

Assessment Guide

Introduction: There are questions from 7 seminars. All parts count equally. Manage your time. The answer must be written in English, Norwegian, Swedish or Danish.

Seminar 1: Running Economy (10 points).

1. Define running economy and explain how it can be measured.
2. Describe spatiotemporal variables (for example ground contact time, stride rate, stride length) and how they can be measured.
3. What mechanisms could explain how spatiotemporal variables may be associated with running economy?

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1. *During steady-state treadmill running, VO₂ 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 kilometre.*
2. *GCT is the time per stride that a foot is in contact with the ground; stride rate is the number of strides per minute; stride length is the length of the total stride [here you could also refer to other variables such as step frequency and step length]. These can be measured using kinetic data to detect stance or kinematic data to identify the foot's landing position in space.*
3. *A higher stride frequency is associated with better running economy. This could be due to an associated shorter stride length which can reduce the horizontal forces. Propulsive horizontal forces cost a lot in terms of oxygen. Spatiotemporal characteristics may be to some extent self-optimised, reflecting that the runners are used to/familiar with these characteristics.*

Seminar 3: Biomechanics of overuse injuries (10 points).

1. Describe the loading that may be experienced by lower limb bones, for example the tibia, during running and how this can influence bone remodelling.
2. When designing a research project to assess biomechanical risk factors for running overuse injury, what are important factors to consider that would influence the quality of the study?

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1. *Lower limb bones experience axial loading and bending, which can result in both compression and tension. There is internal loading experienced, largely due to muscular forces. Bone loading stimulates remodelling where existing material is removed and new material deposited, which results in a stronger bone over time if there is sufficient recovery.*
2. *An RCT would be the strongest study design, and retrospective/cross-sectional would be weakest. Ideally injury outcomes would be measured prospectively, using clear definitions and specific for different injury sites. A lengthy follow-up period would be required with a large sample of participants (>1000) with clear inclusion criteria for the participants. If possible, it would be ideal to control running exposure and footwear, for example.*

Seminar 4: Performance analysis in Team sport (10 points).

1. Briefly explain what a match analysis is. Discuss how match analysis can contribute to improving team performance.
2. When interpreting the results of match analysis studies, two crucial factors must be considered: the context of the data and the methodology used. Explain why this is important.

Assessment guide:

1. *The primary goal of match analysis in team sports is to systematically analyse the performance of teams and players to inform tactical decisions, training focuses, and player development. It involves evaluating various aspects of a game, including tactical, technical, and physical components. For example, in football, match analysis might focus on GPS-derived measures such as high-speed running, sprint frequency, or repeated-effort demands to ensure players are physically prepared for*

the intensity of competition. Similarly, in hockey, GNSS data can be used to examine acceleration and deceleration loads or the total distance covered across different phases of play, helping coaches understand when players are most physically taxed. This data-driven approach allows coaches to tailor their strategies and training programs based on objective insights, ultimately enhancing team performance and competitive advantage. The goal extends beyond mere observation; it's about translating data into actionable strategies to optimize team success.

- 2. The context includes aspects like the level of play, opponent's style, and game situation (e.g., home vs. away). For instance, performance indicators in a high-pressure playoff game might differ significantly from those in a regular-season match. The second factor, methodology, pertains to how data was collected and analysed. This includes the reliability and validity of the data sources (e.g. GNSS), the calculation/definition of different metrics, and the statistical methods used for analysis. An accurate interpretation requires a critical assessment of these factors, as they significantly influence the conclusions drawn from the data. Understanding these aspects ensures that the findings are applied appropriately in practical settings, enhancing their relevance and utility in improving team performance.*

Seminar 6: Integrated performance analysis (10 points).

1. During a 15-km individual-start cross-country skiing competition, oxygen demand and oxygen uptake interact dynamically as athletes navigate varying terrain (uphill, flat, and downhill sections).
 - a. How do changes in terrain influence the relationship between oxygen demand and oxygen uptake? Describe what happens during uphill sections and immediately after, in a downhill section.
 - b. Explain how skiers use this interplay between oxygen demand and uptake to optimize pacing, tactics, and overall performance.

