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

Practical Exercises in Physiology (Spring semester: 4th - 6th weeks)

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Measurement of basal metabolic expenditure using indirect calorimetry and calculation

Metabolism

All chemical and energetical transforamtions in the body

- in relation to food: energical and chemical transformations after food intake (includes processing, digestion, absorption and distribution to cells)
- a living organism oxidizes nutrients to produce H2O, CO2 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, eg ATP)
- Anabolism: The process of formation of more complex substances from simpler, with a consumption of energy

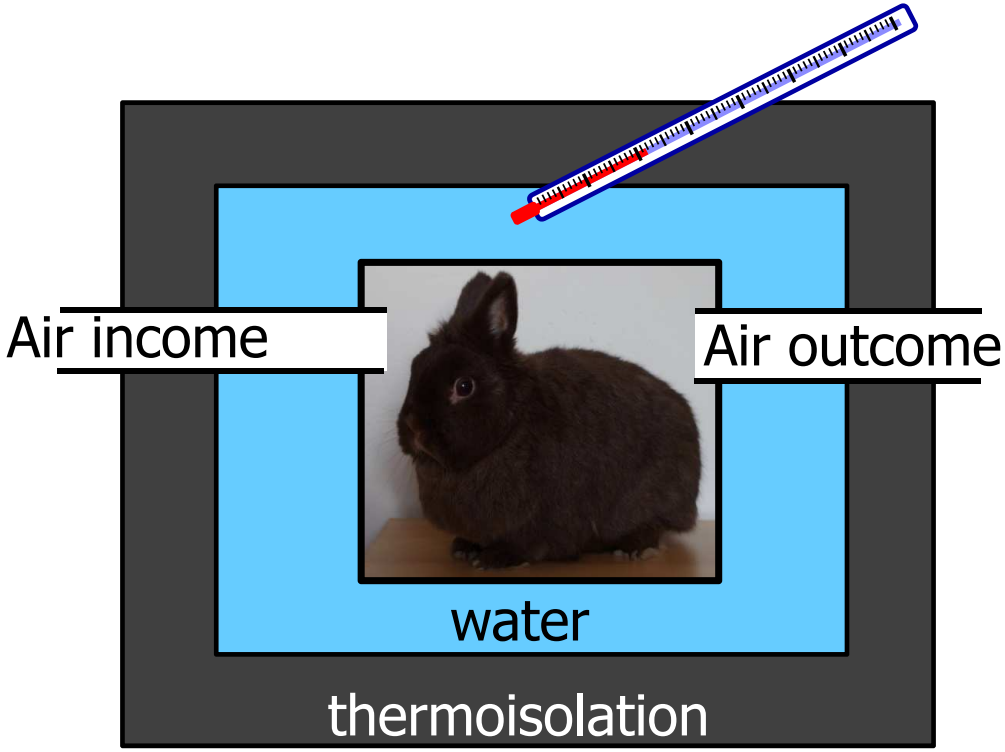
Calorimetry

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

- Direct calorimetry - direct heat measurement with a calorimeter
  - Heat caused by burning food 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 throughout the experiment. The generated heat is removed, and it causes, for example, a phase transformation of pure matter (ice into water)



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Combustion heat

- Total energy released as heat when a 1 g of substance undergoes complete combustion with oxygen
  - energie vztažená na g substrátu
  - physical combustion heat - energy created by burning the substratephysiological combustion heat
  - energy created by oxidation of the substrate by a living organism
- carbohydrates and fats: physiological = physical heat of combustion
- proteins: physical> physiological combustion heat
  - Burning of proteins produces nitrogen oxides. Metabolizing of proteins 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, CO2 output and waste of nitrogen metabolites are related to energy consumption

- possibility to measure in open or closed system
- In practicals – Krogh spirometr (equipped with soda lime – absorption of CO_2)

