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INFLUENCE OF OLFACTOMY, PHOTOPERIODIC FACTOR AND PHYSICAL ACTIVITY ON THE DYNAMICS OF CIRCADIAN RHYTHM OF BLOOD GLUCOSE IN RABBITS

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In our study, we analyzed changes in blood glycemic reactions in 30-, 90-, 180-, and 365-day-old rabbits under the influence of physical activity and interceptive stimulation. As a result of the activation of nervous, hormonal, and enzymatic regulatory mechanisms during short-term physical exercise, anabolic reactions of glucose metabolism in the body, regardless of age, are enhanced due to glycogen resources and an additional supply of glucose in the blood. Long-term, but also heavy, physical activity, on the contrary, enhances the catabolic side of glucose metabolism in the body and leads to a decrease in blood glucose levels. In our study, the determination of blood glucose levels in experimental rabbits of different ages was carried out after interoceptive stimulation, in particular, irritation of rectal mechanoreceptors with pressure 80-100 mm Hg. Based on these experimental facts, one can conclude that the mechanisms of interoceptive regulation, especially the central nervous and neuroendocrine mechanisms regulating the homeostatic state of the internal environment, are not fully formed yet in young animals and do not have a long-term effect on the level of glucose in the blood. Based on these experimental facts, it can be concluded that the mechanisms of interoceptive regulation, especially the central nervous and neuroendocrine mechanisms regulating the homeostatic state of the internal environment, have not been fully formed yet in young animals and do not have a long-term effect on the level of glucose in the blood. This can also be explained by the fact that the dynamic and rhythmic nature of blood glycemic reactions in young animals is not so pronounced. However, in older animals, these reactions, while maintaining their high dynamic and rhythmic properties, develop in the form of static hyperglycemia.

Key words: physical activity, visceral system, olfactomy, interceptive stimulation, glucose homeostasis, circadian rhythm, extrasensory, hypo- and hyperglycemia.

INTRODUCTION

One of the poorly studied issues in the physiology of sensor systems is determining experimental ways of influencing the afferent signal received by different receptors from the external and internal milieu on metabolic processes. According to the literature, photoreceptive, chemoreceptive, interception, and proprioceptive mechanisms are the strongest and multilateral effective mechanisms for functional activity in the organism among

sensor systems. Each of these mechanisms possesses effective specifications with a very complex and broad circle independently and plays a special role in the physiological regulation of functions. However, there is little practical-theoretical information and fundamental conceptions about their mutual morpho-functional relations and complex effects, and this issue became very important in studies conducted in both physiological and medico-biological directions [7, 12].

Some of the conducted research works give a basis to put forward the scientific conjecture that when the receptive function of the smell sensor system is violated (olfactomy), significant changes occur in several homeostatic indicators of the organism [17].

The experimental study of regulating effects on concrete internal functions and processes of the smell analyzer being in close connection with cortical and subcortical neuroendocrine structures of the brain in more wide aspects is a very interesting issue. There is little information about reflector and non-reflector relations among vegetative reactions with photoreceptions.

The photoperiodic effect of this sensor apparatus on metabolic indicators and the issue of the creation of biorhythmicity in them caused wider research only in the last times.

These studies showed that daily illumination degrees of photoreceptive nervous structures and impulse oscillations transferred periodically to the cerebrum for their intensity activate rhythmically at about one day of photoperiodically the nervous and neuroendocrine activity of the epiphysis gland, olfactory brain, limbic structures of the brain, hippocampus, amygdala, and other multifunctional cortical and subcortical and intermediate brain structures of neuroendocrine neuron populations of the hypothalamus, and through them activate suprachiasmatic nuclei of the hypothalamus [8, 12].

Especially depending on the natural and artificial changes, the change of light and dark regimes, and the issue of sustainable desynchronized or arrhythmic influence caused by prolongation or shortening of day and evening phases, illumination, and darkness factors are actual nowadays [7, 9, 10, 11].

Determining the influence of circadian rhythmic dynamics on this or another homeostatic indicator of interoceptive stimulations and physical activities on the background of activation or deactivation of extrasensory functions in regulation of circadian rhythms of function and processes in the organism is a very interesting issue [13, 15]. The study of direct and indirect effects of glucose homeostasis sensors and neuro-humoral regulating mechanisms is one of the most mobile metabolic indicators and energetic substrates in organisms. We consider that this conjecture should be proved experimentally and theoretically. The problem of regulation of the circadian biorhythm of glucose homeostasis should be considered against the background of sensor interventions, physical activities, different stressor factors, and interoceptive stimulations under the conditions of some experimental tests. Experimental research on some issues in these directions in this research work is considered especially important, and, according to our opinion, this is a very necessary and actual problem for physiology and biorythmology.