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- a. On level terrain, oxygen demand ($\text{VO}_{2\text{dem}}$) and oxygen uptake (VO_2) are closely matched. During uphill skiing, $\text{VO}_{2\text{dem}}$ becomes significantly higher than VO_2 , resulting in an oxygen deficit. In contrast, during downhill sections, $\text{VO}_{2\text{dem}}$ is lower than VO_2 , allowing athletes to partially recover the oxygen deficit accumulated on the uphill.
 - b. A sustained oxygen deficit will eventually lead to exhaustion if it persists too long, as there is an individual maximal accumulated oxygen deficit (MAOD). However, because athletes can recover part of the oxygen deficit accumulated during climbs on downhill sections, they can repeatedly utilize portions of their MAOD throughout the race. To optimize performance, athletes should adjust their uphill pacing so that the oxygen deficit remains within a range that can be recovered during the descent. If uphill intensity is too low relative to the recovery capacity on downhills, pacing becomes suboptimal. Conversely, if uphill intensity is too high, recovery will be incomplete, which may lead to premature exhaustion unless adjustments are made later in the race. This, too, represents suboptimal pacing.
2. Pacing is a critical determinant of performance in middle- and long-distance running events held on level ground, such as track races (800 m to 5000 m) and road races (half-marathon and marathon).
 - a. Describe pacing patterns that are considered optimal for performance in the 800 m, 5000 m, and marathon.
 - b. Explain the tactical challenges related to pacing faced by a runner with comparatively lower physical capacity in a competitive field.

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- a. *It is evident that the duration of the 5000m and marathon running (approximately 30 minutes and more than 2 hours, respectively) and the level ground for these activities necessitate a relatively constant aerobic energy production. The absence of up-and-down hills in these activities does not offer opportunities to recover from oxygen deficits, as is the case in cross-country skiing. Consequently, accumulated oxygen deficits would lead to a reduction in performance, with the exception of the final stretch into the finish line. Here, the accumulated oxygen deficit is cleared after the competition, allowing for a higher pace at the end of the competition.*

In the 800 m race, competitors initiate and conclude the event at a higher velocity than during the middle portion of the race. The delayed aerobic response to physical exertion during the initial minutes of exercise is utilised to initiate the race at a higher velocity than during the middle portion of the race. The final segment of the race is completed at a higher velocity, as the accumulated oxygen deficit is eliminated after the conclusion of the event.

- b. Athletes experience psychological benefits and improved air resistance when running in groups. While the most physically capable athletes typically establish an even pacing strategy, this pace is likely to be too high for those with a lower physical endurance capacity. Consequently, athletes with a lower capacity must consider the trade-offs involved in running in groups, following the pacing dictated by their more capable counterparts, as opposed to the increased possibility of running alone and losing ground to those who can maintain the pace without accumulating oxygen deficits.*

Seminar 7: Ergogenic aids (10 points).

A female 100-m sprinter comes to you with a question whether she would benefit from using creatine.

1. Give an overview of the proposed ergogenic mechanisms, quality of scientific evidence and relevance for use of creatine supplementation in her sport.
2. Provide concrete advice for her with respect to supplementation protocol and how to verify if she responds to the supplement.

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1. *Explaining the two main ergogenic mechanisms and level of evidence:*
 - *increased muscle thickness and thus skeletal muscle hypertrophy in both upper and lower body, during periods of maximal intensity resistance training. Strong evidence by several meta analyses in several target groups. Relevant that the student reflects on hypertrophy only appearing in combination with resistance training and not by creatine supplementation only.*
 - *improved capacity during short high-intensity work (20-40s) as creatine supplementation increases muscle creatine stores, augmenting the rate of PCr resynthesis. Medium evidence for effect of short singular sprints, less evidence for repetitive sprints.*

Explaining the relevance of hypertrophy and improved short high-intensity work to 100-m sprint performance. Reflect on importance of muscle mass for power and that most evidence is for 20-40 s, which is slightly longer than a 100-m sprint.

Up to 2 points for correct description of mechanisms, up to 2 points for discussion on their scientific evidence. Up to 2 points for discussing how these are relevant for a 100-m sprinter. 1 point for good reflection and overall discussion. TOTAL max 7 points.

2. *Up to 2 points for good description of proposed protocol:*

- *1 week loading phase of 20 g per day IF the athlete wants a quick response (however not necessary, can go straight on maintenance dose). Distribute in 4 doses of 5 g per day to limit side effects.*
- *Maintenance dose of 3-5g over a longer time, and in combination with resistance training. The student should reflect on the duration of the protocol. Most studies are up to 12 weeks, but there are no known cons of going continuous on creatine. However, the relevance is only present when combining with resistance training.*

Up to 1 point for verification of response: a responder will gain 1-2 kg of water weight within the first week since an increase in creatine stores will bind water. Hypertrophy weight gain will take longer. The student should explain that if there is no initial water weight gain, the athlete is a non-responder to creatine.

Seminar 8: Sex differences in oxygen transport and utilization during exercise (10 points).