- Caloric (energetic) equivalent of oxygen (EE) - energy related to liter 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 / litr O_2
- **EE of nutrients:**
  - Glucose 21,4 kJ / litr O_2
  - Proteind 18,8 kJ / litr O_2
  - Lipids 19,6 kJ / litr O_2

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Respiratory quotient(RQ)

- Ratio: CO_2 produced / O_2 received
- Provides information about the processed substrate
  - Sacharides : RQ = 1 - the same ratio of C and O as in water a CO_2
  - Lipids: RQ = 0.7 - contain less oxygen
  - Proteins: RQ = 0.8 - 0.9 - more complicated, because urine must also be taken into account
  - mixed food: RQ = 0.85
  - Glucogenesis: RQ ≈ 0.4
  - Lipolysis: RQ ≈ 0.7
  - Lipogenesis: RQ ≈ 2.75
  - Fasting, fasting: RQ <0.85 - lipolysis, gluconeogenesis
- Other factors affecting RQ
  - Hyperventilation RQ> 1 - CO_2 is exhaled
  - During exercise or metabolic acidosis RQ> 1
  - Free 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 decompostion or new tissue formation (protein incorporation)

- Negative nitrogen balance
  - nitrogen is more excreted than receiveda
  - 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 geting out of 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 estimate of the actual energy associated with basal metabolism
  - Resting energy expenditure - measurement of exenditure in clinical conditions, when it is not possible to exactly meet all basal conditions – slightly higher than BEE

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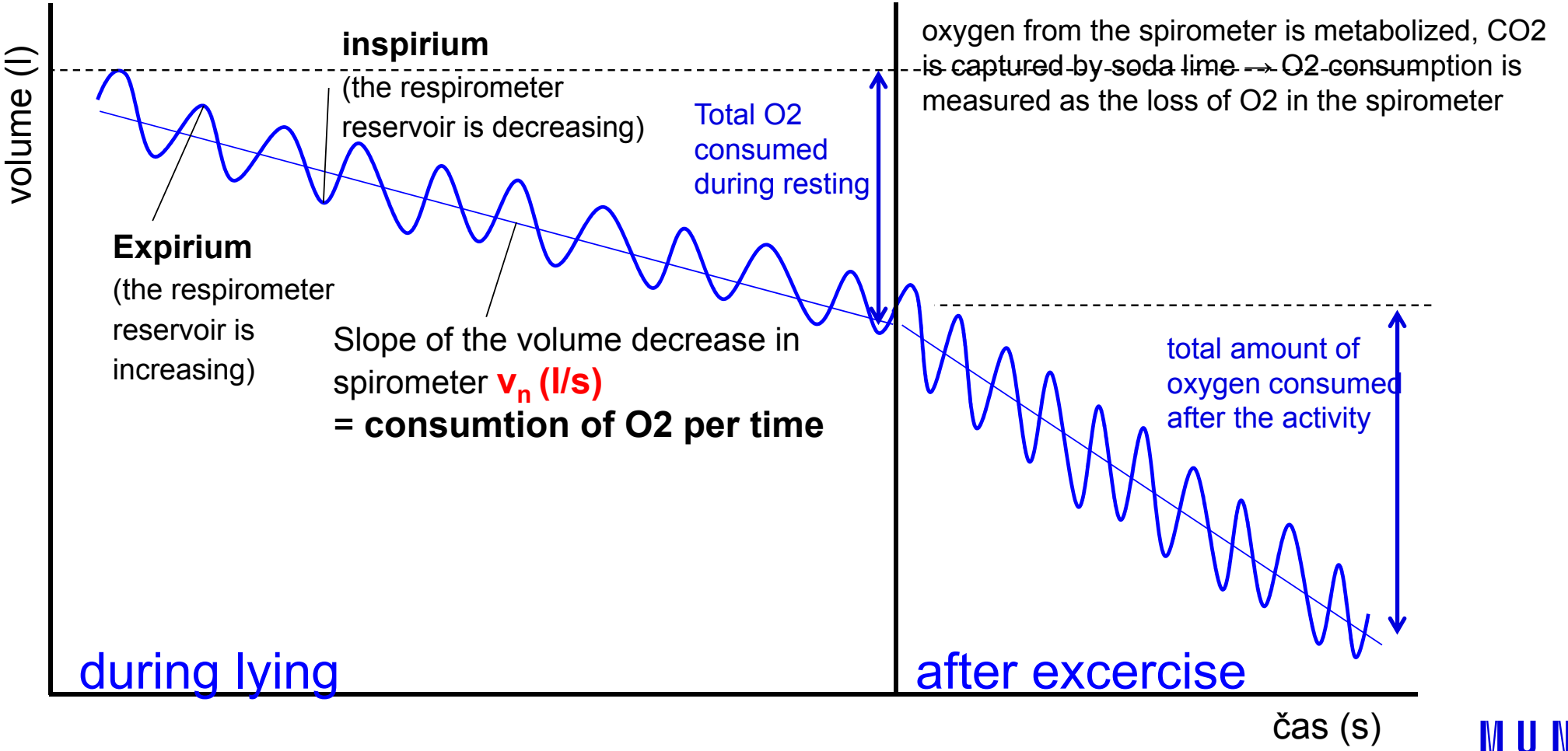
Measurement of O_2 consumption in practicals



