

MASTER I IDRETTSVITENSKAP 2024-2026
ORDINARY EXAM
IN
EXERCISE BIOLOGY AND SPORT PERFORMANCE ANALYSIS I (MA460)

Assessment Guide

Q1

Seminar 3: Oxygen transport and utilization during whole body maximal exercise (10 points)

Questions:

Describe how the following organ systems contribute to or limit maximal oxygen uptake (VO_{2max}). Also, compare their structure and function between untrained and well-trained individuals, and explain how these differences impact VO_{2max} :

- The lungs
- Blood volume and its oxygen-carrying capacity
- The heart
- The muscles

Assessment Guide

The lungs: *In untrained to moderately trained individuals, the lungs (and ventilation) constitute more or less no limitations to the maximal oxygen uptake. The arterial oxygen saturation is kept close to 100%, meaning that the blood, even with higher lung capacity, could not take up more oxygen. However, in well-trained individuals, arterial oxygen saturation can fall close to or below 90% during maximal exercise, which would limit their maximal oxygen uptake proportionally. At higher altitudes, arterial oxygen saturation falls, irrespective of training status, and the decline in VO_{2max} is linear with the fall in saturation. Hence, the lungs gradually become a greater limitation to VO_{2max} with increasing altitude (the impact of altitude is not necessary to mention to get full score. However, it will count as a plus if maximum points are not fulfilled based on the other aspects of the lung's impact on VO_{2max}).*

Blood: *The blood can limit the maximal oxygen uptake in two ways: 1) The haemoglobin concentration decides the upper limit for the arterial oxygen content, and hence, it influences oxygen delivery to the exercising muscles. 2) The total blood volume impacts the venous return to the heart and its filling. Hence, blood volume is of major importance for the stroke volume and maximal cardiac output.*

Well-trained individuals have a greater blood volume and greater venous return to the heart, increasing stroke volume and maximal cardiac output.

The haemoglobin concentration is very similar between well-trained and untrained individuals since training proportionally increases red cell mass and plasma volume.

The heart: *Maximal stroke volume multiplied by maximal heart rate constitutes the maximal cardiac output. The cardiac output determines, combined with the arterial oxygen content, the*

oxygen delivery to the exercising muscles, which is the most important limitation to maximal oxygen uptake. The most evident effect of endurance training is increased stroke volume and maximal cardiac output, which directly impact maximal oxygen uptake.

The increase in stroke volume in well-trained vs untrained is caused by:

- A higher blood volume: this increases the venous return to the heart, which increases the end-diastolic volume, stroke volume and maximal cardiac output. The increased venous return not only increases the heart filling but can also increase the contractility via the Frank-Starling mechanism.
- A bigger heart: the internal volume is greater, thus causing, together with increased blood volume, a higher end-diastolic volume of the left and right ventricles. The cardiac muscle mass/left ventricular mass is also greater.
- Greater compliance: the heart of the well-trained is more stretchable/has higher compliance. This causes a greater change in preload (end-diastolic volume) for a given change in filling pressure/venous return.
- All three points above act to increase preload/end-diastolic volume, which increases the stroke volume proportionally. The ejection fraction is not much different between untrained and well-trained individuals but is nevertheless maintained despite huge differences in preload.
- Maximal heart rate is similar or slightly reduced in well-trained vs untrained. Thus, differences in stroke volume (not heart rate) explain the elevated maximal cardiac outputs.

The muscles: The muscles: Each litre of arterial blood delivers approximately 180/200 ml oxygen to the muscles (women/men). The muscle can take up 70% - 95% of this oxygen (fractional oxygen extraction). The fractional oxygen extraction is determined by “qualities” in the muscle, mostly capillary density and mitochondrial volume. Endurance training has huge impact on these qualities.

Q2

Seminar 2: Running economy, a physiological and biomechanical perspective (10 points)

Questions (the three questions are equally weighted with 3.33 points each):

1. Define running economy and explain how it can be measured!
2. Describe how the relative contributions of body weight support, forward propulsion and leg swing to total running economy can be assessed in a laboratory?
3. Biomechanical “stiffness” has been associated with running economy. How can stiffness be quantified during running, and what mechanisms may explain this association?