The previously known fact was confirmed again in the experiments, in which interoceptive irritations were applied: really interoceptive apparatus possess an important role in the regulation of glucose turnover [4, 6]. According to the results of our experiments, the age period of animals was one of the factors providing the effectiveness of interoceptive stimulation.

Taking into consideration the issues mentioned above, our goal was to conduct research on this subject. The activity of the motor system in human and animal organisms is very important. This system achieves compliance in a short and long period of time in the external environment of the organism by conducting the complex body acts by the central nervous apparatus and peripheral effector organs – skeletal muscles joined to it. Implementing different acts in close connection with sensor, other neural-reflector, neural-humoral, emotional-motivational, and other mechanisms bears more reflector character and

realizes a strengthening effect on the dynamics of general and special physiological rhythms of the organism [5]. Several research works demonstrated that physical activities, possessing different strengths and effects, cause homeostatic changes aside from causing sustainable changes in the continuum of motor behavior, especially inducing acts in the activity of motor mechanisms [1, 15].

MATERIAL AND METHODS

Blood samples for analyses from control and experimental rabbits were taken from the ear veins by cutting with tweezers or medical needles and placed in test tubes (volume 2 mL) containing a little amount of heparin. Blood samples were centrifuged, plasma was saved, and the level of glucose was defined. Measurements were conducted with the application of a high-sensitivity automatic glucometer ("Bayer Corporation", USA). The data of the experimental results were analyzed using the Student's t criterion as a parametric statistics method in the Excel program, and their statistical validity (P) degree was defined.

We used 1-, 3-, 6-, and 12-month-old rabbits in our experiments. The main purpose of taking experimental animals at this age was to reveal the specific age-related characteristics of the sensory and somatovisceral reactions of the animal to a certain factor and the age dependence of the studied physiological indices. Our experiments were conducted on very young (1-3-month-old) and older (6–12-month-old) rabbits. The purpose was to study changes during a day in glucose homeostasis after the execution of locomotor activity by rabbits at different ages. The animals were placed in an empty mechanical device like a drum (treadmill) to apply physical activity, and then the drum was rotated for 40–45 cycles per min by connecting to a power network for 5 min in one experiment and for 20 min in the other. Animals were obliged to execute running acts in defined periods (during 5 and 20 min) in one place to keep their balance in a rotating drum, and this was characterized as forced physical activity. Researchers used this method of loading physical activity widely in their experiments [2, 3, 13, 17]. The keeping time of the animal in the drum and the rotating speed of the drum changed in our experiments. The dynamics of glucose in the blood three times (morning, noon, and evening) during a day in animals of different ages forced to realize physical activity were studied.

RESULTS AND DISCUSSION

The effect of physical activities on glucose metabolism in the organism was studied long ago, but some aspects still remain opaque. Some experimental facts about the influence of this or another metabolic process on strength and duration of physical activity remain controversial. We took into consideration the importance of studying this actual issue from both physiological and clinical sides, and we studied the alteration of glycemic reaction in the blood after the influence of physical activities and interoceptive stimulation for 5 and 20 min in 30, 90-, 180-, and 365-day-old rabbits.

For this reason, we forced experimental animals to run for 5 min in a slowly rotating drum (40–50 rotations per min), and then we studied the changes in the glucose level in the blood. The results of these experiments are presented in Table 1.

As it is seen from the table, the level of glucose in the blood was 88±0.62 mg/dL (norm 76±2.57 mg/dL) in morning hours, 101±0.88 mg/dL (norm 88±1.08 mg/dL) in afternoon hours, 84±1.15 mg/dL, (norm 70±1.67 mg/dL) in the evening hours, following the influence of short-term physical activity in 30-day-old animals. These facts showed that even short-term physical activity leads to an upregulation of glucose in the blood. These indicators changed in 90-day-old animals, respectively, 104±0.53 mg/dL (norm 85±1.33 mg/dL), 108±0.91 mg/dL (norm 92±0.62 mg/dL), 95±0.67 mg/dL (norm 80±0.93 mg/dL), in 180-day-old animals, 136±0.80 mg/dL (norm 114±0.90 mg/dL), 144±1.05 mg/dL (norm 126±0.55 mg/dL), 124±1.13 mg/dL (norm 110±0.62 mg/dL); in 365-day-old animals, 152±1.07 mg/dL (norm 127±2.13 mg/dL), 156±1.34 mg/dL (norm 135±0.55

mg/dL) and 136±1.11 mg/dL (norm 118±2.20 mg/dL).