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Actual energy expenditure (AEE)

Expenditure measured under current conditions

In practicals: AEE

- During lying
- During standing
- After workload – walk on the steps for 5 min

– Determine
  - v_n – consumption of O2 (l/s)
  - v_r – value corrected to 0°C a 101,325 kP (l/s)

$$v_r = v_n \cdot \frac{273}{273 - t} \cdot \frac{B - e}{101{,}325}$$

t: Temperature °C, B: barometric pressure kPa (1 mmHg = 0,133 kPa), pressure of water vapour v kPa (in the table)

– Calculate AEE (error of the calculation is 8%)
  - AEE (kJ/s) = 20,19 . v_r
  - AEE (kJ/den) = 20,19 . v_r . 86400

Calculation of energy expenditure by equation

- Basal energy expenditue (BEE) – Harris-Benedict equation
  - man (kcal/den) $BEE = 66 + 13{,}7 \cdot m + 5 \cdot h - 6{,}8 \cdot r$
  - woman (kcal/den) $BEE = 655 + 9{,}6 \cdot m + 1{,}7 \cdot h - 4{,}7 \cdot r$
  - 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(kJ/den)
  - activity factor, (AF) - student: healthy (AF = woman 1,55; man 1,6)
  - temperature factor (TF) – normal (TF = 1)
  - injury factor, (IF) – no injury (IF = 1)

  Increasing temperature and damage increases AEE

The BEE and AEE calculation is just an estimate of your 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 during lying down and after exercise

Expected results:

BEE < AEE resting < AEE after excercise

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 an 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

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
  - Fiber
- Need to limit
  - Alcohol <30 g / day
  - Limit your intake of canned food and semi-finished products, fried foods and sausages (it is probably important factors causing DM II)
  - NaCl <5 g / day
  - Cholesterol <300 mg / day
  - Other factors - optimal dining culture (Medical Physiology, Javorka et al.)

  and don't smoke!

Daily diet

- For assessing 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 to 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 dosesIdeally calculated daily energy expenditure for an approximate comparison with income
  - Specific dynamic effect of nutrients

Nutrients

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

- Protein - ddd adults: 0.8–1.2 g / kg, children: 1.2-1.5 g / kg
  - must contain all the essential AMK in the correct proportions 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 AMK, plant proteins often lack some AMK - a plant diet is more difficult to compile
  - function: structural, signaling (hormones, receptors), as a source of energy only exceptionally (during starvation).
- Sacharides - ddd adults: 10-15 g / k, children 5-8 g / kg
  - The fastest energy source (17.1 kJ / g), mainly of plant origin.
  - Usable carbohydrates - 64% of energy intake (simple sacharides should be <10%)
  - Unusable carbohydrates - indigestible, part of fiber (mainly cellulose), ddd 25-35g / day - GIT motility support

