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Training Objectives:

- ✓ Knowledge of the most important function of nutrients
- ✓ Description of both, mechanism and function of gluconeogenesis
- ✓ Knowledge of the difference between essential and conditionally essential nutrients
- ✓ Knowledge of the standard energy requirement as well as of energy required in case of illness
- ✓ Explanation of the terms „enteral nutrition“ and „parenteral nutrition“

NUTRITION OF THE BODY

In all phases of life the human body is in need of a constant supply of nutrition, in order to ensure growth or to maintain the normal bodily functions.

This chapter will provide information about the nutrients the human body needs as well as about the functions of the single nutrients. The consequences arising from a deficit of certain nutrients will be shown. You will get to know some mechanisms the body is able to activate in order to compensate these deficits for at least a short period of time. In this context the differentiation between essential and conditionally essential nutrients is of relevance. Furthermore you will get information about the energy required by the human body including the basal metabolic rate as well as the energy required in case of illness. The chapter closes explaining the different methods of feeding that might be applied in case of illness. It is to be distinguished between enteral and parenteral nutrition.

5.1 Nutrient Groups

Nutrients may be divided into two major groups i. e. calorific and non-calorific nutrients. The division of these two major groups of nutrition is based upon the fact that non-calorific nutrients do not provide the body with the necessary substances for energy production which, among other tasks (as described below), is ensured by high calorie nutrients.

Non-calorific nutrients are water, electrolytes, vitamins and trace elements.

- **Water** is the biological „solvent“ in which all biochemical processes take place.
- **Electrolytes** (sodium, potassium, calcium, magnesium, chloride, phosphate and bicarbonate) ensure the correct division of the fluid spaces and maintenance of the correct conditions that are necessary to perform important tasks such as the transmission of stimuli as well as muscle movements. Apart from that electrolytes contribute to the formation of bones and teeth.
- **Vitamines** (A, D, E, K, B1, B2, B6, B12, C, biotin, folic acid, nicotinic acid and pantothenic acid) as well as **trace elements** (iron, copper, zinc, manganese, selenium, molybdenum, chromium, iodine and fluorine) are mainly important as parts of enzymes. Enzymes are substances the human body needs to perform certain biochemical processes that would not go without them.

Calorific nutrients are proteins, carbohydrates and lipids:

- **Proteins** are substances consisting of up to 20 different building blocks, the so-called amino acids. They are the only substances of the body containing a considerable quantity of the element nitrogen, i. e. 16 % of their dry weight. The body produces its own proteins out of amino acids in order to ensure a variety of different functions. In terms of quantity the development of muscles is of prior importance since they provide the ability to perform physical work. Proteins that are solved in fluid spaces as well as in blood are in second place as regards quantity since they ensure defence reactions against infections, the binding and transport of water-insoluble substances as well as blood coagulation in case of injuries, just to name a few.

Important

Proteins are the functional mass of the body. All bodily functions are based upon specialised and body-produced proteins. They are chemically characterised by their 16 % share of the element nitrogen.

Protein metabolism and synthesis are a constant process in the human body. Amino acids that are produced as a result of protein metabolism are largely reused for protein synthesis. Some, however, get lost during the oxidation process, i. e. amino acids are transformed into the carbohydrate glucose (so-called **gluconeogenesis**) serving as energy source for oxidation processes. So, proteins do also contain calories, in fact 4 kcal/g. The process of gluconeogenesis serves to ensure that those cells and organs that cannot make use of an alternative energy source (see section „carbohydrates“) are sufficiently supplied with glucose. Gluconeogenesis is increased in case of infections or injuries (see chapter 5.4).

Those amino acids lost in the process of gluconeogenesis must be supplied to the body in the form of food protein which is found in high concentrations in meat, fish and eggs.

Important

Gluconeogenesis is the production of glucose serving to ensure the supply of brain and red blood cells with this energy source.

- By **carbohydrates** we understand a group of substances consisting of different building blocks, all of them having in common the chemical formula $C_n(H_2O)_n$. In terms of quantity glucose is the most important building block. The main purpose of carbohydrates is to supply energy (4 kcal/g). In food they are mainly found as starch in cereal products or potatoes. Further important carbohydrates are cane sugar (saccharose) and milk sugar (lactose). Cells are only able to oxidise glucose. Other building blocks of carbohydrates such as for example fruit sugar (fructose) are therefore at first transformed into glucose.

Glucose is the only energy source all body cells make use of for energy production. For the brain and the red blood cells it is the only energy source. In view to their central importance the body must ensure a continuous supply with glucose. Therefore, after intake of carbohydrates as part of the food a certain share of glucose is stored in the liver as glycogen. This glycogen means a reserve of 200 g of glucose. In case of a lack of external administration a constant energy supply of the brain and red blood cells is ensured for a period of 18 hours. The only additional source of glucose the human body has is the protein (see above).

Important

Glucose is the only energy source for the brain and blood cells. In case of a lack of external administration the human body makes use of two mechanisms in order to keep these tissues supplied with energy: The conversion of glycogen into glucose and the conversion of amino acids into glucose (gluconeogenesis).

