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Measurement of basal metabolic expenditure
Compiling daily diet
Evaluation of nutritional state

Physiology II – practice
Spring, weeks 1–3

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Measurement of basal metabolic expenditure using indirect calorimetry and calculation

Metabolism

All chemical and energy transformations in the body

- In relation to food: energy and chemical transformations after food intake (includes processing, digestion, absorption and distribution to cells)
- A living organism oxidizes nutrients to produce H_2O, CO_2 and energy needed for life processes
  - Catabolism: a complex, gradual process of decomposing substances into simpler compounds, with the release of energy. Energy is released as heat or as chemical energy (stored in macroergic compounds, e.g. ATP)
  - Anabolism: process of formation of more complex substances from simpler ones, with a consumption of energy

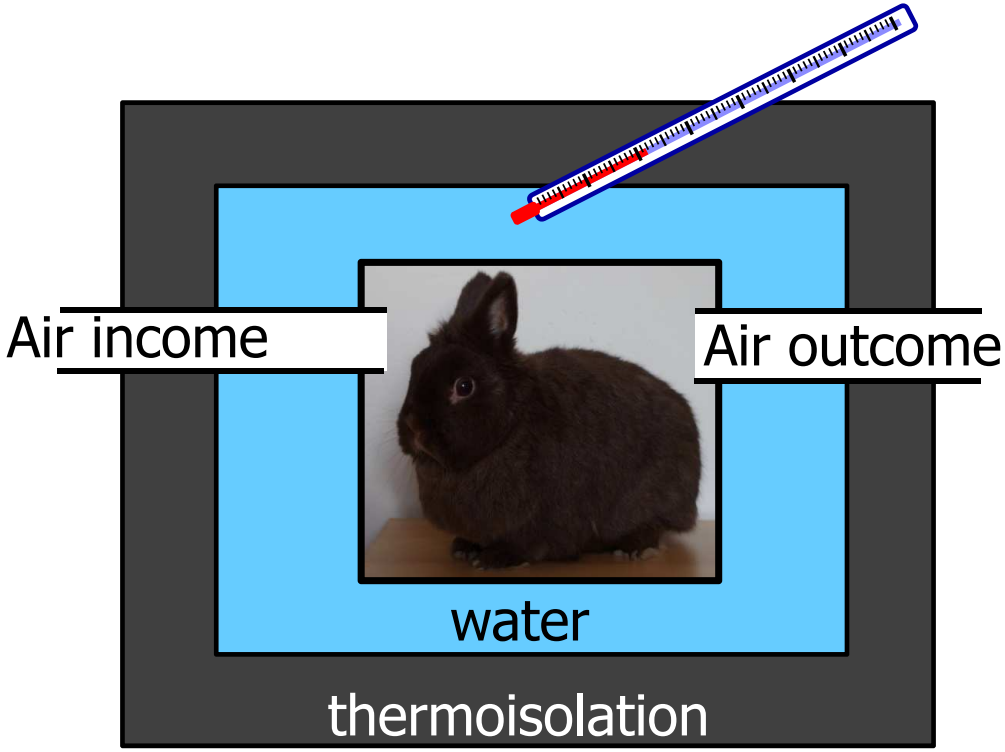
Calorimetry

- Calorimetry – a measurement of heat released in the studied system during a certain process (chemical, physical, biological)
  - Heat = energy, unit joule (J)
- Assessment of animal metabolism: based on the assumption that all metabolic processes are accompanied by heat production
  - Food metabolism is almost equivalent to direct food oxygenation (burning)

- Direct calorimetry – measurement of direct heat with a calorimeter
  - Heat caused by food burning with a sufficient supply of oxygen
  - Heat emitted by the metabolising animal with a sufficient supply of oxygen

Direct calorimetry

- Technically more difficult
- If used in animals, then only in small ones
- Isothermal calorimeter
  - *The temperature does not change during the experiment*. The generated heat is removed, and it causes, for example, a phase transformation of a matter (ice into water)



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Heat of combustion

- Total energy released as heat when a 1 g of substrate undergoes complete combustion with oxygen – energy of a 1 g of substrate
  - **Physical heat of combustion** – energy created via burning the substrate
  - **Physiological heat of combustion** – energy created via substrate oxidation by a living organism

- *Carbohydrates and fats*: physiological = physical heat of combustion
- *Proteins*: physical > physiological heat of combustion
  - The burning of proteins produces nitrogen oxides. Proteins metabolism produces urea which contains a part of the chemical energy
- Combustion heat of nutrients:
  - Carbohydrates = 17.1 kJ/g
  - Fats = 38.9 kJ/g
  - Physical combustion heat of proteins = 23 kJ/g
    Physiological combustion heat of proteins = 17.1 kJ/g

Indirect calorimetry

Principle: O_2 consumption, CO_2 output and waste of nitrogen metabolites are related to energy consumption

- Possibility to measure it in the open or closed system
- In practicals – Krogh spirometer (equipped with soda lime – ensures absorption of CO_2)

