

Comparative analysis of psychophysiological state among in physical active and sedentary persons

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Abstract.

Introduction The use of new technologies in human life leads to an improvement in lifestyle. However, many factors of modern life (environmental, social and others) can provoke a decrease in physical and mental performance, which, as a result, worsens health. One of main factor causing deterioration in health is physical inactivity. Physical activity, in turn, can help improve health and mental well-being. The study of the psychophysiological state of persons with different level of physical active may provide new information about the mechanism of physical inactivity and be of use to improve health. The purpose: We study psychophysiological state in physically active and sedentary persons. We predict that physically active participants buffer environmental stressors better and thus have higher values on their psychophysiological states than sedentary persons. Material and methods 19 physically active men (22-35 years) who practiced sports no more than three times a week were examined. Men with low physical activity and a sedentary lifestyle (20 persons, 26-36 years) were also examined. All of persons are non-clinical subjects. The mental state was studied using an adaptive version of the Luscher color test. Neurodynamic tests included a test of a person's ability to make decisions and anticipate them. Among the cognitive tests, the "Number Comparison" test for perception speed was used. All tests used in the study were part of the Multipsychometer-05 hardware and software complex. Results It was revealed that the lack of physical activity leads to increased tension of the autonomic regulation system and limitation of the body's functional reserves. The relationship of physical inactivity with increased anxiety and tension of the autonomic nervous system was revealed. Thus, the increase in effectiveness and speed of perception in physically active persons indicates the stimulating effect of the motor activity factor. In addition, it was revealed that physically active people have better accuracy and quality of non-verbal perception and information processing. Conclusions Physical activity affects the mental state, cognitive functions and anxiety levels. This is promoted by an increase in the performance of perception and the speed of processing non-verbal information. One of the main useful results of this study is the possibility of the influence of physical activity on improving the mental and cognitive properties of an individual

Keywords: psychophysiological state, physical active, sedentary persons

Introduction

According to the Declaration of the World Health Organization, human health is a state of complete physical, mental and social well-being, and not just the absence of disease. Physical well-being is associated with an active healthy lifestyle (Rueggsegger et al., 2018; Chen et al., 2022). Mental well-being depends on the psychophysiological status and includes information processing competences such as the ability to perceive and process information from the external environment (Morales-Rodríguez et al., 2020; Ruggiero et al., 2021). Social well-being is characterized by the level of the individual in society, a sense of comfort in professional or other activities.

The structure of physical well-being includes the components of physical fitness, level of physical activity and age as factor (Kljajević et al., 2021; Bondarev et al., 2021). Traditionally, physical activity has been considered a preventive health factor (Petrides et al., 2019; Adams et al., 2019).

The question often arises about the definition of a physically active person. We believe that physically active person association with abilities to daily exercises and optimize of body condition. The difference between a physically active people lies primarily in high stress resistance and the absence of sedentary behavior.

One of the main components of mental performance often defined as psychophysiological functions (Cipresso et al., 2019). Those functions can be categorized by the structure of the psychophysiological organization of a person such as neurodynamic functions, cognitive characteristics, and emotional states (Zhang et al., 2013; Korobeynikov et al., 2020). Moreover, psychophysiological functions are a basic of psychological condition of person. Many psychical processes supported of physiological properties. This is important due harmonization of health status of people via improvement of psychophysiological functions (Papale et al., 2023).

A focus on physical activity is currently important. The recent COVID-19 pandemic has highlighted additional problems about physical inactivity among adults. The use of new technologies in human life leads to an improvement in lifestyle. However, many factors of modern life (environmental, social and others) can provoke a decrease in physical and mental performance, which, as a result, worsens health. One of main factor causing deterioration in health is physical inactivity (Panahi et al., 2018). Evidence indicates that lack of physical activity is a destructive component of human life and responsible for disorders of different system of the body (Canu et al., 2019).

A main mechanism that explains why increasing physical and mental performance is associated with better health often refers to the effect of cross-adaptation (Klaperski et al., 2013). Cross-adaptation describes that the accumulated adaptive potential of any physical or mental factor allows persons to resist to environmental stressors. The accumulation of factors for promoting physical and mental health build together the effect of cross-adaptation (Wu et al., 2017). The accumulated adaptive potential of any factor can be understood by compensation such that each factor can be used for resistance to environmental stressors.