Assessment Guide

- 1) Running economy is the energy or oxygen demand per unit distance, normalised to body mass. During steady-state treadmill running, VO_2 is measured at different constant speeds. These values are then interpolated in order to compare across a group at a given velocity, relative to body mass per minute or per kilometer.
- 2) Through experimental study on a treadmill during which body weight is supported (e.g. via a harness), horizontal braking or propulsive forces are applied, and leg swing is

assisted or resisted. Oxygen cost at varying degrees of assistance can be plotted and the values extrapolated to quantify the relative effect of each factor.

- 3) *Stiffness can be quantified using kinematic and kinetic data, by finding the change in vertical height of the centre of mass or of a marker representing the hip, combined with the maximum vertical ground reaction force. Vertical oscillation can also be an indicator of stiffness. The association may be due to a more efficient running technique with less energy transferred vertically during running, and greater elastic energy return.*

Q3

Seminar 1: Muscle mechanics (10 points)

Questions

1. According to a series of cross-sectional studies published in the early 2000s (covered in the lecture), what are the architectural features of the vastus lateralis in sprinters compared to endurance runners and untrained? What advantage could their fascicle length give to sprinters? (2 points)
2. Endurance runners seem to have different architectural features compared to sprinters. How different is fascicle length between sprinters and endurance runners according to these studies? What possible advantage can the fascicle length of endurance runners represent in their sport? What about their pennation angle? (3 points)
3. You are planning a research project to estimate the effect of fatigue induced by a training session on fascicle force production in the soleus muscle during running at 12 m/s. You have access to all the methodologies discussed during the lecture and found at NIH. (3 points)
 - a) In a first step, you plan to use the ankle joint moment recorded during the run, the Achilles tendon moment arm and the relative physiological cross-sectional area (PCSA) of the soleus muscle. Explain how you would use these variables to obtain the soleus force contribution during the run.
 - b) You then plan to multiply the obtained force contribution of the soleus during the run by the cosine of the pennation angle of its fascicles. Why? What is returned from this operation?
4. Define the architecture gear ratio (AGR) and explain what functional advantage a high AGR gives to the muscle. (2 points)

Assessment Guide

1. *Sprinters, in particular faster sprinters have longer fascicles than groups controls (endurance runners and untrained). They also have a lower pennation angle. Longer fascicles may maximise the force that they produce at high contraction velocity. It also gives a greater maximal contraction velocity.*
2. *Endurance runners have a shorter fascicles and greater pennation angles. Although shorter fascicles are an advantage for faster contraction (i.e. more force), they also require more energy consumption. Having shorter fascicles may reduce the running cost. The greater pennation angle may preserve their force potential under fast contractions despite the shorter fascicles.*
3.
 - a) *$F_{\text{soleus}} = \text{Ankle joint moment} / \text{Achilles tendon moment arm} \times (\text{PCSA}_{\text{soleus}} / \text{PCSA}_{\text{plantarflexors}})$. This calculation would give the instantaneous force produced by the soleus during the run.*

- b) *Multiplying the obtained force contribution of the soleus during the run by the cosine of the angle of pennation of its fascicles would allow to account for the fascicle orientation and measure the effective force that fascicles contribute to the motion.*
- 2. *Ratio of muscle contraction velocity over fascicle contraction velocity. A high AGR allows the muscle to contract faster than the fascicle contraction velocity would allow without fascicle rotation. The muscle can then operate at a more favourable portion of the force-velocity relationship.*

Q4

Seminar 4: Biomechanics of overuse injuries (10 points)

Question (the two questions are equally weighted with 5 points each):

1. Explain what pronation is and the problems that have arisen when trying to understand whether pronation is associated with overuse running-related injury risk.
2. Given the conflicting findings in the field of running-related injury risk, what are the primary scientific challenges and limitations in determining risk factors? Additionally, what are some potential strategies for addressing and overcoming these challenges?