Nutrients

- Fats: ddd adults 1g/kg, children 4-5 g/kg
  - The largest source of energy (38.9kJ / g) - especially storage functions
  - Other functions - fat-soluble vitamins, building, thermoregulation (brown adipose tissue, isolation), mechanical protection of organs, bones
  - Optimal ratio of fats in the diet: 10% saturated fatty acid (FA), 10-12% monounsaturated FA, 8 - 10% polyunsaturated FA
  - Cis-configuration FA - vegetable and most animal fats. Trans-configuration - dairy products, beef and mutton, industrial hardened fats (margarines) - increase in LDL-cholesterol concentration
  - Cholesterol (animal products only) - fce structural component of brain tissue, cell membranes, steroid hormone precursor, vit. D, bile acids - 4% of total cholesterol circulates in the blood 75% the body makes itself (liver), 25% from food

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

Metabolic syndrom (MS)

- Diseases of civilization containing 3 or more of the following factors
  - **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
  - **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 because: DM II with consequences, cardiovascular and cerebrovascular thrombotic events (heart attack, stroke, embolism), but as a result 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 → hyperglycemia and glucose deficiency intracellularly
  - **DM I** – starts in childhood, autoimmune destruction of pancreatic beta-cells - insulin substitution required, abolute insuline deficiency
  - **DM II** - in adulthood, insulin resistance (insensitivity) of target tissues (insulin resistance), relative insuline deficiency

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

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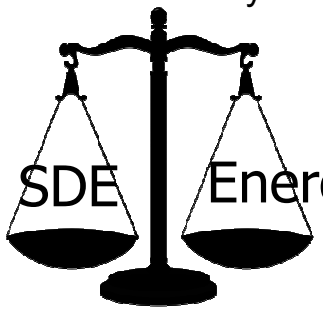
Protocol

- 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 (ane not printing automatically)
- Write in the protocol:
  - Sum of received energy, nutrients, minerals and vitamins,
  - Specific dynamic effect of nutrients
  - 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 state

Obesity

- Obesity - excessive storage of energy reserves in the form of fat. Energy intake is for various reason greater than expenditure.
  - CZ: adults: 35% overweight, 17% obesity – more in man
    children 6-12 year: 10% overweight /10% obesity; 13-17 years together 11%
- Obesity is caused by combination of various 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), education
  - Psychological influences - distress, depression
  - Prenatal influences (mother's behavior during pregnancy, diabetes, obesity - prenatal programming), delivery, early childhood
  - 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, complication in 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 can be malnourished - despite their high energy intake, some nutrients may be lacking
  - Our 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 glycemia):
  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, more saving metabolism). 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 physiologycal 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 / supply 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 aktivity.
    - Newly discovered pink adipose tissue - can differentiate into other cells, the mammary gland

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Adipose and muscle tissue – gender difference

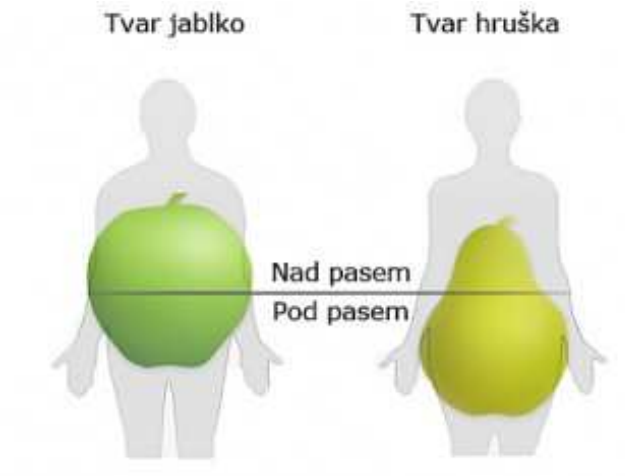
- Men have a larger proportion of muscles, it is easier to increase muscle tissue (testosterone), which is a greater energy consumer - better weight loss
- The same BMI in men and women has different risks - the risk of developing diabetes in women is usually at a much higher BMI than in men
- Different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