A major environmental stressor was recently well studied as in 2020 the COVID-19 pandemic began. For instance, a study showed how training endurance and mental health have been affected in physically active persons during the pandemic (Roche et al., 2022). Effects of the pandemic on health have been attributed for instance to the forced self-isolation and the need of stopping social and economic activities. It seems likely that due to a long break in intense and high frequency of motor activity, most people at the end of quarantine will be in a state of disadaptation, dysfunctional adaptation mechanisms and a lower level of working capacity.

Due the self-isolation observed the increase of depression and anxiety among people of different age (Ubara et al., 2020; Nkire et al., 2021). Simultaneously the data about improvement of physical and psychological condition by the mean of physical activity among people who been ill COVID was received (Precht et al., 2022; Colas et al., 2022).

An important and less studied is the study of psychophysiological functions in people with different levels of physical activity (Paoli et al., 2020; Sarto et al., 2020). Probably, studying the psychophysiological state will allow to better understand the mechanism of health of people with different levels of physical activity. It is possible that physically active participants are better able to tolerate environmental stress and therefore have higher scores on their psychophysiological state than less active people (Klaperski et al., 2018).

There are many studies on cognitive decline over the lifespan. For instance, aging is associated with low physical activity and decreased performance (Löckenhoff et al., 2018; Dully et al., 2018). But the changes that occur with physical inactivity in young age are poorly understood.

It is likely that the connection between cognitive decline and age-related hypokinesia is based on the perception and processing of information from the environment (Krivanek et al., 2021). Moreover, a decrease in mental abilities provokes a slowdown in decision making (Kolesnyk et al., 2019). On the contrary, physical activity leads to improved neural connections and increased decision-making ability.

Our hypothesis believes that the psychophysiological state is the main component of human health. One of the main factors influencing the psychophysiological state is physical activity. We believe that the improvement in cognitive function with physical activity occurs due to increased neural connections. Moreover, studying the mechanisms of the connection between physical activity and psychophysiological state can provide insight into the preventive health of people.

The purpose: We study psychophysiological state in physically active and sedentary persons. We predict that physically active participants buffer environmental stressors better and thus have higher values on their psychophysiological states than sedentary persons.

Methods

Participants

19 physically active men (22-35 years) who practiced sports no more than three times a week were examined. Men with sedentary lifestyle (20 persons, 26-36 years) were also examined. All participants were healthy and are non-clinical subjects.

Among people leading a sedentary lifestyle, all had a profession with reduced physical activity. These people spent more than 6 hours a day in a sedentary position. In addition, none of them had additional physical activity.

All subjects were previously examined by a therapist and given permission to participate in the study. No problems were identified in the health status of the study participants. Volunteers who expressed a desire to receive information about their psychophysiological state took part in the study. The selection of participants was made by prior announcement. Most of the study participants were university staff and researchers. A

preliminary survey of the individuals participating in the study revealed that the presence of the pandemic did not significantly affect the nature of physical activity.

The survey revealed that a group of people leading an active lifestyle during the pandemic continued their training sessions at home. While for sedentary people, the pandemic has not made any changes in terms of physical activity.

All participants agreed to participate in research in accordance with the Ethical Standards of the Declaration of Helsinki, as approved by the local Biomedical Research Ethics Committees. Before the start of the study, each of the experimental participants filled out a questionnaire that contains questions regarding consent or disagreement with the use of the step research for scientific purposes. Ethical clearance on this research was provided by Commission on Biomedical Ethics of the National University of Ukraine on Physical Education and Sport (on 22.08.2023, minutes №. 4).

Tasks and Measures

Were used multiple tests for the assessment of the psychophysiological state.

The mental condition was studied by the adaptive variant of the Lüscher color test. According to the test results, following variables were evaluated: psychical capacity, fatigue, anxiety, deviation from autogenously norms, eccentricity, concentricity, vegetative coefficient, heteronomy, and autonomy. In our previous study, a high degree of correlation was established between the parameters of the Lüscher color test and the mental condition of people (Stanzani et al., 2019).

Neurodynamics refers to a person's ability to adequately perceive information from the external environment, make optimal decisions and respond to external stimuli. One of the neurodynamic tests we used is the decision making task. The concept of decision making indicates as a person's ability to adequately perceive complex information (Raab 2020).

