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The influence of physical activity on selected biochemical parameters - what do physically active people know about it?

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Abstract

Introduction and purpose. Physical activity is an integral part of a healthy lifestyle, and the far-reaching benefits of practising it are invaluable. Raising awareness in this regard seems to be a key element in the prevention of civilization diseases. This study aimed to assess the knowledge of amateur athletes about the influence of physical effort on changes in selected biochemical parameters.

Material and methods. In the study that was conducted using the questionnaire method and electronically using the proprietary form, one hundred physically active people participated. The survey consisted of single-choice and multiple-choice questions as well as open-ended questions. It collected information on (1) demographic and social characteristics, (2) anthropometric measurements, (3) type and duration of physical activity, (4) frequency and time of the training, (5) existing diseases and (6) knowledge about glucose, insulin, lipid profile, alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatine kinase.

The key questions concerned the influence of physical activity on the studied biochemical parameters.

Results. The vast majority of respondents revealed a good knowledge of insulin and insulin resistance, carbohydrate metabolism and creatine kinase. The average results of correct answers amounted to 90%, 79% and 71%. The knowledge of the issues related to the lipid profile, and both ALT and AST was slightly worse. Here the proper answers distribution was respectively 62% and 60%.

Conclusions. Properly conducted education on the influence of physical activity on selected biochemical parameters could be the best solution to broaden the knowledge on this subject.

Keywords: physical activity, knowledge, glucose, insulin, lipid profile, liver function tests.

1. Introduction

According to the definition presented by the World Health Organization (WHO), physical activity is a movement initiated by skeletal muscles, which requires energy [1]. The amenities offered by today's world are associated with the fact that most people in Poland move too little and too rarely. It has led to a more frequent occurrence of civilization diseases - one of the greatest threats to the health of the modern population. These include cardiovascular diseases, lipid disorders, arterial hypertension, type 2 diabetes, metabolic syndrome, osteoporosis, and obesity. As chronic diseases, they significantly reduce the comfort and quality of life of Poles [2]. They also contribute to a significant burden on the Polish economy. According to the Polish Sports Market report published in 2019, physical activity decreased by ten percentage points compared to 2004. Due to a sedentary lifestyle, Poland loses as much as PLN 7 billion [3]. As a result of disturbing public health data, and after examining the scientific evidence regarding the relationship between exercise, hypokinesia, and health in different population groups, the WHO in 2020 updated the guidelines for physical activity targeting children, adolescents, adults, the elderly, and for pregnant and postpartum women and people suffering from chronic diseases and disabilities [4].

Regularly practiced physical activity of moderate intensity is one of the most effective methods of preventing and supporting the treatment of civilization diseases. The benefits of exercise are invaluable-the WHO emphasizes that any physical activity is better than none. Properly adjusted physical effort should be promoted as a modifiable preventive factor contributing to physical and mental health improvement. Physical activity also influences the development of basic motor skills, such as strength, speed, and endurance [4-6]. To improve the quality of life, prophylaxis should be implemented based on consolidating the correct patterns of a healthy lifestyle. Changing the health behaviour can help to deal with the problem of abnormal blood chemistry parameters. The selected blood biochemical parameters change differently under the influence of physical activity depending on its intensity. (Table 1). Exercise intensity can be defined in two ways. Using objective as well as subjective terms. The absolute exercise intensity is determined by calculating the work done, e.g. in metabolic equivalents (MET). Whereas relative exercise intensity is often expressed as a percentage of the oxygen ceiling (VO_2^{max}) for an individual. Using absolute assessment methods, moderate and high physical intensity are classified as 3.0-5.9 MET and ≥ 6 MET, respectively.

In contrast, when assessing relative intensity, physical activity is expressed as 45-59 VO²max for moderate-intensity training, and for high-intensity exercise, the load is ≥85 VO²max [7]. Positive changes in the values, lipid profile, glucose homeostasis, as well as the improvement of tissue sensitivity to insulin, may inspire optimism. However, with extreme physical activity, increased values of liver enzymes, creatine kinase, and blood glucose (among people with abnormal concentrations) may cause some anxiety among sports enthusiasts.

Table 1. Influence of physical activity intensity on selected blood biochemical parameters.

Selected blood chemistry parameters	Influence of physical activity on the value of biochemical parameters	
	moderate physical activity	extreme physical activity
Glucose (elevated values)	↓	↑
Insulin (tissue sensitivity to insulin)	↑	-
Total cholesterol (elevated values)	↓	-
LDL cholesterol (elevated values)	↓	-
HDL cholesterol (lowered values)	↑	-
Triglycerides (elevated values)	↓	-
Alanine aminotransferase (ALAT)	-	↑
Aspartate aminotransferase (AspAT)	-	↑
Creatine kinase	-	↑

Education in the field of the influence of physical activity on selected biochemical parameters could encourage people to undertake physical exertion. Hence, considering education in terms of improving the knowledge of Poles should be regarded as an investment for the future. The introduction of appropriate education from an early age may bring measurable health benefits and reduce healthcare expenditure [8]. This introduction is the basis for further considerations and enables their correct positioning in the entire research process.

2. Materials and Methods

The indirect measurement method was chosen to check the physically active people in Poland's knowledge of the influence of physical effort on selected biochemical parameters. An anonymous online survey was carried out based on a self-designed, structured questionnaire. See questionnaire in the Supplementary Material for comprehensive analysis.

The survey was made available via online social media for approximately three months between January 13 and April 23 2020. Due to the prevailing COVID-19 pandemic and the risk of respondents' infection, research using the Internet was an available and safe method used in the current study. The survey data collected anonymously do not require approval by the local bioethical committee in Poland. Potential respondents were informed about the general subject of the survey, its voluntary and fully anonymous nature. The questionnaire consisted of single-choice, multiple-choice, and open-ended questions. The inclusion criteria for the study were persons over 18 years of age. People professionally involved in sports were excluded. The statement verified these criteria at the beginning of the survey.

By confirming the statement's content, the respondent declared that he was 18 years old, he is not an athlete, and engages in moderate intensity physical activity at least 2.5 hours per week/exercises at least 1.5 hours per week at high intensity/executes approximately 6.000-8.000 steps per day.

The employed questionnaire aimed to assess:

- a) knowledge about the changes taking place in the carbohydrate economy in healthy adults and diabetics during physical activity;
- b) knowledge of the impact of exercise on a common metabolic disorder such as insulin resistance;
- c) knowledge of the parameters included in the lipid profile and the changes in their values during regular exercise;
- d) knowing the names of some liver enzymes and their variability under the influence of intense training;
- e) awareness of physically active people about the impact of exercise on the activity of creatine kinase.

