Course 3

Applied Exercise Physiology

Acute responses, chronic adaptations, and load monitoring

Learning objectives of the course

Upon completion of this course, the student will be able to:

- Distinguish between acute responses to exercise and chronic adaptations to training.
- Describe the major cardiorespiratory, muscular and endocrine changes induced by training.
- Explain the mechanisms of fatigue and recovery.
- Use simple monitoring tools (RPE, HRV, sleep) to prevent overtraining.

Introduction

Understanding what happens in the body during and after exercise is the basis of informed prescription. Without this knowledge, you will not be able to:

- Adjust intensity and volume.
- Recognise signs of overtraining.
- Optimise recovery periods.
- Collaborate effectively with the medical staff.

1. General definitions

Concept	Definition	Example
Acute response	Immediate physiological changes during and just after exercise	↑ HR, ↑ ventilation, sweating
Chronic adaptation	Lasting changes after several weeks/months of training	Resting bradycardia, ↑ VO_2max
Fatigue	Inability to maintain a given exercise intensity, reversible by rest	Decreased strength after a sprint
Recovery	Process of returning to homeostasis and tissue repair	Glycogen resynthesis, repair of micro-tears
Training load	Quantification of the stress imposed on the body	Volume (km, kg) × intensity (%HRmax)
Monitoring	Regular tracking of physiological or behavioural indicators	RPE, HRV, sleep questionnaire

2. Acute responses to exercise

These responses occur within the first seconds and gradually disappear after exercise cessation (minutes to hours).

2.1 Cardiorespiratory responses

Variable	Acute response	Mechanism
Heart rate (HR)	↑ linear with intensity	↑ sympathetic activity, ↓ parasympathetic
Cardiac output (Q)	↑ (up to 4-5× rest)	↑ HR and stroke volume
Systolic blood pressure	↑ moderate	↑ cardiac output
Diastolic blood pressure	↔ or slight ↓	Peripheral vasodilation
Ventilation (VE)	↑ (fast then slow phase)	↑ frequency + tidal volume
O_2 consumption (VO_2)	↑ up to VO_2max	Peripheral extraction + cardiac output

Ventilatory threshold: point where ventilation increases faster than VO_2 (lactate accumulation, CO_2). A reference intensity for endurance.

2.2 Muscular and metabolic responses

- Local arteriolar vasodilation (mediated by adenosine, NO) → increased muscle blood flow.
- **Substrate utilisation**: carbohydrates (glycogen, blood glucose) + lipids (free fatty acids). Intensity determines the ratio: the higher the intensity, the more carbohydrates are used.
- **Heat production**: core temperature ↑ (risk of hyperthermia if not dissipated).
- **Lactate production**: normal at high intensity (lactate is an energy substrate, not a waste product).

2.3 Acute endocrine responses

- Cortisol: ↑ (catabolic, mobilises energy).
- Adrenaline / Noradrenaline: ↑ (increases HR, contractility, lipolysis).
- Growth hormone (GH): ↑ (promotes lipolysis, muscle protection).
- Testosterone: transient ↑ in men (anabolic).
- To remember: these responses are normal and necessary to perform.

3. Chronic adaptations to training

They appear after several weeks of regular training. They are specific to the type of training (endurance, strength, etc.).

3.1 Cardiorespiratory adaptations

Variable	Chronic adaptation (endurance)	Benefit
Resting HR	↓ (bradycardia)	Economical function
Submaximal HR	↓ at same power	Less cardiac stress
Stroke volume	↑ (larger cavity + compliance)	Better cardiac output
VO_2max	↑ (15-25% in 3-6 months)	Improved aerobic capacity
Muscle capillarisation	↑	Better O_2 extraction
Ventilatory threshold	↑ (at a higher %VO_2max)	Tolerance to intense exercise

Note: athlete's bradycardia can fall to 30-40 bpm without pathology, but symptomatic bradycardia (dizziness, syncope) must be investigated.

3.2 Muscular adaptations

Training type	Main adaptation
Endurance	↑ mitochondrial density, ↑ aerobic enzymes (succinate dehydrogenase), ↑ lipid utilisation, fibre type shift toward more oxidative types I and IIa
Strength / resistance	↑ cross-sectional area (hypertrophy), ↑ contractile proteins, ↑ maximal strength, ↓ percentage of type IIx (fast fatigable) fibres

Bone remodelling: weight-bearing training (running, jumping) increases bone mineral density (osteoporosis prevention).

3.3 Endocrine adaptations

- Improved insulin sensitivity (↓ diabetes risk).
- Attenuated cortisol response (less perceived stress).
- Testosterone / cortisol: better regulated, ratio more favourable to anabolism.

3.4 Other adaptations

Immune system: J-shaped effect (moderate PA → protection, extreme PA → transient immunosuppression).