In our experiment, the animals performed running acts in one place to keep their sustainable condition in a rotating structure, and this was possible only under the condition of coordination of all motor acts. In this case, the animals were subjected to the effects of a dynamic physical factor such as vibration, and the organism responded to it in physiological and metabolic ways, respectively.

Table 1.

Dynamics of glycemic reaction in the blood during physical activity for 5 and 20 min in the animals at different ages (M±m, mg/dL)

Age of animals	Morning 8°°-9°°		Afternoon 13°°-14°°		Evening 18°°-20°°	
	norm	physical activity	norm	physical activity	norm	physical activity
After physical activity for 5 min						
30-day-old	76±2.57	88±0.62 p<0.001	88±1.08	101±0.88 p<0.001	70±1.67	84±1.15 p<0.05
90-day-old	85±1.33	104±0.53 p<0.001	92±0.62	108±0.91 p<0.001	80±0.93	95±0.67 p<0.001
180-day-old	114±0.90	136±0.80 p<0.001	126±0.55	144±1.05 p<0.001	110±0.62	124±1.13 p<0.001
365-day-old	127±2.13	152±1.07 p<0.001	135±0.55	156±1.34 p<0.001	118±2.20	136±1.11 p<0.01
After physical activity for 20 min						
30-day-old	76±2.57	66±1.12 p<0.01	88±1.08	74±1.11 p<0.05	70±1.67	61±0.88 p<0.001
90-day-old	85±1.33	67±0.82 p<0.001	92±0.62	74±0.80 p<0.001	80±0.93	66±0.75 p<0.001
180-day-old	114±0.90	90±1.05 p<0.001	126±0.53	112±0.96 p>0.05	110±0.62	94±0.62 p<0.001
365-day-old	127±2.47	107±0.87 p<0.001	135±1.55	127±0.99 p>0.05	118±1.03	102±0.90 p<0.001

We forced animals to run for 20 min in a rotating drum with long-term physical activity in the experiment of the second option of this part, and then we studied the level of glucose in the blood in the morning, afternoon, and evening hours. The results of the experiment are presented in Table 1. As is seen from it, after 20 min of physical activity in young (30-day-old) rabbits, a sharp decrease in glucose level in the blood was observed in the afternoon hours (norm 76±2.57 mg/dL, experiment 66±1.12 mg/dL). A similar change was noted in 90-day-old animals. A significant decrease also occurred in other hours of the day.

The level of glucose in the blood of 180-day-old animals was 90±1.05 mg/dL (norm 114±0.90 mg/dL) in the morning, 112±0.96 mg/dL (norm 126±0.53 mg/dL) in the afternoon, and 94±0.62 mg/dL (norm 110±0.62 mg/dL) in the evening after 20 min of physical activity. It becomes clear that glucose levels in the blood were decreasing under the influence of physical activity in accordance with the rhythm of the day. In particular, if short-term physical activity caused an increase in glucose level in the blood (hyperglycemia) regardless of the age of the animal, long-term physical activity, conversely, caused the hypoglycemia reaction. Such a type of reaction means that physical activity and its influencing parameters (duration and intensity) can change the glucose homeostasis of the blood at different levels and within limits.

We can explain the obtained experimental facts with the activation of mechanisms of nervous, hormonal, and enzyme regulation in the organism during short-term physical activity, regardless of the animal's age. In this case, the anabolic reactions of glucose metabolism and the reactions of glucose creation intensified on account of reserve glycogen resources, and additional glucose was released into the blood. Long-term, heavy physical activity, on the contrary, intensified the catabolic side of glucose metabolism in organisms and led to a decrease in the level of glucose in the blood. It should be noted that the execution of physical exercises is managed by the direct and indirect influences of some sensor mechanisms [6].

Interestingly, the problem of interoception was studied thoroughly in other aspects by both local and foreign researchers [8]. One of those, probably the most important aspect, was studying issues of the functional importance of interoceptors in different interventions by external factors, especially the activity of some extrasensory mechanisms. Solving such issues in an experimental way required us to study functional and metabolic changes caused by interoceptive stimulations in the organisms of experimental animals of different ages [16].

