Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 6), Art 155, pp. 1373- 1379, June 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Individualization of martial arts training based on sensorimotor reaction analysis in students

IVAN BOCHARIN[1], MAXIM GURYANOV[2], ANTON VOROZHEIKIN[3], VIKTOR KRAYNIK[4], ELENA ROMANOVA[5], LARISA RYZHKOVA[6], ALEXANDER BOLOTIN[7], ATANAS SARANDEV[8], NINA ARNST[9], IVAN DAVIDENKO[10], MAXIM ANISIMOV[11], PAVEL TYUPA[12], ANDREY KOVALCHUK[13]
[1, 2] Privolzhsky Research Medical University, Nizhny Novgorod, RUSSIA
[3] Kaliningrad Institute of Management, Kaliningrad, RUSSIA
[4]Altai State Pedagogical University, Barnaul, RUSSIA
[5] Altai State University, Barnaul, RUSSIA
[6] The Russian University of Sport "GTSOLIFK", Moscow, RUSSIA
[7] Peter the Great St. Petersburg Polytechnic University, St. Petersburg, RUSSIA
[8] Medical University - Sofia, Sofia, BULGARIA
[9] Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, RUSSIA
[10,11] St. Petersburg State Agrarian University, St. Petersburg, RUSSIA
[12]Immanuel Kant Baltic Federal University, Kaliningrad, RUSSIA
[13] Yugra State University, Khanty-Mansiysk, RUSSIA

Published online: June 30, 2024
Accepted for publication : June 15, 2024
DOI:10.7752/jpes.2024.06155

Abstract:
The mobility and lability of nervous processes, along with the speed of excitation propagation through reflex arcs, are crucial factors determining the effectiveness of an individual's preparation for sports training and competitive processes. The aim of this study is to perform a comparative analysis of complex visual–motor reactions to moving objects among student-athletes engaged in different forms of physical activity in martial arts, with the goal of personalizing educational and training sessions. ***Materials and methods:*** Fifty-seven male students participated in the experiment, including 32 without specific sports training and 25 with sports experience in sambo and aikido categories. The equipment used was the "TVES" visual-motor reaction console with integrated "Psychophysiology" software. The study used the method of reaction to a moving object. The number of accurate, advanced and delayed reactions, the average reaction time, and the balance of nervous processes were assessed. ***Results:*** Students with sports experience showed more stable functioning of the central nervous system, as well as better mobility and lability of nervous processes, which is confirmed by reliable values of the studied indicators. ***Conclusion.*** During the test, student-athletes showed a predominance of accurate reactions, a more stable change in excitation and inhibition. They had a higher speed of excitation along the reflex arc compared to students from the untrained group. The results of cluster analysis among students without sports experience indicate instability of nervous processes with a predominance of excitation or inhibition processes. In the group of student-athletes, nervous processes are more balanced, which can have a positive impact on sports results.
Key Words*:* **physical education, martial arts, visual-motor reaction, sports training**

Introduction

In physical education and sports practice, one of the key informative predictors of the physiological state of the human central nervous system is the visual-motor reaction. It can be used to determine the characteristics of excitation and inhibition in the cerebral cortex, as well as the speed of nerve signals along the reflex arc (Van Biesen et al., 2018; Trecroci et al., 2021; Hülsdünker, & Mierau, 2021). Studying the speed and accuracy of sensorimotor reactions is of great importance in identifying the psychophysiological characteristics and parameters of the functional state of the central nervous system in athletes of various specializations. This determines the importance in terms of a personalized approach to the training process (Romanova et al., 2023; Wang et al., 2023). It has been established that this physiological function of the body is one of the leading characteristics that affects the quality of sports training (Hunzinger et al., 2020). The visual-motor response to a moving object is one of the most well-known for research processes of foreseeing the course of events in educational, training and competitive activities. It comes to the fore for achieving sports results in martial arts (Islam et al., 2020; Korobeynikov et al., 2020; Vorozheikin et al., 2020).

