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The relationship between psychophysiological indicators and hormonal levels in elite wrestlers

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ABSTRACT

This experimental study aimed to investigate the relationship between psychophysiological characteristics and the levels of the testosterone and cortisol hormones in elite athletes. Twenty elite Greco-Roman wrestlers (aged 20–33 years) from the Ukrainian national team participated in the study, with a total of 40 examinations conducted. The athletes had experience competing at World, European, and Olympic Championships. The concentration of testosterone and cortisol was determined in blood serum using an enzyme-linked immunosorbent assay, ChemWell (Awareness Technology, USA). Psychophysiological parameters were investigated using the "NS-Psychotest" computer system for psychophysiological evaluation, developed by Ukrmedspectr in Ukraine. A correlation analysis between the obtained endocrine and neurodynamic indicators showed a significant relationship ($p<0.05$) between testosterone levels and complex visual-motor reactions, cortisol levels, and the number of reactions delayed in the test of response to a moving object. For further analysis, athletes were divided into two groups according to the speed of sensorimotor response. The groups significantly differed ($p<0.05$) in the level of complex visual-motor reactions but did not significantly differ in simple reaction-time tests ($p>0.05$). In addition, differences in hormone levels between these groups were found. Thus, athletes with a better complex visual-motor reaction had significantly higher testosterone levels and lower cortisol levels. Research on the relationship between hormonal and psychophysiological markers may improve athlete monitoring and enable early detection of excessive stress responses.

KEYWORDS

Hormones; Performance; Stress; Martial Arts; Exercise

1. INTRODUCTION

One of the topical issues of modern sports science is the operational control of the functional state of athletes to optimize their training and competitive activities. A promising direction of this issue is the control of the psychophysiological state and hormonal markers (Maydanyuk & Vdovenko, 2021; Tota & Wiecha, 2022; Kokhanevich & Korobeynikov, 2024; Maydanyuk et al., 2024). Several studies in recent years have shown the existence of a relationship between hormonal and psychophysiological indicators during competitions (Carré et al., 2009; Grebe et al., 2019; Parmigiani et al., 2009; Maidaniuk et al., 2022; Geniole, 2017). The most significant interest in martial arts is caused by studies of hormones such as cortisol and testosterone (Gonzalez-Bono et al., 1999; Grebe., 2019). As recent studies have shown, testosterone levels, in addition to the anabolic effect, have a relationship with some psychological characteristics and can be reflected in behavior and character traits (Zitzmann, 2020; Carré et al., 2009; Schultheiss et al., 2005; Serrano et al., 2000; Knight et al., 2022). Separate studies suggest that testosterone levels may rise after victory and decline after defeat (Wood & Stanton, 2012), also noted the growth of his level before the competition. These variations of this hormone can affect the athletes` levels of motivation and physical abilities (Suay et al., 1999; Wood & Stanton, 2012).

Some studies demonstrate the relationship between hormones (cortisol and testosterone) and various human emotions and behaviors (Carré & Robinson, 2020; Cook & Crewther, 2012b; Crewther et al., 2016; Galatzer-Levy et al., 2014; Mehta et al., 2017; Serpell & Cook, 2021). It has been shown that high cortisol levels can lead to increased anxiety and aggressive behavior (Papacosta et al., 2016; Serpell & Cook, 2021), and high testosterone reduces empathy and increases self-confidence (Lohani et al., 2019; Serpell & Cook, 2021). In studies by Zilioli & Watson (2013), individual differences in the level of motivation to increase their rating are considered changes in testosterone levels in a competitive environment. Scientists suggest that the state of mood (fear, combat readiness, etc.) and motivation to increase their rating (testosterone level) interact with each other in regulating the hypothalamic-pituitary-adrenal axis (Mbiydzenyuy & Qulu, 2024). Researchers suggest that testosterone levels before competition may be an individual bio-psychophysiological marker that interacts in regulating the hypothalamic-pituitary-hormonal axis under stress and reflects the level of motivation for obtaining victory status and the degree of dominance.