The demographic data on each surveyed individual included age, gender, place of living (rural area, urban area to 50.000 residents, urban area to 50.000-100.000 residents, urban area to 100.000-500.000 residents, urban area over 500.000 residents), level of education (primary, secondary, tertiary, vocational or student), and body mass index (BMI)-calculated using a person's height and weight.

The statistical data was developed in a spreadsheet program - Microsoft Excel. The collected material was analyzed with the use of descriptive statistics. A tabular description and determination of distribution measures were used to present the data. The following were used: measures of central tendency-reflecting the numerical characteristics of the distribution of the variable's value, groups of results (arithmetic mean) and measures of dispersion-describing the degree of differentiation of the results around the central value (standard deviation (SD)).

3. Results and Discussion

3.1. Demographic Characteristics

Almost one hundred Poles completed the questionnaire. Finally, three of them had to be excluded due to non-acceptance of the obligatory declaration at the beginning of the questionnaire. The demographic characteristics of the studied population are presented in Table 1. Most of the surveyed people were women aged 18-25, from cities with more than 500.000 inhabitants, with higher education and BMI within the normal ranges. Men accounted for 37%. The mean age of all participants was 34 ± 13.5 years.

Table 1: Demographic characteristics of surveyed participants ($n=97$).

Variable	Result
Age (years) mean \pm SD (min–max)	34.2 \pm 13.5 (18-73)
18-25, n (%)	44 (45.4)
26-35, n (%)	18 (18.6)
36-45, n (%)	14 (14.4)
>45, n (%)	21 (21.6)
Gender Female, n (%) / Male, n (%)	61 (62.9) / 36 (37.1)
Weight (kg) mean \pm SD (min–max)	68.8 \pm 12.6 (44-115)
BMI (kg/m ²) mean \pm SD (min–max)	23.4 \pm 3.4 (17.0-37.2)
Underweight (<18.5), n (%)	3 (3.1)
Normal weight (18.5–24.9), n (%)	64 (66.0)
Overweight (25.0–29.9), n (%)	27 (27.8)
Obesity (\geq 30.0), n (%)	3 (3.1)
Place of living	
Urban area to 50 000 residents, n (%)	12 (12.4)
Urban area to 50 000 - 100 000 residents, n (%)	5 (5.2)
Urban area to 100 000 - 500 000 residents, n (%)	32 (33.0)
Urban area over 500 000 residents, n (%)	26 (26.8)
Rural area, n (%)	22 (22.7)
Education	
Primary, n (%)	0 (0)
Secondary, n (%)	11 (11.3)
Tertiary, n (%)	63 (64.9)
Vocational, n (%)	2 (2.1)
Student, n (%)	21 (21.6)

The respondents' BMI was calculated based on their given weight and height. According to the range of BMI values, the following categories were distinguished: underweight (17-18.49 kg/m²), normal body weight (18.5-24.99 kg/m²), overweight (25.00-29.99 kg/m²), obesity I° (30.0-34.99 kg/m²) and II° (35-39.99 kg/m²). Overall (66%) of the respondents had a normal body weight. 28% of respondents were overweight. Underweight and obesity constitute 1% and 5% of the respondents, respectively.

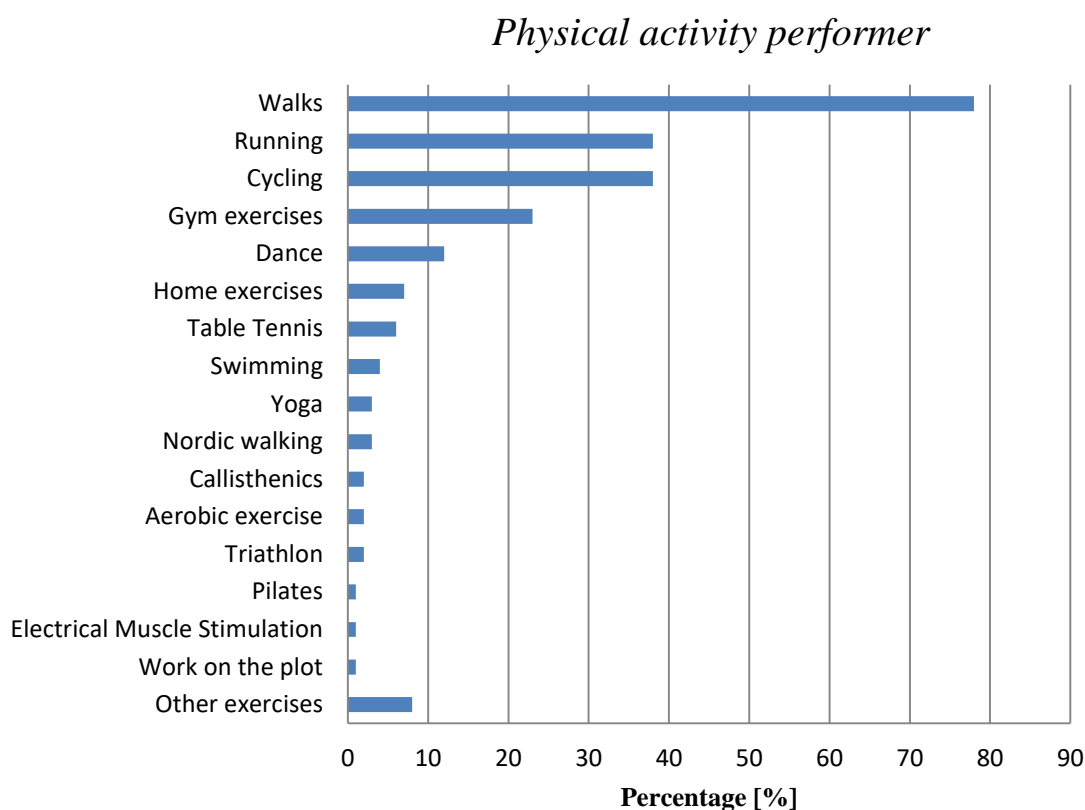
Most of the respondents (33%) came from cities with a population of 100.000 to 500.000, 27% lived in cities with more than 500.000 inhabitants, 23% were rural, and the rest lived in smaller towns.

The questionnaire's respondents' education was divided into five categories: primary, secondary, tertiary, vocational, student. The largest group was represented by people with higher education (65%), then students (22%), people with secondary education constituted the smallest group (2%). At the same time, the smallest group (2%) were people after vocational schools.

3.2. Physical activity

The respondents were asked about their preferred physical activity. This question encouraged to provide more than one answer and was open-ended, thanks to which the respondent had the opportunity to add his favourite discipline.

Figure 1. The type of physical activity practiced by the respondents.