Corresponding Author: ELENA ROMANOVA, E-mail: romanovaev.2007@mail.ru

It is known that information about the current physiological state of the body involved in physical education or sports can be obtained by monitoring motor skills and abilities, as well as functional capabilities. However, the information obtained will not fully reflect a person's readiness for physical activity (Liu et al., 2020; Ferschl et al., 2021; Buchmann et al., 2023). Consequently, fairly complete information about readiness for the training and competitive stages of an athlete's preparation can be obtained by accessing neuro-dynamic characteristics.

The implementation of physical education disciplines at universities is associated with the training of athletes who are members of the national teams of the educational institution. Individual characteristics for the implementation of complex coordination movements, as well as maintaining an optimal level of functioning of the vestibular apparatus when performing physical exercises, come to the fore in the sports training of such student-athletes (Popovich et al., 2021, Vorozheikin et al., 2021). This factor is determined using neuro-dynamic and psychophysiological examination.

Determining the reaction time to a moving object is one of the ways to diagnose the speed of the visual-motor reaction. This method makes it possible to assess the athlete's ability to spatial and temporal forecasting. This ability is a significant factor in athletic performance (Colvett et al., 2023; Simmons et al., 2023). Research materials from scientists have demonstrated the possibility of this ability to accurately determine, timely change the body position and carry out movement in the right direction (Bruton, & O'Dwyer, 2018; Shoja et al., 2023). Researchers believe that this is due to the perception of information from the environment, its processing and making the right decision for a motor act. It is also interesting to note studies related to differentiated characteristics of the speed of sensorimotor reactions in individuals with different physical training. They confirm that the speed of the sensorimotor reaction has an inverse correlation with an increase in the physical fitness of the body (Maudrich et al., 2022; Buurke et al., 2023). This contingent of people also has a higher level of attention.

When studying a sensorimotor reaction, it is customary to distinguish two components: a latent or latent period. This is the time from the moment of perception of a visual impulse and its transmission to the cerebral cortex and motor period. It involves the propagation of a nerve impulse from the cerebral cortex to muscle motor neurons to perform a movement and the implementation of proprioceptive control over its parameters (McPherson, Bandres, 2021; Maudrich et al., 2021). Such experiments make it possible to assess the properties of nervous processes, the characteristics and speed of the nerve impulse along the reflex arc, the level of processing of incoming information, the strength and type of the human nervous system.

Determining the reaction to a moving object is an important direction in studying the functional state of an athlete's body in situational sports. In these types of sports activities, it is important to determine the possible motor actions of the opponent in order to develop counteractions. Such forecasting allows the athlete to prepare the necessary response actions in a timely manner. The athlete's key task is to determine the amount of lead given the speed of the object, the remaining distance, and the speed of their motor responses (Burris et al., 2020; Hunzinger et al., 2020; Janicijevic, & Garcia-Ramos, 2022). In this case, the actions of the subject under the experimental conditions are completely associated with the motor acts of athletes in situational sports. This allows you to determine the reaction speed and accuracy of motor skills.

The scientific literature presents data on the comparative characteristics of the visual-motor reaction of athletes mainly in team sports (basketball, football, handball, volleyball and others). At the same time, it is relevant to study the characteristics of sensorimotor reactions under the combined influence of educational and training factors of the educational environment at the university when practicing martial arts. Due to insufficient coverage of these issues in the scientific literature, there is a need to expand information in this area of research. The results obtained during the study will provide an opportunity for a personalized approach to the educational and training process for students involved in martial arts.

Research aim. To conduct a comparative analysis of a complex visual-motor reaction to a moving object among student-athletes who have different forms of organizing physical activity in martial arts to individualize educational and training sessions.