- Caloric (energy) equivalent of oxygen (EE) – energy related to litre of oxygen
  - The amount of energy that is released when consuming 1 liter of oxygen
  - Universal constant for calculating energy expenditure in a mixed diet

    EE = 20.19 kJ / litre O_2
- **EE of nutrients:**
  - Glucose 21.4 kJ / litre O_2
  - Proteins 18.8 kJ / litre O_2
  - Lipids 19.6 kJ / litre O_2

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Respiratory quotient (RQ)

- Ratio: CO_2 produced / O_2 consumed
- Provides information about the processed substrate
  - Saccharides : RQ = 1 – the same ratio of C and O as in water and CO_2
  - Lipids: RQ = 0.7 – contain less oxygen
  - Proteins: RQ = 0.8 - 0.9 - more complicated because urine must be taken into account
  - Mixed food: RQ = 0.85
  - Glucogenesis: RQ ≈ 0.4
  - Lipolysis: RQ ≈ 0.7
  - Lipogenesis: RQ ≈ 2.75
  - Fasting, starvation: RQ <0.85 – lipolysis, gluconeogenesis
- Other factors affecting RQ
  - Hyperventilation RQ > 1 – CO_2 is exhaled
  - During exercise or metabolic acidosis RQ > 1
  - Hypoventilation or metabolic alkalosis: RQ < 0.7
  - Particular organs – brain RQ = 0.97-0.99 (glucose consumption), stomach RQ < 1

Nitrogen balance

The ratio between the nitrogen ingested in the diet (proteins, amino acids) and the excreted nitrogen (mainly in the urine)

- Indicator of protein and amino acid decomposition or new tissue formation (protein incorporation)

- Negative nitrogen balance
  - Nitrogen is more excreted than consumed
  - Sign of protein and amino acid degradation
  - Starvation, forced long-term immobility, lack of some essential amino acids, tissue breakdown (extensive injuries, burns, tumor breakdown, postoperative conditions)
- Positive nitrogen balance
  - Nitrogen is more absorbed than excreted
  - Growth, pregnancy, reconvalescence

Basal metabolism

The amount of energy necessary to maintain basic vital functions

- Basal energy expenditure (BEE): energy expenditure of the organism under defined – basal conditions:
  - Thermoneutral environment
  - Physical and mental peace (in the morning before getting out of a bed)
  - Protein-free diet 12-18 hours before measurement
- BEE varies depending on many factors
  - Muscle tissue increases BEE
  - Repeated weight loss reduces BEE
- The obtained value is only an estimation of the actual energy associated with basal metabolism
  - **Resting energy expenditure** – measurement of expenditure in clinical conditions, when it is not possible to exactly meet all basal conditions – slightly higher than BEE

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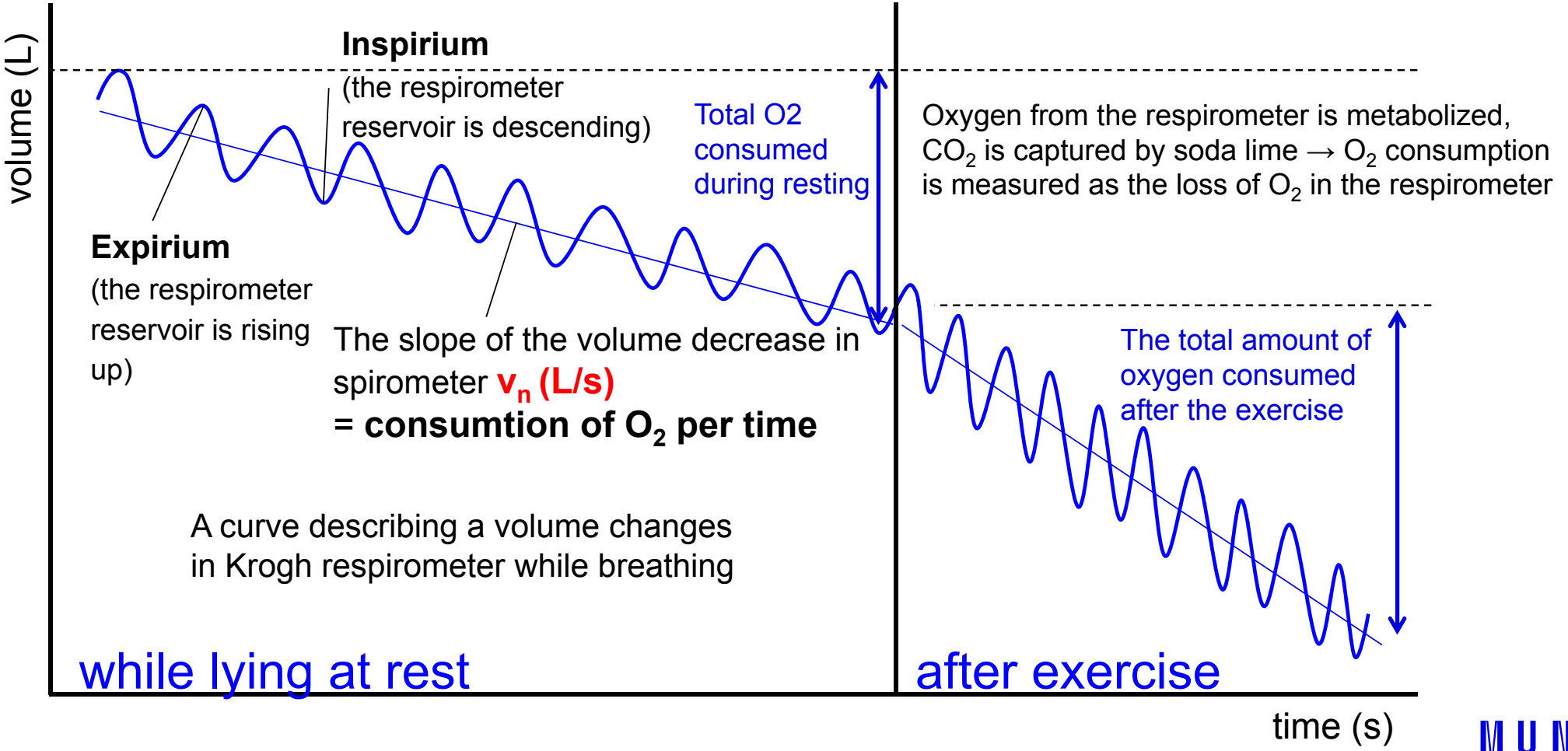
Measurement of O_2 consumption in practicals