Android type of fat storage (apple, jablko)

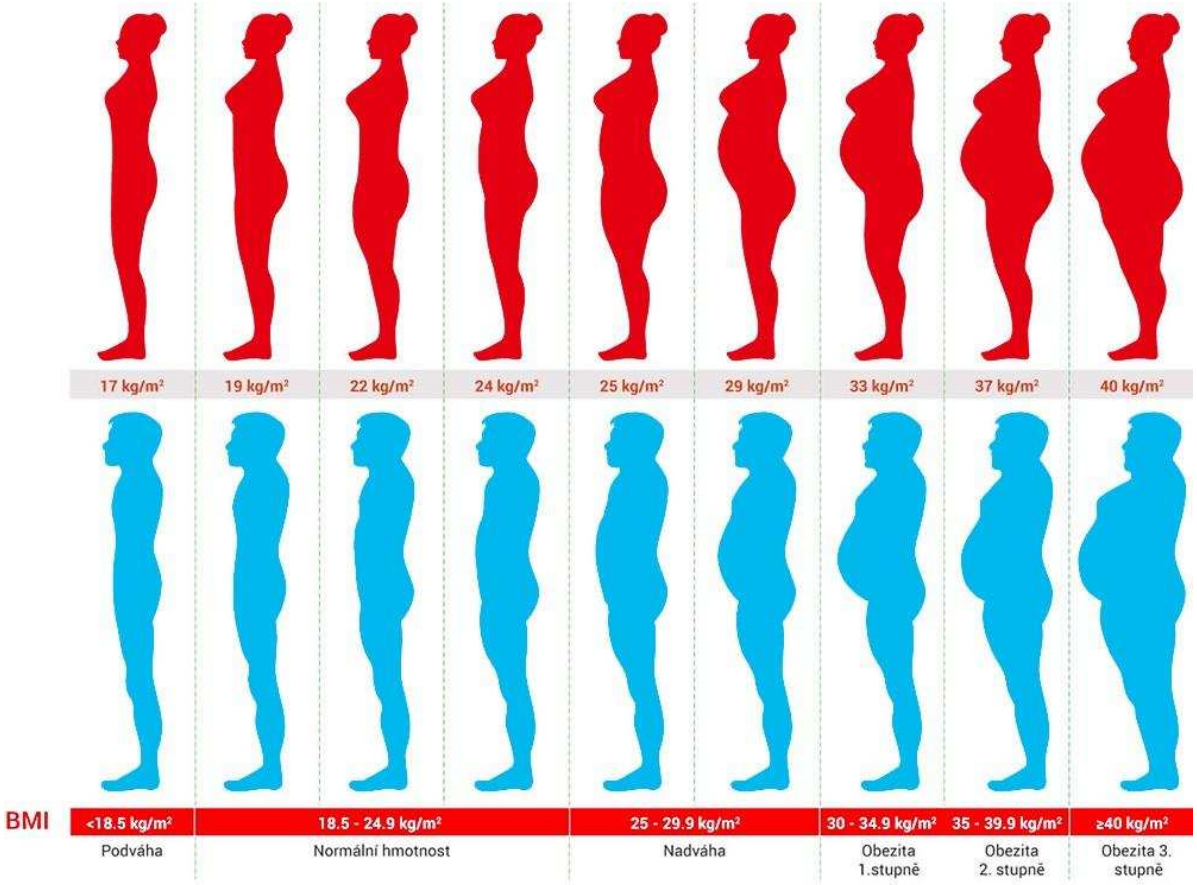
- accumulation of fat in the abdomen, subcutaneous tissue and between organs
- more harmful (greater cardiovascular risks)

