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The Influence of Physical Activity on the Secretory Function of the Pancreas in Athletes

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Abstract The primary objective of this research endeavor was to delve into the intricate relationship between physical activity and the secretory function of the pancreas. This involved a comprehensive examination involving a total of 78 athletes, meticulously categorized into two distinct groups: the first comprising 45 wrestlers, and the second consisting of 33 track and field athletes. Employing the enzyme immunoassay method, the study meticulously scrutinized the activity levels of amylase and lipase in these athletes, juxtaposed against their respective physical activity regimes. Through rigorous analysis, this study unearthed specific patterns of change and adaptation within the athletes' pancreatic secretory function, revealing fascinating insights into the dynamic interplay between physical exertion and pancreatic response. These findings illuminate the nuanced ways in which individuals from diverse sporting disciplines, each characterized by unique demands and levels of daily physical activity, undergo distinct physiological adaptations within the pancreas. Such revelations not only deepen our understanding of the intricate mechanisms governing human physiology but also hold profound implications for optimizing athletic performance and promoting overall health and well-being.

Keywords Wrestlers, Athletes, Physical activity, Amylase, Blood lipase

1. Introduction

Addressing the complexities surrounding the body's response to muscle tension stands as a pivotal challenge in contemporary physiology research. As muscle tension persists, the significance of assessing the adequacy of the body's response and the stability of its functional systems amplifies. Gryaznykh A.V.'s seminal work in 2011 laid the groundwork by unveiling a profound correlation between anabolic and catabolic hormones and the secretory function of digestive glands during recovery from muscle tension. Intriguingly, this research illuminated a multifaceted interplay of endogenous hormones, intricately linked to the unique nuances of restoring digestive gland secretion.

Against this backdrop, the investigation into the functional stability of the pancreas under the duress of stress factors, manifesting as both acute and chronic physical activity, emerges as a focal point of inquiry. A deeper comprehension of the mechanisms governing the impact of muscle tension and subsequent recovery on pancreatic activity, reactivity, and stability holds immense promise in mitigating adverse outcomes on the athlete's physiology. Notably, the dearth of systematic data on the intricacies of pancreatic function restoration amid acute physical stress underscores the pressing need for further exploration.

In light of these considerations, delving into the secretory activity of the pancreas among athletes during the recuperative phase following submaximal muscle loading assumes paramount importance. Such research endeavors not only contribute to elucidating the intricacies of pancreatic function under varying degrees of physical stress but also offer invaluable insights for devising targeted strategies to safeguard athlete well-being. By unraveling the underlying mechanisms and dynamics at play, we pave the way for informed interventions aimed at optimizing performance, preserving health, and mitigating the deleterious effects of sustained muscle tension on the body's intricate physiological milieu.

In the contemporary landscape of scientific understanding, it is widely acknowledged, and indeed no longer necessitates explicit demonstration, that the pancreas operates within stringent constraints regarding its capacity to continuously synthesize enzymatic proteins for secretion into the gastrointestinal tract. Seminal research by SS Rothman et al.

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in 2002 meticulously elucidated this intricate dynamic, shedding light on the intricate balance between enzymatic synthesis and replenishment within the pancreatic ecosystem.

The seminal work of SS Rothman et al. in 2002 provided quantitative insights into the pancreas's limitations, revealing that under specific physiological conditions, it can only synthesize a fraction—estimated at approximately 25-50% — of the total complement of pancreatic enzymes required for optimal digestive function. This revelation underscores the inherent constraints imposed upon the pancreas, highlighting its inability to solely rely on endogenous synthesis to meet the demands of intestinal digestion. Without recurrent replenishment of enzymes absorbed from the intestine and circulating within the bloodstream, the pancreas finds itself inadequately equipped to fulfill the exigent need for enzymatic activity during the digestive process.