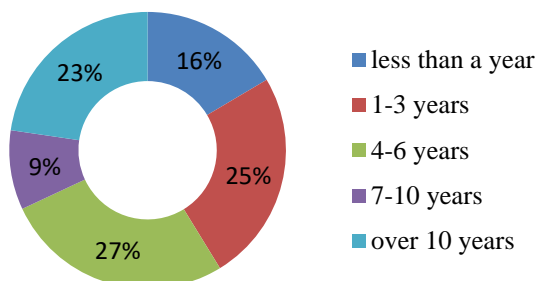


After analyzing the obtained data, see (Figure 1), it appeared that the respondents' most willingly practised physical activity was walking (34%), which is the simplest form of physical activity. No special skills or equipment are required. It is a rhythmic, dynamic, aerobic effort involving large groups of skeletal muscles. It should be underlined that regularly walking has many benefits with minimal side effects. Fast walking should be above 70% of the maximum heart rate to be beneficial. This intensity of exercise supports and develops cardiovascular capacity and endurance. It also strengthens the muscles of the legs, limb girdles and torso, and makes the joints more flexible. Walking was the most natural activity performed by healthy people daily; therefore, it can be classified as a long-term dynamic aerobic exercise [9].

Then *ex aequo* responders answered: running (16%) and cycling (16%). Attending gyms was only 10%. Other activities accounted for 5% or less and included: dancing, exercising at home, football, and similar.

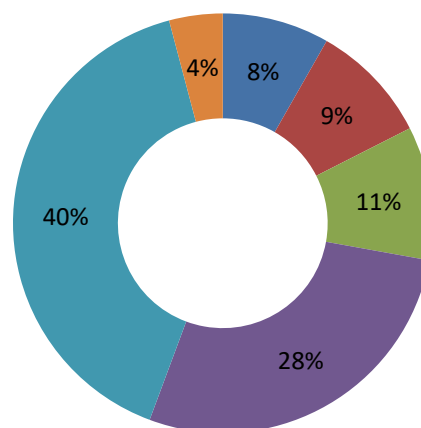
Figure 2: (A) Reported period of physical activity performed. (B) Experienced daily length of training. (C) The distribution of physical activity over time.

A *The period of physical activity performed*

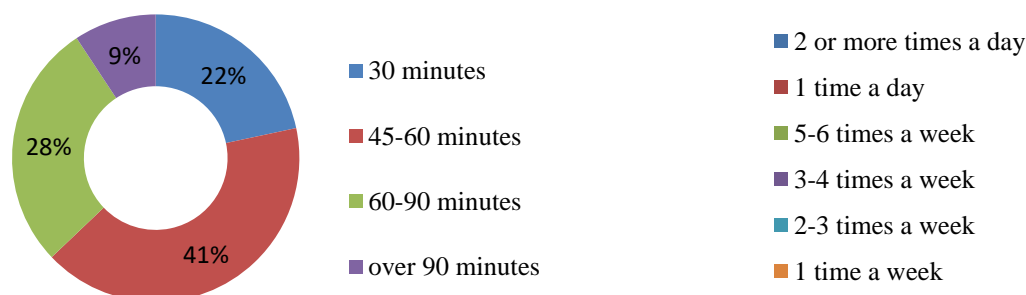


Regularly practised physical activity for 4 to 6 years is performed by 27% of respondents. Less than 25% of respondents declared that their adventure is with activity it lasts a little shorter than in the previous group, i.e. from 1 to 3 years. Interestingly, over 20% of the respondents have been attending physical activities for over ten years. People with training lasting less than a year accounted for 16%. The smallest number of respondents (less than 10%) practised regular physical activity for 7-10 years. See Figure 2 (A).

C *Training frequency*



B *Average length of training sessions*



Next, in the survey, the respondents were asked to define the training frequency, i.e. the distribution of training units over time. Exercises were most often performed 2-3 times a week (40%), less than 30% of the respondents declared that they practised physical

activity 3-4 times a week, 11% of them implemented physical effort 5-6 times a week. Responses below 10% concerned: persistent physical activity-once a day (9%), two or more times a day (8%) and low frequency of training-once a week (4%). See Figure 2 (B).

The duration of physical activity represented by the subjects varied. Most respondents perform the physical effort at 45 minutes-60 minutes/day (41%). An effort lasting over an hour and not exceeding 1 hour and 30 minutes concerned 28% of the respondents. Workouts performed for 30 minutes or 90 minutes and more accounted for 22% and 9% of responses, respectively. See Figure 2 (C).

Physical activity combined with adequately balanced nutrition is an effective measure in the prevention of overweight and obesity. Numerous follow-up studies show a significant effect of exercise on body weight, depending on the amount of activity. They also affect the energy balance, which is conducive to generating an energy deficit [10,11]. In addition to physiological benefits, physical effort influences numerous psychosocial features, such as coping with anxiety or building self-esteem. Nowadays dominated by social media, strengthening these features is very important, especially for the youngest recipients. They spend too much time in front of TV screens, smartphones, or tablets, which reduces the amount of time spent on physical activity. Physical ability is a fundamental and vital ability that teaches motivation, self-confidence, and healthy competition. Thanks to it, physical competencies, knowledge, and understanding are acquired. The strength of these features depends on the type of physical activity [12,13].

The joy of physical exertion was hampered by the COVID-19 pandemic, which resulted in the closure of sports and recreational facilities. Therefore, the choice of sports at that time was limited [11]. Studies show that people who were physically active before the outbreak of the COVID-19 pandemic reduced their physical effort by an average of 32%, and people subjected to self-isolation by 43% [14].