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Actual energy expenditure (AEE)

Expenditure measured under current conditions

In practicals: AEE

- While resting (≠ resting energy expenditure!) – lying down
- While standing
- After exercise – walking on the steps for 5 min

– Determine
  - v_n – consumption of O_2 (L/s)
  - v_r – value corrected to 0°C a 101,325 kP (L/s)

$$v_r = v_n * \frac{273}{273 - t} * \frac{B - e}{101.325}$$

t: temperature °C, B: barometric pressure kPa (1 mmHg = 0.133 kPa), pressure of water vapour kPa (in the table)

– Calculate AEE (error of the calculation is aprox. 8%)
  - AEE (kJ/s) = 20.19 * v_r
  - AEE (kJ/day) = 20.19 * v_r * 86400

Calculation of energy expenditure via equation

- Basal energy expenditure (BEE) – Harris-Benedict equation
  - Man (kcal/day) $BEE = 66 + 13.7 * m + 5 * h - 6.8 * r$
  - Woman (kcal/day) $BEE = 655 + 9.6 * m + 1.7 * h - 4.7 * r$
  - m: weight (kg), h: height (cm), r: age (years)
- BEE (kJ/day) = BEE (kcal/day) * 4.184
- AEE (kJ/day) = BEE * AF * TF * IF
  - Basal energy expenditure (BEE, kJ/day)
  - Activity factor (AF) – in practicals: healthy (AF = woman 1.55; man 1.6)
  - Temperature factor (TF) – normal (TF = 1)
  - Injury factor (IF) – no injury (IF = 1)

  Increased temperature and damage increases AEE

The BEE and AEE calculation is just an estimation of a real value. The equation was based on statistical evaluation but two people with the same parameters will never have the same AEE, only similar. For example, the equation does not take into account the composition of body mass, the proportion of muscle and fat, and the individual metabolism.

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Conclusion

Compare the calculated BEE and the measured AEE while lying down and after exercise

Expected results:

BEE < AEE resting < AEE after exercise

Explain observed results

It might happen :

BEE ≥ AEE resting

Explain

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Compiling daily diet
Principles of proper nutrition

Principles of proper nutrition

- Energy intake and expenditure should be in balance
- Try to maintain adequate body weight (according to BMI and waist circumference)
- Eat at least 3 times a day at regular intervals (every 3-4 hours) – the number of meals depends on the total energy intake
- Exercise regularly – at least 30 minutes of mild physical activity at least 5 times a week (or 30 minutes of intermediate physical activity 3-4 times a week)

Principles of proper nutrition

- The diet should be **varied** – it should include:
  - All the necessary nutrients (proteins, fats, sugars) of the right composition, energy value and ratio
  - Vitamins
  - Minerals in the optimal amount
  - Water
  - Fibre

- To limit
  - Alcohol <30 g/day
  - Limit your intake of canned food and semi-finished products, fried foods and sausages (probably important factors causing diabetes mellitus type II)
  - NaCl <5 g/day
  - Cholesterol <300 mg/day
  - Other factors – optimal dining culture

  and don't smoke!

