease resistance to level 8. Levels 9 and 10 can then be completed.
- If level 10 is completed again, repeat the above procedure.
- The key is to select a starting cadence that is appropriate to the fitness of the participant. Use the following as a guide:

Table 1 – Suggested starting Cadence (RPM) for various participants

	Male	Female
Untrained	70	65
Recreationally Active	75	70
Aerobically Trained	80	75
Highly Aerobically Trained	85	80

Douglas bag preparation

- Ensure you have at least three Douglas bags for your participant.
- Evacuate Douglas bags using the vacuum using the following procedure:
- Attach the bag to the vacuum, open the valve on the bag, turn on the vacuum and run until the number on the vacuum remains stable.
- Close the valve on the bag, turn off the vacuum.

Participant preparation

- Confirm that participant has completed a parQ and informed consent form, and has no health-related issues that contradict performing maximal exercise testing.
- Fit participant with HR monitor.
- Set up cycle ergometer for participant, ensuring that there is only a slight bend in the knee when the pedal is at the lowest point.
- Prepare for the given exercise protocol using the Wattbike Power Table to calculate the correct combination of level and cadence for the desired work rate.
- Ensure the participant has a mouthpiece, breathing tube and nose clip for data collection. Attach the mouthpiece to the breathing tube. Give participant time to familiarise themselves with the equipment. The mouthpiece will only be worn towards the end of the test, however it is important to familiarise prior to the test.

Douglas bag data collection

- It is imperative that data collection is precisely timed using the stopwatch.
- Respiratory gases are collected for an exact period of time.
- It is important that the mouthpiece and nose clip are worn by the participant PRIOR to the start of the data collection period (e.g. ask the participant to attach the nose clip and mouth piece in the 30 seconds before the planned time for data collection).
- The data collection period should have a clear count down from the timekeeper e.g. 3, 2, 1, GO, in which the valve of the designated Douglas bag is opened/closed in line with the count down.
- Once this data collection has been completed, remove the mouthpiece and nose clip from the participant.
 - It may be advisable to provide the participant with some blue roll to remove the mouthpiece.

Conducting the test

- Select an appropriate starting workload and increment workload for your participant.
- On the wattbike monitor, select a 1 minute repeated interval with 0s recovery.

- One tester should be responsible for managing workload intensities throughout the test, and ensuring the participant keeps to the required cadence.
- Each minute, ask the participant to rate their perceived exertion using the Borg scale, and record the Average Heart Rate and Average Power at the end of each minute.
- Every other minute (minutes 2,4,6,8,10, etc), collect a sample of expired air for the final 30s of the minute.
- Instruct the participant to place the nose clip on and insert the mouthpiece at the start of the minute.
- Use a timer to ensure you collect exactly 30s sample of air into the Douglas bag. Once collection is complete, participant may remove mouthpiece and nose clip if required.
- If you have sufficient testers, evacuate the bags whilst the test is continuing.
- Instruct the participant to inform you when they think they are close to being within 1 minute of volitional fatigue (i.e. their maximum effort).
- At this point, instruct the participant to put the mouthpiece in and wear the nose-clip.
- When they have approximately 30s left, begin collecting expired air in the Douglas bag and start the stopwatch. Instruct the participant to cycle maximally for the final 30s.
- When 30s is reached, or the participant stops, close the Douglas bag and record the time.
- Record the highest Heart Rate recorded during the final minute, and the average power for the final interval.
- If any Heart Rate or Power data has been missed, it can be recalled through the Monitor once the test is complete.

Douglas bag data analysis

- Firstly, the gas concentration (%O₂, %CO₂) of each bag must be sampled.
 - Analysing the gas concentration is completed for an exact period of time (60 seconds) and is precisely timed using the stopwatch.
 - A 60 second sampling period equals the removal of 1.8 L of air.
 - Hold the sample line of the Douglas bag firmly closed and THEN remove the clip/stopper from the end.
 - Still holding this sample line closed, attach the sample line of the Douglas bag to the sample line of the Servomex gas analyser.
 - The sampling period should have a clear count down from the timekeeper e.g. 3, 2, 1, GO, in which the sample line is opened/closed in line with the count down.
 - Record the numbers on the Servomex within the last 15 seconds of the sampling period. If these are not recorded at this point, they will disappear when the sample line of the Servomex is put back into ambient air.
 - At the end of the sampling period, hold the sample line of the Douglas bag firmly closed until the clip/stopper has been replaced.
- Secondly, the volume of gas within the bag must be measured.
 - Attach the Douglas bag to the vacuum as previously.
 - Make sure the vacuum monitor is reset to 0 before starting.
 - Opening the valve and turning on the vacuum must be coincided for accurate measurement of volume. Again, an individual should countdown, e.g. 3, 2, 1, GO, when the vacuum should be turned on, and the valve of 1 bag opened.
 - When the number is stable, note the value.

- Add 1.8 L to the value. This is to accommodate for the 1.8 L removed during the gas concentration sampling.

Cleaning

All mouthpieces, nose clips and breathing tubes must be sterilised with Milton between participants.

Results

Use the Gas Calc Excel document on the PC in order to convert the raw data into relevant variables.

Ensure the ambient conditions and participant characteristics have been input into the datasheet.

Results

Sample	Ambient Temp (Deg C)	Ambient Pressure (mmHg)	Humidity (%)	Subject Weight (kg)	Subject Height (m)	Bag Volume (L) (+ 1.8l)	Time Sampled (s)	FEO2 (%)	FECO2 (%)	HR