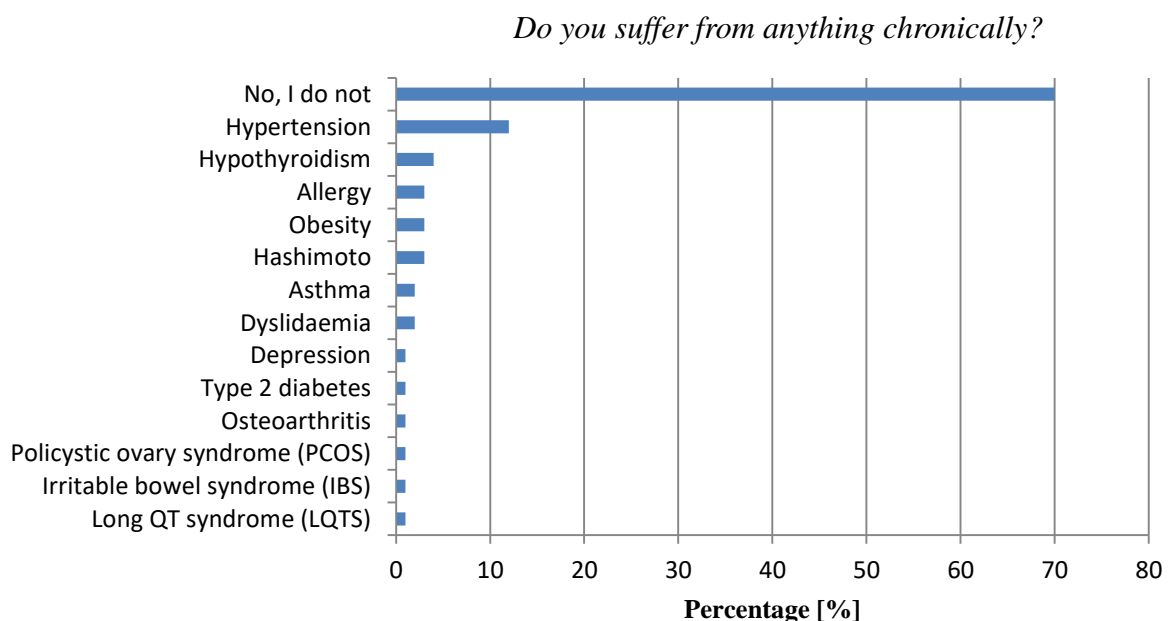
It is worth mentioning that the lack of exercise has been classified as the real cause of chronic diseases and death [15]. There is evidence that physical activity most of life can delay the onset of approximately 40 chronic conditions/diseases. Physically active people can enjoy a longer, healthy life. The physical effort essentially improves circulatory and respiratory fitness [16]. According to the results of a study focusing on the assessment of exercise capacity, it was shown that each increase by one metabolic equivalent (MET) resulted in a 12% improvement in survival [17]. Regularly initiated physical exercise, both aerobic and strength exercises, play an essential role in preventing diseases related to cognitive disorders and reduces the likelihood of depression and anxiety disorders. It reduces the risk of developing neurodegenerative diseases and reduces the symptoms of disorders, i.e. dementia. It is vital for the elderly. Seniors engaged in moderate and high-intensity physical activity reported better health [18,19]. During the COVID-19 pandemic, exercise can help better cope with the adverse effects of isolation on the psyche [20].

The most frequently recommended physical activity is an effort involving large groups of muscles of a continuous nature. Regularly practised physical activity contributes to a significant improvement in the efficiency of the system. The new guidelines of the WHO 2020 regarding physical activity and sedentary lifestyle indicate that all adults without health contraindications should engage in 150-300 minutes of moderate-intensity exercise per week or 75-150 minutes of vigorous exercise.

There are no obstacles to combine the two intensities of aerobic exercise. The central part of the training should be preceded by a few minutes of warm-up and ended with calming activities. It should be emphasized that a small amount of exercise will not contribute to the achievement of significant physiological effects, while an excessive amount of training not adapted to the abilities and state of health may be potentially harmful. It is recommended to limit the time spent in a sitting position [21]. A sedentary lifestyle is associated with the risk of death from all causes, including cardiovascular disease. The introduction of moderate or intense physical activity in people with very low physical activity effectively alleviates such associations [22]. However, not always a long time spent in a sitting position, e.g. 5-8 hours a day, is associated with a low level of physical activity. A study conducted among students of health-related faculties shows that despite spending 46 hours per week (2781.8 ± 1238.5 MET min/week) sitting, an active lifestyle can be represented. The level of physical activity of 65% of students was in the high category [23].

3.3 Diseases

Figure 3: The prevalence of chronic diseases in physically active respondents.



The questionnaire also included questions about the occurrence of diseases in respondents (Figure 3). Most of the respondents were healthy (66%). Hypertension concerned 11% of the respondents. The category of other diseases included disease entities that most often coexisted with obesity, arterial hypertension, or as particular abnormalities. Individuals had type 2 diabetes, degenerative joint changes, depression, rheumatoid arthritis, polycystic ovary syndrome, hypersensitive bowel, and long QT syndrome (6%). Other disease entities did not exceed 5%, including: hypothyroidism (4%), allergies (3%), disease hashimoto (3%), obesity (3%), dyslipidaemia (2%), asthma (2%).

Regular exercise contributes to both maintaining and improving health [24]. The scientifically proven health benefits of regular, moderate-intensity activity include a positive effect on bone mass density, maintenance of healthy body weight, the efficiency of the cardiovascular system, efficiency of the respiratory system, and cognitive functions.

In addition, it reduces the risk of cardiovascular events, obesity, depression, hypertension, abnormal lipid values, the incidence of type 2 diabetes. It also contributes to reducing the incidence of cancer: colon, breast, bladder, uterus, esophagus, kidney, lungs, and stomach. It reduces the risk of dementia, anxiety, and depression. In women expecting or having children, it reduces the risk of gestational diabetes and postpartum depression [25].

There has been an increasing interest in biochemical parameters for assessing health aspects that can be modulated through regular, moderate-intensity physical activity in recent years. The value of selected parameters depends on many factors, including the amount of time and frequency of physical activity performed [26].

The second part of the analysis allows you to go to the research stage, which presents the scope of knowledge about the influence of physical activity on selected biochemical parameters in the subjects.

3.4 Knowledge of selected biochemical parameters

3.4.1. Glucose

The first question (Table 2) concerned the normal fasting venous blood glucose level.

Table 2: Percentage distribution of the answer to the question about the normal fasting venous blood glucose level.

<i>Please indicate proper fasting blood glucose level?</i>	
at least 126 mg/dL, n (%)	1 (1.03)
100 mg/dL to 125 mg/dL, n (%)	14 (14.43)
70 mg/dL to 99 mg/dL, n (%)	82 (84.5)

Most of the respondents (85%) marked the correct answer-from 70 mg/dL to 99 mg/dL. Only 15% of them gave the wrong answer.

Table 3: Percentage distribution of answers to the question about the influence of aerobic exercise on glycemia in type 2 diabetes.

<i>Please indicate, whether the sentence or statement is true or false.</i>	True	False
Aerobic exercise reduces hyperglycemia in type 2 diabetes, n (%)	83 (85.6)	14 (14.4)
Intensive anaerobic exercise may increase glycemia in the body of diabetics and increase glucose concentration after exercise, n (%)	42 (43.3)	55 (56.7)
Any physical activity causes hypoglycemia in people with diabetes, n (%)	20 (20.6)	77 (79.4)
Physical activity consumes glucose in the body, n (%)	80 (82.5)	17 (17.5)
Regular exercise has a positive effect on the metabolism of glucose, n (%)	93 (95.9)	4 (4.1)

In the following question (Table 3), the respondents were asked whether the given statement was true or false. The first one was as follows: aerobic exercise reduces hyperglycemia in type 2 diabetes. Most of the respondents answered correctly-that it is true (86%), less than 15% indicated that the above statement is false. The second was the effect of intense exercise on blood glucose levels. More than half of the respondents (57%) gave an incorrect answer, describing the statement as false. The rest of the people (43%) answered truthfully. Another statement assessed respondents' knowledge in terms of the risk of people with type 2 diabetes, hypoglycemia. More specifically, the participant's task was to find out whether any physical activity causes hypoglycemia in people with diabetes. Most of them answered this question correctly - that it is not true (79%), the rest (21%) stated that it was true. The penultimate statement examined whether the participants had knowledge about glucose as a source of energy used during exercise. The vast majority (82%) stated that glucose is used in physical activity, which is the correct answer. 18% of the responses were incorrect. The last statement concerned the effect of regular exercise on carbohydrate metabolism. Only 4% of the respondents gave a wrong answer, and 96% marked a correct reply.