Cortisol is a key hormone, and its levels increase in the body's defense responses to stress (Urhausen et al., 1995; Serpell et al., 2024). An increase in cortisol is observed during prestart fever

(Mehta et al., 2008; Filaire et al., 2001). Structural changes occur in the adrenal tissues when adapting to physical exercises, leading to increased corticoid hormone synthesis. However, the growth of training volume leads to decreased cortisol levels at rest and after exercise (Slimani et al., 2018).

Scientists from the Federal University of São Paulo (Brazil) (Cadegiani & Kater, 2017-2019) suggest using changes in hormone levels to differentiate between the functional states of athletes. Our research provides a practical application of this concept, offering a valuable tool for diagnosing conditions such as functional overexertion (FOR - functional overreaching), non-functional overexertion (NFOR − non-functional overreaching), and overtraining syndrome (OTS − overtraining syndrome). These conditions, diagnosed in athletes with fatigue and reduced performance, were due to hormonal, metabolic, immune, and other dysfunctions resulting from an imbalance between the training process and proper recovery.

The subject of many studies in martial arts is the search for factors that maximize the achievement of success (Gierczuk et al., 2017). It is determined that neurodynamic abilities are important in martial arts practice and contribute to special skills improvement and the ability to concentrate and resist psycho-emotional tension (Baybikov & Romanenko, 2023). As evidenced by studies by many authors (Gierczuk et al., 2018; Borysiuk, 2006; Pervachuk et al., 2017; Tropin et al., 2016; Tropin & Boychenko, 2018; Rovnyy & Romanenko, 2016), one of the success factors for martial artists is considered to be the athlete's high reaction speed, which can ensure good results in the fight. Reaction time is a significant factor that affects the effectiveness of technical and tactical actions in the fight (Gierczuk et al., 2017). Sensorimotor responses are indicators of the interaction between the nervous and the muscle systems (Makarenko & Lyzogub, 2015; Korobejnikov, 2004). In addition, due to the presence of fatigue in the nerve centers during intense muscle activity, the state of psychophysiological functions can be a sensitive indicator of the athletes` functional state and the presence of fatigue. The study of the psychophysiological features of sensorimotor functions can indicate the level of reactivity, coordination of movements, and other aspects of the body's functioning (Tsyhanovska et al., 2017). Thus, a high reaction speed level allows athletes to implement adequate technical and tactical actions, anticipate opponents' actions, and fight more effectively (Gierczuk et al., 2017). During the fight, wrestlers, in addition to complex actions (a series of techniques), which can last from hundreds of milliseconds to several seconds, perform short-term movements lasting even less than 100 ms. Thus, the variability of situations during the fight requires quick, simple, and selection reactions. So, the most important type of stimulus in

martial arts is visual information. It is known that the time of a simple reaction to a visual stimulus varies according to various studies, from 180 to 263 ms (Gierczuk et al., 2017; Pervachuk et al., 2017; Baibikov & Romanenko, 2023).

Among the existing studies of the functional state of wrestlers there are works devoted to complex control (Kokhanevich & Korobeinikov, 2024; Sazonov, 2017), diagnostics, assessment of mental state (Karninčić et al., 2018). In modern research, they are used as hormonal markers (Tota & Wiecha, 2022; Cadegiani et al., 2019; Wood & Stanton, 2012; Rossokha et al., 2021), as well as psychophysiological parameters (Kokhanevich & Korobeinikov, 2024; Pervachuk et al., 2017; Gierczuk et al., 2017; Baibikov & Romanenko, 2023). However, among these works, the question of the relationship between the activation of the endocrine system and the psychophysiological characteristics of athletes remains little studied, which can further help optimize the informative criteria for assessing the adaptive capabilities of athletes, as well as for timely correction of the training process and recovery measures. Research in this direction will allow us to more effectively solve the problems of selection, prognosis, and correction of the functional state of athletes. Our research equips sports scientists, coaches, and sports medicine professionals with the knowledge and tools to understand better and manage the health and performance of elite athletes, empowering them to make informed decisions and improve the overall well-being of athletes. This study aims to determine the relationship between athletes' psychophysiological characteristics and testosterone and cortisol hormone levels.

