Department of medical physiology

13th week

Semester: summer

Study program: Dental medicine

Lecture: RNDr. Soňa Grešová, PhD.
Pregnancy

1. Baby's head stretches cervix
2. Cervical stretch excites fundic contraction
3. Fundic contraction pushes baby down and stretches cervix some more
4. Cycle repeats over and over again
Maturation and fertilization of the ovum

- The fimbriated ends of each fallopian tube fall around the ovaries.
- The fimbriated tentacles are lined with ciliated epithelium (cilia - estrogen activation).
- The ovum enters one of the fallopian tubes.
Fertilization of the ovum

- Transport of the sperm is aided by contractions of the uterus and fallopian tubes stimulated by prostaglandins in the male seminal fluid and also by oxytocin released from the posterior pituitary gland of the female during her orgasm.

- Sperm – penetration the corona radiata and then zona pellucida (surrounding the ovum itself) - capacitation and acrosome reaction.

- Female and male pronucleus (sex of the fetus – X or Y chromosome)
Transport of the fertilized ovum in the fallopian tube

- **Transport** (3-5 days) is effected:
  - mainly by a feeble fluid current in the tube
  - epithelial secretion
  - action of the ciliated epithelium that lines the tube;
  - the cilia beat toward the uterus
  - weak contractions of the fallopian tube may also aid the ovum passage
- **Progesterone** activates the receptors, (tubular relaxing effect that allows entry of the ovum into the uterus)

Transport of the fertilized ovum

• Transport of the fertilized ovum through the fallopian tube allows several stages of cell division:
  – early *morula* stage (3rd day) with about 16 cells
    • process of compaction (electrical windows):
      – central cells – embryo (inner cell mass)
      – outer cells – placenta (outer cell mass)
    • Fluid filled cavity – blastocyst is made
  – *blastocyst*, with about 100 cells—enters the uterus
    • embryoblast
    • *trophoblast* – outer cells (placenta)
Early nutrition of the embryo

- The **progesterone** secreted by the ovarian corpus luteum (the latter half of each monthly sexual cycle)
  - converting the endometrial stromal cells into large swollen cells - **decidual cells** (glycogen, proteins, lipids, minerals)
- The trophoblastic cords from the blastocyst are attaching to the uterus (selectin-trophoblastic cells, receptors on compact layer of endometrium, fibrinogen layer (**syncytiotrophoblast**))
- Blood capillaries grow into the cords (**blood sinuses**)
The blastocyst in the uterus

- Blood capillaries grow into the cords (blood sinuses) - the 16th day after fertilization
- *Placental villi* (more projections of trophoblast cells)
- Bilaminar disc (2nd week)
  - Epiblast
  - Hypoblast
- Two cavity:
  - Amnioblast (amniotic cavity)
    - Definitive yolk sac (from hypoblast – connective tissue -mesoderm)
  - Chorionic cavity (chorionic plate)
- Gastrula – treelaminar disc (3rd week)
  - Ectoderm (NS, skin)
  - Mesoderm
  - Endoderm (GIT)
Placental permeability and membrane diffusion conductance

- **Diffusion of oxygen**
  - by simple diffusion
  - Fetal hemoglobin
  - hemoglobin concentration of fetal blood is about 50 per cent greater than that of the mother
  - Bohr effect
- **Diffusion of carbon dioxide**
  - the PCO$_2$ of the fetal blood is 2 to 3 mm Hg higher than that of the maternal blood
- **Diffusion of foodstuffs**
  - *facilitated diffusion* of glucose through the placental membrane
  - slowly diffusion of fatty acids
  - easy diffusion of ketone bodies and potassium, sodium, and chloride ions
- **Excretion of waste products**
  - carbon dioxide
  - nonprotein nitrogens (urea, uric acid, and creatinine)
**Placenta hormones**

- The hormone **human chorionic gonadotropin** (syncytial trophoblast cells)
  - causes the corpus luteum to secrete even larger quantities of its sex hormones—progesterone and estrogens (few months)
  - stimulating effect on the testes of the male fetus
- Secretes **progesterone**
  - essential for a successful pregnancy
- Secretes **estrogens**
  - Increase receptors (for LDL and oxytocin)
- **Human chorionic somatomammotropin** (*human placental lactogen*)
  - similar as growth hormone and prolactin

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**Figure 82-7**

*Rates of secretion of estrogens and progesterone, and concentration of human chorionic gonadotropin at different stages of pregnancy.*

