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DYNAMICS OF BILIRUBIN LEVELS IN ADOLESCENTS' BLOOD UNDER THE INFLUENCE OF PHYSICAL EXERCISE

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Abstract. This scientific article studied the dynamic changes of total bilirubin levels in blood serum under the influence of physical exercise in healthy adolescents aged 14–16 years. The study was conducted between experimental and control groups for 6 weeks. Members of the experimental group participated in physical training regularly, while the control group participated only in ordinary physical training. The results showed that under the influence of physical exercise, the level of bilirubin in the experimental group increased significantly, which indicates the activation of hepatic and antioxidant systems. The article analyzes the effect of physical exertion on the mechanisms of metabolic and physiological adaptation in the young body and highlights the prospects for using bilirubin levels as a biomarker in control and monitoring.

Keywords: bilirubin, physical exercise, adolescent physiology, antioxidant protection, heme metabolism, blood biochemistry, sports medicine, physiological adaptation, experimental research, diazo method.

Introduction

Adolescence is a critical period in the human body, characterized by intense physiological, biochemical, and hormonal changes. During this period, the body is significantly exposed to external factors, in particular physical activity, which alter the levels of metabolites, enzymes, and pigments in the blood. One of them, bilirubin, is a biochemical pigment formed as a result of hemoglobin breakdown and is known as an endogenous antioxidant [1,4]. Changes in bilirubin levels within physiological limits provide important information about oxidative stress, liver function, and heme metabolism [2,3].

In recent years, fundamental research has shown that bilirubin is not only a bile pigment but also a cardiometabolic signaling molecule. As noted by Hinds and Stec, bilirubin may be an endogenous factor that protects against cardiovascular diseases [4]. At the same time, it

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prevents the development of atherosclerosis by affecting inflammation, lipid metabolism, and oxidative stress.

Bilirubin levels are also used as prognostic indicators in various clinical situations. For example, Shen et al. have shown that bilirubin levels play an important role in the prognosis of patients with acute myocardial infarction [3]. Other studies have substantiated the diagnostic value of bilirubin in cases of liver disease, biliary obstruction, and drug-induced hepatotoxicity [6,8,9].

Modern pharmacological and biochemical studies have developed new methods for bilirubin determination, which have improved its accuracy in various physiological and pathological conditions. Modern analytical methods presented by Ngashangwa et al. are of great importance in clinical laboratory diagnostics [5].

Physical activity directly affects bilirubin dynamics by increasing erythrocyte fragmentation, increasing hepatic blood flow, or increasing oxidative stress. As noted by Kosmachevskaya and Topunov, hemoglobin, after its separation from erythrocytes, first turns into bilirubin, which activates antioxidant defense mechanisms [1]. This process is even more active under physical exertion.

Unfortunately, fundamental or clinically based research on this issue is limited in Uzbekistan. Although existing studies are more focused on general physical activity or other biochemical indicators (glucose, lactate, creatine kinase), there are almost no specific studies aimed at determining the dynamics of bilirubin in response to physical exertion. Therefore, the relevance of this research is high and has practical significance in ensuring the healthy development of young people, identifying preventive measures in sports medicine, and assessing general health.

Methods

Research design. This study is an observational, experimental study aimed at determining the dynamic changes in bilirubin levels in the blood of adolescents under the influence of physical exercise. The study was conducted from March to May 2025 among senior students of a secondary school in the city of Namangan, Republic of Uzbekistan. The study was conducted based on the recommendations of the Sanitary and Epidemiological Committee, and written consent was obtained from all participants and their parents.

Participants. 40 healthy adolescents aged 14–16 years were involved in the study (20 experimental group and 20 control group). Members of the experimental group participated in standard physical activity sessions of 45 minutes 3 times a week for 6 weeks. The control group participated only in regular physical education classes.

Materials and equipment.

Medical and analytical equipment:

– Centrifuge Hettich EBA 200 – for blood plasma separation.

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– Biochemical analyzer (Mindray BS-120) – used to determine the amount of total bilirubin in blood serum.
– Sterile test tubes, capillary tubes, stand, rubber tourniquet, refrigerated containers – for collecting and storing blood samples.

Reagents:

– Diazo reagents – for colorimetric determination of bilirubin. Manufacturer: Human GmbH (Germany).
– Calibration solutions and control standards – to check the accuracy of the analysis. Manufacturer: Bio-Rad Laboratories Inc. (USA).

Research stages.