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from inappropriate insulin secretion or action. Type 2 diabetes accounts for up to 95% of all cases. This type of diabetes is mainly modulated by lifestyle. One of the external factors contributing to the development of the disease is precisely low physical activity [27]. At this point, it is worth mentioning that skeletal muscles play a significant role in maintaining blood glucose homeostasis. Both aerobic and resistance exercise improves glucose tolerance in people with diabetes [28,29]. Many studies have been carried out to prove the beneficial effect of aerobic exercise on its concentration in the blood. For example, in a 2007 study involving 60 overweight subjects with type 2 diabetes, reductions were observed in: HbA1c ($-0.63\% \pm 0.41$ vs $0.31\% \pm 0.10$, $p < 0.001$) and fasting blood glucose ($-18.6 \text{ mg/dL} \pm 4.4$ vs $4.28 \text{ mg/dL} \pm 2.57$, $p < 0.001$), after a six-month aerobic exercise program that took place 4 times per week for 45-60 minutes [30].

A systematic review and network meta-analysis documented that supervised aerobic exercise reduced fasting plasma glucose levels by 9.38 mg/dL compared with no physical activity [31]. Observations carried out with the participation of men and women with type 2 diabetes showed the following effects: after cycling for 12 weeks with a frequency of 60 minutes a week, fasting blood glucose decreased by approx 14% [32]; after introducing a 30-minute walk for three days a week for eight weeks, the glycated haemoglobin (HbA1c) level was reduced by about 18% [33]. Proper selection of resistance exercises also brings many benefits. The training focused on exercising the legs and arms three days a week for 16 weeks reduced fasting glucose by about 7% and HbA1c levels by about 5% [34]. Exercising the same muscle groups using free weights and the equipment available in a sports facility, conducted for eight weeks, twice a week, reduced HbA1c by 18% [33]. Many other studies in the literature focus on this aspect. The widely studied influence of exercise on carbohydrate metabolism should be presented to patients as often as possible to prevent and combat type 2 diabetes.

3.4.2. Insulin

The following questions assessed the respondents' knowledge about insulin and insulin resistance.

Table 4: Percentage distribution of the answer to the question about the insulin-producing organ.

<i>Please indicate, which organ produce insulin?</i>	
Liver, n (%)	
Kidneys, n (%)	4 (4.1)
Pancreas, n (%)	0 (0)
Lungs, n (%)	91 (93.8)
	0 (0)

The first question was related to the insulin-producing organ (Table 4). It was noticed that as many as 94% of the respondents answered correctly. Only 6% of them responded incorrectly - that it is the liver.

Table 5: Percentage distribution of answers to the question about the definition of insulin resistance.

<i>Please indicate, what insulin resistance is?</i>	
A disorder of glucose homeostasis consisting of an increase in the sensitivity of muscles, adipose tissue, liver, and other tissues to insulin. n (%)	0 (0)
A metabolic disorder in which there is a decrease in the sensitivity of tissues to the action of insulin despite its normal or increased level in the blood. n (%)	90 (92.8)
A metabolic disorder that is not a cause of type 2 diabetes . n (%)	7 (7.2)

The following question asked the respondents to indicate the correct definition of insulin resistance (Table 5). There were three variants of answers to choose from 83% of respondents chose the proper definition of insulin resistance, 10% of them stated that it is a disorder of glucose homeostasis, consisting in increasing the sensitivity of muscles, adipose tissue, liver, and other tissues to insulin. 7% of the respondents did not notice the relationship between insulin resistance and the development of type 2 diabetes.

Table 6: Percentage distribution of responses to knowledge about insulin resistance.

<i>Please indicate, whether the sentence or statement is true or false.</i>	True	False
Lack of physical activity and a high-energy diet can contribute to the development of insulin resistance. n (%)	84 (86.6)	13 (13.4)
Physical activity worsens the tissue sensitivity to insulin. n (%)	4 (4.1)	93 (95.9)
Both aerobic and resistance training improve insulin sensitivity and reduce the risk of cardiovascular disease. n (%)	90 (92.8)	7 (7.2)

In the next question, the respondents were asked to determine whether the given statement regarding insulin and related disorders was true or false. The first of them assessed knowledge about the possible cause of insulin resistance. 87% of respondents believed that lack of physical activity and a high-energy diet can contribute to the development of insulin resistance and this is the correct answer, while 13% excluded the influence of a sedentary lifestyle and an energy-rich diet as the cause of this disorder. A large majority (96%) denied that exercise made tissues less sensitive to insulin, while 4% believed this to be true. The last recent claim was about the effect of aerobic and resistance training in improving insulin sensitivity and reducing the risk of cardiovascular disease. 93% of the respondents answered correctly, the remaining part (7%) believed that it was a false statement.

Insulin resistance is a metabolic disorder associated with insulin malfunction and excess body weight. It is also related to the occurrence of chronic inflammation in the body [35,36]. The prevalence of this phenomenon has prompted me to research the knowledge on this subject among physically active people.

Insulin resistance is thought to precede the development of type 2 diabetes by 10-15 years. The introduction of physical activity and a diet with a low glycemic index and a glycemic load is the best non-pharmacological drug helping to deal with this disorder [37,38]. Regular physical activity reduces insulin resistance. Both aerobic and resistance training has a positive effect on the sensitivity of tissues to insulin. There is evidence in studies that the introduction of repetitive exercise has some of the most visible results [39-42].

It is also worth mentioning eating habits in the context of insulin resistance. Despite a number of observations investigating this phenomenon, the exact influence of various eating habits and nutrients on the development of insulin resistance is still unknown [43]. Nevertheless, the composition of the diet significantly affects the severity of insulin resistance and type 2 diabetes or cardiovascular diseases. It has been known for a long time that products that are a source of simple sugars and rich in saturated fats should be limited. The first group of food products causes a rapid increase in postprandial glycemia and, consequently, a rapid insulin release, while the second group contributes to the increase in the release of free fatty acids, which are mediators of insulin resistance. However, important components of the diet will be: dietary fiber and mono- and polyunsaturated acids positively influencing tissue resistance to insulin [44]. It was observed that the DASH diet was most strongly associated with lower insulin levels and a lower index indicating the insulin resistance index based on serum blood glucose and insulin concentrations (HOMA-IR), and had a positive effect on the sensitivity of tissues to insulin [45].