Daily diet

- For assessment of food intake:
  - Determination of caloric intake, diet composition, distribution of food during the day
- For therapeutic intervention:
  - Daily diet plan according to the individual needs and the principles of proper nutrition, adjusting the diet regarding diseases, health status, allergies, activity, weight adjustment
- The table should contain
  - Food
  - Meal time
  - Amount in g
  - Energy value of food in kJ
  - Ingredients – proteins, fats, sugars
  - Vitamins, minerals
  - Resulting values of all parameters and recommended daily doses
  - Ideally calculated daily energy expenditure for an approximate comparison with income
  - Specific dynamic effect of nutrients

Nutrients

- Recommendation: 10% proteins, 26% lipids, 64% carbohydrates
  (alcohol is also a source of energy, but not recommended)

- Protein – RDA adults: 0.8–1.2 g/kg, children: 1.2-1.5 g/kg
  - Must contain all the essential amino acids in the correct ratio suitable for the synthesis of new proteins – intake replaces 20-30 g of proteins that are daily degraded
  - Animal proteins have a balanced ratio of amino acids, plant proteins often lack some amino acids – a plant diet is more difficult to compile
  - Function: structural, signalling (hormones, receptors), as a source of energy only exceptionally (during starvation).
- Saccharides – RDA adults: 4-6 g/kg
  - The fastest energy source (17.1 kJ/g), mainly of plant origin.
  - Usable carbohydrates – 64% of energy intake (simple saccharides should be <10%)
  - Unusable carbohydrates – indigestible, part of fibre (mainly cellulose), RDA 25-35 g/day – GIT motility support

Nutrients

- Fats: RDA adults 1g/kg
  - The largest source of energy (38.9 kJ/g) – mainly storage functions
  - Other functions – fat-soluble vitamins, building, thermoregulation (brown adipose tissue, isolation), mechanical protection of organs and bones
  - Optimal ratio of fats in the diet: 10% saturated fatty acids (FA), 10-12% monounsaturated FA, 8-10% polyunsaturated FA
  - Cis-configuration FA – vegetable and most animal fats.
  - Trans-configuration – dairy products, beef and mutton, industrially hardened fats (margarine) – increase in LDL-cholesterol concentration
  - Cholesterol (animal products only) – a structural component of brain tissue, cell membranes, steroid hormone precursor, vit. D, bile acids - 4% of total cholesterol circulates in the blood. 75% of cholesterol is produced in the liver, 25% is obtained from food

  - Specific dynamic effect of nutrients (SDE): the energy needed for nutrient processing, about 10% of the energy from consumed mixed foods (proteins have a higher SDE than glucose)

Metabolic syndrome (MS)

- MS is a cluster of 3 or more of the following conditions together
  - **Obesity**: waist circumference >102 cm in men, >88 cm in women
  - **Dyslipidemia**: TAG >1.7 mmol/L
    HDL <1 mmol/L in men, <1.3 mmol/L in women
  - **Hypertension**: BP >130/85 mmHg or treatment
  - **Hyperglycaemia**: fasting glycaemia >5.6 mmol/L ← insulin resistance, diabetes II. type (DM II)
  - Czech Republic: 32% men, 24% women, mainly in the elderly population
  - Genetic predisposition (mainly insulin resistance) and poor lifestyle (higher energy intake, lack of exercise)
  - Significant pro-inflammatory, procoagulatory and proatherogenic state, the risk for cardiovascular diseases is higher than the risk caused by the simple sum of the risks of its individual risk factors – all factors mutually support each other
  - Consequences: reduced quality of life and life expectancy: DM II with complications, cardiovascular and cerebrovascular thrombotic events (heart attack, stroke, embolism)
  - It is a complex disease of the whole organism

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Diabetes mellitus (DM)

- It includes a heterogeneous group of chronic metabolic diseases, the basic manifestation is **hyperglycemia**.
- It is caused by a lack of insulin, its lack of effect (sometimes referred to as relative deficiency) or a combination of both.
- *Impairment of glucose transport* from the blood to the cell through the cell membrane → hyperglycaemia and glucose deficiency intracellularly
  - **DM I** – starts in childhood, autoimmune destruction of pancreatic beta-cells – insulin substitution required, absolute insulin deficiency
  - **DM II** – in adulthood, insulin resistance (insensitivity) of target tissues (insulin resistance), relative insulin deficiency

- DM complicates treatment, increases the risk and worsens the other diseases, worsens healing. As a result, DM is a disease also of the cardiovascular system

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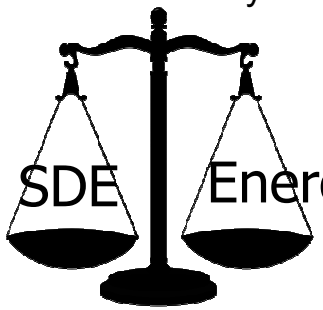
Protocol: prepare before your lesson!