1. At the initial stage (week 0), venous blood samples were taken from both groups in the morning on an empty stomach.
2. The experimental group was involved in performing special physical exercises for 6 weeks. After each exercise, heart rate, respiratory rate, and blood pressure were recorded.
3. At the end of the study (week 6), blood samples were taken again from all participants, and bilirubin levels were measured again.
4. Blood sampling, storage, and analysis were carried out in full compliance with GOST and laboratory safety standards.

Determination of bilirubin levels.

The level of total bilirubin in blood serum was measured by the colorimetric method using diazotized sulfanilic acid. Measurements were performed on an automated analyzer at a wavelength of 546 nm. Each analysis was repeated twice, and the average value was recorded.

Statistical analysis.

Data were analyzed using IBM SPSS Statistics 26.0. Descriptive statistics (mean, standard deviation, median) were used, as well as the Student t-test (for paired and unpaired cases), and the Wilcoxon test (for nominal changes). A value of $p < 0.05$ was considered statistically significant.

Results

The study investigated the dynamic changes of total bilirubin levels in blood serum under the influence of physical exercise in healthy adolescents aged 14–16 years. At the initial stage, bilirubin levels in the experimental and control groups were statistically similar and amounted to 10.3 ± 1.2 μmol/l and 10.5 ± 1.1 μmol/l, respectively ($p > 0.05$).

After 6 weeks of standard physical exercise, a significant change in bilirubin levels was observed in the experimental group. At the end of the training, the level of UB in this group

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increased to 13.8 ± 1.4 μmol/l ($p < 0.01$), i.e. an increase of 34% compared to the initial value was recorded on average. In this case, a greater increase in conjugated (direct) bilirubin was found, which is explained by increased metabolic activity in hepatocytes [1, 4].

In the control group, no statistically significant change in total bilirubin levels was observed over 6 weeks (10.6 ± 1.3 μmol/l; $p > 0.05$). This indicates that metabolic stability was maintained against the background of low physical activity.

Table 1. Changes of total bilirubin levels in the blood of adolescents (μmol/l)

Group	**In the beginning (week 0)**	**after 6 months**	**Δ% change**	**p-value**
Experimental	10,3 ± 1,2	13,8 ± 1,4	+34%	<0,01
Control	10,5 ± 1,1	10,6 ± 1,3	+0,9%	>0,05

Also, the increase in bilirubin observed under the influence of physical loads is interpreted as a sign of the activation of the antioxidant defense system against oxidative stress in the body. Since bilirubin itself is known as a powerful endogenous antioxidant [2, 3, 4]. This has been confirmed by other researchers, who have shown that prolonged aerobic exercise increases the concentration of bilirubin in the blood plasma, which may protect the cardiovascular system [3, 5].

Along with these data, it should not be overlooked that the increase in bilirubin levels may sometimes be associated with an increased load on the hepatobiliary system [6, 7]. However, since liver enzymes (ALT, AST) were normal in all participants, this was considered an adaptive response occurring within the physiological norm.

The results of the study are consistent with data presented in foreign literature and show that the activation of metabolic and antioxidant defense systems is observed in the body of adolescents against the background of physical activity [1, 2, 4, 8].

Discussion

During the study, an increase in total bilirubin levels was observed in healthy adolescent children under the influence of physical exercise. These results indicate that bilirubin is not only a metabolic product of liver activity, but also an indicator of physiological changes in the body. In particular, the participation of bilirubin in antioxidant activity, heme metabolism and protective mechanisms against cellular stress is one of the current issues in modern science [1, 3, 4].

In recent years, scientific studies have noted bilirubin as a substance with high biological activity as an endogenous antioxidant. It neutralizes free oxygen radicals and protects cells from oxidative stress [2, 4]. Studies by Hinds and Stec have shown the role of bilirubin as a cardio-metabolic signaling molecule that protects the cardiovascular system [4]. It has also

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been found that a small increase in bilirubin can be a protective factor in chronic diseases such as ischemic heart disease, hypertension and diabetes [3, 5].

According to the results of this study, the total bilirubin level in adolescents who underwent physical exercise significantly increased. This is primarily due to the increased breakdown of hemoproteins, the activation of hepatocyte activity and the process of bilirubin conjugation during adaptation to physical exertion. Such changes, as previously shown in foreign sources, are a mechanism that represents physiological adaptation [1, 4, 6].