3.4.3. Lipid profile

The respondents also were assessed in the state of their knowledge about the lipid profile (Table 7). Its measurement is mainly used as a screening test for dyslipidemias. Awareness of these parameters changes is associated with faster diagnosis in the event of lipid disorders and effective treatment that reduces cardiovascular risk.

Table 7: Percentage distribution of answers to questions about the lipid profile.

<i>Please indicate which parameters are usually included in the lipid profile?</i>	
Total cholesterol and triglycerides, n (%)	6 (6.2)
Total cholesterol, HDL and LDL cholesterol, n (%)	11(11.3)
Total cholesterol, HDL and LDL cholesterol, triglycerides, n (%)	80 (82.5)
<i>Please indicate, the proper level of total cholesterol in healthy people?</i>	
<200 mg/dL, n (%)	37 (38.1)
<190 mg/dL, n (%)	57 (58.8)
<220 mg/dL, n (%)	3 (3.1)

The first question verified the knowledge of parameters included in the lipid profile. Basic knowledge was possessed by 83% of the respondents; 11% said that total cholesterol, HDL, and LDL cholesterol should be assessed, while 8% believed that total cholesterol and triglycerides testing was enough.

On the other hand, the question about the correct values of total cholesterol was correctly answered by 59% of respondents; 38% decided that these values were <200 mg/dL, and 3% that the norm was <220 mg/dL.

It is also worth mentioning that the non-HDL cholesterol parameter has recently been introduced. It is calculated by subtracting HDL cholesterol from total cholesterol [46]. It includes the small lipoprotein (VLDL) fraction, which, like LDL cholesterol, are atherogenic lipoproteins. They correlate with the risk of developing cardiovascular diseases.

Determination of non-HDL cholesterol is recommended for all lipid profile measurements. It is calculated by subtracting the high-density lipoprotein concentration from the total cholesterol concentration (non-HDL=TC-HDL). Non-HDL cholesterol is a lipoprotein complex containing apolipoprotein B, which includes: LDL, VLDL, IDL, chylomicrons, remnants, and lipoprotein (a). It is currently a routinely given parameter [47].

The parameter of non-HDL cholesterol is particularly important in patients with high triglyceridemia, which occur, inter alia, in diabetes mellitus, metabolic syndrome, and chronic kidney disease as well as with the high and very high risk of cardiovascular disease.

It is recommended that people with a low and moderate risk of death from cardiovascular causes within 10 years, based on age, gender, systolic blood pressure, total cholesterol and smoking (<1% according to Pol-SCORE 2015 [48]), keep non-HDL cholesterol values below 145 mg/dL (3.8 mmol/L). The target non-HDL cholesterol concentration in patients with a high ($\geq 5\%$ and <10% Pol-SCORE) and very high ($\geq 10\%$ Pol-SCORE) risk of death from cardiovascular disease is <130 mg/dL, respectively (3.3 mmol/L) and <100 mg/dL (2.6 mmol/L). The indication for maintaining the concentration <130 mg/dL is also: strong single risk factor, i.e. familial dyslipidemia or severe arterial hypertension, type 1 and type 2 diabetes without additional risk factor or organ damage, and moderate stage of chronic kidney disease (GFR: 30-59 ml/min/1.73 m²). It is also recommended that people with known cardiovascular disease, type 1 and type 2 diabetes with one or more risk factors or organ damage (e.g. microalbuminuria) or severe chronic kidney disease (GFR: <30 ml/min/1.73 m²), kept the non-HDL cholesterol values below 100 mg/dL [49,50].

The standard recommendation is to measure the fasting lipid profile. However, recent systematic studies suggest that there are no significant differences in most parameters between fasting rather than non-fasting samples. In studies involving non-fasting samples, it was noticed that the concentration of triglycerides was about 0.3 mmol/L (27 mg/dL) higher compared to the parameters determined in the fasting samples [51,52].

Table 8: Percentage distribution of answers to questions about the influence of physical activity on the lipid profile.

Questions about the lipid profile	Yes, I do	No, I do not	I do not know
<i>Do you think, that physical activity reduces the total cholesterol level? n (%)</i>	75 (77.3)	3 (3.1)	19 (19.6)
<i>Do you think, that physical activity increases the level of HDL cholesterol in the blood serum? n (%)</i>	34 (35.1)	29 (29.9)	34 (35.1)
<i>Do you think, that physical activity increases the level of LDL cholesterol in the blood serum? n (%)</i>	6 (6.2)	55 (56.7)	36 (37.1)
<i>Do you think that the introduction of physical activity will reduce the concentration of triglycerides in people with high concentrations? n (%)</i>	63 (64.9)	5 (5.2)	29 (29.9)

The next questions concerned the influence of physical effort on selected parameters of the lipid profile (Table 8). First, the respondents were asked to answer the question - can physical activity lead to a reduction in total cholesterol in the blood? 77% of the respondents correctly answered that exercise reduces total cholesterol, 20% did not know the answer to this question, 3% answered incorrectly. The next question was about serum HDL cholesterol levels. Only 35% of respondents believed that physical activity increased the level of high-density lipoproteins, the same percentage of respondents did not know the answer to this question, while 30% of them said that physical activity did not increase HDL cholesterol levels.

More than half (57%) of the respondents answered the question correctly - does physical activity increase the level of low-density lipoproteins? 37% of them did not know the answer, while 6% said that physical activity increases the level of LDL cholesterol in the blood serum. The last question assessed knowledge about the effect of exercise on triglyceride levels in people with high baseline levels. 65% of the respondents gave the correct answer, 30% did not know whether physical activity influenced their level, 5% said that exercise did not lower triglyceride levels in people with elevated values.

Physical activity helps to reduce and maintain healthy body weight. There is also an increase in HDL cholesterol of 0.01 mmol/L (0.4 mg/dL) for every kilogram of body weight lost. Aerobic exercise may also increase the concentration of this parameter. Studies have shown that 25-30 km of fast walking a week can have a positive effect on HDL cholesterol levels by 0.08-0.15 mmol/l (3.1-6 mg/dL). Moreover, smoking cessation also benefits this parameter [53,54].

It is worth mentioning that LDL cholesterol and lipoprotein with cholesterol-containing large amounts of apoprotein B are involved in the formation of atherosclerotic plaques, which in the future may contribute to cardiovascular incidents. Scientific evidence clearly shows that elevated LDL values are associated with atherosclerotic cardiovascular disease. Therefore, it is worth trying to lower these parameters [55].