- Write the weight, height, age and gender of the person for whom you will compile the menu
- Calculate his/her daily energy expenditure
- Compile the daily diet on www.myfitnesspal.com
- Print the menu, write down BEE and AEE calculated based on weight, height, age and gender and daily activities. Copy BEE and AEE in the protocol (not printed automatically)
- Write in the protocol:
  - Sum of received energy, nutrients, minerals and vitamins
  - Specific dynamic effect of nutrients (SDE)
  - Recommended values of all monitored parameters
  - Compare energy intake and expenditure, received and recommended daily doses of nutrients, minerals and vitamins. Evaluate whether the subject's diet is correct, describe the mistakes and suggest improvements



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Evaluation of nutritional status

Obesity

- Obesity – excessive storage of energy reserves in the form of fat. Energy intake is for various reasons higher than expenditure.
  - CZ adults: 35% overweight, 17% obese – more in men
    children 6-12 years: 10% overweight and 10% obese; 13-17 years together 11%
- Obesity is caused by a combination of factors – rarely just one factor
  - A combination of higher energy intake, lack of exercise
  - Hereditary influences – genetic (usually only predisposition, purely genetic cause is rare)
  - Psychological influences – distress, depression
  - Prenatal influences (mother's behaviour during pregnancy, diabetes, obesity – prenatal programming), delivery, early childhood, learned eating habits
  - Endocrine diseases – hypothyroidism, Cushing disease
  - It can be the result of other illnesses or injuries
  - Consequence of treatment – some antidepressants
  - Low socioeconomic status, lack of nutritional education

  - The problem from the healthcare professional's point of view: more demanding patient handling, a complication in the treatment of other diseases

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Malnutrition

- Malnutrition is a disease caused by insufficient intake of nutrients, inability to absorb nutrients in diseases of the digestive tract, excessive catabolism of nutrients (septic shock), serious diseases (oncological), nauzea,…
- Even the obese patients can be malnourished – despite their high energy intake, some nutrients may be lacking
  - In western countries, the cause is not a lack of food, but rather a poor diet, eating disorders, diseases causing impaired absorption and processing of nutrients

Adipose and muscle tissue

- **Lipolytic hormones** (and increasing glycaemia):
  Adrenalin, Noradrenalin, Somatotropin, Glucagon, ACTH, Prolactin, Glucocorticoids
- Body mass: active (muscles) and passive (fat)
  - Slow weight gain with increasing age is physiological (insulin sensitivity decreases, slower metabolism). Being overweight in old age (from about 65 years) is not harmful if it is the result of slow weight gain (about 0.25 kg/year).
- **Types of adipose tissue**
  - **White subcutaneous** – not harmful (within physiological values)
  - **White abdominal** – "beer belly" (between the abdominal organs) – strongly hormonally and metabolically active, **production of pro-inflammatory factors**, high cardiovascular risks – greater incidence in men
  - **White organ adipose tissue** – protection/storage in some organs – around the kidneys, around the heart, pancreas, in the liver – useful (within physiol. values) – mobilization faster than subcutaneous (during weight loss)
  - **Brown adipose tissue** – thermogenic – mainly in young children, rarely present in some adults between the shoulder blades and on the neck (useful, overweight prevention)
    - **Beige adipose tissue** – white containing a lot of mitochondria – a consequence of physical activity.
    - Newly discovered pink adipose tissue – can differentiate into other cells, the mammary gland

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Adipose and muscle tissue – gender difference

- Men have a larger portion of muscles, it is easier to increase muscle tissue (testosterone), which is a greater energy consumer – easier weight loss
- The same BMI in men and women has different risks – the similar risk of developing diabetes in women is usually at a much higher BMI than in men
- Different stages of weight gain – women during pregnancy and after menopause, men during lifestyle change (starting a family, divorce, change of job)

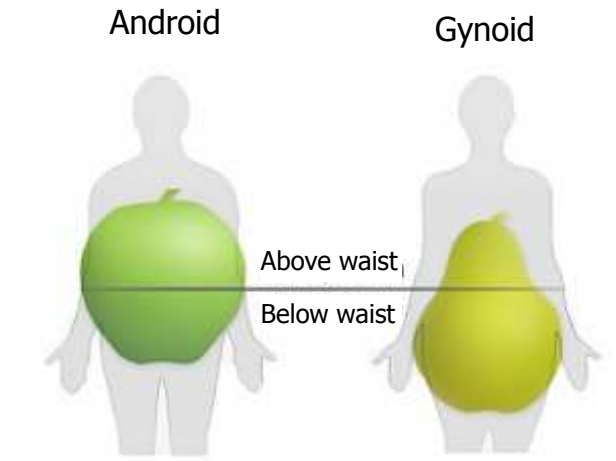
Above waist

Android type of fat storage (apple)