2. METHODS

2.1. Participants

The study, conducted at the State Research Institute of Physical Culture and Sports (SSRIPCS), involved 20 elite athletes specializing in Greco-Roman wrestling, and 40 examinations were conducted. The athletes who participated in the study are members of the national team of Ukraine in Greco-Roman wrestling and participated in the World, European, and Olympic Championships. The athletes were aged 20-33 years. The study was conducted by the basic bioethical norms of the World Medical Association Declaration of Helsinki on the Ethical Principles of Scientific and Medical Research, as amended (2000, as amended in 2008), the Universal Declaration on Bioethics and Human Rights (1997), and the Council of Europe Convention on Human Rights and Biomedicine (1997). All participants in the study were familiar with the protocols and conditions of the study and provided written consent to participate.

2.2. Measurements

The concentration of testosterone and cortisol was determined in blood serum on a ChemWell enzyme-linked immunosorbent assay (Awareness Technology, USA) using AccuBind ELISA test systems (Monobind Inc., USA). Blood samples from the cubital vein were taken at rest on an empty stomach. Their further processing was carried out according to the manufacturer's instructions. The study of psychophysiological parameters was carried out on a computer complex for psychophysiological testing «NS-Psychotest» («Ukrmedspectr», Ukraine). It included the sequential conduct of the following measurements: determination of the time of simple and complex sensorimotor reactions, power and mobility of nervous processes, and reaction to a moving object.

2.3. Statistical Analyses

The research results were statistically processed using the software package STATISTICA 12. The normality of the distribution of digital arrays was checked using the Shapiro-Wilk test. In the case of normality of the distribution, the t-test was used to estimate the reliability of the difference between the groups. Differences were considered significant at $p < 0.05$. Pearson's correlation coefficient tested correlations in normally distributed data and Spearman's correlation coefficient in skewed data.

3. RESULTS

The results of the study of the athletes` psychophysiological and hormonal parameters are presented in Table 1.

Table 1. Hormonal and psychophysiological indicators of elite wrestlers (n = 40)

Indicators	X ± m	CI 95
Hormonal		
Total testosterone, nmol/l	18.0 ± 0.9	16.0 – 19.9
Cortisol, nmol/l	678.9 ± 27.5	623.1 –734.6
Psychophysiological		
Simple visual-motor reaction, ms	205.8 ± 2,4	200.8 – 210.7
Complex visual-motor reaction, ms	338.6 ± 5.0	328.4 – 348.7
The power of nervous processes, cu	1.5 ± 0.16	1.1 – 1.8
Mobility of nervous processes, cu	1,5 ± 0.2	1.1 – 1.9
Number of accurate reactions, %	55.2 ± 2.3	60.5 – 59.9
Number of premature reactions, %	28.3 ± 3.1	21.9 – 34.7
Number of delayed reactions, %	16.2 ± 1.2	13.7 – 18.8

Note. *X = mean; m = standard error; CI = confidence interval; cu = conventional units.*

Table 1 shows that the elite wrestlers had a mean total testosterone level of 18.0 nmol/L and a mean cortisol level of 678.9 nmol/L, indicating their hormonal status during the study period. Regarding psychophysiological performance, the athletes demonstrated a mean simple visual-motor reaction time of 205.8 ms and a complex visual-motor reaction time of 338.6 ms, reflecting relatively fast response abilities. The mean values for the power and mobility of nervous processes were both 1.5 conventional units, suggesting balanced nervous system functioning. In addition, the wrestlers achieved 55.2% accurate reactions, while 28.3% were premature and 16.2% were delayed, indicating that accuracy predominated over incorrect response types.