Material & methods

The research project involved 57 male students who studied at the medical university of Nizhny Novgorod (Russia). The age of the boys was 19-20 years (19.4±1.5). Two groups were identified. The first group included 32 students. They had no sports training, had never practiced martial arts and had no sports rank or title. Students of this group began to engage in martial arts in elective classes in the discipline of "physical education" at a medical university. In this group, martial arts training sessions were carried out once a week, lasting 60 minutes. The second group included 25 people. All students in this group are members of the university's national aikido and sambo team and have sports ranks up to candidate master of sports, as well as at least six months of experience in educational and training sessions and competitive activities. Representatives of this group trained at least 3 times a week, and the duration of each workout ranged from 90 to 120 minutes.

The study of the relationship between the processes of excitation and inhibition in the central nervous system was carried out using the complex visual-motor reaction test "reaction to a moving object (RMO) ". For this purpose, we used the software and hardware complex "TVES visual-motor reaction console" (Russia, model TU9442-051-00226454-2014) with integrated "Psychophysiology" software. The complex included a visual-motor analyzer, including a control panel with buttons to press during the test. Testing of sensorimotor parameters was carried out outside the training process, in a quiet room in the complete absence of extraneous stimuli, during the daytime. During the experiment, the subject, while observing the movement of an object in the form of a rectangle, had to press a button on the remote control at the moment when its position supposedly coincided with the mark, to stop the moving object. The speed of movement of the object and the side from which it began to move were constantly changed so that the participants in the experiment did not develop a conditioned reflex. The number of stimulus presentations was at least 50.

For monitoring, the following indicators were used: the relative value of the number of accurate reactions, advances and lags (%), average reaction time (M, ms) and the coefficient of variation. In addition, in each group of subjects, the number of people who, after testing, showed the conclusions "balance of nervous processes", "imbalance of nervous processes with a predominance of excitation", "imbalance of nervous processes with a predominance of inhibition" was determined. This part of the experiment was performed using cluster analysis of K-means methods. All project participants gave written voluntary consent to participate in the survey. The conducted project does not contradict the ethical requirements of the 2003 Declaration of Helsinki. All requirements of the declaration were met.

The material was processed using the Statistica 10.0 software package and MS Excel 2016. Testing for normality of distribution was carried out using the Shapiro-Wilk test. The results are presented as the arithmetic mean (M) and standard error of the mean (m). The parametric Student's t-test and the non-parametric Mann-Whitney U-test were used to test for statistically significant differences in the performance of the study groups of students. To assess the reliability of qualitative characteristics, the chi-square value ($\chi 2$) was determined; statistically significant differences were accepted at $\chi 2 > \chi 2$critical. Before performing cluster analysis, hierarchical clustering was performed to determine the number of clusters in each group. Then the parameters were standardized to equalize the composition of the populations. Cluster analysis was performed using K-means methods, determining the distance between centroids and the nearest points. Differences between indicators were considered significantly significant at $p<0.05$.

Results

The results of testing a complex sensorimotor reaction in male students without sports experience and student-athletes are presented in Table 1. In male students without sports experience, the number of accurate reactions was 50.5% of the total. The ratio of the lead and lag reaction was 30.4% and 19.1%, respectively. For students with experience in martial arts, the number of accurate reactions was higher – 65.5%, respectively, $p <0.05$. The leading and lagging reactions were 17.5% and 16.9%, respectively, $p <0.05$.

Thus, the period of complex processing of sensory signals by the central nervous system is characterized by more fine-tuning in individuals who have had sports training experience. These could be more precise accommodative and convergent changes in the perception of a moving signal in athletes, which is due to long-term sports experience. It should be noted that perceptual extrapolation is one of the trainable human qualities.

Table 1. Values of visual-motor reaction to a moving object of students involved in combat sports in various forms of organization of educational and training sessions

Indicator	Type of training sessions		Reliability according to the χ^2 criterion
	Элективный курс (n=32)	Спортивная секция (n=25)	
Exact reactions, %	50.5	65.5	1-2
Advance reactions, %	30.4	17.5	1-2
Delay reactions, %	19.1	16.9	1-2
Average reaction time, мс (M±m)	62.2±9.1	44.1±6.2	1-2 (according to Student's t test)
Coefficient of variation, % (M±m)	83.6±15.4	81.4±19.7	