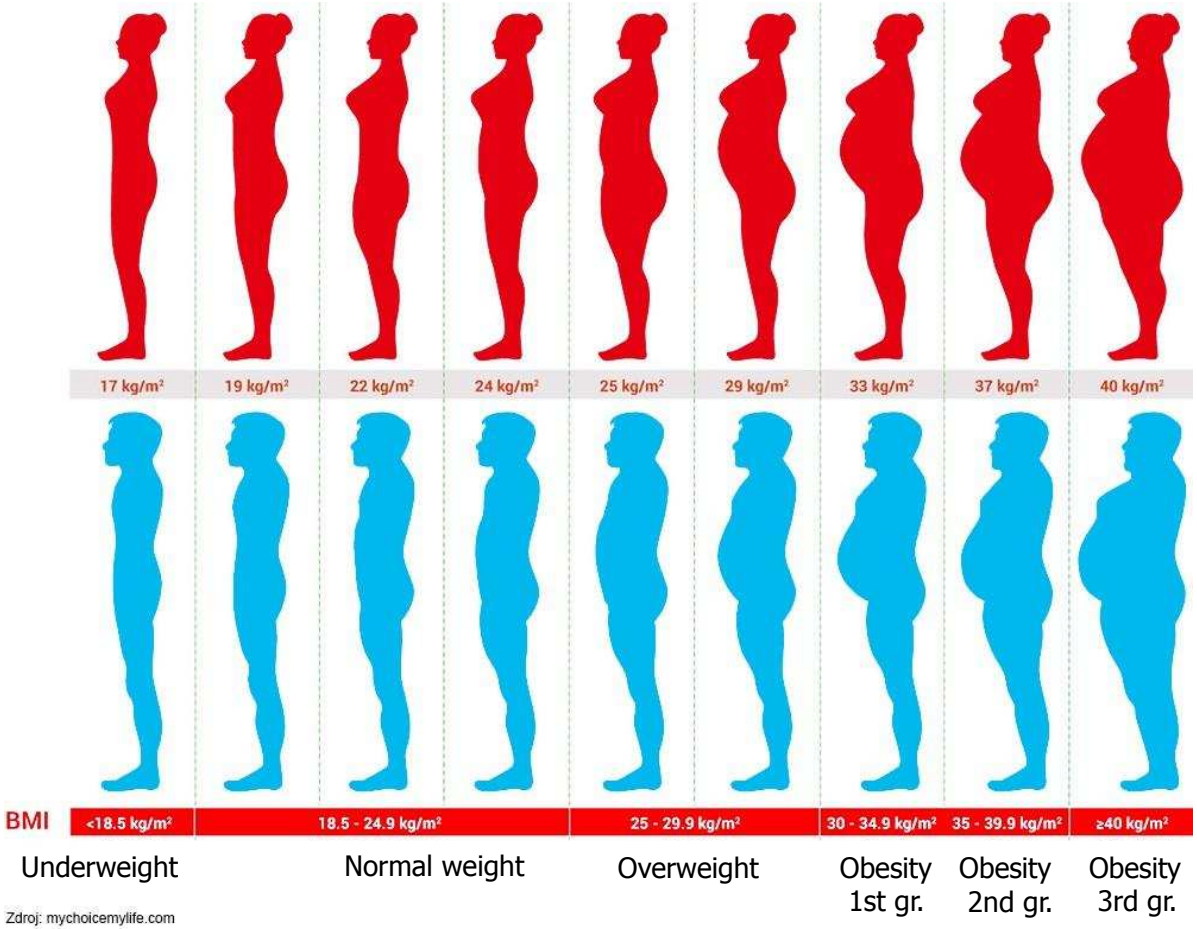
- Accumulation of fat in the abdomen, subcutaneous tissue and between organs
- More harmful (higher cardiovascular risks)

Gynoid type of fat storage (pear)

- Storage in the thighs and buttocks – the function is storage
- Energy for pregnancy and breastfeeding (lower cardiovascular risk)



Adipose and muscle tissue



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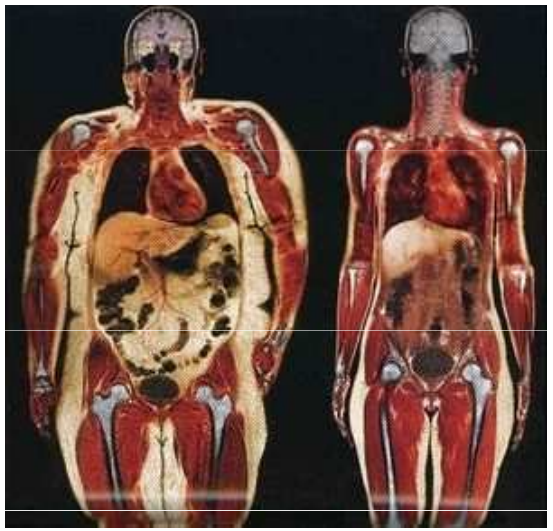

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A relatio between compounds of MS

- Dyslipidemia – overweight – hyperglycemia – hypertension
  - High LDL → atherosclerosis
- Overweight and DM II
  - Insulinoresistance
- DM II and hypertension
  - Hyperglycemia + hyperinsulinemia + dyslipidemia → endothelial dysfunction → higher vascular resistance → hypertension
  - Insulin resistance (and hyperglycemia) ↔ sympathetic activity → hypertension
  - Hyperglycemia → autonomic neuropathy → blood pressure regulation disorder
  - Dyslipidemia – atherogenic process – hypertension

