Influence of diet on the results of laboratory tests

Wpływ sposobu odżywiania na wyniki badań laboratoryjnych

Kinga Lis

Department of Laboratory Medicine, Nicolaus Copernicus University in Torun, Collegium Medicum, Bydgoszcz, Poland
Head of Department: Prof. Grażyna Odrowąż-Sypniewska MD, PhD

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Abstract

Blood and urine laboratory tests are necessary to diagnose the state of the patient. These tests are also helpful in the assessment of diet and nutritional status of the organism. It is recommended that both blood and urine for laboratory tests be collected in the morning, from fasting patients after an overnight rest. These conditions are defined as the standard conditions for collection of material for laboratory testing. Before testing, patients should follow their natural diet and avoid physical exertion, night work, long-distance travel, as well as consumption of alcohol and drugs. They should also reduce the consumption of synthetic vitamins and herbal remedies and other dietary supplements. Medications should be limited to those that are absolutely necessary. All of these factors can affect the results of laboratory tests.

Streszczenie

Badania krwi i moczu stanowią niezbędny element diagnostyki stanu klinicznego pacjenta. Badania te są również pomocne w ocenie stosowanej diety oraz stanu odżywienia organizmu. Zarówno krew, jak i mocz do badań laboratoryjnych wykonywanych rutynowo i wcześniej zaplanowanych trzeba pobierać rano, po całonocnym wypoczynku, na czczo. Przed badaniami pacjent powinien stosować swoją naturalną dietę oraz unikać wysiłków fizycznych, pracy w godzinach nocnych, dalekich podróży oraz spożywania alkoholu etylowego i środków odurzających. Należy ograniczyć także spożycie syntetycznych witamin, środków ziołowych i innych suplementów diety. Leki powinno się ograniczyć do tych, które są absolutnie konieczne. Warunki te określa się jako standardowe warunki pobierania materiału do badań laboratoryjnych.

Introduction

There are a variety of different biological materials which can be used for laboratory tests. Depending on the type of research and the clinical condition of the patient, for laboratory tests appropriate types of biological material are collected: blood (venous, arterial, capillary), urine (first morning sample, second morning sample, a random sample or a sample from the daily collection), stool, cerebrospinal fluid, fluids from body cavities (pleural, peritoneal, pericardial), synovial fluid, sections, smears, biopsies, scrapings, nails, hair, sputum, saliva, sweat, and others [1, 2].

Biochemical, immunochemical and morphological blood tests provide a lot of essential information about both hematological function and functioning of all organs of the body. Inclusion of urine testing is an essential part of the patient's diagnosis. Laboratory testing is also often helpful in assessing the nutritional status of the organism. During the diagnosis of pathological changes, a blood and urine test allows one to evaluate intrasystemic metabolic balance, the type and severity of dysfunction of organs and systemic diseases or acute and chronic poisoning. Laboratory tests are necessary in the selection of appropriate drug therapy, and monitoring the effectiveness of the treatment [1, 2].

It is assumed that both blood and urine laboratory tests routinely performed and already planned should be taken between the hours of 7 and 9 am, from persons who are after an overnight rest, fasting, or 10–12 h after the last meal. In the period preceding the survey, patients should stay on their current diet, unless special requirements of the test require additional special dietary restrictions. Material for laboratory tests must be taken before the start of treatment or after a possible discontinuation of medications that may affect the level of the measured analyte, if it does not disturb the treatment process. These requirements are referred to as standard conditions of collection of material for laboratory testing [1, 3].

Why is it so important to prepare for the laboratory?

The laboratory test results are influenced by many factors. Some of them depend on us, while on others

we have no influence. Factors changing laboratory test results, on which we have an influence, are called modifiable factors or variables. They are determined by the patient and are subject to change caused by him. In this way patients may affect the results of laboratory analysis both consciously and unconsciously. Factors that affect the results of laboratory analysis and are dependent on the patient include physical activity, height above sea level, mental stress, medication, drugs and dietary supplements, as well as nutrition. Here are also included those factors that are associated with the collection and transport of the material to the laboratory [1, 2, 4–8].