Other hormonal factors in pregnancy

- **Pituitary secretion**
  - increasing corticotropin, thyrotropin, prolactin
  - decreasing FSH, LH

- **Corticosteroid secretion**
  - increasing glucocorticoids
  - increasing aldosterone - *pregnancy-induced hypertension*

- **Secretion by the thyroid gland**
  - increasing 50% of thyroxine

- **Secretion by the parathyroid glands**
  - In calcium-deficient diet
  - more intensified during lactation (after the baby’s birth)

- **Secretion of “Relaxin” by the ovaries and placenta**
  - the relaxin softens the cervix of the pregnant woman at the time of delivery
Response of the mother’s body to pregnancy

- **Wait gain**
  - 25-35 pounds (11-15 kg)
    - fetus 8 pounds
    - amniotic fluid, placenta, fetal membranes 4 pounds
    - uterus and breast increased 5 pounds
    - extra fluid in the blood and extracellular fluid 5 pounds
    - fat accumulation 3-13 pounds

- **Metabolism**
  - 15% (she frequently has sensations of becoming overheated)

- **Nutrition**
  - Iron deficiency - *hypochromic anemia*
  - vitamin D,
  - vitamin K

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**Figure 82-8**

Effect of pregnancy to increase the mother’s blood volume.

Response of the mother’s body to pregnancy

- **Circulatory system**
  - the mother’s cardiac output to 30 to 40 per cent above normal
  - the maternal blood volume shortly before term is about 30 per cent above normal
    - basal metabolic rate of a pregnant woman is about 20 per cent above normal

- **Maternal respiration**
  - the mother’s minute ventilation to increase (50%) and a decrease in arterial pCO2

- **Maternal urinary system**
  - the renal tubules’ reabsorptive capacity for sodium, chloride, and water is increased (50 per cent)
    - increased production of steroid hormones by the placenta and adrenal cortex
  - the glomerular filtration rate increases (50 per cent)

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**Figure 82-8**

Effect of pregnancy to increase the mother’s blood volume.

Parturition

- **The first stage of labor** is a period of progressive cervical dilation, lasting until the cervical opening is as large as the head of the fetus
  - the fetal membranes usually rupture and the amniotic fluid is lost suddenly through the vagina
- **The second stage of labor**,  
  - the fetus’s head moves rapidly into the birth canal, and with additional force from above, it continues to wedge its way through the canal until delivery is effected
- **Separation and delivery of the Placenta**

*Figure 82–9*

Theory for the onset of intensely strong contractions during labor.

Lactation

• important for growth of the ductal system are:
  – Estrogens,
  – growth hormone,
  – prolactin,
  – the adrenal glucocorticoids,
  – Insulin

• the first few days after parturition is called colostrum

• Process in milk secretion (oxytocin)
Fetal and Neonatal physiology

• the gross characteristics of all the different organs of the fetus (within 1 month)
• most of the details of the different organs are established (2 to 3 months)
• the organs of the fetus are grossly the same as those of the neonate (beyond month 4)
• cellular development in each organ (from 5 month)
• lack full development in the nervous system, the kidneys, and the liver (at birth)
Fetal physiology

• **Circulatory System**
  – heart begins beating during the fourth week after fertilization,
  – contracting at a rate of about 65 beats/min.
  – increases to about 140 beats/min immediately before birth

• **Formation of Blood Cells**
  – nucleated red blood cells (third week of fetal development) the bone marrow (from the third month) red blood cells as well as most of the white blood cells

• **Respiratory System**
  – attempted respiratory movements (from the end of the first trimester of pregnancy)

• **Gastrointestinal Tract**
  – the fetus begins to ingest and absorb large quantities of amniotic fluid *(meconium)*

• **Kidneys**
  – fetal kidneys begin to excrete urine during the second trimester pregnancy
  – fetal urine accounts for about 70 to 80 per cent of the amniotic fluid
**Neonatal physiology**

- 28 days
- weight 3000-4000 grams, height 50cm
- Breathing at Birth (20-30 sec):
  - Decrease $pO_2$ and increase $pCO_2$
  - 1) a slightly asphyxiated state incident to the birth process, but also from
  - 2) sensory impulses that originate in the suddenly cooled skin
  - 3) the pulmonary vascular resistance greatly decreases as a result of expansion of the lungs
- Closure of the foramen ovale and ductus arteriosus
- Breathing frequency 50/min
- Tidal volume 16 ml
- $MV = 600-640$ ml
- $HR = 120-150$/min
- $Ery = 7-8 \times 10^{12}$/l
- $Leu = 16-18 \times 10^9$/l
- $BP = 60/40$ mmHg after a few months = 90/60 mmHg
Sports Physiology
Sports Physiology

