Question # 1 (10 points).

Oxygen transport and utilization during whole body maximal exercise.

1. Explain how and to what extent the following organs limit maximal oxygen consumption during whole-body maximal exercise
   a. The lungs
   b. The heart
   c. The blood
   d. The muscles
2. What are the underlying causes of the stroke volume being higher in endurance athletes than in untrained individuals?

Sensor guide:

1. Explain how and to what extent the following organs limit maximal oxygen consumption during whole-body maximal exercise
   a. 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, irrespectively of training status, and the decline in VO2max is linear with the fall in saturation. Hence, the lungs become gradually a greater limitation to VO2max with increasing altitude.

   b. The heart: Maxial 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.

   c. The 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 influence 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.

   d. 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.

2. What are the underlying causes of the stroke volume being higher in endurance athletes than in untrained individuals?

   Endurance athletes have:

   1. A higher blood volume: this increases the venous return to the heart which increases the end-diastolic volume, stroke volume and the maximal cardiac output. The increased venous return not only increases the heart filling but can also increase the contractility via the Frank-Starling mechanism.
   2. 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.
   3. Greater compliance: the heart of the elite athlete 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.
   4. 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.

Question # 2 (10 points).

Force-velocity profile and performance

Explain the concept of force-velocity profiling. How can it be measured and what kind of equipment is necessary? What is meant by an optimal profile? Discuss potential methodological issues with the Samozino approach.

Sensor guide:

Force-velocity profiling can be conducted in different movements or exercises, such as jumping and sprinting. Vertical jumping (SJ or CMJ) can be used by having the athlete perform maximal jumps with body weight and 1-5 external loads (typically 20, 40, 60, and 80 kg). With the so-called Samozino method, jump height is calculated via flight time, measured by a force plate, contact mat, linear encoder, accelerometer, or video (iPhone). To use flight time, the push-off distance of the jump must be defined, as the student should explain. The optimal profile is based on the idea that maximal power is achieved with only body weight as load (resistance). A force-velocity imbalance implies that maximal power is reached with a (theoretically) lower or higher load than body weight. By training for strength or velocity, it is assumed that an optimal profile can be obtained without changes to the maximal power. The force-velocity imbalance is hence corrected by a shift or tilt in the force-velocity profile. The Samozino approach has several methodological issues. Firstly, the estimations of force and velocity from jump height are based on flawed assumptions, as they consider only the distance of the push-off and not its duration. Second, the extrapolation of the regression line to derive F0 and V0 is prone to random errors.

Question # 3 (10 points).

Match Analysis in team sports

a) Briefly explain what a match analysis is. Discuss how match analysis can contribute to improving team performance.
b) 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.

Sensor guide:

a) 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 passing patterns or player positioning to improve team coordination and exploit opposition weaknesses. Similarly, in handball, it can be used to assess defensive formations or shot efficiency. 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.
b) 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 of the data sources (like video analysis vs. live observations) 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.

Question # 4 (10 points).

Integrated performance analysis

Compare cross country skiing 10km for females and 15km for males to 10’000m track and field running. The duration of these competitions is comparable. In this question you are asked to describe the differences between these sports with the following sub-questions:

1. Describe the differences in Course and competition characteristics and how that affects the general competition demands. Do not go into detail here yet but give an overview over the most important factors that are different in the course characteristics.
2. Describe the differences in physiological demands in competition
3. Describe the differences in technical and tactical demands in competition
4. Given the differences in the demands, how might the training be different between the sports?
5. Is a heart rate monitor a suitable device to measure intensity
   - in cross country skiing
   - track and field running 800m – 10'000m

Sensor guide:

Compare cross country skiing 10km for females and 15km for males to 10'000m track and field running. The duration of these competitions is comparable. In this question you are asked to describe the differences between these sports with the following sub-questions:

Describe the differences in:

- Course and competition characteristics and how that affects the general competition demands. Do not go into detail here yet but give an overview over the most important factors that are different in the course characteristics.
- XC:
  - Undulating terrain, uphills 10s – 2min, downhills, turns → pacing
  - Distance skiing: individual start → tactics
  - Changes in surface (snow)
  - Weather (visibility, wind, ..) → drafting
- Track and field:
  - Flat terrain, turns, straights
  - Mass start → tactics / pacing
  - Changes in surface (track stiffness, rain, …)
  - Weather (wind → drafting)

- physiological demands in competition
- XC:
  - interplay between anaerobic contribution in uphills and recovery in downhills
  - Limting factor: MAOD
- technical and tactical demands in competition
  - incline → speed → technique/gear choice
  - Snow conditions → technique/gear choice
  - Pacing (results experiments Thomas)
  - Downhills / turns (results Beito study)

Given the differences in the physiological demands, how might the training be different between the sports?

