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Characteristics of neurodynamic properties in volleyball players of different skill levels

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Abstract

Statistical data on the psychophysiological indicators of high-qualification volleyball players are presented and compared with lower-qualification volleyball players. Characteristics of sensorimotor skills, feedback, rhythm, reaction to a moving object, and the tapping test are shown. A link was established between the autonomic nervous system and the improvement of individual-typological characteristics of the higher nervous activity of volleyball players. The aim of the research was to determine and compare the psychophysiological state indicators of healthy volleyball players and those with hearing impairments, as well as to compare the results of high-qualification volleyball players with lower-qualification ones. To accomplish this task, 18 high-qualification volleyball players with Master of Sports (MS) or Candidate for Master of Sports (CMS) titles, who have hearing impairments—full or partial sensory deprivation ("GROUP 1", KKLPU volleyball team) - and 8 qualified volleyball players (CMS and lower ranks, "GROUP 2", NUPESU volleyball team) were selected. The age of the subjects varied significantly, ranging from 18 to 36 years. Based on the analysis of literature on the chosen research topic, a lack of scientific study regarding this issue specifically in volleyball was identified. The obtained indicators allow for the assessment of the individual level of the psychophysiological state of high-qualification volleyball players in comparison with lower-qualification players.

Keywords: CNS (Central Nervous System); Volleyball players; Neurosoft – Multipsycometer; LP SVMR (Latent Period of Simple Visual-Motor Reaction); LP CR (Latent Period of Choice Reaction); FRLP (Functional Reliability of Labor Performance / Functional Level of Nervous Processes); SLN (Stability of Localized Reactions / Stability of Nervous State); Tapping test.

Testing of neurodynamic characteristics of the central nervous system (CNS) in healthy volleyball players and comparison with volleyball players having partial or total hearing loss. Athletes were asked to perform specialized tests with maximum concentration, which informatively reflect the level of their psychophysiological state. Determination of the individual-typological properties of higher nervous activity (HNA) and sensorimotor functions of the athletes was provided using the "Neurosoft - Multipsycometer" computer system. Data processing was carried out using mathematical statistics methods, calculating the significance of differences ($p < 0,05$).

Test1: Testing was conducted based on the following indicators: The study of visual-motor reactions of varying complexity began with determining the latent period of a simple visual-motor reaction (LP SVMR) of the athletes. Subjects were required to press the right (left) button quickly upon the appearance of any stimulus on the screen.

Table 1.

Indicator - Sensomotomics:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
LP SVMR	270,87	Average	294,11	Below average	8

Notes: $p < 0,05$

Sensorimotor function was evaluated based on the characteristics of the latent period of simple visual-motor reaction (LP SVMR) and was determined to be—from 294,11 ms (below average according to the scale of the methodology developers) in "GROUP 1" to 270,87 ms (average level) in "GROUP 2" (percentage improvement is 8%).

Test 2: Following the LP SVMR, the latent period of a visual-motor choice reaction to one of three stimuli (LP CR 1-3) was tested. Athletes were required to quickly press the right (left) button with their right (left) hand when a "square" geometric figure appeared on the screen. In the case of other stimuli, which were considered inhibitory, they were instructed not to react.

Table 2.

Indicator - Sensomotorics:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
CR 1-3	368,82	Average	397,99	Average	7

Notes: $p < 0,05$

Based on the obtained data, we established a percentage improvement in the latent period of the choice reaction to one signal out of three (LP CR 1-3) — 397,99 ms from (average level) in "GROUP 2" to 368,82 ms (average level) in "GROUP 1" (the percentage improvement is 7%).

Test 3, Assessing the sensory-motor skills of athletes, included determining the latency period of the visual-motor choice reaction for two out of three stimuli (LP VCR 2-3). The research methodology differed from the previous test in that the athlete was required to quickly press the right button with the right hand when a "square" geometric shape appeared on the screen. If a "circle" appeared, they had to press the left button with the left hand, and not react to other stimuli.