Nervous system: better coordination, movement efficiency gain (economy of motion).

4. Fatigue: mechanisms and types

Fatigue is a protective phenomenon. You must learn to recognise and respect it.

4.1 Peripheral (muscular) fatigue

Mechanism	Explanation
Substrate depletion	↓ muscle glycogen (heavy legs sensation)
Metabolite accumulation	H^+, inorganic phosphate (disrupt contraction)
Impaired excitation-contraction coupling	↓ Ca^{2+} release from sarcoplasmic reticulum
Muscle damage	Micro-tears (muscle soreness, DOMS)

4.2 Central (neural) fatigue

- Decreased voluntary motor drive (↓ motor neuron recruitment).
- Neurotransmitters: ↑ serotonin (drowsiness), ↓ dopamine (motivation).
- Perceived as a mental "crash".

4.3 Clinical signs of excessive fatigue (warning)

- Performance plateaus or declines.
- Disturbed sleep (difficulty falling asleep, night awakenings).
- Irritability, anxiety.
- Lack of motivation.
- Persistent muscle pain > 72h.
- Recurrent infections.

5. Recovery: processes and strategies

Good recovery is as important as training itself.

5.1 Physiological recovery processes

Process	Typical duration
Glycogen resynthesis	24-48h (maximised if carbohydrates ingested post-exercise)
Lactate elimination	30-60 min (active recovery: light cycling)
Muscle micro-tear repair	24-72h (protein intake, sleep)
Hormonal rebalancing	12-24h
Rehydration	4-6h (more if significant losses)

5.2 Recovery strategies (for your athletes)

Strategy	Usefulness
Sleep (7-9h)	Essential: GH secretion, memory consolidation, repair
Hydration + electrolytes	Replace losses, avoid hyponatraemia
Post-exercise nutrition (carbs + protein)	Glycogen resynthesis + muscle repair
Active recovery (walking, very light cycling)	Lactate elimination, maintain blood flow
Stretching	No proven reduction of soreness or injuries
Compression (stockings, sleeves)	Possible benefit on perceived pain
Cryotherapy (cold water)	Analgesic effect, but may blunt adaptations if systematic

Practical advice: prioritise sleep, hydration, nutrition. Avoid systematic use of anti-inflammatory drugs (they delay muscle adaptation).

6. Training load and monitoring

6.1 External load and internal load

Load type	Definition	Tools
External	What the athlete does (objective)	Distance (km), repetitions, weight lifted (kg), accelerations (GPS)
Internal	What the athlete feels (subjective + physiological)	RPE (Borg), HR, HRV, lactate

6.2 Main field monitoring tools (affordable)

Tool	Measurement	Interpretation for you
RPE (session-RPE)	Perceived difficulty (0-10 or 6-20) after session	Multiply RPE × duration (min) = internal load in AU. Easy, reliable.
Morning HR	HR upon waking, lying down	Abnormal ↑ (>5-10 bpm over several days) → fatigue or stress
HRV (heart rate variability)	Interval between heartbeats	↓ HRV indicates need for recovery (wearables provide trend)
Recovery questionnaire (e.g., short REST-Q)	Subjective state (fatigue, sleep, stress, pain, etc.)	Low score = overtraining risk
Sleep (duration, quality)	Hours, night awakenings, feeling upon waking	Recurrent <7h → injury risk

6.3 Acute : chronic workload ratio (ACWR)

- Acute load = sum of loads over the last 7 days.
- Chronic load = average load over the last 28 days.
- ACWR = acute load / chronic load

ACWR	Injury risk
0.8 – 1.3	Optimal zone
< 0.8	Detraining (moderate risk)
> 1.3	High injury risk (training spike)
> 1.5	Very high risk

Application: Never increase load by more than 10-15% from one week to the next. Plan unloading weeks (-30% volume) every 4-6 weeks.

7. Prevention of overtraining

7.1 Early signs to watch for (daily)

- Disturbed or non-restorative sleep.
- Morning fatigue.
- Irritability or apathy.
- Lack of appetite or desire to train.
- Prolonged soreness (>48h).
- Decreased performance despite feeling of hard training.

7.2 What the coach should do

- Detect: use a simple questionnaire (e.g., “How do you feel from 1 to 10?”).
- Immediately reduce load (active or passive rest depending on severity).
- Evaluate: medical check-up if persists >1-2 weeks (blood work: iron, vitamin D, cortisol, testosterone, CPK).
- Reintroduce progressively (50% of volume then +10%/week if symptoms resolved).

7.3 When is an absolute medical opinion required?

- Chest pain, palpitations, syncope.
- Unexplained weight loss.
- Recurrent fever, lymphadenopathy (viral infection).
- Perceived heart rhythm disorders.
- Severe depressive state.