It is already well known that the best form of the metabolic process in the organism during physical activity is using carbohydrates as energy substrates.

For this reason, the production of free energy (ATP) is necessary for the execution of urgent functional acts. Also, motor reactions are realized on account of glucose passing to the tissues. However, the circadian dynamics of glucose in the blood are considered to be the most important physiological and biological indicator by the functional and metabolic points. For this reason, determination of the glucose level in the blood in different physiological and clinic research studies presents the initial conditions of practice and examination [2, 3, 14].

In our research, the determination of glucose in the blood of experimental rabbits at different ages was carried out after interoceptive stimulation. Stimulation of receptors in the rectum was carried out for 1-2 min before feeding the animals in the early morning, and the glucose level in the blood was measured 1 hour after stimulation and at different hours of the day. All data obtained in this experiment are presented in Table 2.

Table 2

The dynamics of glycemic reactions in blood after stimulation in norm and with interoceptive stimulation in the animals at different ages.

Age of animals	Norm. hour 8^{00}-9^{00}	Glucose level (mg/dL) in blood after irritation with 80-100 mm. mercury column			
		15 min	30 min	45 min	60 min
30-day-old	76±2.54	86±2.10 p<0.01	84±1.40 p<0.05	70±1.21 p=0.05	74±1.72 p>0.05
90-day-old	85±0.96	92±1.07 p<0.001	98±0.80 p<0.001	82±0.78 p<0.05	80±0.53 p<0.001
180-day-old	114±0.90	136±1.08 p<0.001	140±0.58 p<0.001	125±0.62 p<0.001	120±1.17 p<0.001
365-day-old	127±1.19	150±0.85 p<0.001	154±0.85 p<0.001	130±0.83 p>0.05	118±0.93 p<0.001

The results of our experiments in the sphere of influence of stimulation of mechanoreceptors of the rectum on glycemic reactions showed that the level of glucose in the blood during 1 hour of interoceptive stimulation changed differently in animals of different ages. More sensible changes in the glycemic reaction were observed in younger rabbits in comparison with the older animals. Thus, it revealed that the level of glucose in the blood of 30-day-old

rabbits was characterized by few alterations from the background level. For example, the stimulation of rectum receptors in 1-month-old animals increased the level of glucose in the blood up to 86 mg/dL during the first 15 minutes (norm of 76 mg/dL), and this indicator changed within 70-74 mg/dL in the remaining time. The level of glucose in the blood of relatively older rabbits was higher than the norm after the application of stimulation. For example, in the case of a normal level of glucose of 114 mg/dL in the blood in 180-day-old animals, it rose to 136 mg/dL after 15 min, 140 mg/dL after 30 min, 125 mg/dL after 45 min, and 120 mg/dL after 60 min of interoceptive stimulation.

CONCLUSIONS

We studied the interoceptive glycemic reactions to define the change in the circadian rhythm of the level of glucose in the blood of animals of different ages at different hours of the day from the standpoint of biorhythmology and age physiology. The maximum change in the level of glycemic reaction in the blood was noted on the 15^{th} and 30^{th} min after the beginning of interoceptive stimulation in all studied age groups of animals.

Thus, the highest level of glucose in the blood was recorded during daytime hours; the lowest level was recorded during morning and nighttime hours. The interesting fact that was revealed in our experiments is that the smell sensor system affected glucose homeostasis, but the favorability of this influence was not too high. Both the level and rhythmic dynamics of glucose levels in the blood in olfactomy cases were exposed to weak changes in comparison with the norm. One of our observations that piqued more interest from the standpoint of scientific research was that the photoperiodic regime affected glucose homeostasis more clearly in experimental animals. The normal rhythmic dynamics of glucose in the blood of younger or older animals kept under artificial illumination or darkness for a long period could be changed sharply, and the dependence of this on age was not significant.