Central to the findings of SS Rothman et al. is the notion of enteropancreatic circulation—an ingenious mechanism posited by the authors as an energy-conserving strategy employed by the body. This intricate system facilitates the recycling of enzymes from the intestine back to the pancreas, thereby conserving vital energy resources and optimizing the efficiency of enzymatic utilization. Such insights not only deepen our understanding of the sophisticated regulatory mechanisms governing pancreatic function but also underscore the remarkable adaptability and resourcefulness inherent within the human physiological framework.

By unraveling the complexities of pancreatic enzyme dynamics, the research spearheaded by SS Rothman et al. not only enriches our comprehension of digestive physiology but also unveils potential avenues for therapeutic intervention. Armed with this nuanced understanding, researchers are better poised to explore novel strategies aimed at bolstering pancreatic function and ameliorating disorders rooted in enzymatic dysregulation. Thus, the legacy of SS Rothman et al.'s seminal contributions reverberates across the scientific community, inspiring further inquiry and innovation in the quest for enhanced human health and well-being.

The intricate dynamics of enzymatic circulation within the bloodstream represent a fascinating aspect of physiological intricacy, as elucidated by esteemed researchers such as Korotko G.F. in 2011 and Mozheiko L.A. in 2017. These scholars have underscored the multifaceted nature of enzymatic distribution, highlighting how these vital biological catalysts can exist in various states within the bloodstream.

According to the insightful analyses put forth by Korotko G.F. in 2011 and Mozheiko L.A. in 2017, circulating enzymes exhibit diverse modalities of interaction within the vascular milieu. Enzymes may traverse the bloodstream in a dissolved state, or they may become absorbed by an array of blood components, including blood cells, distinct fractions of plasma proteins, and even the endothelium lining the blood capillaries. This intricate interplay culminates in the formation of a reservoir of deposited pancreatic enzymes within the systemic circulation.

Furthermore, the research elucidates the intricate pathways through which these enzymes become desorbed by specialized pancreatic cells, known as pancreatocytes, under specific physiological conditions. This intricate process involves enzymes traversing the bloodstream through various avenues, including endocretion from exocrinocytes within the pancreas, resorption from the lumen of the small intestine, and extraction from the ductal system, predominantly from microreservoirs.

Indeed, the formation of this pool of deposited pancreatic enzymes, as meticulously outlined by Korotko G.F. in 2014, represents a pivotal aspect of pancreatic physiology. This reservoir serves as a dynamic repository of enzymatic activity, poised to respond to the body's metabolic demands and regulatory cues.

The insights gleaned from the groundbreaking research conducted by Korotko G.F. and Mozheiko L.A. not only deepen our understanding of enzymatic dynamics within the bloodstream but also unveil the remarkable adaptability and sophistication inherent within the body's regulatory mechanisms. By unraveling the intricacies of enzymatic circulation and deposition, these studies pave the way for novel avenues of exploration in both basic science and clinical practice, holding profound implications for our comprehension of human physiology and the development of therapeutic interventions aimed at optimizing health and wellness.

Based on the above, recycling of digestive enzymes can be considered as a process necessary to maintain enzyme homeostasis and normal digestion. The a mount of pancreatic enzymes entering the blood through different routes and the mechanisms regulating their recirculation are being clarified. This explains the appearance in the complex composition of lymph and blood flowing from the small intestine, along with signal molecules of hormone proteins, antigens and other substances, digestive enzymes - lipase, amylase, maltase [Korotko, G. F. 2013].

In our opinion, for specialists in the field of sports medicine are interested in data on the functional state of pancreatic secretion in both athletes and non-athletes under various conditions of the body’s functioning (physiological rest, muscle tension). These prerequisites determined the purpose and directions of this study. The purpose of this study was to study the effect of physical activity on the secretory function of the pancreas.

2. Material and Research Methods

The comprehensive investigation unfolded against the backdrop of the esteemed Republican College of the Olympic and Paralympic Reserve in Tashkent, spanning a significant duration from January 2022 to November 2023. This institutional setting provided an optimal environment for the meticulous scrutiny of athletes and their physiological responses to varying degrees of physical activity.