  - Atherosclerosis – thrombembolic complications

Healthy life style

- Principles of behavior that support our body in maintaining health for as long as possible
- Generally: a healthy diet, sufficient exercise, sufficient sleep, a healthy environment (no smog, no smoking), stress management, well-being, etc. (just everything you, as a student or health care professional, have no chance to accomplish)
- Slim people without sufficient exercise have worse cardiovascular prognosis than overweight people who exercise (unfit-unfat / fit-fat)
- Regular physical activity
  - Helps weight loss
  - Improves parameters of DM and metabolic syndrome
  - Positive effect on the psychical health (important in the therapy of depression)
  - Muscle strength (such as a handgrip test) is an important indicator of a patient's ability to recover
  - Reduces postprandial inflammation in adipose tissue (immune response that occurs after a meal)

Evaluation of nutritional state

- Indices based on anthropometric indicators
- Measurement of body fat with a caliper
- Measurement of fat in the body by bioimpedance method
- Measurement of muscle mass

Indices based on anthropometric indicators

- Degree of obesity according to the Broca index
  - Based on the calculation of the ideal weight and the percentage of the ideal weight
  - Some physiological parameters are estimated based on the ideal weight – for example, the initial setting of tidal volume in mechanical ventilation

Degree of obesity	% of ideal weight
Mild	115 – 129
Medium	130 – 149
Heavy	150 – 199
Morbid	> 200

- Ideal weight:
  - For men:
    - Height (cm) – 100
    - Or (height in m)^2 – 23
  - For women:
    - Height (cm) – 100 – 10%
    - Or (height in m)^2 – 21.5
- Index = actual weight/ideal weight x 100

Indices based on anthropometric indicators

– BMI (body mass index) = weight (kg)/height $(m)^2$

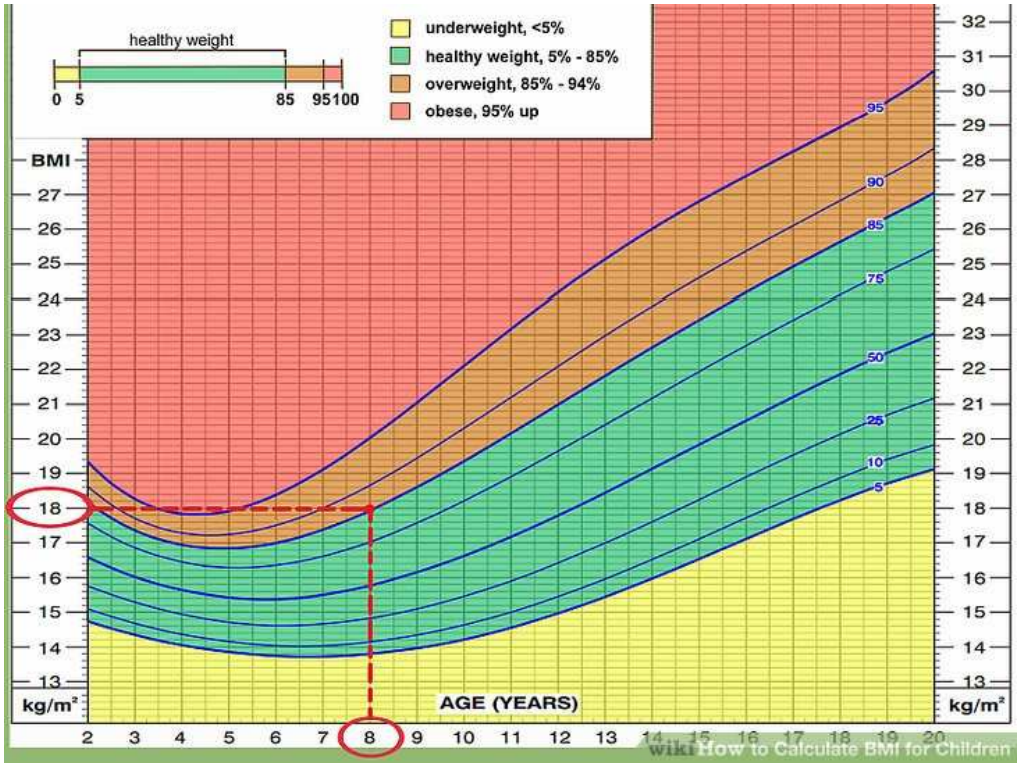
For adults

	man	woman
Underweight	< 20	< 19
Norm	**20 – 24.9**	**19 – 23.9**
Overweight	25 – 29.9	24 – 28.9
Obesity	30 – 39.9	29 – 38.9
Serious obesity	> 40	> 39

BMI – various tables for men / women, adults / teens / children

Indices based on anthropometric indicators

- Advantages: simple calculation
- Disadvantages
  - BMI does not take into account the constitution of body mass. A man with great musculature can be in the overweight area of a table without having a nutrition problem
  - **Broca index** uses a linear relationship between height and weight – the index is approximate
  - **BMI** – a quadratic relationship between height and weight – better than Broca, but it is still necessary to use different tables for adults, adolescents and children – BMI 17 is normal at 15 years, but in adulthood it means underweight



  - **Rohrer's index** (100 * weight (g) / height (cm)^3).
    Weight is determined by volume (the cube of the dimension), so this index is the best. More consistent in age. More suitable for children and teenagers.