At the next stage of working with data, a correlation analysis of endocrine and neurodynamic parameters was conducted (Table 2).

Table 2. Indicators of the correlation coefficient (r) between psychophysiological and hormonal indicators in elite martial arts athletes (n = 40)

Indicators		
Psychophysiological	**Hormonal**	
	Total testosterone, nmol/l	Cortisol, nmol/l
Simple visual-motor reaction, ms	0.11	-0.11
Complex visual-motor reaction, ms	-0.61*	0.16
The power of nervous processes, cu	-0.04	0.34
Mobility of nervous processes, cu	-0.04	0.04
Number of accurate reactions, %	-0.07	0.21
Number of premature reactions, %	0.18	-0.32
Number of delayed reactions, %	-0.30	0.39*

Note. ** = the level of significance of the p≤0,05*

As can be seen from the above data, a significant level of correlation (p≤0,05) was found between the indicator of testosterone and complex visual-motor reactions, as well as between the level of cortisol and the number of delayed reactions in the test «reaction to a moving object».

For further data analysis, the athletes were divided into two groups based on the level of complex sensorimotor reaction. The first group included 22 athletes with a high reaction speed (313.0 ± 3.1 ms), while the second group consisted of 18 athletes with a slower reaction speed (369.7 ± 3.0 ms).

Table 3. Psychophysiological and hormonal parameters in athletes with different levels of sensorimotor reaction rate (X ± m)

Indicators	Group 1 (n = 22)	Group 2 (n = 18)
Simple visual-motor reaction, ms	205.5 ±3.6	206.0 ± 3.2
Complex visual-motor reaction, ms	313.0 ±3.1*	369.7 ± 3.0
The power of nervous processes, cu	1.5 ± 0.2	1.4 ± 0.2
Mobility of nervous processes, cu	1.5± 0.3	1.4 ± 0.3
Number of accurate reactions, %	52.6 ± 3.4	59.2 ± 2.3
Number of premature reactions, %	33.9 ± 4.4	19.7 ± 3.2
Number of delayed reactions, %	13.5 ± 1.6	20.5 ± 1.3
Total testosterone, nmol/l	21.5 ± 1.3*	13.7 ± 0.4
Cortisol, nmol/l	665.0 ± 40.3	695.8 ± 37.2

Note. *X = mean; m = standard error; * - p≤0,05 compared to the initial data.*

Table 3 indicates that athletes in Group 1 demonstrated significantly faster complex visual-motor reaction times (313.0 ms vs. 369.7 ms) and significantly higher total testosterone levels (21.5 vs. 13.7 nmol/L) than athletes in Group 2. No notable differences were observed in simple visual-motor reaction, power and mobility of nervous processes, or cortisol levels. Group 1 also showed a tendency toward more premature reactions and fewer delayed reactions, whereas Group 2 exhibited more delayed reactions and a higher percentage of accurate responses.

4. DISCUSSION

According to the data obtained, the testosterone level in athletes was 18.0 ± 0.95 nmol/l (CI 16.0-19.9 nmol/l) (Table 1), which is consistent with the research data of scientists Chernozub et al. (2022), who investigated the criteria for adaptive changes to training loads in athletes of mixed martial arts and in which this indicator was at the level of 19.42 ± 1.28 nmol/l. Cortisol levels were 678.9 ± 27.55 nmol/l (CI 623.1 -734.6 nmol/l), which was almost twice as high as in the aforementioned study of mixed martial arts athletes, in which this indicator was noted at 320.53 ± 14.72 nmol/l.

Studies of the neurodynamic properties of the nervous system showed that the level of simple visual-motor reaction in athletes was noted at the level of 205.8 ± 2.44 ms (CI 200.8 - 210.7 ms), which was consistent to some extent with the data obtained by scientists Rovnyy & Romanenko (2016), according to which the level of simple visual-motor reaction in martial arts athletes ranged from 210.8 ms to 234.2 ms. Other studies on simple sensorimotor reactions in skilled wrestlers (Pervachuk et al., 2017) reported values ranging from 214 to 246 ms.