Gynoid type of fat storage (pear, hruška)

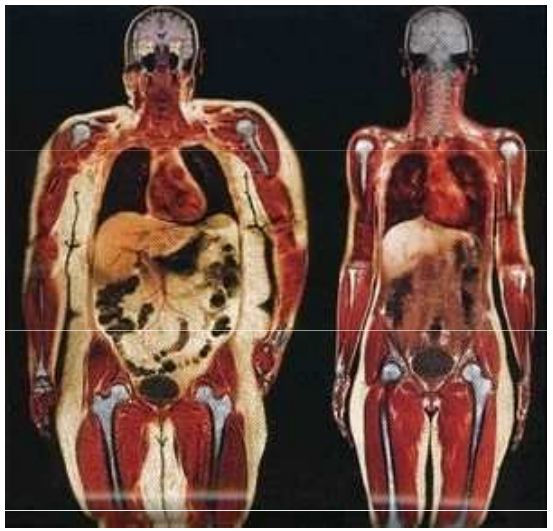
- storage in the thighs and buttocks - the function is storage
- energy for pregnancy and breastfeeding (lower cardiovascular risk)



Adipose and muscle tissue



Zdroj: mychoicemylife.com



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Vztah mezi jednotlivými faktory MS

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

  - Atherosclerosis - Trombembolic 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)
- Regular physical activity
  - Supports weight loss
  - Improves parameters of DM and metabolic syndrome
  - Positive effect on the psychical health (key 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 acording to the Broca‘s 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 ventilator

Ideal weight:

- man:
  - height (cm) – 100
  - Or (height in m)^2 – 23
- Pro ženy:
  - height (cm) – 100 – 10%
  - Or (height in m)^2 – 21,5