The anticipation property indicates anticipation of what will happen. Thus, the anticipation test assesses the balance of the nervous process and indicates the relationship between excitation and inhibition of the nervous system. The previous studies showed a connection between neurodynamic functions and the physical development of the junior schoolchildren (Korobeynikov et al., 2003; Lyzohub et al., 2016; Kozina et al., 2019).

Perception from the environment is an important characteristic of the nervous system. The quality and speed of perception determine the level of psychophysiological state. A visual perception test was used. Participants were asked to identify a geometric figure between four reference figures to close the missing element. Cognitive functions were studied using the "Comparison of numbers" test. The connection between cognitive function and physical activity has been revealed previously (Caponnetto et al., 2021).

Testing was carried out in the first half of the day, after instructions to the subjects. All persons were in satisfactory condition and mood. Complaints about health problems are excluded.

All the tests used in the study were part of the hardware-software complex "Multipsychometer-05". The tests used have been tested for reliability and validity (Akhapkin et al., 2018). In addition, our previous experience in examining people of different ages and levels of functional fitness convinces us of the reliability and validity of the tests used.

Procedure

Two different groups of persons were examined: physically active and sedentary. The research was carried out in the morning.

After receiving informed consent, were tested all persons with multiple tests. The task of the Lüscher color test is to find the preferred color among the presented colors. The principle of this test is the correlation between mental state and color preferences. The most relevant indicators for assessing the current mental state are mental capacity, fatigue, and anxiety.

Previous studies showed correlation of color test from Lüscher and emotional states of persons with cognitively disorders [Stanzani et al., 2019]. In addition, the Lüscher color test is used to assess emotional and post-traumatic stress disorder (Karimovna et al., 2023). A decision-making test related to a person's ability to process external stimuli with varying levels of difficulty. Different color stimuli were presented on a monitor. The task required participants to respond quickly and correctly to the appropriate task program. From the results of the test the following parameters were evaluated: dynamism, capacity of visual analyzer, decision-making time and impulsiveness.

To assess anticipation ability, we used the moving object response test. This test includes a complex of sensory-motor reactions to complex signals. According to the test results, the following parameters are evaluated: accuracy, stability, arousal and arousal trend.

The purpose of the method "Visual perception" is to assess perception, attention and thinking by quickly and efficiently solving a non-verbal stimulus (geometrical figures). The following variables were assessed: productivity, speed, accuracy and effectiveness of processing of non-verbal information. The value of productivity is determined by the total number of correctly completed tasks for the total time of the test. The property of perception is a criterion of sensitivity to cognitive impairment (Jessen et al., 2020; Korobeynikov et al., 2022).

The purpose of the "Comparison of numbers" test is to assess non-verbal cognitive resources. The display was presented with a number series from 2 to 9. The person must compare the current number with the previous one.

As a result of the test, the following variables were evaluated: effectiveness, latency of solution, accuracy and stability were estimated.

Among all the tests used, the main assessment is the ability to perception and information processing. However, if for a decision-making test time is the main criterion, then for an anticipation test it is important to assess the balance between excitation and inhibition of the nervous system. Accordingly, cognitive tests determine the speed of perception and the quality of processing of non-verbal information.

Statistical analysis

Statistica 12" software was used for data analysis. Due to the lack of normal distribution of our sample, we used non parametric methods of statistical analysis. Wilcoxon rank sum test was used in all study values for all analyses to assess statistical difference between groups of individuals and were considered statistically significant at $p < 0.05$. The interquartile range was computed using the first (25% percentile) and third quartile (75%). Spearman correlation analysis was used to study the relationships between the parameters of physiological states.

Results

Table 1 presents the results of a study of the Lüscher color test. According to the results obtained, the values of mental capacity, anxiety and vegetative coefficient were increased in sedentary individuals compared to active individuals. In addition, a decrease in physical activity was accompanied by an increase in anxiety and activation of the sympathetic tone of the autonomic nervous system.