Note: p – reliability of the difference in indicator values between students involved in martial arts in elective courses and in the sports section, p <0.05

Among young men of different organizational forms of training sessions, the average reaction time obtained during the study also showed a difference. It should be noted that the average reaction time to a moving

object depends on the mobility and lability of nervous processes, that is, on the change in excitation/inhibition in the central nervous system and the speed of excitation along the reflex arc. For students who are members of national teams for martial arts, the reaction speed is statistically significantly 29.1% lower compared to those studying martial arts in elective courses (44.1±6.2 and 62.2±9.1 ms, $p < 0.05$), respectively. This characterizes the predominance of balance in nervous processes in athletes, as well as a higher speed of nerve impulse transmission to the effector. This factor may be related to the level of training. The coefficient of variation indicator did not show statistically significant differences between the two groups of observed students.

In addition, processing of the results obtained should include analysis and comparison of the number of advanced and delayed reactions, on the basis of which the balance of nervous processes, or imbalance with a predominance of excitation or inhibition, is diagnosed.

To do this, we distributed each group of subjects into several subgroups using cluster analysis using the K-means method. In the first group, 3 clusters were displayed among untrained individuals, and 2 clusters were noted in the group of athletes (Table 2, Table 3). Quantitative data were standardized to be closer to zero.

Table 2. Number of subjects and average values of indicators of visual-motor reaction to a moving object in each cluster among untrained students, M±m

Indicator	Clusters		
	Cluster 1 (n=5)	Cluster 2 (n=15)	Cluster 3 (n=12)
Exact reactions, %	1.96±0.38	0.15±0.51*	0.4±0.27*#
Advance reactions, %	2.11±0.34	0.2±0.36*	-0.8±0.29*#
Delay reactions, %	-1.05±0.25	-0.51±0.3*	0.84±0.5*#
Average reaction time, мс (M±m)	2.12±0.47	-0.05±0.26*	-0.6±0.26*#
Coefficient of variation, % (M±m)	-1.02±0.65	0.53±0.17*	-0.3±0.2*#

*Note: * – the reliability of the values of visual-motor reaction indicators between the first and second clusters is statistically significant, $p < 0.05$; # - the reliability of the values of visual-motor reaction indicators between the second and third clusters is statistically significant, $p < 0.05$*

It was established that the number of subjects making up the first cluster among untrained individuals was 5 (15.6%) people. As a conclusion, they note the balance of nervous processes. Of the 27 (84.4%) people, 15 (55.5%) fell into the second cluster, with a predominance of excitation processes, and 12 (44.5%) people - into the third cluster, with a predominance of inhibition in the central nervous system.

Students with experience in sports were divided into two clusters, based on the strength and mobility of nervous processes when reacting to a moving object, Table 3.

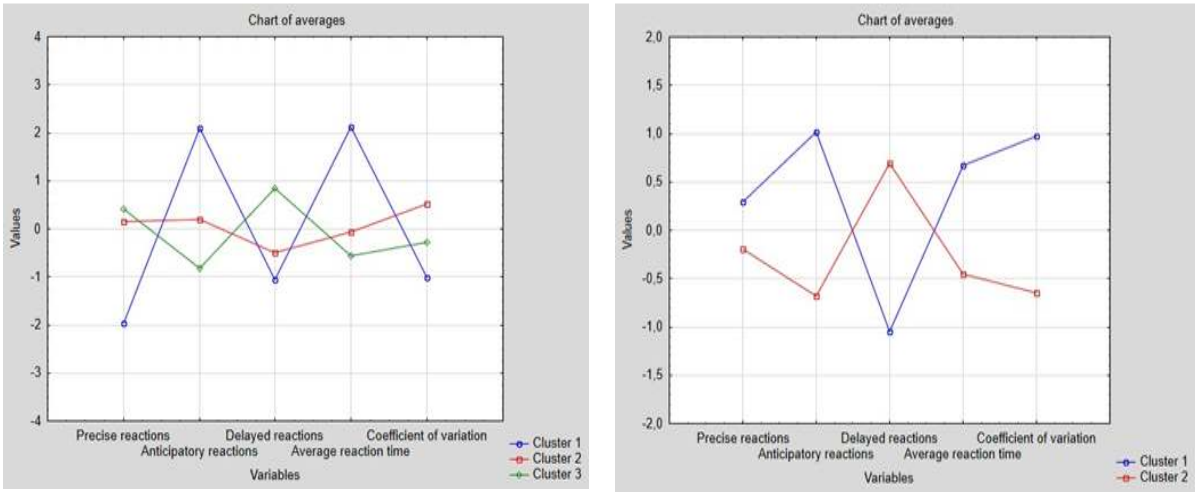
Table 3. Number of subjects and average values of indicators of visual-motor reaction to a moving object in each cluster among students with sports experience, M±m