The study cohort comprised a total of 78 athletes, carefully selected to represent a diverse spectrum of sporting disciplines and performance levels. Among them, 45 individuals, constituting 58% of the sample, belonged to the

esteemed cadre of wrestlers, forming the core of Group 1. Meanwhile, Group 2 consisted of 33 athletes, comprising 42% of the cohort, who specialized in track and field disciplines. This stratification ensured a balanced representation of athletes from different sporting backgrounds, allowing for nuanced comparisons and analyses.

Crucially, to provide essential benchmarks for comparison, a meticulously curated control group, denoted as Group 3-14, was established. This control cohort comprised individuals not actively engaged in organized sports activities. By juxtaposing the physiological parameters of athletes against those of non-athletic counterparts, the study aimed to discern the specific impacts of athletic training and physical exertion on pancreatic function and enzymatic activity.

The selection of participants from diverse sporting disciplines and the inclusion of a non-athlete control group underscored the study's comprehensive approach to understanding the nuances of pancreatic physiology in the context of physical activity. Furthermore, the protracted duration of the study allowed for longitudinal assessments, enabling researchers to capture potential fluctuations and adaptations in pancreatic function over time.

By situating the investigation within the esteemed confines of the Republican College of the Olympic and Paralympic Reserve, the study benefitted from state-of-the-art facilities and expert guidance, ensuring the integrity and rigor of the research process. Ultimately, the findings gleaned from this meticulously designed study hold the promise of illuminating novel insights into the complex interplay between physical activity, pancreatic function, and overall athlete well-being.

Inclusion criteria: Patients were included in the study if the clinical signs and history of their disease met the Rome IV criteria (2016) for functional gastrointestinal diseases with signed informed consent to participate in the study.

The criteria for exclusion from the study were the presence of organic pathology of the gastrointestinal tract, symptoms of “anxiety” that allow one to suspect an organic disease (unmotivated weight loss; dysphagia; vomiting with blood; melena, hematochezia); symptoms of dyspepsia; concomitant use of medications that could potentially lead to gastrointestinal dysfunction; progressive course of the disease, leading to the formation of organic pathology; fever; changes in objective status (hepatomegaly, splenomegaly, etc.), laboratory changes (blood in stool, leukocytosis, anemia, accelerated ESR, changes in biochemical blood test, etc.), as well as the presence of any acute diseases or exacerbations of chronic processes.

At the initial stage, all subjects underwent an in-depth medical examination at the regional medical and physical education clinic, which included the study of the gastrointestinal tract, anthropometry, somatoscopy, and medical and pedagogical observation. Based on their health status, all of them were classified into the main medical group. All studies were carried out with the obligatory written consent of the subjects in strict accordance and in compliance with bioethical standards. The subjects' sports specialization, qualifications and experience were taken into account. Based on the study conditions, the subjects were divided into three groups. The first group (n=45) of subjects were athletes developing speed and strength qualities, training primarily in anaerobic energy mode. These representatives included martial artists (Greco-Roman wrestling). The second group (n=33) are athletes developing the quality of endurance, training primarily in an aerobic energy mode (track and field athletes). All subjects were adolescent athletes in college. Various sports were taken as a model of hyperdynamia.

3. Research Results

To study the effect of physical activity on the body of athletes and on the functional state of the pancreas, dosed bicycle ergometric load was used. This made it possible to individually set the power of the bicycle ergometer work performed at the level of 70-75% of the MPC (S.B. Tikhvinsky, I.V. Aulik, 1990). A 60-minute physical load was performed at a level of 70 - 75% of the VO2max (a load close to a load of submaximal power), and the pedalling frequency was 65-75 rpm. The study of the functional state of the pancreas was carried out at rest (background data), with indicators immediately after an hour of bicycle ergometer exercise, after 1 hour of rest after the exercise and after 2 hours of rest at the end of the exercise.