- Among the lipids triglycerides mainly serve as energy source. Triglycerides consist of glycerol and fatty acids, the latter being of importance for the synthesis of membranes. Triglycerides also serve as the major medium for energy storage in the body. Triglycerides mainly occur in oils and fats as well as in the fatty tissue of meat. Oxidation of 1 g of triglycerides produces an average of 9 kcal.

Table 5 gives a survey on the calorific values of calorific nutrients

Table 5: Average calorific value of important nutrients per gram

1 g Carbohydrate	4 kcal	17 KJ
1 g Protein	4 kcal	17 KJ
1 g Fat	9 kcal	40 KJ

5.2 Essential and Conditionally Essential Nutrients

Since the body has to sustain a natural loss of all nutrients, these losses need to be compensated. In view to this fact the following questions arise:

1. To which extent may nutrients be interchanged against one another?

2. When does the reduced intake of a single nutrient lead to a deficit?

3. What consequences does the deficit of a nutrient have?

Since the answers to these questions are rather complex and extensive only basic information will be given.

Ad 1) Substitution of nutrients:

In most cases nutrients cannot be substituted against one another. This is the case, for example, in all non-calorific nutrients, in 8 out of the 20 amino acids as well as in the nitrogen contained in proteins, where the body is either not able to produce these substances itself or the quantity produced is so small that the natural losses cannot be compensated. These nutrients are called essential.

While the absolute need of calories must be covered by administration, carbohydrate calories may to a large extend be substituted by lipid calories and vice versa. The triglycerides of certain lipids, however, do contain two essential fatty acids, the linoleic acid and the α-linolenic acid. Their functions in the membranes cannot be replaced by any other nutrient.

Important

The majority of nutrients is essential which means, the body needs the substance for functioning. However, it is not in a position to produce the substance at all or the quantity produced is only insufficient.

Ad 2) Development of deficits:

Essential nutrients need to be supplied by the intake of food in order to avoid the development of deficits. The development of deficits depends on the degree of nutrient demand. So in normal life a severe deficit in water develops after a period of a few days already while a protein deficit is the result of a several weeks lasting lack

of supply. In case of illness, a nutrient deficit can develop much more quickly. So, a severe diarrhoea, for example, might lead to a serious water deficit within a few hours‘ time and the considerably increased gluconeogenesis going along with infections makes severe protein deficits occur after a few days already.

Ad 3) Consequences resulting from deficits

If a deficit of certain nutrients occurs, their tasks are ensured to a limited degree only and finally are no longer fulfilled at all. This leads to the development of diseases that may be treated by supplying the respective nutrient. An increase in deficit goes along with a progression of the disease, increased disturbance of the bodily functions and finally death from nutrient deficit.

Important

Nutrient deficits lead to severe illness that might result in deficit-related death

Apart from essential nutrients there is the group of so-called conditionally essential nutrients. In concrete terms, as regards their function these nutrients may not be substituted by other nutrients. The healthy adult, however, does not really need to supply them by way of food intake, since the body is able to produce them itself. In elder or ill patients the demand of conditionally essential nutrients may be increased or the endogenous production reduced which leads to a nutrient deficit. 12 out of 20 amino acids, for example, are not essential for the healthy adult while none of the 12 amino acids‘ functions may be compensated by another amino acid. Thus, a deficit of such an amino acid will lead to the same consequences as it is the case for essential nutrients (see above). Infants are a typical example, since almost all 20 amino acids are essential.

Important

Any nutrient getting into a deficit becomes essential, if its function cannot be ensured by a substitute nutrient

For most of the nutrients there exist valuable recommendations for an adequate and well-balanced food intake in healthy people, e. g. recommendations issued by the „Deutsche Gesellschaft für Ernährung“.

5.3 Human Energy Requirements

The human energy requirements mainly depend on age, sex, height and weight as well as of the degree of physical activity.

Apart from the need resulting from physical activity there is a minimum of energy a person needs during the state of rest, the so-called basal metabolic rate. Depending on the person's constitution it amounts to 1110 – 1800 kcal/day for an adult , however, it may vary in very small or very tall persons. There are different possibilities to determine the basal metabolic rate, such as tables giving standard basal metabolic rates depending on age, sex and height. Apart from that the empirical formulas acc. to Harris and Benedict have proven their usefulness:

BMR_{male}	**= 66 + (13.5 x BW) + (5 x H) – (6.8 x A)**

BMR_{female}	**= 655 + (9.6 x BW) + (1.8 x H) – 4.7 x A)**

Fig. 8: Formula to determine the basal metabolic rate acc. to Harris & Benedict BMR = basal metabolic rate, BW = body weight in kg, H = height in cm, A = age

The basal metabolic rate is ensured by the body's utilisation of calorie-containing nutrients. Proteins, carbohydrates and lipids contribute their respective share in this process depending on the amount of intake respectively. In Europe the usual nutrition consists of 10 – 20 % proteins, 40 – 60 % carbohydrates and 20 – 40 % lipids, the total always amounting to 100 %, of course.