Indicator	Clusters		
	Cluster 1 (n=5)	Cluster 2 (n=15)	Cluster 3 (n=12)
Exact reactions, %	0.29±0.1	-0.19±0.55*	0.29±0.1
Advance reactions, %	1.02±0.45	-0.68±0.34*	1.02±0.45
Delay reactions, %	-1.04±0.29	-0.7±0.39*	-1.04±0.29
Average reaction time, мс (M±m)	0.68±0.53	-0.45±0.22*	0.68±0.53
Coefficient of variation, % (M±m)	0.97±0.47	-0.65±0.35*	0.97±0.47

*Note: * – reliability in the values of visual-motor reaction indicators between the first and second clusters is statistically significant, $p < 0.05$*

The first cluster consisted of 17 (68.0%) representatives of combat sports, for whom the conclusion was recorded as the balance of nervous processes. Among this group, the number of accurate reactions is the largest, and the number of advances slightly exceeds the number of delays.

The second cluster included 8 (32.0%) athletes who had an imbalance of nervous processes with a predominance of excitation. In this group, the number of accurate reactions is also greatest, but the number of advances significantly exceeds the number of delays. Graphs of average indicators using cluster analysis in groups of untrained students and students with sports experience are presented in Figures 1, 2.



А) Б)

Fig. 1. Graphs of average visual-motor reaction indicators for untrained students (A) and students with sports experience (B)

It has been established that athletes are distinguished by more stable functioning of the central nervous system, a high speed of excitation along the reflex arc and a predominance of balance in nervous processes. This factor is influenced by the level of fitness of the body. Thus, among students involved in the sports sections of sambo and aikido, a high level of adaptation of the central nervous system to physical activity can be noted. The organizational form of martial arts training sessions and the level of fitness influence the achievement of sports results. This must be taken into account by the teaching staff of educational institutions when organizing educational and training sessions with students.

Discussion

An informative indicator for monitoring a person's physical and mental health are indicators of the functional state of the body (Romanova et al., 2023; Gryaznykh at al., 2021). When performing any type of activity or motor activity, all physiological systems are activated (Miko et al., 2020). At the same time, timely monitoring of the functional state will allow not only to control the level of physical performance, but also to prevent states of maladaptation in a person performing physical activity. In conditions of physical education and sports activities, this is of great importance in the implementation of educational and training programs, preparation of physical education classes and sports performances (Bocharin et al., 2022). Constant monitoring and correction of the educational and training process, in accordance with individual capabilities, is an important factor in achieving success in various sports, including situational ones (Islam et al., 2020; Korobeynikov et al., 2020). Undoubtedly, the execution of any movement is associated with activation of the central nervous system, which acts as an analyzer of the external signal, its processing and the launch of a certain program for the implementation of a motor act (Wang et al., 2023; Buchmann et al., 2023). In addition, achieving high results in sports requires the development of complex coordination skills and movements, and this is possible with complete coordination in the functioning of regulatory systems (Francino et al., 2022). Improving a person's speed of response to external stimuli allows them to more effectively improve complex coordination abilities and vestibular stability during physical exercise (Hülsdünker & Mierau, 2021).