On the other hand, an excessive increase in bilirubin levels or the accumulation of its unconjugated form may be a sign of hepatotoxicity. However, since liver enzymes (ALT, AST) were within the normal range in this study, it is determined that the observed changes are due to physiological adaptation. This conclusion is fully consistent with the approach previously proposed by Benesic that when assessing liver diseases, not bilirubin alone should be considered, but together with other laboratory indicators [6].

It should be noted that the colorimetric (diazo) method was used to determine changes in bilirubin levels in blood plasma. This method is currently considered one of the most reliable, economical and accurate methods in clinical and scientific medicine. The high accuracy of this method was noted in the work of Ngashangwa et al. [5].

However, in the context of Uzbekistan, the number of studies in this area is still small. Although the effect of physical activity on the heart, muscles and respiratory systems has been studied in depth in most cases, the dynamics of biochemical indicators, in particular, bilirubin levels, have not yet been sufficiently elucidated. Such scientific research is relevant against the background of measures being taken at the republican level to form a healthy lifestyle, physical education and youth health. Another important aspect is that adaptive responses to physical loads in a young organism are specific, and metabolic responses can differ significantly from those in adults. Kosmachevskaya and Topunov studied the additional functions of erythrocyte hemoglobin and its metabolites, showing that energy supply and antioxidant protection in young organisms are associated with complex systems [1].

Based on the above, it can be said that physical activity increases the activity of metabolic and antioxidant systems in the adolescent body and improves overall health. An increase in bilirubin levels without deviation from the norm indicates the adaptability of these systems. In the future, it is recommended that such studies be conducted in conjunction with other biochemical markers, such as malondialdehyde, superoxide dismutase, glutathione peroxidase, and inflammation indicators.

Conclusion

Physical exercise leads to a temporary increase in the amount of total and free bilirubin in the blood of adolescents. This, in turn, is important in assessing the functional state of the liver and heme metabolism. In the future, it is necessary to study in more depth how the duration and intensity of physical activity affect the biochemical indicators of adolescents of different ages. The results of the study proved that physical exercise has a significant effect on the biochemical indicators of the adolescent body, in particular, on the level of total

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bilirubin in the blood serum. Based on the data studied, it was found that after physical exertion, a relative increase in the amount of bilirubin in the blood was observed, which indicates the activation of physiological adaptation mechanisms in the body [1, 3, 4].

An increase in bilirubin levels indicates, first of all, an increase in the rate of breakdown of heme molecules. Since erythrocytes and other hemoproteins work actively during physical exercise, their non-nuclear forms are broken down, and bilirubin formation increases. This leads, on the one hand, to increased liver function, and, on the other hand, to the activation of the antioxidant defense system [2, 5].

The results obtained in the study are consistent with the data published in the international scientific literature. In particular, the antioxidant properties of bilirubin, its protective effect against the cardiovascular system, and cellular stress have been noted in many scientific works [3, 4]. This is especially important during adolescence - a period of high growth, development, and metabolic activity.

Also, an increase in bilirubin levels as a response to oxidative stress caused by physical exercise can be considered a physiological compensatory mechanism. Through this mechanism, the body maintains its internal balance and ensures stability to metabolic changes [5, 6].

Some studies conducted by Uzbek scientists have also highlighted the effect of physical exertion on the body, particularly, changes in blood biochemistry. In particular, changes in the level of bilirubin, along with hemoglobin, erythrocytes, and other indicators, were noted in students at sports schools after physical activity. This fact further enhances the relevance of this topic and requires further research.

In addition, the colorimetric detection method used in the study (based on diazo reagent) showed high accuracy, sensitivity, and reproducibility. This method is suitable for practical laboratory conditions and can be used to monitor the physiological state of healthy and sports-playing adolescents [7, 8].

Based on the results of the study, the following conclusions can be drawn:

1. Physical activity, although short-term, increases the level of bilirubin in the blood serum, which is associated with the activation of heme metabolism.

2. An increase in bilirubin levels is a sign of physiological adaptation, indicating the activation of the antioxidant defense system.

3. This condition is considered not pathological, but a normative physiological process and is one of the important biomarkers indicating the health of a young organism.

4. The methodological approaches and reagents used in the study allowed for a high-precision assessment of these processes.

5. The level of bilirubin can be proposed as an assessment criterion in the physiological monitoring system of sports-playing adolescents.

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It is important for future research to delve deeper into this topic, that is, to conduct research taking different age groups, intensity of physical activity, type of sport, and gender differences into account.

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