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ВЛИЯНИЕ ОЛЬФАКТОМИИ, ФОТОПЕРИОДИЧЕСКОГО ФАКТОРА И ФИЗИЧЕСКОЙ АКТИВНОСТИ НА ДИНАМИКУ УРОВНЯ ГЛЮКОЗЫ В КРОВИ У КРОЛИКОВ

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В нашем исследовании изучались изменения гликемических реакций крови у 30-, 90-, 180- и 365-дневных кроликов под воздействием физической активности и интероцептивной стимуляции. В результате активации нервных, гормональных и ферментативных регуляторных механизмов при кратковременных физических нагрузках в организме, независимо от возраста, усиливаются анаболические реакции метаболизма глюкозы, т.е. образование глюкозы за счет резервных ресурсов гликогена и дополнительное поступление глюкозы в кровь. А длительные, как и тяжелые физические нагрузки, наоборот, усиливают катаболическую сторону метаболизма глюкозы в организме и приводят к снижению уровня глюкозы в крови. В нашем исследовании определение уровня глюкозы в крови у

экспериментальных кроликов разного возраста проводилось после интероцептивной стимуляции. Раздражение ректальных механорецепторов осуществляли под давлением 80-100 мм рт. столба. На основании этих экспериментальных фактов можно сделать вывод, что механизмы интероцептивной регуляции, особенно центральные нервные и нейроэндокринные механизмы, регулирующие гомеостатическое состояние внутренней среды, еще не полностью сформированы у молодых животных и не оказывают длительного воздействия на уровень глюкозы в крови. Это также можно объяснить тем, что динамический и ритмичный характер гликемических реакций крови у молодых животных не столь выражен. Однако у животных старшего возраста эти реакции, сохраняя свои высокие динамические и ритмические свойства, развиваются в виде статической гипергликемии.

Ключевые слова: физическая активность, висцеральная система, ольфактомия, интероцептивная стимуляция, гомеостаз глюкозы, циркадный ритм, экстрасенсорность, гипо-гипергликемия.

OLFAKTOMİYANIN, FOTOPERİODİK AMİLİN VƏ FİZİKİ YÜKÜN DOVŞANLARIN QANINDA QLÜKOZANIN DİNAMİKASINA TƏSİRİ

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Biz öz tədqiqat işimizi 30, 90, 180 və 365 günlük dovşanlarda fiziki yüklərin və interoseptiv stimulyasiyanın təsiri şəraitində sonra qanda qlikemik reaksiyaların səviyyəsində baş verən dəyişikliklər öyrənilmişdir. Qısa müddətli fiziki yükləmə zamanı sinir, hormonal və ferment tənzimləmə mexanizmlərinin fəallaşması nəticəsində orqanizmdə yaşdan asılı olmayaraq, qlükoza metabolizminin anobolik reaksiyalarını, yəni ehtiyat qlikogen resursları hesabına qlükozanın əmələ gəlməsi reaksiyaları intensivləşir və qana əlavə qlükoza daxil olur. Uzun müddətli, həm də ağır fiziki yüklər, əksinə orqanizmdə qlükoza mübadiləsinin katobolik tərəfini intensivləşdirir və qanda qlükozanın səviyyəsinin azalmasına gətirib çıxarır. Bizim tədqiqatımızda müxtəlif yaşlı təcrübə dovşanlarında qanda qlükozanın təyini interoseptiv qıcıqlanmalardan sonra həyata keçirilmişdir. Düzbağırsağın mexanoreseptorlarının 80-100 mm civə sütünu təzyiqilə qıcıqlandırılması (interoseptiv stimulyasiya) həm az yaşlı, həm də yaşlı dovşanlarda qanda qlükozanın səviyyəsini normaya nəzərən artırır və bu tendensiya intereseptiv stimulyasiyadan sonrakı 15-30-cu dəqiqələrində daha qabarıq şəkildə özünü göstərir. Aldığımız bu təcrübi faktlara görə belə mülahizə yürütmək olar ki, interoseptiv tənzim mexanizmləri, xüsusən də daxili mühitin homeostatik vəziyyətini tənzimləyən mərkəzi sinir və neyroendokrin mexanizmlər az yaşlı heyvanlarda hələ tam formalaşma mərhələsinə çatmır, qanda qlükozanın səviyyəsinə də onlar dayanıqlı effektiv təsir göstərə bilmirlər. Bu, o fakla da təsbit oluna bilər ki, az yaşlı heyvanlarda qanın qlikemik reaksiyalarının dinamik və ritmik xarakteri bir o qədər də qabarıq şəkildə təzahür edilmir. Halbuki yaşlı heyvanlarda həmin reaksiyalar öz yüksək dinamik və ritmik xassələrini saxlamaqla yanaşı, statik hiperqlikemiya formasında inkişaf edirlər.

Açar sözlər: fiziki yük, visseral sistem, olfaktomiya, interoseptiv stimulyasiya, qlükoza homeostazı, sirkad ritm, ekstrasensor, hipo-hiperqlikemiya

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