The determination of the functional mobility of nervous processes (FMNP) in athletes was carried out in feedback mode, where the duration of the signal exposure changed automatically depending on the nature of the subject's reactions. For this purpose, during testing, athletes were presented with 120 stimuli (geometric shapes) for information processing. An equal representation of each type of signal was maintained in the sequence of stimulus presentation. The subject had to quickly press the right button with the right hand when a "square" geometric shape appeared on the screen. In case a "circle" appeared, they had to press the left button with the left hand, and not react to other stimuli.

Table 3.

Indicator - Sensomotorics:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
CR 2-3	458,35	Average	477,81	Below average	4

Notes: $p < 0,05$

Latency period of the choice reaction to two out of three signals (LP VCR 2-3) ranged from 477.81 ms (below average) in "GROUP 2" to 458.25 ms (average level) in "GROUP 1" (a percentage improvement of 4%).

Test 4-5: Assessment of the Strength of Nervous Processes (SNP)

The indicator of the strength of nervous processes (SNP), i.e., the brain's working capacity, is the total number of signals presented and processed. This manifests in the athletes' ability to maintain focus for long periods while differentiating between positive and inhibitory stimuli at an individually high pace, requiring sustained concentrated excitation in the nervous elements.

The methodology for determining the functional mobility of nervous processes (FMNP) at a stepwise increasing presentation rate is as follows: When a "square" appears on the screen, the subject must quickly press the right button with the right hand. If a "circle" appears, they must press the left button with the left hand, ignoring other stimuli. The initial presentation rate was 30 stimuli per minute. In each series, stimuli were presented at a constant speed, selected randomly. Each subsequent task automatically increased the pace by 5 or 10 signals per minute. A response is considered correct if the motor reaction occurs during the exposure time (no delay) or during the pause following the exposure (if delayed). In all other cases, the reaction is recorded as an error. The FMNP indicator is the maximum stimulus presentation rate at the absolute limit of speed. The SNP indicator is the total number of errors (as a percentage of the total signals presented) committed during the entire test in the forced-pace mode. It is assumed that fewer errors indicate higher brain working capacity and, consequently, a higher SNP level.

Table 4.

Indicator - Sensomotrics:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
FMNP	107,17	Average	87,73	Below average	2
SNP	6,93	Above average	13,62	Below average	9

Notes: $p < 0,05$

According to the research results, feedback mode was determined by the characteristics of: Functional Mobility of Nervous Processes (FMNP): from 71.76 s (average level) in "GROUP 2" athletes to 62.23 s (average level) in "GROUP 1" (a 13% improvement); Strength of Nervous Processes (SNP): from 598.89 signals (below average level) in "GROUP 2" to 641.43 signals (average level) in "GROUP 1" (a 7% improvement). The forced-pace mode (imposed rhythm) was recorded by the characteristics of: Functional Mobility of Nervous Processes (FMNP): from 87.73 signals/min (below average level) in

"GROUP 2" to 107.17 signals/min (average level) in "GROUP 1" (a 22% improvement); Strength of Nervous Processes (SNP): from 13.62% errors (below average level) in "GROUP 2" to 6.93% errors (above average level) in "GROUP 1" (a 49% improvement).

Table 5.

Indicator - Sensomotorics:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
FMNP	62,23	Average	71,76	Average	3
SNP	641,43	Average	598,89	Below average	

Notes: $p < 0,05$

Test 6: Determination of the Reaction to a Moving Object (RMO)
This test was aimed at studying the accuracy of sensorimotor response and judging the balance of excitatory and inhibitory processes in the cerebral cortex of athletes. The current version of the methodology involves recording motor responses (at a designated point) to an object moving at a constant speed.

Ultimately, the balance of nervous processes is judged by the total number of correct responses and the ratio of anticipatory to delayed movements, taking into account average and total values, as well as the total magnitude of all deviations expressed in milliseconds (ms).

Table 6.