The factors outside of our control are called non-modifiable factors. These are the environmental factors intrinsic to the patient, which are independent of his will, and have an impact on the results of laboratory tests. The factors inherent to the patient that influence the results of laboratory tests include gender, age, race or ethnic origin, and in the case of pregnant women the stage of its duration and the period of confinement [1, 2].

What does it mean to be fasting?

The patient often is not aware of the meaning of "fasting". Many respondents could not correctly determine the time of refraining from eating, after which it can be said that a person is "fasting". "Fasting" means being 10 to 12 h after the last meal intake. At that time one is allowed to drink small amounts of water if absolutely necessary. It also involves keeping a dietary regimen for the last meal prior to collection of the material for the analysis. It should be a small and easily digestible meal [1, 2, 4–8].

What is a diet?

Nutrition has a strong impact on the overall condition of the body. It is also one of the most important factors affecting the results of a large number of basic laboratory tests such as complete blood count, blood glucose, total protein, albumin, sodium, potassium and lipids, enzymes and urinalysis. Diet is also one of the most common ways of modifying the patient's test results in both a conscious and accidental way. Diet is known as nutrition with adjustment of the amount and type of food to individual needs. It is also considered that the diet is often not only a means of nutrition but also a lifestyle. It is one of the main factors affecting the various parameters evaluated in the laboratory [9–11].

The effect of diet on the results of laboratory tests can be temporary or long lasting. Acute effects of diet on the results of laboratory tests are understood to mean both due to the effect of eating a meal before taking blood for testing, and due to the occasional consumption of food unusual for a person. The long-term impact of diet on the results of laboratory tests mean effects associated with the use of patient-specific diet for a long time. Also noted is the significant impact of hunger and malnutrition on the results of laboratory tests [9–11].

What will the effect of a standard meal be?

Consumption of a standard meal, defined as 75 g of carbohydrates, leads to changes in the concentration of many routinely tested parameters and serum turbidity, due to the presence of fat from the meal. Eating a meal of approximately 700 kcal constituting about 25% of the energy requirements of an adult human, balanced with regard to protein, fat and carbohydrate contents, can cause a few percent increase in the blood concentration of sodium ions and calcium ions. There is also observed a several percent increase in the concentration of urea, uric acid, albumin and total protein. Increase in the concentration of said analytes, however, does not exceed 5%. It is believed that important parameters are those whose level after a meal increases more than 5%. After the meal, however, there is observed in the serum a nearly 10% increase in the concentration of potassium ions and alanine aminotransferase (ALT). The concentration of phosphate, glucose or bilirubin in these conditions is higher by about 15%, and aspartate aminotransferase (AST) by up to 18% in relation to the analysis of the blood collected in the fasting state. The largest increase in the blood, as much as 50%, relates to triglyceride, fat derived from consumed food [1, 2, 4–10].

After approximately 2 h following a meal, the concentration or activity of most of these parameters returns to baseline, measured in the fasting state. This does not apply to triglycerides, high concentrations of which after a meal are maintained up to 6–8 h after eating [1, 2, 4–10].

There is a panel of laboratory tests for which the blood must necessarily be taken in the fasting state. Such tests include measurement of the concentration of iron, phosphorus, cortisol, folic acid, triglycerides, total cholesterol and its fractions (LDL, HDL), insulin, C-peptide, and glucose. Oral glucose tolerance test must also be performed in the fasting state [1, 2, 4–10].

It is also recommended, but not absolutely necessary, blood sampling in the morning, in the fasting state, for such research as coagulation parameters (PT, APTT, fibrinogen), magnesium, calcium, urea, creatinine, uric acid, prolactin, total protein, bilirubin, AST, ALT, alkaline phosphatase (ALP), lactate dehydrogenase (LDH), peripheral blood count and erythrocyte sedimentation rate (ESR) [1, 2, 4–10].