The relative share of calorie-containing nutrients in energy production corresponds to their amount of intake. However, excessive intake of lipids leads to a storage of lipids in the adipose tissue. Furthermore, excess quantities of carbohydrates resulting from excessive intake are also transformed into lipids which is finally stored in the adipose tissue.

In healthy subjects a calorie demand exceeding the basal metabolic rate is mainly due to an increase in physical activity.

Important

Energy requirements are defined as the amount of energy the body needs depending on the situation. It is made out by the basic metabolic rate and possible additional requirements resulting from physical work.

5.4 Energy Requirements in Case of Disease

A disease may cause a substantial increase of energy demand at rest. This is a disease-induced increase of basal metabolic rate.

In clinical practise the energy requirement of an adult is simply determined as 25 kcal/kg body weight per day. In case of acute infections and inflammation or severe injuries this value may increase to about 30 kcal/kg body weight per day. In very rare cases such as severe burns it may be even increased to 35 – 40 kcal/kg body weight per day.

Situations as described are characterised by a strongly increased consumption of proteins. It may amount to four times the standard value and is due to a strong increase of the gluconeogenesis. Since proteins represent the body's functional mass a severe, even life-threatening protein deficiency may develop.

Important

Infections, inflammations and injuries go along with an increase in energy demand. The body's proper functioning is critically at risk because of the protein catabolism which is due to the considerably increased gluconeogenesis.

5.5 Enteral and Parenteral Nutrition

In clinical practise there may be situations where normal food intake by eating and drinking is not possible. In case the intestine may be used as access, patients may receive special diets by way of feeding tubes. This is called **enteral nutrition** (enteros: greek for intestine). If enteral nutrition is not possible feeding is done via the veins, the method being called **parenteral nutrition** (passing the intestine). Both,

enteral and parenteral nutrition serve to supply the body with a sufficient quantity of nutrients in order to maintain the body's function. However, particular with regard to maximum protein supply deficits can often not be completely compensated.

Important

If diseases make normal food intake impossible feeding has to be done via tubes (enteral nutrition) or via the veins (parenteral nutrition) since otherwise life-threatening nutrient deficits may develop. In this respect a protein deficit represents a particular risk.

Nutrient supply in enteral nutrition is mainly standardised by using tube feedings. As regards composition and quantity of the respective single components these tube feedings meet international dietetic demands.

Nutrient supply in enteral nutrition is done in accordance with a special diet regimen consisting of suitable individual components such as

- Amino acid solutions
- Glucose solutions
- Lipid emulsions
- Electrolyte concentrates
- Vitamins and trace element preparations

Sooner or later all nutrients develop into a deficit if they are not adequately supplied. Since such a deficit entails severe consequences, it must be ensured that in parenteral nutrition all nutrients are supplied in sufficient large quantities.

As regards nutrient supply in different clinical situations scientific literature provides a number of useful recommendations (e. g. Safe Practices for Parenteral Nutrition Formulations, JPEN 22 (1998) 49 – 66).

5.6 Summary

Nutrients may be divided into two large groups: Among the non-calorific nutrients are water, electrolytes, vitamins and trace elements while proteins, carbohydrates and lipids belong to the group of calorific nutrients. The single nutrients contribute their individual shares to maintain the body's function.

The majority of nutrients is essential, i. e. the body is in absolute need of them, however, it cannot produce them itself (either at all or in sufficiently large quantities). Talking of conditionally essential nutrients, we mean those nutrients, which the human body is actually able to produce in sufficient quantities. However certain circumstances may cause these nutrients to develop into a deficit.

The basal metabolic rate of humans depends on age, sex, body height and weight. In addition, energy demand is influenced by the degree of physical activity. The relative share of energy-containing nutrients in the body's energy production corresponds to the amount of them being supplied.

Illness may lead to a (significant) increase of energy demand. In case of severe injuries, such as burns, the metabolism of proteins is significantly increased due the process of gluconeogenesis which may result in a life-threatening protein deficiency. Enteral nutrition (by way of tubes into the intestine) as well as parenteral nutrition (by way of catheters into the veins) are supplied in order to ensure sufficient intake of all nutrients and thus maintenance of the body's function.

5.7 Comprehension Questions

- Name the four non-calorific nutrient classes and explain their function for the body!
- Explain the great importance of glucose!
- What function do triglycerides have?
- How many kcal of energy are respectively produced during metabolisation of glucose, proteins and fat?
- Explain the process of gluconeogenesis, its purpose as well as the resulting consequences in parenteral nutrition of severely injured patients!
- Explain the difference between essential and conditionally essential nutrients!
- What is to be understood by enteral and parenteral nutrition?
- On which factors does the human energy demand depend?
- What is the simplified formula to be applied for determining the energy demand in enteral and parenteral nutrition?
- What consequences do acute infections and inflammations or severe injuries have with regard to energy consumption?
- What individual components does a regimen for parenteral nutrition consist of?