Indicator - Reaction to a Moving Object:	Group 1, n=8	Psychophysiological state level	Group 2, n=18	Psychophysiological state level	Difference%
<i>Anticipatory movements</i>	26.06	Above average	37,17	Average	0
Late responses	23,68	Above average	34,73	Average	2

Notes: $p < 0,05$

Reaction to a Moving Object (RMO), based on the average values of anticipatory deviations in the best attempt, ranged from 37.17 ms (average level) in "GROUP 2" to 26.06 ms (above average level) in "GROUP 2" (a 30% improvement); the average value

of delayed deviations in the best attempt ranged from 34.73 ms (average level) in low-skilled volleyball players to 23.68 ms (above average level) in "GROUP 1" (a 32% improvement).

Finally, a tapping test was conducted to measure the maximum movement speed of the athletes' wrists. According to the test methodology, the subject had to maintain their maximum possible wrist movement pace for a specified period. Pace indicators were recorded every 5 seconds, as well as for the entire duration of the test, and the best result was determined by the number of taps made.

Tapping test (number of taps in 30 s): from 159.56 times (average level) in "GROUP 2" to 187.27 times (above average level) in "GROUP 1" (a 17% improvement).

Table 7

Indicator	Elite volleyball players, n=8		Psychophysiological state level	Novice volleyball players, n=18		Psychophysiological state level	Difference%
	x			x			
Tapping test	1		Above average	1		Average	7
	87,27	,05		59,56	,93		

Notes: $p < 0,05$

Sensorimotor skills were assessed based on the characteristics of the Simple Visual-Motor Reaction Latency (SVMR Latency): from 294.11 ms (below average level, according to the methodology developers' scale) in low-skilled volleyball players to 270.87 ms (average level) in highly skilled volleyball players (an 8% improvement).

The Latency Period of the Choice Reaction to one out of three signals (VCR 1-3) ranged from 397.99 ms (average level) in low-skilled volleyball players to 368.82 ms (average level) in highly skilled volleyball players (a 7% improvement).

The Latency Period of the Choice Reaction to two out of three signals (VCR 2-3) ranged from 477.81 ms (below average level) in low-skilled volleyball players to 458.25 ms (average level) in highly skilled volleyball players (a 4% improvement).

The feedback mode was determined by the characteristics of: Functional Mobility of Nervous Processes (FMNP): from 71.76 s (average level) in low-skilled volleyball players

to 62.23 s (average level) in highly skilled volleyball players (a 13% improvement). Strength of Nervous Processes (SNP): from 598.89 signals (below average level) in low-skilled volleyball players to 641.43 signals (average level) in highly skilled volleyball players (a 7% improvement). The forced-pace mode (imposed rhythm) was recorded by: Functional Mobility of Nervous Processes (FMNP): from 87.73 signals/min (below average level) in low-skilled volleyball players to 107.17 signals/min (average level) in highly skilled volleyball players (a 22% improvement). Strength of Nervous Processes (SNP): from 13.62% (below average level) in low-skilled volleyball players to 6.93% (above average level) in highly skilled players. In highly skilled volleyball players (a 49% improvement). Reaction to a Moving Object (RMO), based on the average values of anticipatory deviations in the best attempt, ranged from 37.17 ms (average level) in low-skilled volleyball players to 26.06 ms (above average level) in highly skilled players (a 30% improvement). The average value of delayed deviations in the best attempt ranged from 34.73 ms (average level) in low-skilled players to 23.68 ms (above average level) in highly skilled players (a 32% improvement). Finally, the tapping test results (number of taps in 30 s) ranged from 159.56 taps (average level) in low-skilled players to 187.27 taps (above average level) in highly skilled players (a 17% improvement). Based on the studied indicators presented above, it is evident that across all characteristics of the individual neurodynamic functions, the scores of athletes with different qualifications—according to the methodology's evaluation scales—range from average to above average. Furthermore, highly skilled volleyball players demonstrate significant statistical improvement compared to low-skilled players.