What could be the effect of long-term use of a particular type of diet on the results of laboratory tests?

There are many dietary patterns that deviate from the accepted and recommended balanced diet based

on the "pyramid of healthy eating". These include a number of therapeutic diets and periodically popular weight loss diets, often colloquially called "miracle diets" [9–11].

Low-protein diet

Low-protein diet is a therapeutic diet, used in chronic kidney disease. This way of eating is associated with a significant reduction in protein intake. It aims to reduce products of protein metabolism harmful for the body and reduce the burden on the kidneys. The supply of protein per day in the diet is 40–50 g (about 0.6–0.7 g protein/1 kg body weight/day). This is less than the daily demand for this component provided for an adult (about 1 g of protein/1 kg of body weight/day). In special cases, the protein content of the diet is less than 40 g. This should be mostly complete protein of animal origin [9, 10].

The result of laboratory tests is primarily a visible reduction in the concentration of prealbumin and retinol binding protein in the blood. As low protein diets are incomplete diets, they lead to a reduced concentration of calcium and iron in the blood. There may also be a deficiency of water soluble vitamins. In the blood, also increased concentration of phosphorus is noted [1, 2].

High-protein diet

Protein intake per day is about 1.5 and up to 2.5 g of protein per pound of body weight. Most of the ingested protein is of animal origin. A high-protein diet is especially recommended for athletes during the building of muscle mass, as well as those with a chronic disease process or starvation, and one of the weight-loss diets called the Dukan diet. Such a high content of protein in the diet is a significant burden on the kidneys, liver and pancreas [9–12].

The results of the laboratory tests that are available on the high protein diet show an increase in the concentration of ammonia, urea, uric acid, total protein and homocysteine in the blood. Ingestion of such large amounts of protein, in particular of animal origin, is also accompanied by significant acidification of urine [2, 9, 10, 12].

Low-fat diet

Low-fat diets are used as a therapeutic diet in conditions associated with impaired digestion or absorption of fats (such as cholecystolithiasis or inflammation of the pancreas). Sometimes they are also used as an unbalanced weight loss diet (for example the Ornish diet) [9, 10, 13, 14].

The low-fat diet assumes a reduced intake of fat, especially animal. The content of fat in the diet is from 30 to 50 g per day, including both vegetable fats and animal fats. Adults following a basic balanced diet consume an average of about 65 g of fat per day [9, 10, 13, 14].

Low-fat diets are deficient in fat-soluble vitamins, such as A, E and D. A deficiency of antioxidant vitamins (A, E) carries a higher risk of damage due to free radicals and faster aging of the body. A low-fat diet does not provide appropriate quantities of essential fatty acids, including linoleic acid and linolenic acid, indispensable for the proper functioning of the nervous system and the immune system [9, 10, 13, 14].

The results of laboratory tests primarily show a decrease in total cholesterol (approximately 8%), LDL cholesterol and triglycerides (TG). There is also lowered concentration of fat-soluble vitamins and minerals. It is associated with vitamin D deficiency. As a result of an unbalanced diet restricting mainly fats and animal products, there may be deficiency anemia (vitamin B_{12} deficiency, such as iron) [9, 10, 13, 14].

High-fat diet (e.g. Kwasniewski diet)

Recommended, in this model of nutrition, proportions expressed in grams of protein : fat : carbohydrates are in the initial period 1.0 : 2.5–3.5 : 0.8. Then it is assumed to reduce the amount of protein. It is recommended to consume fatty animal products and vegetables low in carbohydrates, such as tomatoes, cucumbers and brassicas. Due to the excess of animal fats, which are a source of cholesterol, a high-fat diet is considered to be conducive to atherosclerosis [9, 10, 15–17].