- Energy for muscle contraction
- Blood supply
- Gas exchange
- Removing of waste products
- Eliminate the heat
- The supply of oxygen and nutrients
Body and its reserves

• Oxygen bound to hemoglobin
  – 25% at rest
  – Bohr’s effect

• Energy source
  – glycogen
  – Glucose
  – Fatty acids
  – Amino acids

• Gas exchange in lungs
  – Increase ventilation area

Body and its reserves

- **Cardiac output**
  - **Frank-Starling mechanism**

  Preload, or degree of stretch, of cardiac muscle cells before they contract is the critical factor controlling stroke volume; \( \uparrow \) EDV leads to \( \uparrow \) stretch of myocard.
  - \( \uparrow \) preload \( \rightarrow \) \( \uparrow \) stretch of muscle \( \rightarrow \) \( \uparrow \) force of contraction \( \rightarrow \) \( \uparrow \) SV
  - Unlike skeletal fibers, cardiac fibers contract MORE FORCEFULLY when stretched thus ejecting MORE BLOOD (\( \uparrow \) SV)
  - If SV is increased, then ESV is decreased!!

- **Slow heartbeat and exercise increase venous return (VR) to the heart, increasing SV**
  - VR changes in response to blood volume, skeletal muscle activity, alterations in cardiac output
  - \( \uparrow \) VR \( \rightarrow \) \( \uparrow \) EDV and \( \downarrow \) in VR \( \rightarrow \) \( \downarrow \) in EDV
  - Any \( \downarrow \) in EDV \( \rightarrow \) \( \downarrow \) in SV

- **Blood loss and extremely rapid heartbeat decrease SV**
Body and its reserves

- **Gas exchange in lungs**
  - Increase ventilation area

- Normally, the lungs have only zones 2 and 3 blood flow—zone 2 (intermittent flow) in the apices, and zone 3 (continuous flow) in all the lower areas

- **Zone 1:**
  - no blood flow during all portions of the cardiac cycle

- **Zone 2:**
  - intermittent blood flow

- **Zone 3:**
  - continuous blood flow

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Muscle metabolic systems in exercise

- 1) the phosphocreatine-creatine system,
- 2) the glycogen-lactic acid system
- 3) the aerobic system
Muscle metabolic systems in exercise

- **Adenosine Triphosphate** (used to cause muscle contraction)
  - one phosphate radical is removed, more than 7300 calories of energy are released to energize the muscle contractile process
  - to sustain maximal muscle power for only about 3 seconds

- **Phosphocreatine-Creatine System**
  - release large amounts of energy (10,300 calories per mole)
  - can provide maximal muscle power for 8 to 10 seconds
  - the energy from the phosphagen system is used for maximal short bursts of muscle power
Muscle metabolic systems in exercise

• **Glycogen-lactic acid system**
  – the muscle glycogen is transformed to lactic acid
  – can form ATP molecules about 2.5 times as rapidly as can the oxidative mechanism of the mitochondria
  – this anaerobic glycolysis mechanism can be used as a rapid source of energy
  – can provide **1.3 to 1.6 minutes** of maximal muscle activity

• **Aerobic System**
  – is the oxidation of foodstuffs in the mitochondria to provide energy
  – glucose, fatty acids, and amino acids from the foodstuffs—after some intermediate processing—combine with oxygen to release tremendous amounts of energy that are used to convert AMP and ADP into ATP
  – **Unlimited time** (as long as nutrients last)
# Muscle metabolic systems in exercise