Table. 1. Comparative analysis between persons with different levels of physical activity according to the parameters of the Lüscher color test (Median, Lower and Upper Quartiles)

Variables	Groups	
	Active (n=19)	Sedentary (n=20)
Mental capacity, conditional unit	10.0	12.50*
	9.00; 12.00	8.00; 13.00
Anxiety, conditional unit	1.00	3.00*
	0.00; 3.00	1.00; 4.00
Concentricity, conditional unit	9.00	5.50*
	6.01; 10.00	4.00; 7.00
Vegetative coefficient, conditional unit	13.00	17.50*
	10.00; 18.00	12.00; 22.00
Autonomy, conditional unit	10.00	8.00*
	8.00; 12.00	6.00; 8.00

Legend: * Wilcoxon, $p < 0.05$

At the same time, the values of concentricity and autonomy in physically active people were associated with independence from external influences. The following variables: fatigue, deviation from autogenously norms, eccentricity and heteronomy did not differ between groups.

Table. 2. Comparative analysis between persons with different levels of physical activity according to the parameters of neurodynamic tests (Median, Lower and Upper Quartiles)

Variables	Groups	
	Active (n=19)	Sedentary (n=20)
Decision making test		
Dynamism, %	68.59	73.10*
	65.66; 80.53	68.84; 81.55
Capacity of visual analyzer, conditional unit	1.82	1.65*
	1.69; 1.97	1.58; 1.80
Decision making time, ms	335.00	380.00*
	320.00; 410.00	350.00; 410.00
Impulsiveness, conditional unit	-0.03	-0.01*
	-0.07; 0.03	-0.17; 0.11
Anticipation test		
Arousal, conditional unit	-0.60	-0.21*
	-1.50; 0.16	-1.1; 0.06
Arousal trend, conditional unit	-38.59	-13.55*
	-205.00; 53.38	-230.10; 116.61

Legend: * Wilcoxon, $p < 0.05$

According to data Table 2 results of the decision test indicates that physically active individuals present better values. All the parameters analyzed were statistically different between groups.

The result of the test anticipation (Table 2) indicates the significance of the differences between both groups of studied individuals in terms of variables of arousal and the arousal trend. The result obtained indicates a high

level of excitation in sedentary people compared to physically active people. The following variables: accuracy and stability were not different.

Data from the cognitive functions test (Table 3) show significant differences between both groups in terms of the studied variables. Indicators of the speed of perception was higher in physically active individuals. Higher productivity among physically active individuals indicates a greater number of correctly solved tasks. The accuracy variable were not different.

Tab. 3. Comparative analysis between persons with different levels of physical activity according to the parameters of cognitive tests (Median, Lower and Upper Quartiles)

Variables	Groups	
	Active (n=19)	Sedentary (n=20)
Visual perception		
Productivity, conditional unit	72.00 64.00; 78.00	65.50* 52.00; 80.00
Speed of information processing, number stimulus/min	19.25 17.00; 21.00	16.49* 13.50; 18.75
Effectiveness, conditional unit	57.25 44.87; 62.24	48.90* 38.93; 62.43
Comparison of numbers		
Effectiveness, conditional unit	979.73 870.28; 1085.70	876.24* 769.25; 1028.10
Latency of solution, ms	862.55 759.70; 988.00	952.96* 845.03; 1048.20

Legend: * Wilcoxon, $p < 0.05$

The results of comparison of numbers test revealed the best effectiveness values in physically active men. Lower values in latency of solution in physically active persons indicates an increase in the speed of perception of non-verbal information. The following variables: accuracy and stability were not different.

Correlation analysis between psychological state parameters and neurodynamic characteristics showed higher coefficients in the group of physically active people compared to sedentary ones.

In the active group the analysis showed a significant correlation between eccentricity and stability in the anticipation test ($r_s = -0.53$, $p < 0.05$). The study showed a significant relationship between heteronomy and anticipation test variables: stability ($r_s = -0.63$, $p < 0.05$), arousal ($r_s = -0.73$, $p < 0.01$) and correlation of autonomy with arousal ($r_s = -0.55$, $p < 0.05$).

In sedentary persons, the correlation between psychical capacity and arousal trend ($r_s = 0.60$, $p < 0.05$) indicates a multidirectional vector correlation. There was a correlation between concentricity and dynamism according to the anticipation test in sedentary persons ($r_s = 0.55$, $p < 0.05$).

Discussion

This study examined the relationship between parameters of psychophysiological state in men with different levels of physical activity.