One of the goals of cardiovascular disease prevention is the implementation of 3.5–7 hours of moderate-intensity physical activity per week or 30–60 minutes of physical activity almost daily [55,56].

Systematically practiced sport contributes to the reduction of plasma triglycerides [56,57]. The use of stimulants such as alcohol significantly affects the concentration of this parameter, especially in people with hypertriglyceridemia [58]. People with dyslipidemia should be encouraged to engage in regular physical activity for at least ≥ 30 minutes a day.

3.4.4. Alanine aminotransferase (ALT) and aspartate aminotransferase (AST)

The next questions concerned the liver enzymes ALT and AST (Table 9 and 10).

Table 9: Percentage distribution of answers to the question about abbreviations of ALT and AST.

<i>Please indicate, the abbreviations ALT and AST</i>	
Deoxyribonucleic acid and ribonucleic acid, n (%)	6 (6.2)
Thyrotropin and adrenocorticotropin, n (%)	5 (5.1)
Alanine aminotransferase and aspartate aminotransferase, n (%)	86 (88.7)

Table 10: Percentage distribution of answers to the question about the influence of intense physical activity on ALT and AST.

	Yes, I do	No, I do not	I do not know
<i>Do you think, that intense physical exercise increases the level of the liver enzymes ALT and AST? n (%)</i>	30 (30.9)	25 (25.8)	42 (43.3)

The subjects were asked to elaborate on the abbreviations mentioned above. The correct answer - alanine aminotransferase and aspartate aminotransferase was given by 89% of the respondents, 11% did not manage to develop abbreviations. 43% of the respondents did not know the answer to the question - does intense exercise increase the level of the liver enzymes ALT and AST? Only 31% of the respondents gave the correct answer.

Serum ALT and AST determinations are readily available and relatively cheap biochemical tests used in clinical practice.

However, the ALT and AST liver tests are not specific - this means that they are not only found in liver cells, but also in other organs, such as muscles, heart, bones, and brain. Therefore, their increased values do not always indicate organ damage. Their values may also be influenced by demographic factors, such as gender or age [59]. Heavy, intense physical effort leads to muscle microdamage, which leads to the increased release of the enzymes ALT and AST into the interstitial fluid, and thus the predetermined standards are exceeded [60]. Many studies confirm this relationship. For example, in triathletes and amateurs of cycling after the race, an increase in alanine and aspartate aminotransferase were observed by 140% and 250%, respectively [38]. However, in the group of runners, after crossing the finish line, there was an increase: 2.5 times AST and 1.4 times ALT. Interestingly, the incorrect values continued for 15 days after the end of the run [61]. The studies also found a strong correlation between ALT and AST, and BMI in the general population. In the case of athletes, basketball players showed a strong negative correlation between BMI and AST, ALT, and the percentage of body fat. Such a relationship did not occur in the case of men [62]. Turning to the opposite situation, i.e. studies focusing on the reduction of the value of liver enzymes, two different positions are presented. On the one hand, the available literature includes studies where physical exercise did not significantly affect the increased amounts of ALT and AST. Such an observation occurred in a meta-analysis in the study group with overweight or fatty liver [63]. However, in the next study, it was observed that physical activity introduced in women with metabolic syndrome for 6 months showed a significant reduction of these parameters [64]. It is also observed that moderate physical activity has a positive effect on at least one of the parameters mentioned [65,66]. More research is needed to reach consistent conclusions on this subject.

3.4.5. Creatine kinase

The last questions concern the knowledge about creatine kinase (Table 11).

Table 11: The percentage distribution of answers to the question of what is creatine kinase.

<i>Please indicate, what creatine kinase is?</i>	
A hormone that plays a major role in the construction of the skeleton. n (%)	8 (8.2)
A key enzyme involved in cell bioenergetics and plays an important role in cellular ATP homeostasis. n (%)	83 (85.6)
Fat-soluble vitamin. n (%)	6 (6.2)

For 86% of respondents, determining what creatine kinase is was not a problem. However, 14% could not define it.

Table 12: Percentage distribution of answers to the question concerning the influence of exercise intensity on the activity of creatine kinase.

	Yes, I do	No, I do not	I do not know
<i>Do you think, that intense physical exercise affects the value of creatine kinase activity? n (%)</i>	52 (53.6)	2 (2.1)	43 (44.3)

Questions regarding the impact of physical activity on the value of creatine kinase activity turned out to be a real challenge for the respondents (Table 12). More than half of the respondents gave the correct answer, but 44% did not know the answer to this question. In the subject of physical activity, it is worth paying attention to the muscle-specific isoform of this enzyme - creatine kinase-MM. It is the cytoplasmic, dimeric form of creatine kinase produced by skeletal muscle. It induces the reversible exchange of high-energy bond phosphate bonds between phosphocreatine and ADP, forming ATP and creatine. Its appearance in serum may indicate, for example, sarcomere disorders [67].

The information on the increase in CK activity after intense exercise is a well-documented fact. With a significant load on the body during heavy exercise, the activity of creatine kinase may increase up to 30 times. However, after about 7 days of rest, these values return to normal [68]. Other studies indicate that in 70% of cases, activity returns to normal values a little faster, within 3 days [69]. In the observations taking into account high physical effort, it was noticed that after the end of the high-intensity ultra-endurance race, the activity of creatine kinase reached 300%, in the group of men preparing for the marathon these values increased by 33% after 15 weeks of training [38,70]. Another study noted that heavy eccentric effort may lead to increased values of this enzyme [71]. After intensive training, an increase in creatine kinase by 58% was observed [72].

In some studies, creatine kinase has even been used as an indirect indicator of muscle damage. Therefore, it can be assumed that exceeding the reference values of serum creatine kinase was associated with excessive training intensity and indicated the degree of overtraining. However, the proposed method was not fully accurate as there is a large interindividual variability in serum creatine kinase. Its level also depends on the level of training, the group of muscles involved during exercise, and gender. Compared to women, men have a higher resting creatine kinase activity. All these factors contribute to the difficulty in establishing standards for athletes [69,72].

Table 13: The percentage breakdown of responses to creatine kinase statements.

<i>Please indicate, whether the sentence or statement is true or false.</i>	True	False
The greater the training load, the higher the value of creatine kinase activity. n (%)	66 (68,0)	31 (32,0)
The higher the training load, the lower the creatine kinase activity value. n (%)	12 (12,4)	85 (87,6)
Training load does not affect the activity of creatine kinase. n (%)	28 (28,9)	69 (71,1)

The set of questions ended with three statements (Table 13). The task of the respondents was to contradict or confirm a given thesis. The first was as follows: the more significant the training load, the higher the value of creatine kinase activity. 68% of the respondents gave the correct answer, 32% did not agree with the given statement.