A significant increase in blood TG levels is observed from 1 to 4 h after intake of a meal. After absorption from the gastrointestinal tract TG are present in the plasma for a period of 6–12 h. A high-fat diet causes evident lipemia in serum. This reflects turbidity of the sampled material, caused by triglycerides contained therein. This often makes the collected blood sample unsuitable for any laboratory tests. In the laboratory test results of persons on a high-fat diet there can be observed a significant increase in TG and cholesterol levels in the blood, especially LDL cholesterol (commonly known as "bad cholesterol"). Also there are increased concentrations of free fatty acids and glycerol. A high-fat diet, with a significant deficit of carbohydrates, is among the ketogenic diets. Therefore it is conducive to the development of diabetic ketoacidosis, as an effect of abnormal lipid metabolism in the absence of adequate amounts of glucose. In serum a reduced glucose level is observed. Shortage of dairy products, fruits and vegetables results in deficiency of minerals such as calcium and magnesium. Consuming large quantities of animal products leads to excess sodium, phosphorus, iron and zinc. There is a deficiency of water-soluble vitamins (C, B_6 and folic acid) and excess of lipid-soluble vitamin A. Ketone is a product of lipid metabolism which also appears in the urine [9, 10, 15–17].

High-fat, low-carbohydrate diet (e.g. Atkins diet)

A high-fat diet with low carbohydrate content involves much consumption of fats, which must be combined with protein and carbohydrate-containing foods avoidance. Besides sugar, the daily diet completely eliminates potatoes, cereal, rice, pasta, flour and bread. The first phase of this diet is also associated with complete prohibition of the consumption of fruit. Eating large amounts of fat quickly leads to a feeling of fullness. This reduces the volume of meals, which leads to weight loss. The amount of carbohydrates is significantly reduced in the initial phase of the diet (30–40 g a day) and fat intake is well above 100 grams per day, while maintaining the right amount of protein (0.8–1.0 g per kg body weight). The result is rapid weight loss. This state of the organism is sometimes referred to as a hidden starvation state and involves significant ketosis [9, 10, 13, 18].

The results of laboratory tests show elevated levels of cholesterol and lowered blood glucose levels. The developing ketoacidosis can be seen as the presence of ketones in the urine. The reduction of consumption of fruit is associated with deficiency of water-soluble vitamins, accompanied by an excess of fat-soluble vitamins, due to their excessive consumption [9, 10, 13, 18].

The diet of easily digestible carbohydrate restriction

The diet of easily digestible carbohydrate restriction is prescribed for patients with diabetes. It involves exclusion from the diet of glucose, fructose and sucrose, while the supply of complex carbohydrates including dietary fiber is increased. Carbohydrates should provide about 55–60% of the energy value of the diet. The amount of protein in the diet per day should be 0.8–1.0 g per 1 kg of body weight, which is consistent with the assumptions of the basal diet. The share of energy from fat in the diet should not exceed 30%. This model is aimed at alignment of nutrition blood glucose levels and prevents daily fluctuations. Good control of glucose levels prevents the complications of diabetes and diabetic ketoacidosis. The results of laboratory tests show slight variations of daily glycemic profile, with the assumption that the maximum concentration should not exceed the renal threshold. Due to the controlled content of fat, particularly of animal origin in the diet, there is also observed a reduction in total cholesterol and triglyceride levels [9, 10, 19–22].

High-carbohydrate diet (such as the Mediterranean diet)

It is a diet based on the "healthy eating pyramid". It consists of cereals, vegetables, fruit, a limited amount of animal products (meat, eggs), a small amount of fats (mostly vegetable) and a minimum amount of sugar. Reducing the amount of animal products in the diet, especially fat, affects the level of cholesterol in the blood. The high content of fruit and vegetables and complex carbohydrates (whole wheat bread, pasta) raises the level of folic acid, vitamins B_6 and B_{12}, and vitamin C. The continuation of good health is also helped by a large intake of vegetable fats and fish rich in polyunsaturated fatty acids [2, 9–11, 22].

Vegetarian diet

There are many different varieties of a mainly vegetarian approach to eating animal products and fish and the type and form of plant products consumed. The vegan diet is restricted to foods of plant origin, including cereals, root crops, pods, vegetables, fruits, nuts and mushrooms. Semi-vegetarianism however allows consumption of limited amounts of fish, poultry, eggs and dairy products [9, 10, 23, 24].