Our results extend knowledge that the lack of physical activity leads to increased tension of the autonomic regulation system and limitation of the body's functional reserves (Canu et al., 2019). In addition, the development of psycho-emotional fatigue under conditions of physical activity limitation can provoke a weakening of cortical activation (Panahi et al., 2018). As is known from previous studies, physical activity contributes to an increase in human resilience (Ávila et al., 2018; Bondet et al., 2020). The main mechanisms of this process are associated with adaptation to physical activity and the formation of a functional system that is resistant to negative environmental factors. Mental deterioration is associated with internal anxiety and uncertainty about the limitations of physical inactivity (Bélair et al., 2018; Romero-Blanco et al., 2020). Thus, decline of physical activity, along with autonomic functions, the mental state of the individual is substantially affected.

The results showed an increase in anxiety and autonomic nervous system tension in sedentary people. In physically active people, optimized functioning of the autonomic nervous system, reduced anxiety and increased mental resource were observed. These results are consistent with the authors' data showing the connection between well-being and the level of physical fitness (Kljajević et al., 2021; Bondarev et al., 2021). High levels of well-being and fitness may slow the decline in physical dysfunction in humans and improve cardiovascular function (Petrides et al., 2019; Adams et al., 2019).

Our study showed improved decision-making characteristics and decreased arousal in physically active individuals. In contrast, sedentary individuals showed decreased decision-making ability and increased arousal. The results obtained were consistent with the data of the authors who showed an increase in cognitive activity due to the activation of neural circuits of the brain under conditions of moderate physical activity. At the same

time, a decrease in physical activity is accompanied by deterioration in memory and information processing ability. Among physically active persons, the best values were observed for solving tasks productivity and perceptual speed. In sedentary persons the characteristics of productivity, efficiency, and perceptual speed lost to physically active persons.

In contrast to sedentary individuals, an increase in the ability to accelerate the perception and processing of non-verbal information has been shown in physically active individuals. These results are consistent with other studies that show improvements in nonverbal learning even when using perceptual-motor training. In addition, the presence of a connection between speed indicators of cognitive activity and sensorimotor reaction indicates possible mechanisms for improving neurodynamic functions during motor activity.

The obtained results can help to build a concept of prevention of deterioration of psychophysiological states in accordance with the mechanisms of improvement of the mental condition, neurodynamics and development of cognitive functions.

To conclude our results, we proposed a scheme of the relationship between physical activity and psychophysiological state (Figure 1).

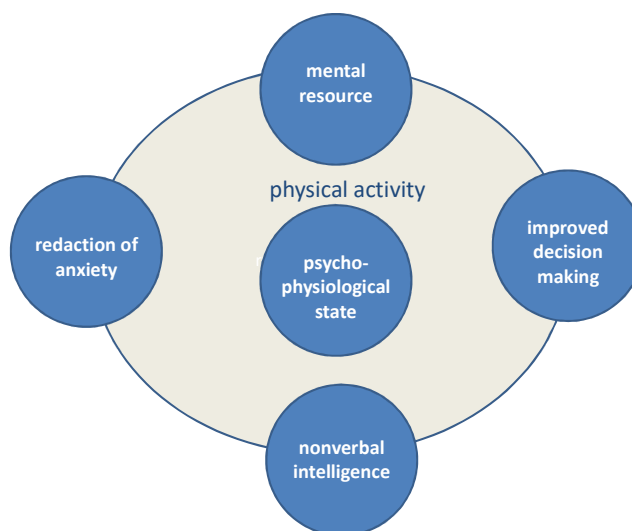


Fig. 1 Schema of relationship of physical activity and psychophysiological state

Thus, psychophysiological state includes the following components: mental, emotional, neuropsychological and cognitive. Physical inactivity leads to deterioration of the mental condition, increased anxiety, decreased speed of perception from space and deterioration of decision making on non-verbal information. Physical activity as a preventive factor leads to an improvement in the psychophysiological state. In particular, physically active individuals were observed to have increased mental resource, decreased anxiety, improved decision-making and speed of speed perception and advancement of non-verbal intelligence. In fact, physical activity leads to the construction of new connections between neurodynamics and cognitive properties. This process improves the perception of visual information and decision making.