Assessment Guide:

- 1) *Combination of eversion, dorsiflexion and abduction of the foot relative to the shank. It is a necessary motion during each step of running that contributes to impact attenuation (cushioning) and adaptation to different surfaces. Problems arise from over-generalised interpretation of findings, challenges in accurately representing rearfoot motion, the difference between measuring the foot and the shoe, small numbers of participants and injury outcomes.*
- 2) *Key limitations include the study design (cross-sectional/retrospective), requirement for lengthy follow-up, sample size and power, conflicting definitions, for example. They can be overcome with RCTs or prospective studies in which individual injuries are considered separately, with a large enough sample size to detect these injuries. Factors such as footwear, volume, level, sex must be accounted for.*

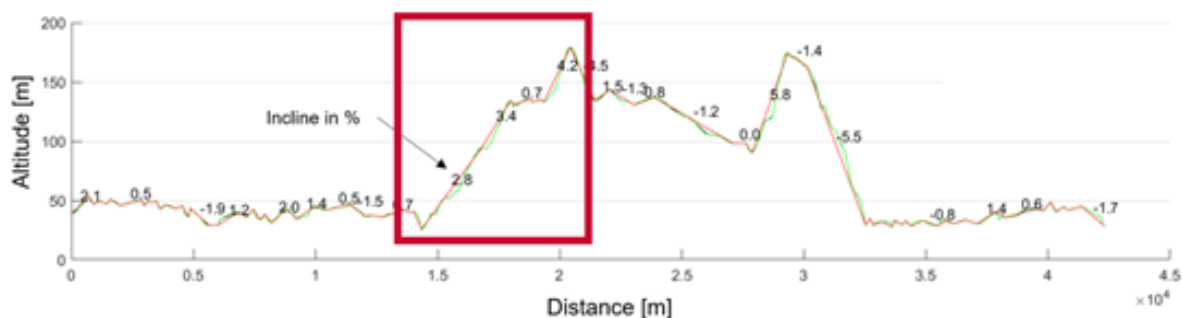
Q5

Seminar 6: Integrated performance analysis (10 points)

Questions:

1. During cross-country skiing, where there are uphill and downhill, the oxygen demand will vary. On the uphill, oxygen demands may be higher than the oxygen uptake, causing skiers to experience an oxygen deficit. Define oxygen demand, oxygen uptake, and oxygen deficit. In addition, define maximal accumulated oxygen deficit. (3 points)
2. Compare the relationship between oxygen demand, oxygen uptake, and accumulated oxygen deficit in short uphill (approximately 20 seconds) and a long uphill (approximately 1 minute)? (3 points)
3. How would you expect the relationship between oxygen demand, oxygen uptake, and maximal accumulated oxygen deficit (MAOD) to play out in a 5km long uphill?

approximately 3% incline after 15km at the Olympic marathon in Paris 2024? Below you find an altitude profile and the question relates to the uphill framed in red. (4 points)



Assessment Guide

Spm 1. Oxygen demand: The oxygen needed to sustain an intensity (pace or power), given that all energy comes from aerobic metabolism. Oxygen uptake: The oxygen that is taken up. Oxygen deficit: Oxygen demand minus oxygen uptake. Maximal accumulated oxygen deficit: For a person, the maximal achievable accumulated difference between oxygen demand and oxygen uptake. This is a measure of anaerobic capacity.

Spm 2 The relationship between oxygen demand, oxygen uptake, and accumulated oxygen deficit varies significantly between short (approximately 20 seconds) and long (approximately 1 minute) uphill efforts due to differences in the duration and intensity of the activity.

Short Uphills (Approximately 20 Seconds):

- **Oxygen Demand: High:** Oxygen demand spikes quickly due to the intense nature of the effort, as the muscles require immediate energy to power the uphill sprint.
- **Oxygen Uptake: Lagging:** Oxygen uptake is initially insufficient to meet the high oxygen demand because the aerobic system takes time to respond. During the short duration, the body cannot fully ramp up oxygen delivery to meet the demand.
- **Accumulated Oxygen Deficit: Large:** Due to the rapid onset of exercise and the short duration, there is a significant oxygen deficit. The body relies heavily on anaerobic energy systems (e.g., phosphocreatine and anaerobic glycolysis) to supply the necessary ATP, leading to a quick accumulation of the oxygen deficit.