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Waistline, waist/hip ratio

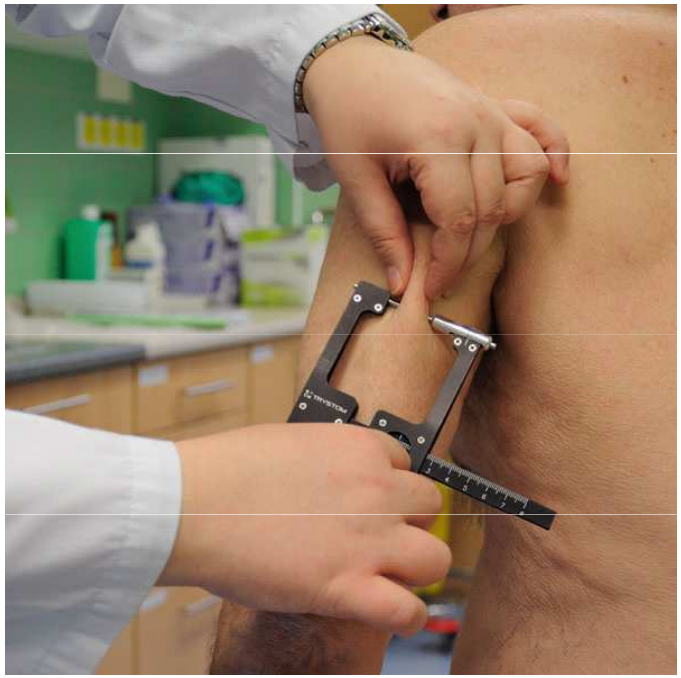
- Very simple but effective predictive parameters for nutrition evaluation

- **Waist/hip ratio**
  - Men < 1
  - Women < 0.8

Waistline in cm		
Category	**Men**	**Women**
Recommended	≤ 94	≤ 80
Necessary to reduce weight	95 – 102	81 – 90
Weight loss requires medical assistance	> 102	> 90

Measurement of body fat with a caliper

- The subcutaneous fat layer is measured
- It reflects the energy balance of the organism
- It does not cover possible differences in the distribution of subcutaneous and visceral fat
- The most common place of measurement: the triceps skinfold (other places: above the shoulder blade, the abdomen, the spina iliaca, the thigh, the lower leg)



The triceps skinfold			
	Normal (mm)	Mild to moderate deficit (mm)	Significant deficit (mm)
Women	> 16.5	10 – 15	< 10
Men	> 12.5	7.5 – 11	< 7.5

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Bioimpedance method

Measurement of fat portion in the body

- Different body tissues have different impedance for very small electric currents (muscle conductivity versus adipose tissue)
- The method is based on bioelectrical impedance analysis; the bioelectric impedance (resistance) of the adipose tissue is measured
- The ratio of adipose tissue to other tissues is calculated
- It depends on the amount of fluid in non-fat tissues – on the hydration of the organism (reason for fluctuations in values during the day if the standard conditions of individual measurements are not observed)
- The device can evaluate the % of fat, water and bone tissue

Bioimpedance method

Measurement of fat portion in the body

- The handpiece measures the upper half of the body, the scale measures the lower half
- Whole body measuring devices are now used

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Measurement of muscle mass

Muscle tissue is an important parameter of nutritional status

Arm muscle circumference (OSP) – in cm

$$OSP\ (cm) = arm\ circumference - \pi \cdot the\ triceps\ skinfold$$

- Corected area of arm muscle (kPSP) – in cm
  - Men

$$kPSP = \frac{(arm\ circumference - \pi \cdot the\ triceps\ skinfold)^2}{4 \cdot \pi} - 10$$

  - Women

$$kPSP = \frac{(arm\ circumference - \pi \cdot the\ triceps\ skinfold)^2}{4 \cdot \pi} - 6.5$$

Muscle loss	No loss (cm)	Medium (cm)	Heavy (cm)
Women	> 23.2	14.1 – 23.1	< 14
Men	> 25.3	15.1 – 25.2	< 15

Deficit	No deficit	Mild	Medium	Heavy
Women	> 36.3	29.1 – 36.2	25.5 – 29.0	< 25.4
Men	> 40.9	32.8 – 40.8	28.7 – 32.7	< 28.6

Conclusion

- Evaluation of the nutritional state is an important indicator in all areas of medicine
- Both malnutrition and obesity may be detrimental to the human organism
- The process of evaluation of nutritional state starts with simple formulas and continues with sophisticated measuring instruments
- The results help to set the diet correctly (rational, reducing, high-energy, etc.)