Limitations

This study cannot be extended to the entire population and is limited to just this contingent. In further research, we plan to develop real ways to improve psychophysiological state through physical activity.

Conclusions

Physical activity affects the mental state, cognitive functions and anxiety levels. This is promoted by an increase in the performance of perception and the speed of processing non-verbal information. One of the main useful results of this study is the possibility of the influence of physical activity on improving the mental and cognitive properties of an individual. Health prevention involves physical activity and improving psychophysiological state by optimizing emotions, perception and processing of non-verbal information.

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Conflicts of interest

The authors declare no conflict of interest

References

- Adams V, Linke A. Impact of exercise training on cardiovascular disease and risk. Lifestyle changes for disease prevention. *Prim care*. 2019;1865(4):728-34. <https://doi.org/10.1016/j.bbadis.2018.08.01>.
- Akhapkin R.V., Fedorova A.I., Faizulloev A.Z., Emelin K.E. Effects of sertraline on cognitive function in patients with unipolar depressive disorders. *Medical council*. 2018;(18):24-29. <https://doi.org/10.21518/2079-701X-2018-18-24-29>.
- Ávila MP, Corrêa JC, Lucchetti AL, Lucchetti G. The role of physical activity in the association between resilience and mental health in older adults. *J Aging Phys Act*. 2018;26(2):248-53. <https://doi.org/10.1123/japa.2016-0332>.
- Bélaïr MA, Kohen DE, Kingsbury M, Colman I. Relationship between leisure time physical activity, sedentary behaviour and symptoms of depression and anxiety: Evidence from a population-based sample of Canadian adolescents. *BMJ Open*. 2018;8(10):e021119. <https://doi.org/10.1136/bmjopen-2017-021119>.
- Bond S, Arena R, Berra K, Popovic D, Smirmaul BP, Ortega FB. Introducing the HL-PIVOT network: Promoting human resilience and quality of life through healthy living initiatives. *J Cardiopulm Rehabil Prev*. 2020;40(6):356-8. <https://doi.org/10.1097/HCR.0000000000000555>.
- Bondarev D, Sipilä S, Finni T, et al. Associations of physical performance and physical activity with mental well-being in middle-aged women. *BMC public health*. 2021;21(1):1-1. <https://doi.org/10.1186/s12889-021-11485-2>.
- Canu MH, Fourneau J, Coq JO, et al. Interplay between hypoactivity, muscle properties and motor command: How to escape the vicious deconditioning circle? *Ann Phys Rehabil Med*. 2019;62(2):122-127. <https://doi.org/10.1016/j.rehab.2018.09.009>.
- Caponnetto P, Casu M, Amato M, Cocuzza D, Galofaro V, La Morella A, Paladino S, Pulino K, Raia N, Recupero F, Resina C. The effects of physical exercise on mental health: From cognitive improvements to risk of addiction. *Int. J. Environ. Res. Public Health*. 2021;18(24):13384. <https://doi.org/10.3390/ijerph182413384>.