To identify the mechanisms of regulation of pancreatic secretion, blood was taken from the ulnar vein in parallel. The activity of a-amylase (Diacon-DS, Russia) and lipase (Biocon, Russia) was determined in the blood serum using the Mindray enzyme immunoassay analyzer and reagents. The obtained data were processed using the method of variation and correlation analysis (G.F. Lakin, 1990; Statistica 5.11 software package). Statistical processing was carried out using the Student-Fisher method. Differences between the compared values were considered significant with a probability of at least 95% ($p < 0.05$).

Assessing the influence of physical activity on the exocrine activity of the pancreas in athletes with different levels and specifics of daily physical activity, a peculiar dynamic of indicators of the pancreatic enzyme system was identified, which is aimed at studying various physical qualities. At the same time, a peculiar dynamic of indicators was revealed between groups of athletes (wrestlers and track and field athletes) and a group not involved in sports. The results of the study indicate a unique feature and direction of the training process, which has a certain impact on the exocrine activity of the pancreas.

The results of the studies (Table 1) indicate that endurance athletes (track and field athletes) are characterized by a pronounced hyperfunction of pancreatic a-amylase, while athletes performing speed-strength work (wrestlers) showed a less pronounced increase in a-amylase activity. -pancreatic amylase compared with levels in individuals who do not engage in sports. In our opinion, the degree of multidirectional hyperfunction of the pancreas in wrestlers and track and field athletes is determined by the type of substrate for ATP

synthesis, as well as the athlete's qualifications, experience and age.

Table 1. Content of a-amylase in the blood mg/ml in athletes before and after physical activity

Condition	Control group n=14	Wrestlers n=45	Track and field athletes n=33
Peace	0.47 ±0.03	0.52±0.04*	0.56±0.05*
Exercise stress	0.72±0.06	0.76±0.06	0.93±0.08*
After 1 hour. after recovery	0.15±0.01	0.47±0.03*	0.31±0.03*
2 hours after recovery	0.48±0.04	0.45±0.05	0.53±0.05*

Note; *-differences are significant in relation to background data p <0.05

The observed dynamics may be most often found in wrestlers, who often resort to procedures such as weight cutting, which leads to dehydration of the body and loss of necessary cofactors and coenzymes. Of particular interest is the study of the secretory relationships of the pancreas in athletes after muscular activity. It is possible that physical activity, depending on the volume and intensity, can cause hyper- and hypofunction of the pancreatic secretory apparatus. At the same time, an irrational training regime can lead to significant changes in the activity of pancreatic enzyme systems, which is consistent with research (A.P. Kuznetsov, 2007). One of the reasons for the observed dynamics regarding the activity of a-amylase in the blood of the examined individuals after 30- and 60-minute bicycle ergometer exercise may be due to the acidification of the contents of the duodenum with lactate. This condition can lead not only to fermentopathy, but also to a state of dysbacteriosis, which in turn impairs the absorption of essential ingredients. At the same time, the significantly high level of amylase in the blood that we observed is apparently due to the younger age of the athletes. Such enzymatic differences in adolescents may be due to the specific metabolic processes characteristic of the puberty period. 1 hour after recovery, as indicated in Table 1, athletes experience a significant decrease in the level of a-amylase in the blood of endurance athletes. As for athletes who train speed-strength qualities (wrestlers), they have higher amylase levels. Differences in the studied indicators between groups of athletes not involved in sports were also revealed. Analysis of the dynamics of recovery of indicators of exocrine activity of the pancreas in the subjects showed that a two-hour period of aftereffect of the load relatively ensured the recovery of amylase concentration in the blood.

4. Discussion

Different dynamics were noted regarding the activity of the lipase enzyme in the blood of the examined athletes, which is presented in (Table 2). As can be seen from the results of the study, physical activity is accompanied by a significant increase in lipase activity in the blood of wrestlers, compared with the indicators of the studied enzyme in track and field athletes. Consequently, in physical activity in athletes, speed-strength qualities, the main energy substrate for supplying the body is lipids, which, when broken down, release more energy in the form of ATP. We observe a different picture regarding track and field athletes, where lipase activity is less pronounced during physical activity. In the process of recovery after physical activity, a restoration of the studied indicators in wrestlers is observed. 2 hours after recovery, the studied indicator remains at higher values relative to the comparison groups and control group indicators.