1. Briefly describe the main steps in the oxygen cascade and identify which steps most strongly limit maximal oxygen uptake (VO_2max) during whole-body maximal exercise.
2. Compare the relative roles of the lungs, blood, heart, and skeletal muscles in limiting VO_2max in untrained versus endurance-trained individuals. Explain why the cardiac output is larger in the endurance-trained individual.
3. In well-trained individuals, VO_2max normalized for lean body mass is typically about 10% higher in males than in females. Explain the physiological mechanisms behind

this biological sex difference (e.g., cardiac output, hemoglobin concentration, muscle oxidative capacity).

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Q1 – Oxygen Cascade

Steps:

1. *Ventilation and alveolar gas exchange*
2. *Diffusion across the alveolar-capillary membrane*
3. *Transport in blood by haemoglobin*
4. *Delivery to tissues (cardiac output and capillary perfusion)*
5. *Diffusion into muscle fibres*
6. *Mitochondrial respiration*

Limiting factors: Primarily cardiac output.

Q2 – Untrained vs. Well-Trained:

- *Lungs:*
 - *Untrained: No limitation; arterial O₂ saturation is 95-100%.*
 - *Well-trained: Possible desaturation (<90%) at VO₂max. Hence, a small limitation.*
- *Blood:*
 - *Haemoglobin concentration is similar in both groups*
 - *Well-trained: Higher blood volume → better venous return and stroke volume.*
- *Heart:*
 - *Cardiac output = stroke volume x heart rate*
 - *Versus untrained, endurance-trained individuals have larger stroke volume and cardiac output through:*
 - *A higher blood volume: this increases the venous return to the heart → increased end-diastolic volume → enhanced contractility via the Frank-Starling mechanism.*
 - *A bigger heart: the internal volume is greater*
 - *Greater cardiac compliance → greater change in end-diastolic volume for a given change in filling pressure/venous return.*
- *Muscles:*
 - *Well-trained: Higher capillary density and mitochondrial volume than in untrained → improved O₂ extraction.*
- *Summary (can substitute points over addressing “relative roles”):*

- *Since O_2 extraction is not maximised in untrained individuals (70-80%), the muscle's ability to extract oxygen also limits VO_{2max} . However, trained individuals with O_2 extraction of 90-95% can only increase VO_{2max} further by elevating O_2 delivery. Hence, the untrained are limited by a combination of central and peripheral mechanisms, whereas the well-trained are limited “only” by central mechanisms.*

Q3 – Females vs. Males

- **Cardiac Output:**
 - *Per kg lean body mass, males and females have similar cardiac output.*
- **Blood:**
 - *Females have ~10% lower haemoglobin concentration → lower O_2 content and delivery*
- **Muscles:**
 - *Similar capillary density and mitochondrial volume → similar leg O_2 extraction*

Seminar 9: Strength training (10 points).

1. Discuss the role of satellite cells in muscle hypertrophy in response to strength training.
2. Explain how satellite cells contribute to the “muscle memory” phenomenon.

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Satellite cells are essential for muscle hypertrophy over a critical level and play a key role in the “muscle memory” phenomenon by contributing new nuclei to muscle fibers, which may persist even after detraining and facilitate faster regrowth.

Q1: Satellite Cells and Muscle Hypertrophy

- *Satellite cells are muscle-resident stem cells located between the basal lamina and sarcolemma of muscle fibers.*
- *Strength training triggers mechanical stress and microdamage, which activates satellite cells. They proliferate, differentiate into myoblasts, and fuse with existing muscle fibers.*

- *This fusion adds new myonuclei to the muscle fiber, expanding its capacity for protein synthesis and supporting fiber growth.*
- *Muscle fibers have a limit to how much they can grow per nucleus. Satellite cell fusion is essential once this threshold is reached, especially in high-volume or progressive overload training. Some studies even indicate that myonuclear accretion occurs before hypertrophy.*
- *Some studies show that individuals with a stronger satellite cell response tend to experience greater hypertrophy.*

Q2: Satellite Cells and Muscle Memory

- *Myonuclear permanence: Once satellite cells fuse and donate nuclei, these myonuclei are retained even if the muscle later atrophies due to detraining or disuse. Pluss if the student discuss the conflicting results on whether or not the new myonuclei are permanent!*
- *Faster regrowth: Upon retraining, muscles with retained myonuclei can resume protein synthesis and hypertrophy more rapidly than naïve muscle. This is the cellular basis of “muscle memory.” Pluss if the student indicate that this has been challenging to show in humans, but more convincing evidence from animal studies!*

Implications for aging and rehabilitation: Older adults or previously trained individuals may benefit from early-life training that builds myonuclear reserves, supporting faster recovery and adaptation later in life.