The purpose of this study was to identify the characteristics of mobility and lability of nervous processes in the cerebral cortex of students involved in martial arts with various forms of its organization. The test indicator was the assessment of the visual-motor reaction to a moving object. The results of the analysis of the data obtained indicate that students who engage in martial arts on the basis of the sports section demonstrate significantly better indicators of reaction to a moving object, compared to students without sports experience. This is reflected in more stable and accurate reactions to object movement, which characterizes more accurate proprioceptive control in the central nervous system. Also, this group of students showed a better level of mobility and lability of nervous processes, in accordance with the average response time. Our findings are consistent with research materials obtained by other authors (Islam et al., 2020; Colvett et al., 2023; Simmons et al., 2023, (Vorozheikin et al., 2020). It is generally accepted that this physiological function of the body is one of the important qualities influencing the quality of sports training (Hunzinger et al., 2020). The materials of our study confirm this conclusion of the authors.

In accordance with cluster analysis, the majority of students in the group of athletes had balanced nervous processes, and in the group of untrained individuals, the majority of subjects had unbalanced nervous processes with a predominance of excitation or inhibition. This feature of the central nervous system is especially

important for students whose activities are associated with the intense educational process of mastering a profession. Sports activities once again confirm the importance of this activity for students, which creates more favorable conditions for studying at the university.

Thus, student-athletes have a predominant balance of the nervous system and better mobility and lability of nervous processes. Consequently, regular monitoring of the visual-motor reaction to a moving object makes it possible to assess the complex sensorimotor reaction and the degree of balance between the processes of excitation and inhibition. We believe that functional changes in the cerebral cortex, which are associated with sports activity, have a positive impact on the educational activity and performance of students at the university. The prospect for further research is to study the issue of the relationship between visual-motor reaction and regular sports activities and students' academic performance in mastering their chosen profession.

Conclusions

It has been established that students who engage in martial arts in sports sections have more stable functioning of the central nervous system. This is indicated by significantly better results of the visual-motor reaction to a moving object compared to students who master martial arts in elective physical education courses.

Among students with sports experience, a predominance of accurate reactions during the test was recorded, as well as a more stable change of excitation and inhibition and a high speed of nerve impulse transmission along the reflex arc.

During the cluster analysis, it was found that among students without sports experience, 27 (84.4%) subjects have an imbalance of nervous processes with a predominance of excitation or inhibition, and only among 5 (15.6%) students a balance of nervous processes was found. The group of student-athletes was divided into two clusters: 17 (68.0%) representatives of one of which were characterized by balanced nervous processes and 8 (32.0%) students of the second cluster with a predominance of excitation processes in the cerebral cortex. It can be assumed that the organization of martial arts classes in the sports section and the existing sports experience influence the mobility and lability of nervous processes, helps improve physical performance and ensures high sports results.

Timely assessment of the functional state of the central nervous system using the visual-motor reaction to a moving object allows you to individualize sports training in martial arts and make the necessary adjustments to the educational and training process.

Conflicts of interest. The authors declare no conflict of interest.

References:

Bocharin, I., Guryanov, M., Martusevich, A., Apoyan, S., Kolokoltsev, M., Melnichuk, A., Vorozheikin, A., & Romanova, E. (2022). Young men's body hemodynamics variability in different states of motor activity. *Journal of Physical Education and Sport*, *22(3),* 562-569. DOI: 10.7752/jpes.2022.0307

Bruton, M., & O'Dwyer, N. (2018). Synergies in coordination: a comprehensive overview of neural, computational, and behavioral approaches. *J Neurophysiol*, *1,* 120 (6), 2761-2774. DOI:10.1152/jn.00052.2018

Buchmann, M., Jordan, S., Loer, A.M., Finger, J.D., & Domanska, O.M. (2023). Motivational readiness for physical activity and health literacy: results of a cross-sectional survey of the adult population in Germany. *BMC Public Health, 23(1),* 331. DOI:10.1186/s12889-023-15219-4