Long Uphills (Approximately 1 Minute)

- **Oxygen Demand: Similar to short uphill,** the oxygen demand remains high due to the sustained effort required to climb the hill, but the intensity might be slightly lower compared to an all-out 20-second effort.
- **Oxygen Uptake: Over the course of the minute,** the oxygen uptake increases as the cardiovascular and respiratory systems have more time to catch up with the demand. The body begins to transition from anaerobic to aerobic energy production as oxygen uptake rises towards a steady state.
- **Accumulated Oxygen Deficit: While there is still an oxygen deficit at the beginning of the effort,** it is less pronounced than in the short uphill because the aerobic system has more time to ramp up. The accumulated oxygen deficit is moderate, as the body gradually meets the oxygen demand through aerobic pathways.

Spm 3: Longer duration of the uphill and limited capacity to recover in downhills due to running where muscular work is needed to larger extent than in skiing will limit the difference between

oxygen demand and the actual oxygen uptake to larger extent than in typical uphill in cross country skiing that have a much shorter duration than the 5km in the marathon.

Q6

Seminar 7: Performance analysis in Team sport (10 points)

Questions:

1. How can match analysis contribute to the training planning process?
2. Several contextual factors can influence the outcome of a match analysis. List three (3) possible factors.
3. A sprint in a typical match analysis is defined by a (so called) speed threshold (e.g. 25 km/h). What is the challenge with this definition when it comes analyzing the training load players are subjected to?

Assessment Guide

1. *A match analysis of physical performance can inform decisions related to the load athletes need to be prepared for in competition (needs assessment). This is important in training planning.*
2. *Game location, quality of opposition, match status, match half*
3. *The use of speed thresholds in match analysis results in that everything before you reach the threshold (e.g. 7 m/s) does not count as a sprint. That means that even though you accelerate with full effort, the effort will not be categorized as a sprint as long as you are below the defined threshold. The definition might therefore not be in line with how coaches/players define a sprint. The use of speed threshold is not problematic in itself, but its important to be aware of the definition to be able to analyse and use the data. Measurements of accelerations may therefore be important to get a wider picture of the training load.*

Q7

Seminar 9: Force-velocity profile and performance (10 points)

Question:

Discuss factors that may interfere with the outcome of a force-velocity profile test based on jumping. You can decide on how force and velocity are measured, including this as a source of error.

Assessment Guide

A force-velocity profile test from jumping requires 2-5 jumps with different exertional loads, such as a barbell across the shoulders. Ideally, the jumps are done in random order. The lowest load is only body weight (unloaded jump); the heaviest jump should yield a jump height of about 10 cm.

There are three categories of error sources: 1) the measurements of force and velocity (equipment and/or calculations), 2) standardization of the movement, and 3) estimating the force-velocity slope and the intercepts (F_0 and V_0).

- 1) *It is possible to use different measuring devices, such as a force plate, linear encode, and contact mat. All devices have errors, but the candidate is not expected to give exact numbers of that. If the Samozino method is used, there are potential errors in the estimation of the push-off distance, and the way force and velocity are estimated from only flight time during jumping. Details are not expected, but the candidate may remember that this has something to do with mixing time and distance average force and calculating average velocity as take-off velocity/2.*
- 2) *Prerequisites of a valid force-velocity test are maximal effort in each jump and the same range of motion during the push-off. Many studies have not controlled for this (only visual assessment), but even if we try, controlling multi-joint movements such as jumping is difficult. The main point here is that the external loads will affect the positioning of the center of mass, the joint configuration at the*

start and end (at take-off) of the movement, and the joint contributions during the jump. This means there is a specific skill requirement for each external load, and comparing the jumps is problematic.

The force-velocity profile is based on a linear relationship between force and velocity. This is not true for skeletal muscles (the relationship is non-linear). However, the relationship appears linear due to certain segmental dynamics. Moreover, using linear regression to fit the data and then extrapolating to get the intercepts (F_0 and V_0) is problematic for two reasons. First, small force and velocity data errors may cause large errors in the F_0 and V_0 estimated (error amplification). Second, large changes in, e.g., F_0 may “force” a reduction in V_0 even if the velocity properties of the athlete are unchanged. This is due to the procedure of using a linear regression line.