- Colas C, Bayle M, Labeix P, Botelho-Nevers E, Gagneux-Brunon A, Cazorla C, Schein F, Breugnot E, Garcin A, Feasson L, Roche F. Management of Long COVID—The CoviMouv/Pilot Study: Importance of Adapted Physical Activity for Prolonged Symptoms Following SARS-CoV2 Infection. *Frontiers in Sports and Active Living*. 2022;4:877188. <https://doi.org/10.3389/fspor.2022.877188>.
- Chen Z, Chen J, Collins R, et al. China kadoorie biobank of 0.5 million people: Survey methods, baseline characteristics and long-term follow-up. *International Journal of Epidemiology*. 2011;40(6):1652-66. <https://doi.org/10.1093/ije/dyr120>.
- Cipresso P, Colombo D, Riva G. Computational psychometrics using psychophysiological measures for the assessment of acute mental stress. *Sensors*. 2019;19(4):781. doi:10.3390/s19040781
- Dully J, McGovern DP, O'Connell RG. The impact of natural aging on computational and neural indices of perceptual decision making: A review. *Behav Brain Res*. 2018;355:48-55. <https://doi.org/10.1016/j.bbr.2018.02.001>.
- Jessen F, Amariglio RE, Buckley RF, van der Flier WM, Han Y, Molinuevo JL, Rabin L, Rentz DM, Rodriguez-Gomez O, Saykin AJ, Sikkes SA. The characterisation of subjective cognitive decline. *Lancet Neurol*. 2020;19(3):271-8. [https://doi.org/10.1016/S1474-4422\(19\)30368-0](https://doi.org/10.1016/S1474-4422(19)30368-0).
- Klaperski S, von Dawans B, Heinrichs M, Fuchs R. Does the level of physical exercise affect physiological and psychological responses to psychosocial stress in women? *Psychology of sport and exercise*. 2013;14(2):266-274. <https://doi.org/10.1016/j.psychsport.2012.11.003>.
- Karimovna NY, Nasirovna MR, Tursunaliyevna AM, Abduvaliyevna AN, Ravshanovna US. Psychodiagnostics of psychosomatic diseases. *Journal of survey in fisheries sciences*. 2023;10(2S):2903-2911. <https://doi.org/10.17762/sfs.v10i2S.1430>.
- Klaperski S. Exercise, stress and health: The stress-buffering effect of exercise. *Handbuch stressregulation und sport*. 2018:227-249.
- Kljajević V, Stanković M, Đorđević D, et al. Physical activity and physical fitness among university students—A systematic review. *Int. J. Environ. Res. Public health*. 2021;19(1):158. <https://doi.org/10.3390/ijerph19010158>.
- Kolesnyk TV, Nadiuk AV, Kosova HA. Relationship of anxiety-depressive disorders and cognitive dysfunction in patients with arterial hypertension depending on the age and status of physical activity. *Ukrainian interventional neuroradiology and surgery*. 2019;29(3):46-53. [https://doi.org/10.26683/2304-9359-2019-3\(29\)-46-53](https://doi.org/10.26683/2304-9359-2019-3(29)-46-53).
- Korobeynikov G, Korobeynikova L. Physical development and psychical function states in junior schoolchildren. *Bratisl Lek Listy*. 2003;104(3):125-9.
- Korobeynikov G, Korobeynikova L, Bulatova M, et al. Relationship of successful formation of choreographic skills in young athletes with psychophysiological characteristics. *Journal of physical education & sport*. 2020;20(2):915-20. <https://doi.org/10.7752/jpes.2020.02130>.
- Korobeynikov G, Baić M, Potop V, Korobeinikova L, Raab M, Starčević N, Korobeinikova I, Chernozub A, Romanchuk S. Comparative analysis of psychophysiological states among Croatian and Ukrainian