XC: Training the frequent oxygen deficit situations → MAOD → anaerobic training

Track and field: steady state training

Is a heart rate monitor a suitable device to measure intensity

- in cross country skiing
- track and field running 800m – 10’000m

XC: no

Track and field: yes

Question # 5 (10 points).

Muscle mechanics

During a running test, a researcher uses ultrasound to record the changes in architecture of the vastus lateralis muscle, and electromyography (EMG) to record the activity of this muscle. She also calculates the (instantaneous) extension moment produced at the knee joint from kinetics and kinematics data.

1. How can she calculate the force produced by the quadriceps muscles group?

2. She then wants to use typical values of physiological cross-sectional area of each of the quadriceps muscles from the literature to estimate the force produced by the vastus lateralis. How could she do this? Referring to what you have learned about force sharing between synergists muscles, why is this approach limited?

3. She wants to try and measure the instantaneous force produced by the vastus lateralis in a different way. In a previous experiment, she also collected data from isokinetic and isometric maximal voluntary contractions to reconstruct the force-length and force-velocity relationships of the vastus lateralis for each participants. How can these data and the collected ultrasound data be used to estimate the instantaneous force potential during running?

4. She also measured the maximal EMG activity of the vastus lateralis. How can the EMG data be used with the force potential derived from the previous step to estimate the instantaneous force production?

Sensor guide:

1. Moment / knee moment arm. This is expected knowledge from the bachelor curriculum and was covered in several parts of the lecture (e.g. slide 50). It refers to the learning objective "To be able to distinguish between strength, force and moment of force".

2. The expected answer should explain how to use the PCSA ratios and that this approach is limited because of inter-individual variability. This was covered in the lecture in slides 29 and 30. It refers to the learning objective "To be familiar with hypothetical relations between activation patterns and force-sharing".

3. The expected answer should explain how instantaneous length and contraction velocity are related to FL and FV relationships and can be used to estimate the theoretical maximal force

(force potential) that is produced under these conditions. This was covered in several parts of the lecture, in slides 31 to 42. It refers to the learning objectives "To be able to define the concepts of operating muscle architecture and force potential during movement", "To be able to explain how the concept of force potential can be used to estimate force production during movement from a theoretical perspective", "To be able to explain how the concept of force potential can be used to estimate force production during movement from a practical perspective".

4. The expected answer should point to using the EMG activity as a means to estimate the fraction of the force potential for any time point. It should specify that the ratio of EMGi / EMGmax can be multiplied by the force potential to estimate instantaneous force. It refers to the learning objectives "To be able to define the concepts of operating muscle architecture and force potential during movement", "To be able to explain how the concept of force potential can be used to estimate force production during movement from a theoretical perspective", "To be able to explain how the concept of force potential can be used to estimate force production during movement from a practical perspec

Question # 6 (10 points).

Overuse Injury

Discuss biomechanical risk factors that have been associated with overuse running injuries. Consider possible mechanisms explaining these risk factors (i.e. *how* could they lead to injury development) and provide a critical evaluation of the literature. What are the limitations and challenges of research in this area? Provide specific examples from the literature to support your answers.

Sensor guide:

There are biomechanical variables associated with running overuse injury that have been investigated in the literature, including force loading rates, hip adduction angle, rearfoot eversion angle etc. Students must show understanding of limitations and challenges of many of the relevant studies, including the study design, requirement for lengthy follow-up, sample size and power, various definitions, etc.

In line with the learning objectives, the student should: show how research design can influence our understanding of risk factors; explain the biomechanical variables that are being discussed – this could include how they can be measured.