<table>
<thead>
<tr>
<th><strong>Table 85-1</strong> Energy Systems Used in Various Sports</th>
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<tbody>
<tr>
<td><strong>Phosphagen System, Almost Entirely</strong></td>
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<tr>
<td>100-meter dash</td>
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<tr>
<td>Jumping</td>
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<tr>
<td>Weight lifting</td>
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<tr>
<td>Diving</td>
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<tr>
<td>Football dashes</td>
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<td>Baseball triple</td>
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<tr>
<th><strong>Phosphagen and Glycogen–Lactic Acid Systems</strong></th>
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<tr>
<td>200-meter dash</td>
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<tr>
<td>Basketball</td>
</tr>
<tr>
<td>Ice hockey dashes</td>
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<tr>
<td>Glycogen–lactic acid system, mainly</td>
</tr>
<tr>
<td>400-meter dash</td>
</tr>
<tr>
<td>100-meter swim</td>
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<tr>
<td>Tennis</td>
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<tr>
<td>Soccer</td>
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<table>
<thead>
<tr>
<th><strong>Glycogen–Lactic Acid and Aerobic Systems</strong></th>
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<tr>
<td>800-meter dash</td>
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<tr>
<td>200-meter swim</td>
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<tr>
<td>1500-meter skating</td>
</tr>
<tr>
<td>Boxing</td>
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<tr>
<td>2000-meter rowing</td>
</tr>
<tr>
<td>1500-meter run</td>
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<tr>
<td>1-mile run</td>
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<tr>
<td>400-meter swim</td>
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<tr>
<th><strong>Aerobic System</strong></th>
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<tbody>
<tr>
<td>10,000-meter skating</td>
</tr>
<tr>
<td>Cross-country skiing</td>
</tr>
<tr>
<td>Marathon run (26.2 miles, 42.2 kilometers)</td>
</tr>
<tr>
<td>Jogging</td>
</tr>
</tbody>
</table>

Cardiovascular system in exercise

• Increasing HR (72b/m-180b/m)
• Stimulation SNS
• The muscle work output increases oxygen consumption, and oxygen consumption in turn dilates the muscle blood vessels, thus increasing venous return (EDV=140ml to 170ml, SV=70ml to 140ml) and cardiac output
• The blood flow to muscles during exercise increases markedly
• The direct effects of increased muscle metabolism
• The moderate increase in arterial blood pressure (30%)
• Stretches the walls of the arterioles and further reduces the vascular resistance
Respiration in Exercise

- Increase oxygen consumption and total pulmonary ventilation
- The maximal breathing capacity is about 50 per cent greater than the actual pulmonary ventilation (15 L/min) during maximal exercise
- In maximal exercise, increased blood flow through the lungs causes all the pulmonary capillaries to be perfused at their maximal rates
- Is stimulated mainly by neurogenic mechanisms during exercise (to keep the blood respiratory gases—the oxygen and the carbon dioxide—very near to normal)
Effect of athletic training on muscles and muscle performance

- Bradycardia
- Hypotension (SBP)
- neg. chronotropic effect
- neg. dromotropic effect
- pos. inotropic effect
- Dilatation and muscle hypertrophy (CVS)
- Adaptation of ANS
- Parasympathetic tone increases
- fast-twitch fibers can deliver extreme amounts of power for a few seconds to a minute
- slow-twitch fibers provide endurance, delivering prolonged strength of contraction over many minutes to hours
- Decrease oxygen debt
- Decrease production of lactic acid
Body heat in exercise

• the body temperature often rises from its normal level of 98.6° to 102° or 103°F (37° to 40°C)
• very hot and humid conditions or excess clothing, the body temperature can easily rise to 106° to 108°F (41° to 42°C)
• Termoregulation
• Vasodilatation in the skin (SNS)
Steady state during exercise

- **The muscle metabolic systems** (glucagon and epinephrine)
  - phosphocreatine can be used to reconstitute ATP
  - energy from the glycogen-lactic acid system can be used to reconstitute both phosphocreatine and ATP
  - energy from the oxidative metabolism of the aerobic system can be used to reconstitute all the other systems-the ATP, the phosphocreatine, and the glycogen-lactic acid system
  - the removal of the excess lactic acid (*causes extreme fatigue*)
- Male (glucose burning)
- Female (fat burning)
Steady state during exercise

• **Cardiovascular system**
  – Increase mean arterial pressure (SNS)

• **Respiratory Systems**
  – Bronchodilatation
  – Synchronization breathing movements

• **Termoregulation**
  – Skin (excessive exercise - 2l/hour - hypotonic)
End of the steady state

- Due to hypovolemia and hyperosmria:
  - Redistribution fluids
  - Decrease production of urine
  - Thirst

Fatigue

• Depletion of energy stores
  – decrease of ATP
• Production of hydrogen ions
  – inhibition of glycolysis
  – release of calcium from binding to troponin
  – stimulation of pain receptors
  – mobilization of fatty acids is limited
• Changes acting on the nervous system
  – due to decreasing of pH
  – more dangerous hyperthermia and dehydratation
After a stress condition

- Decrease brain’s blood supply
  - Horizontal position

- Extreme cases
  - Fluid into intracellular space
    - headache, nausea, vomiting
  - Fever
    - cytokines and interleukins