The second concerned the decrease in the value of creatine kinase activity along with the increase in training load. The majority of respondents (78%) thought it was a false statement and it was the correct answer.

In comparison, 22% said it was true. The last statement was related to the lack of influence of training load on creatine kinase activity. A significant percentage of the respondents (71%) decided it was false, 29% that it was true. All three statements were very similar to each other and were designed to test not only the knowledge but also the vigilance and reliability of the respondents.

4. Conclusions

The appropriate level of knowledge about physical activity helps in choosing a healthy lifestyle. However, information on health or diseases is obtained from various, not always reliable sources. Therefore, checking the knowledge about the influence of physical activity on selected blood biochemical parameters among sports enthusiasts would seem most justified. Among all the questions, the subjects most problematic were questions related to changes in the values of the lipid profile during regular physical exercise and the impact of intense exercise on the liver enzymes ALT and AST. Most of the answers to the questions concerning such biochemical parameters as glucose, insulin, and creatine kinase were correct.

For better results, a structured knowledge transfer tool should be developed. It is possible that the knowledge obtained, for example, in the course of didactic classes would contribute to the improvement of the health of Poles. It is worth considering creating an appropriate educational program, including a series of meetings, e.g. in places that promote a healthy lifestyle, such as sports clubs, gyms, schools, and workplaces. In order to emphasize the value of physical activity and to properly prepare for it, such meetings could be enriched with workshops related to proper balancing of meals and hydration adapted to the needs of sports enthusiasts.

At the end of July 2019, in Poland, there was a proposal to introduce a new subject in schools, "Knowledge about Health". The scope of knowledge and skills acquired during the classes would include, inter alia, principles of a healthy lifestyle, laws, basic knowledge of balanced food preparation, the importance of sport. According to the plans, the subject should be implemented in schools by the end of 2022. Education in this area may result in a better quality of life for Poles.

It is also worth considering information on the influence of physical activity on selected blood biochemical parameters on the websites of medical laboratories so that the patient is aware that physical exercise performed on a daily basis or the day before the test may affect its results.

The effects of the work can contribute to increasing the awareness of gaps in the systematization of information in physically active people, but also be used in the process of improving educational schemes and translate into increasing knowledge on this subject.

TRANSLATED QUESTIONNAIRE

Statement: I am over 18 years old. I am not an athlete. I am a physically active person, my activity: it lasts at least 2.5 hours a week and its intensity is moderate / lasts at least 1.5 hours a week and its character is intense / it is about 6-8 thousand steps a day.

- I agree
- I do not agree

Your age (in years): ...

Your weight (in kg):

Your height (in cm):

Your gender:

- a) female b) male

Your place of living:

- a) rural area b) urban area to 50 000 residents c) urban area to 50 000-100 000 residents d) urban area to 100 000-500 000 residents e) urban area over 500 000 residents

Your education level:

- a) primary b) secondary c) tertiary d) vocational e) student

Physical activity performer

(multiple answer question)

- a) walks
- b) running
- c) football
- d) gym
- e) cycling
- f) another answer

The period of physical activity performed:

- a) less than a year
- b) one to three years
- c) four to six years
- d) seven to ten years
- e) over ten years

Training frequency

- a) two or more times a day
- b) one time a day
- c) five-six times a week
- d) three-four times a week
- e) two-three times a week
- f) one time a week

Average length of training sessions:

- a) 30 minutes
- b) 45-60 minutes
- c) 60-90 minutes
- d) over 90 minutes

Do you have any chronic diseases?

(multiple answer question)

- a) I do not have
- b) obesity
- c) hypertension
- d) type 2 diabetes
- e) insulin resistance
- f) dyslipidemia
- g) another answer

What do you think is the proper fasting blood glucose level?

- a) at least 126 mg/dL
- b) 100 mg/dL to 125 mg/dL
- c) 70 mg/dL to 99 mg/dL

Please indicate, whether the sentence or statement is true or false.

- a) Aerobic exercise reduces hyperglycemia in type 2 diabetes.
- b) Intensive anaerobic exercise may increase glycemia in the body of diabetics and increase glucose concentration after exercise.
- c) Any physical activity causes hypoglycemia in people with diabetes.
- d) Physical activity consumes glucose in the body.
- e) Regular exercise has a positive effect on the metabolism of glucose.

Please indicate, which organ produce insulin?

- a) liver
- b) kidneys
- c) pancreas
- d) lungs

Please indicate what insulin resistance is?

- a) A disorder of glucose homeostasis consisting of an increase in the sensitivity of muscles, adipose tissue, liver, and other tissues to insulin.
- b) A metabolic disorder in which there is a decrease in the sensitivity of tissues to the action of insulin despite its normal or increased level in the blood.
- c) A metabolic disorder that is not a cause of type 2 diabetes.

Please indicate, whether the sentence or statement is true or false.

- a) Lack of physical activity and a high-energy diet can contribute to the development of insulin resistance.
- b) Physical activity worsens the tissue sensitivity to insulin.
- c) Both aerobic and resistance training improve insulin sensitivity and reduce the risk of cardiovascular disease.

Please indicate which parameters are usually included in the lipid profile?

(Please indicate the set of all parameters included in the lipid profile)

- a) Total cholesterol and triglycerides
- b) Total cholesterol, HDL and LDL cholesterol
- c) Total cholesterol, HDL and LDL cholesterol, triglycerides

Please indicate, the proper level of total cholesterol in healthy people?

- a) <200 mg/dL
- b) <190 mg/dl
- c) <220 mg/dl

Do you think, that physical activity reduces the total cholesterol level?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Do you think, that physical activity increases the level of HDL cholesterol in the blood serum?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Do you think, that physical activity increases the level of LDL cholesterol in the blood serum?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Do you think that the introduction of physical activity will reduce the concentration of triglycerides in people with high concentrations?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Please indicate, the abbreviations ALT and AST

- a) Deoxyribonucleic acid and ribonucleic acid
- b) Thyrotropin and adrenocorticotropin
- c) Alanine aminotransferase and aspartate aminotransferase

Do you think, that intense physical exercise increases the level of the liver enzymes ALT and AST?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Please indicate, what creatine kinase is?

- a) A hormone that plays a major role in the construction of the skeleton.
- b) A key enzyme involved in cell bioenergetics and plays an important role in cellular ATP homeostasis.
- c) Fat-soluble vitamin.

Do you think, that intense physical exercise affects the value of creatine kinase activity?

- a) Yes, I do
- b) No, I do not
- c) I do not know

Please indicate, whether the sentence or statement is true or false.

- a) The greater the training load, the higher the value of creatine kinase activity.
- b) The higher the training load, the lower the creatine kinase activity value.
- c) Training load does not affect the activity of creatine kinase.

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