Burris, K., Liu, S., & Appelbaum, L. (2020). Visual-motor expertise in athletes: Insights from semiparametric modelling of 2317 athletes tested on the Nike SPARQ Sensory Station. *J Sports Sci., 38(3),* 320-329. DOI:10.1080/02640414.2019.1698090

Buurke, T.J.W., van de Venis, L., den Otter, R., Nonnekes, J., & Keijsers, N. (2023). Comparison of ground reaction force and marker-based methods to estimate mediolateral center of mass displacement and margins of stability during walking. *J Biomech, 146*, 111415. DOI:10.1016/j.jbiomech.2022.111415

Colvett, J.S., Weidler, B.J., & Bugg, J.M. (2023). Revealing object-based cognitive control in a moving object paradigm. *J Exp Psychol Hum Percept Perform*, *49(11),* 1467-1484. DOI:10.1037/xhp0001158

Ferschl, S., Till, M., Abu-Omar, K., Pfeifer, K., & Gelius, P. (2021). Scientific cooperation and the co-production of scientific outcomes for physical activity promotion: Results from a transdisciplinary research consortium. *Front Public Health, 11*, 9, 604855. DOI:10.3389/fpubh.2021.604855

Francino, L., Villarroel, B., Valdés-Badilla, P., Ramirez-Campillo, R., Báez-San, Martín E., Ojeda-Aravena, A., Aedo-Muñoz, E., Pardo-Tamayo, C., &Herrera-Valenzuela, T. (2022). Effect of a six week in-season training program on wrestling-specific competitive performance. *Int J Environ Res Public Health*, *19(15)*, 9325. DOI:10.3390/ijerph19159325

Gryaznykh A, Butakova M, Grebenyuk L, Kiseleva M, Nasyrov T, Kolokoltsev M, Vorozheikin A, Romanova E, Bayankin O., Kowalski W., & Tyupa P. (2021). Effect of carbohydrate intake on endogenous hormones: anabolic and catabolic orientation content of highly qualified sportsmen–combat athletes. *Journal of*

Physical Education and Sport ® (JPES), Vol. 21 (3), Art 181, pp. 1421 – 1428. DOI:10.7752/jpes.2021.03181

Hülsdünker, T., & Mierau, A. (2021). Visual perception and visuomotor reaction speed are independent of the individual alpha frequency. *Front Neurosci, 15*. DOI:10.3389/fnins.2021.620266

Hunzinger, K. J., Sanders, E. W., Deal, H. E., Langdon, J. L., Evans, K. M., Clouse, B. A., Munkasy, B. A., & Buckley, T. A. (2020). The use of a visual motor test to identify lingering deficits in concussed collegiate athletes. *Journal of clinical and translational research*, *5(4),* 178–185. PMID: 32637719, PMCID: PMC7330924 Available from https://pubmed.ncbi.nlm.nih.gov/32637719/

Islam, M.S., Rahman, M.H., & De, A. (2020). Exercising with face mask during the pandemic: A qualitative analysis. *Saudi Journal of Sports Medicine, 20(3),* 59-63. http://dx.doi.org/10.4103/sjsm.sjsm_37_20

Janicijevic, D., & Garcia-Ramos, A. (2022). Feasibility of Volitional Reaction Time Tests in Athletes: A Systematic Review. *Motor control*, *26(2),* 291–314. DOI:10.1123/mc.2021-0139

Korobeynikov, G., Shtanagey, D., Ieremenko, N., Aksiutin, V., Danko, T., Danko, G., Goletc, A., Korobeynikova, L., Maximovich, N., Dudorova, L., & Kolumbet, A. (2020). Evaluation of the speed of a complex visual-motor response in highly skilled female boxers. *Journal of Physical Education and Sport, 20 (4),* 1734 - 1739. DOI:10.7752/jpes.2020.04235