Conclusions

A connection has been established between the autonomic nervous system and the improvement of individual typological characteristics of functional reactions and the psychophysiological state of athletes. The psychophysical state of their bodies showed improvements in sensorimotor characteristics by 4–8%, feedback mode by 7–13%, forced-pace mode (imposed rhythm) by 22–49%, reaction to a moving object by 30–32%, and the tapping test by 17%. The quantitative characteristics obtained during the research can serve as an incentive for volleyball practice for highly skilled athletes, low-skilled athletes, and beginners alike. A greater amount of processed information corresponded to a higher level of SNP (Strength of Nervous Processes). The determination of BNP (Balance of Nervous Processes) involved recording the accuracy of reactions to a moving object. BNP was judged by the total magnitude of anticipatory or delayed reactions. The smaller the sum of motor reaction deviations (ms), the higher the BNP level. Sensorimotor reactivity was assessed by the latency

periods (ms) when responding to stimuli of varying degrees of complexity (Simple Visual-Motor Reaction – SVMR and choice reaction of two stimuli out of three – VCR 2–3). Lower latency values corresponded to better sensorimotor reactivity. An expert evaluation of the volleyball players' game performance was conducted by a group of experienced coaches. For high-level volleyball players, the maximum, minimum, and average values of the neurodynamic properties of the higher divisions of the central nervous system were established, specifically: FMNP, SNP, BNP, and sensorimotor reaction latencies (SVMR, VCR 2–3). Thus, the distribution of volleyball players by quantitative and qualitative indicators of game activity coincided with the integral index of neurodynamic and sensorimotor properties in our study. In most cases, volleyball players with high or above-average game performance scores were also characterized by high or above-average values of the studied neurodynamic properties: FMNP (Functional Mobility of Nervous Processes), SNP (Strength of Nervous Processes), BNP (Balance of Nervous Processes), and the complex sensorimotor choice reaction VCR 2–3. This indicates a connection between the individual typological properties of the HNA (Higher Nervous Activity) and game performance. To establish the relationship between the efficiency of game activity and the functional state of neurodynamic and sensorimotor properties, a correlation analysis was conducted. It was found that the correlations between the game performance of professional volleyball players and their sensorimotor and individual typological properties (VCR 2–3, FMNP, SNP, BNP) were within the range of $r = 0.29-0.35$ ($p < 0.05$). This indicates that volleyball players with high and above-average game performance scores were, in most cases, also characterized by high values of the studied typological properties: FMNP, SNP, BNP, and the VCR 2–3 differentiation reaction. No significant correlation was established between the players' game performance ratings and the latency periods of simple sensorimotor reactions (SVMR) ($p > 0.05$).

Consequently, based on the obtained data, it was established that volleyball players with better neurodynamic and sensorimotor indicators were characterized by higher efficiency ratings in game activity, which is further supported by the presence of significant correlations. Therefore, while selection criteria may include physical, technical, and functional fitness, playing positions, body types, biological age, and individual characteristics, coaching staffs should place particular emphasis on highly genetically determined markers. These markers are the most informative for managing and predicting the game performance of volleyball players. According to the results of our work, such criteria are met by the neurodynamic and individual-typological properties of the higher divisions of the central nervous system: functional mobility, strength, and balance of nervous processes, as well as complex sensorimotor differentiation reactions, all of which possess a robust and stable biological

nature. The results of the examination of highly skilled athletes and their correlation with game success have become the basis for developing and substantiating criteria and recommendations regarding the athletic suitability of each candidate.

Establishing suitability criteria is one of the crucial stages of our work and recommendations for selection. Based on the results of our study, it is proposed to carry out the selection for national teams and the Ukrainian Championship by dividing players into four groups: unconditionally suitable, suitable, conditionally suitable, and unsuitable. The first group (unconditionally suitable) should consist of highly skilled athletes capable of successfully executing technical-tactical tasks and the coach's instructions during a game. For these volleyball players, there is a complete alignment between their high level of sensorimotor properties, neurodynamic functions, and the game performance requirements set by the coach. The integrated index of neurodynamic and sensorimotor properties for these players must be at least 41 points. The second group (suitable) includes volleyball players who are characterized by above-average levels of neurodynamic and sensorimotor properties. Future studies are planned to investigate the psychophysiological indicators of highly skilled volleyball players with hearing impairments and to compare these data with the indicators of healthy high-level athletes.

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