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

- Index= actual weight/ideal weight x 100

Indices based on anthropometric indicators

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

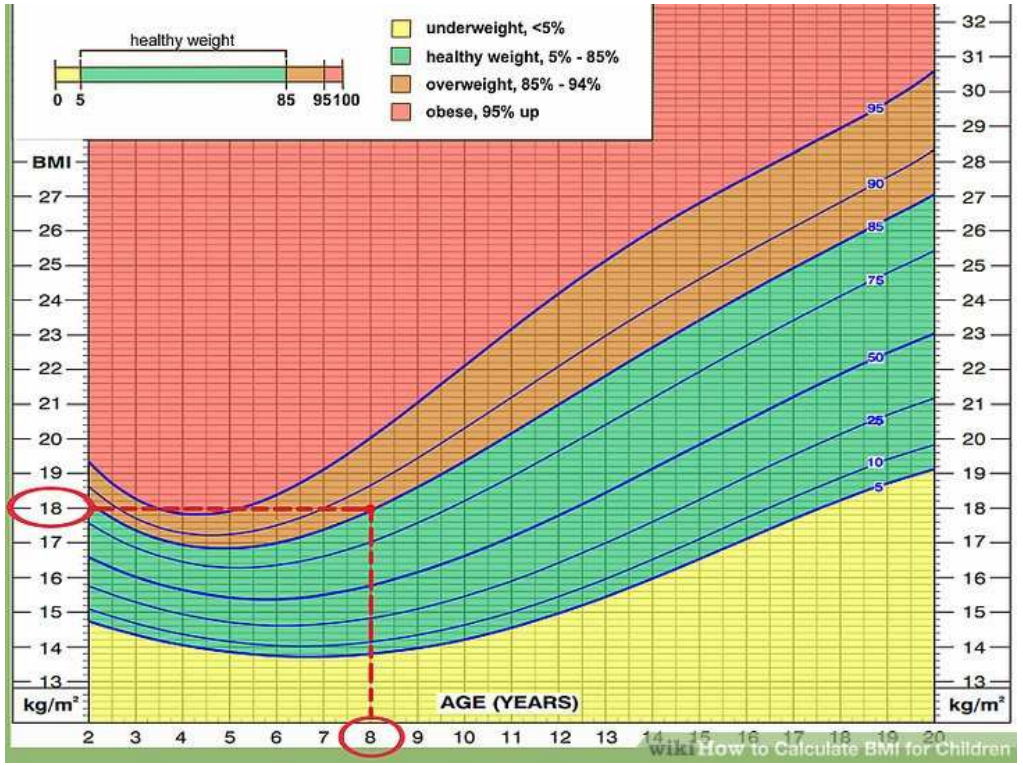
for adult

	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

- advantage: simple calculation
- disadvantages
  - BMI do not deal with constitution of body mass. A man with great musculature can be in overweight area of table without having a nutrition problem
  - **Broc's index** uses a linear relationship between height and weight - the index is very approximate
  - **BMI** - quadratic relationship between height and weight - better than Broc's, 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
  - **Rohrerův 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

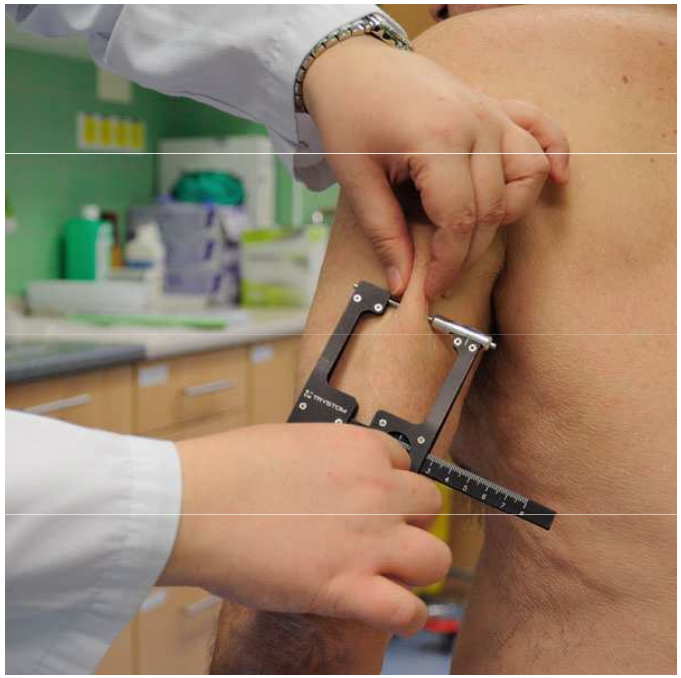
- Very simple but effective predictive parameters of nutrition evaluation

- waist/hip
  - man <1
  - woman < 0,8

Waistline in cm		
Category	**man**	**woman**
recomended	≤ 94	≤ 80
Necesary 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 reflests 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, above the abdomen, above the spina iliaca, above the thigh, on the lower leg)



the triceps skinfold			
	Normal (mm)	Mild to moderate deficit (mm)	Significant deficit (mm)
Woman	> 16,5	10 – 15	< 10
Man	> 12,5	7,5 – 11	< 7,5

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Bioimpedance method

Measurement of fat in the body

- Different body tissues have different impedance for very small electric current (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 is able to evaluate the % of fat, water and bone tissue

Bioimpedance method

Measurement of fat in the body

– The handpiece measures the upper half of the bodywhole 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
  - man

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

  - woman

$$kPSP = \frac{(arm\ circumference - \pi \cdot the\ triceps\ skinfold)^2}{4 \cdot \pi} - 6{,}5$$

Muscle loss	No loss (cm)	mediu m (cm)	heavy (cm)
woman	> 23,2	14 – 21	< 14
man	> 25,3	15 – 23	< 15

Deficit	No deficit	mild	medium	heavy
woman	> 36,3	29,1 – 36,3	25,5 – 29,0	< 25,4
man	> 40,9	32,8 – 40,8	28,7 – 32,7	< 28,6

Conclusion

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