Liu, M., Zhang, X., Xiao, J., Ge, F., Tang, S., & Belza, B. (2020). Community readiness assessment for disseminating evidence-based physical activity programs to older adults in Changsha, China: a case for Enhance®Fitness. *Glob Health Promot, 27(1),* 59-67. DOI:10.1177/1757975918785144

Maudrich, T., Hähner, S., Kenville, R., & Ragert, P. (2022). Somatosensory-evoked potentials as a marker of functional neuroplasticity in athletes: A systematic review. *Front Physiol, 12,* 821605. DOI:10.3389/fphys.2021.821605

Maudrich, T., Kenville, R., Schempp, C., Noack, E., & Ragert, P. (2021). Comparison of whole-body sensorimotor skill learning between strength athletes, endurance athletes and healthy sedentary adults. *Heliyon*, 7(8), e07723. DOI:10.1016/j.heliyon.2021.e07723

McPherson, J.G., & Bandres, M.F. (2021). Spontaneous neural synchrony links intrinsic spinal sensory and motor networks during unconsciousness. *Elife, 10*, e66308. DOI:10.7554/eLife.66308

Miko, H. C., Zillmann, N., Ring-Dimitriou, S., Dorner, T. E., Titze, S., & Bauer, R. (2020). Effects of physical activity on health. *Gesundheitswesen (Bundesverband der arzte des offentlichen gesundheitsdienstes) 82* (S03), S184-S195. DOI:10.1055/a-1217-0549. *(Germany)*,

Popovich, M., Almeida, A., Lorincz, M., Eckner, J.T., Freeman, J., Streicher, N., & Alsalaheen, B. (2021). Does exercise increase vestibular and ocular motor symptom detection after sport-related concussion? *J Neurol Phys Ther, 45(3),* 214-220. DOI:10.1097/NPT.0000000000000356

Romanova, E., Vorozheikin, A., Bayakin, O., Limarenko, O., Bolotin, A., Tyupa, P., Aganov, S., Pronin, E., & Anisimov, M. (2023). Enhancing physical and functional fitness through the integration of health fitness elements in young gymnasts. *Journal of physical education and sport, 23(10),* 2685-2691. DOI:10.7752/jpes.2023.10307

Shoja, O., Shojaei, M., Hassanlouei, H., Towhidkhah, F., Amiri, M., Boroomand, H., Rahimi, N., & Zhang, L. (2023). Lack of visual information alters lower limb motor coordination to control center of mass trajectory during walking. *J Biomech, 155,* 111650. DOI:10.1016/j.jbiomech.2023.111650

Simmons, C. M., Moseley, S. C., Ogg, J. D., Zhou, X., Johnson, M., Wu, W., Clark, B. J., & Wilber, A. A. (2023). A thalamo-parietal cortex circuit is critical for place-action coordination. *Hippocampus, 33(12*), 1252-1266. DOI:10.1002/hipo.23578

Trecroci, A., Duca, M., Cavaggioni, L., Rossi, A., Scurati, R., Longo, S., Merati, G., Alberti, G., & Formenti, D. (2021). Relationship between Cognitive Functions and Sport-Specific Physical Performance in Youth Volleyball Players. *Brain sciences*, *11(2),* 227. DOI:10.3390/brainsci11020227

Van Biesen, D., Jacobs, L., McCulloch, K., Janssens, L., & Vanlandewijck, Y. C. (2018). Cognitive-motor dualtask ability of athletes with and without intellectual impairment. *J Sports Sci, 36(5),* 513-521. DOI:10.1080/02640414.2017.1322215

Vorozheykin, A. V., Pavel Ivanovich, T., & Volkov, A. P. (2020). State and perspective directions of scientific researches by the type of hand fight sport based on analysis of scie. *Health, Physical Culture and Sports, 1(17),* 74-80. Retrieved from http://hpcas.ru/article/view/7478. DOI 10.14258/zosh(2020)1.9

Wang, X., Liu, Z., Zhang, H., & Ji, C. (2023). Effects of High-Intensity interval training on executive functions in college students: evidence from different doses. *Brain Sci, 13(4).* DOI:10.3390/brainsci13040571