The level of complex visual-motor reaction in athletes was 338.6 ± 5.01 ms (CI 328.4 - 348.7 ms). It was consistent with the data obtained in other studies in which the level of this indicator in elite wrestlers ranged from 308.4 to 404.5 ms (Pervachuk et al., 2017).

As can be seen from the data given in Table 2, a significant level of correlation ($p \leq 0,05$) was found between the indicator of testosterone and complex visual-motor reaction, as well as between the level of cortisol and the number of delayed reactions in the test «reaction to a moving object». That is, according to the data obtained, a higher level of a complex visual-motor reaction corresponded to a higher level of testosterone ($r = -0.61$), and a lower level of cortisol ($r = 0.39$) corresponded to a lower number of delays in the reaction to a moving object.

The results showed significant differences between the two groups of athletes in several indicators (Table 3). First, the groups significantly differed in the level of complex sensorimotor response but did not have probable differences in the level of simple sensorimotor response. This may indicate that a complex sensorimotor reaction will be a more significant prognostic indicator in diagnosing the athlete's psychophysiological state. Secondly, differences in hormone levels between these groups were found. Thus, athletes with a better complex sensorimotor response had significantly higher testosterone levels and lower cortisol levels (although the differences were not likely significant for this indicator).

According to modern scientific ideas, the identified correlations make it possible to speak about the influence of testosterone on the reaction rate through the activation of psychophysiological mechanisms (Schultheiss et al., 2005), and confirm its role as a marker of the realization of motivation to dominate and achieve success (Carré et al., 2009; Zilioli & Watson, 2013; Zitzmann, 2020). A high concentration of cortisol, in turn, may indicate increased stress and emotional tension levels, which also affect neurodynamic properties (Serpell & Cook, 2021).

The obtained results are consistent with our previous findings (Maydanyuk et al., 2024), which confirm the importance of monitoring hormonal markers in combination with psychophysiological indicators for diagnosing the functional state of combat sport athletes.

These data have practical significance for the organization of athlete training, particularly under conditions of high physical and psycho-emotional stress. Taking into account individual levels of testosterone and cortisol enables a more accurate assessment of the athlete's adaptive capacity, timely identification of signs of functional overstrain or overtraining (Cadegiani et al., 2019), and adjusting the training process.

Moreover, combining the analysis of hormonal levels with psychophysiological indicators, such as sensorimotor reactions, can serve as a foundation for personalized training programs aimed at enhancing stress resilience and competitive performance (Korobejnikov, 2004; Baibikov & Romanenko, 2023). This is especially relevant in combat sports, where decision-making speed and the level of combat readiness are critical for the outcome of the fight (Gierczuk et al., 2017; Kokhanevich & Korobeinikov, 2024).

5. CONCLUSIONS

A significant relationship between hormonal indicators and neurodynamic properties of the nervous system has been identified. Thus, in elite martial arts, a more sensory level of complex sensorimotor reaction corresponded to a significantly higher testosterone level at rest on an empty stomach. In contrast, a tendency was found that high cortisol levels are associated with delayed reactions. This may indicate that increased stress hormones can adversely affect psychomotor performance.

Studying the relationship between hormonal markers and psychophysiological indicators can improve the quality of diagnostic support for athletes during training and competitive training periods and timely identify the impact of excessive stress response. These studies are especially important for martial arts, where rapid decision-making, fine motor skills, and stress resistance are crucial to success. This creates the prerequisites for further study of the influence of hormonal changes on sports results.

Future research should focus on testosterone and cortisol levels dynamics during different training and competitive phases. Understanding these hormonal changes in response to acute stress and recovery periods may expand their use as biomarkers in elite sports.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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