-
- wrestling. Journal of physical education & sport. 2022;22(8):1832-8. <https://doi.org/10.7752/jpes.2022.08230>.
- Kozina ZL, Cretu M, Safronov DV, Gryn I, Ruban I, Khrapov SB, Pasichna TV. Interrelation of neurodynamic indicators with indicators of physical and technical readiness of young footballers of 12-13 and 15-16 years in the preparatory and competitive periods of the annual cycle of the training process. Health, sport, rehabilitation. 2019;5(1):36-46. <https://doi.org/10.34142/HSR.2019.05.01.04>.
- Krivanek TJ, Gale SA, McFeeley BM, Nicastrì CM, Daffner KR. Promoting successful cognitive aging: a ten-year update. J Alzheimers Dis. 2021;81(3):871-920. <https://doi.org/10.3233/JAD-201462>.
- Löckenhoff CE. Aging and decision-making: A conceptual framework for future research-a mini-review. Gerontology. 2018;64(2):140-8. <https://doi.org/10.1159/000485247>.
- Lyzohub V, Nechyporenko L, Pustovalov V, Suprunovych V. Specialized training and bioenergy state of football players with different typological properties of the higher parts of the nervous system. Science and Education. 2016;8:107-112.
- Morales-Rodríguez FM, Espigares-López I, Brown T, Pérez-Mármol JM. The relationship between psychological well-being and psychosocial factors in university students. Int. J. Environ. Res. Public health. 2020;17(13):4778. <https://doi.org/10.3390/ijerph17134778>.
- Nkire N, Mrklas K, Hrabok M, Gusnowski A, Vuong W, Surood S, Abba-Aji A, Urichuk L, Cao B, Greenshaw AJ, Agyapong VI. COVID-19 pandemic: demographic predictors of self-isolation or self-quarantine and impact of isolation and quarantine on perceived stress, anxiety, and depression. Frontiers in Psychiatry. 2021;12:553468. <https://doi.org/10.3389/fpsy.2021.553468>.
- Panahi S, Tremblay A. Sedentariness and health: is sedentary behavior more than just physical inactivity? Frontiers in public health. 2018;6:258. <https://doi.org/10.3389/fpubh.2018.00258>.
- Papale O, Festino E, Condello G, Di Rocco F, De Maio M, Cortis C, Fusco A. Psychophysiological data harmonization for the sustainability of outdoor activities. Sustainability. 2023;15(22):15838. <https://doi.org/10.3390/su152215838>.
- Petrides J, Collins P, Kowalski A, Sepede J, Vermeulen M. Lifestyle changes for disease prevention. Primary care: Clinics in office practice. 2019;46(1):1-2. <https://doi.org/10.1016/j.pop.2018.10.003>.
- Precht LM, Stirnberg J, Margraf J, Brailovskaia J. Can physical activity foster mental health by preventing addictive social media use?—A longitudinal investigation during the COVID-19 pandemic in Germany. Journal of affective disorders reports. 2022 Apr 1;8:100316. <https://doi.org/10.1016/j.jadr.2022.100316>.
- Raab M. Judgment, decision-making, and embodied choices. Academic Press; 2020.
- Roche M, Sainani K, Noordsy D, Fredericson M. The impacts of COVID-19 on mental health and training in US professional endurance athletes. Clin J Sport Med. 2022;32(3):290-6. <https://doi.org/10.1097/JSM.0000000000000983>.
- Romero-Blanco C, Rodríguez-Almagro J, Onieva-Zafra MD, Parra-Fernández ML, Prado-Laguna MD, Hernández-Martínez A. Physical activity and sedentary lifestyle in university students: changes during confinement due to the COVID-19 pandemic. Int. J. Environ. Res. Public Health. 2020;17(18):6567. <https://doi.org/10.3390/ijerph17186567>.
- Rueggsegger GN, Booth FW. Health benefits of exercise. Cold spring harb perspect med. 2018;8(7):a029694. <https://doi.org/10.1101/cshperspect.a029694>.
- Ruggiero G, Rapuano M, Cartaud A, Coello Y, Iachini T. Defensive functions provoke similar psychophysiological reactions in reaching and comfort spaces. Scientific reports. 2021;11(1):1-2. <https://doi.org/10.1038/s41598-021-83988-2>.
- Sarto F, Impellizzeri FM, Spörri J, Porcelli S, Olmo J, Requena B, Suarez-Arrones L, Arundale A, Bilsborough J, Buchheit M, Clubb J. Impact of potential physiological changes due to COVID-19 home confinement on athlete health protection in elite sports: a call for awareness in sports programming. Sports Med. 2020;50:1417-1419. <https://doi.org/10.1007/s40279-020-01297-6>.
- Stanzani Maserati M, Mitolo M, Medici F, D'onofrio R, Oppi F, Poda R, De Matteis M, Tonon C, Lodi R, Liguori R, Capellari S. Color choice preference in cognitively impaired patients: a look inside Alzheimer's disease through the use of Lüscher Color Diagnostic. Frontiers in Psychology. 2019;10:1951. <https://doi.org/10.3389/fpsyg.2019.01951>.
- Ubara A, Sumi Y, Ito K, Matsuda A, Matsuo M, Miyamoto T, Kadotani H. Self-isolation due to COVID-19 is linked to small one-year changes in depression, sleepiness, and insomnia: results from a clinic for sleep disorders in Shiga Prefecture, Japan. International journal of environmental research and public health. 2020;17(23):8971. <https://doi.org/10.3390/ijerph17238971>.
- Wu XY, Han LH, Zhang JH, Luo S, Hu JW, Sun K. The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. PloS one. 2017;12(11):e0187668. <https://doi.org/10.1371/journal.pone.0187668>.
- Zhang JH, Peng XD, Liu H, Raisch J, Wang RB. Classifying human operator functional state based on electrophysiological and performance measures and fuzzy clustering method. Cogn. Neurodyn. 2013;7:477-94. <https://doi.org/10.1007/s11571-013-9243-3>.
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