Both products of plant origin and dairy products have alkaline properties. Therefore, the laboratory test shows a change of apparent pH of the urine from slightly acidic to alkaline (pH > 7). There are observed limited deficiencies associated with the avoidance of products of animal origin, such as low levels of iron and vitamin B_{12} in the blood serum, arising out of iron-deficiency anemia and vitamin B_{12} deficiency, or mixed anemia [9, 10, 23, 24].

Starvation or malnutrition

Starvation can involve either the total absence of food (total starvation) or situations in which the quantity of food is insufficient to meet the body's needs (incomplete starvation). Incomplete starvation may be determined as a quantitative starvation when the body is provided a balanced diet in terms of the content of primary nutrients, but with insufficient energy value, and qualitative starvation when there is a deficiency in certain nutrients such as proteins, minerals, carbohydrates, lipids or vitamins. An example of a quantitative starvation diet is lower energy value than 1000 kcal per day, while qualitative starvation diets are considered as all those unbalanced in terms of proteins, lipids and carbohydrates. This includes the majority of weight loss diets based on one group of nutrients, called mono-diets (e.g., high-protein or high-fat diet), and elimination diets [1, 9, 10, 25].

Changes in results of laboratory tests observed in the process of starvation are the result of breakdown of the stocks held in the body and loss of water. First, carbohydrates are metabolized (supply of them is small, about 400 g). Lipids and proteins (mainly contained in the muscle) are used in a more advanced stage of starvation. In results of laboratory tests, there is a growing concentration of serum uric acid and creatinine, a degradation product of the organism's own

proteins and the level of ketones as lipid combustion products. Prolonged starvation entails the destruction of the body and ketoacidosis. The increased excretion of ammonia, creatinine, phosphates, ions of calcium, sodium and potassium with urine is observed. Simultaneously in the blood, a decrease in protein levels, cholesterol, triglycerides, calcium, apolipoprotein and urea is observed. It reduces the concentration of thyroid hormones (T3 and T4) in serum. This leads to a significant slowdown in the organism metabolism [2, 25].

Summary

The laboratory test is a complex multistage process. Detailed here are the pre-analytical, analytical and post-analytical phase. Each of them is fraught with a certain error, which ultimately affects the quality of collected, in the course of research, laboratory test results. It is estimated that 61.9% of the errors are related to the pre-analytical phase, 15% to the analytical phase, and 23.1% to post-analytic phases of laboratory testing [26]. A significant percentage of error in the pre-analytical phase of laboratory testing is related to its complexity and the human factor. This error can be caused by improper collection and transport of biological material to the laboratory, its registration and identification, and pre-treatment or archiving for later determinations, and also correct filling of orders for testing, selection of research and education and preparation of the patient. The patient is often the weakest link of this stage of laboratory testing [26–28].

There are many factors that can affect the result of the laboratory tests having to do with the preparation of the patient. These include non-modifiable factors, including age, gender or ethnic origin and variable factors, such as diet and lifestyle of the patient and his education in preparation for the planned laboratory tests [26–28].

In order to avoid erroneous interpretation of the results of laboratory tests it is recommended that sampling be done in the morning, the fasted state, 10–12 h after the last meal, which should be easy to digest. Before testing, the patient should keep the natural diet and avoid physical exertion, night work, long-distance travel and consumption of alcohol and drugs. The person should also limit the intake of synthetic vitamins, herbal remedies and other dietary supplements, and medications should be limited to those that are absolutely necessary.

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Address for correspondence:

Kinga Lis MD, PhD
Department of Laboratory Medicine
ul. M. Skłodowskiej-Curie 9, 85-094 Bydgoszcz, Poland
Phone: +48 52 585 40 46
Fax: +48 52 585 36 03
E-mail: k2lis@cm.umk.pl