Table 2. Content of lipase in the blood units/ml in athletes before and after physical activity

Condition	Control group n=14	Wrestlers n=45	Track and field athletes n=33
Peace	9.6±0.81	11.5±0.92*	8.2±0.79
Exercise stress	8.2±0.89	18.9±1.19*	7.4±0.63*
After 1 hour. after recovery	7.4±0.87	10.2±1.23*	6.8±0.74*
2 hours after recovery	8.5±0.78	15.1±1.11*	8.0±0.72

Note; *-differences are significant in relation to background data p <0.05

Thus, among the examined athletes of various qualities, the aftereffect period of physical activity is characterized by heterochronicity of recovery reactions of various indicators of pancreatic secretion.

A study of the exocrine function of the pancreas in subjects of the control group and athletes of various specializations under conditions of muscular rest and during recovery after physical activity showed that, depending on the specifics of everyday physical activity, differences in the concentration of lipase and amylase in the blood are observed. These differences are revealed to a greater extent during acidification of the duodenum with lactate. When acidification of the duodenum with lactate occurs in wrestlers during exercise and recovery after muscle exercise, a tendency toward a decrease in amylase activity is observed. Amylase activity after physical activity, compared with background indicators, increases in subjects of the control group and athletes developing endurance (in track and field athletes); in the process of recovery after physical activity, the volume decreases to background indicators. When studying the activity of lipase in the blood, more pronounced changes in the studied indicator are observed in wrestlers relative to the compared groups.

The data obtained characterize specific changes and adaptations to physical activity in athletes of various sports with different levels of daily physical activity.

5. Conclusions

The following conclusions can be drawn about the influence of physical activity on the secretory function of the pancreas in athletes:

1. The research revealed specific patterns of change and adaptation within athletes' pancreatic secretory function, highlighting the dynamic interplay between physical exertion and pancreatic response. This underscores the complex physiological adaptations that athletes undergo due to their distinct daily physical activities and the unique demands of their sports.
2. A notable finding was the difference in the dynamic indicators of pancreatic enzyme systems between groups of athletes, namely wrestlers and track and field athletes, and a control group not involved in sports. This indicates that the nature and intensity of physical activity have a distinct impact on the exocrine activity of the pancreas.
3. Endurance athletes, such as track and field athletes, exhibited pronounced hyperfunction of pancreatic α-amylase, whereas speed-strength athletes, like wrestlers, showed a less pronounced increase. This suggests that the type of physical activity—endurance versus speed-strength—plays a significant role in determining the level of pancreatic enzyme activity, possibly due to the different substrates used for ATP synthesis.
4. The study highlighted the mechanisms regulating pancreatic secretion during and after physical activity, with findings indicating the potential for both hyper- and hypofunction of the pancreatic secretory apparatus depending on the volume and intensity of exercise. This emphasizes the need for rational training regimes to prevent adverse effects on pancreatic enzyme activity.
5. The study underlines the necessity of maintaining enzyme homeostasis for normal digestion and the role of the recirculation of digestive enzymes in this process. The research points out that understanding the mechanisms of enzyme entry into the blood and their recirculation can offer insights into optimizing athlete health and performance.
6. The findings offer valuable insights for sports medicine professionals regarding the functional state of pancreatic secretion in athletes. This information is crucial for developing targeted strategies to safeguard athlete well-being, optimize performance, and mitigate the effects of sustained muscle tension.

In summary, the study provides profound insights into the nuanced ways physical activity influences pancreatic secretory function in athletes, offering valuable perspectives for enhancing athletic performance and health through informed interventions and training practices.

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