PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Comparative analysis of motor functional asymmetry indicators in athletes of cyclic sports, martial arts, and esports

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Abstract

Background and Study Aim: Understanding and assessing functional asymmetry among athletes is pivotal, as it has the potential to reveal hidden strengths and weaknesses that can profoundly influence competitive performance. Study Aim: to perform a comparative analysis of functional asymmetry indicators among athletes in cyclic sports (short track), martial arts (karate, taekwondo), and esports (CS:GO).

Material and Methods: The study involved athletes of martial arts (n=10, age 18.9±0.12, experienced athletes), elite players of semi-professional CS:GO teams (n=10, age 19.2±0.50), and short track athletes (n=10, age 19±0.09, experienced athletes). The functional asymmetry was determined using a specialized program for iOS tablets.

Results: Esports athletes a higher number of taps during the test within a given unit of time. They also exhibit shorter reaction times and have briefer tap durations using both their right and left hands, in comparison to athletes specializing in other disciplines. Across all three specializations, athletes display minimal disparities between their right and left hands regarding tap count, reaction time, and tap duration at each of the six test stages. The variance in tap count ranges from 0 to 1.40 times, while reaction time differs by 0 to 2.33 milliseconds, and tap duration varies between 1.53 to 8.69 milliseconds.

Conclusions: The exploration of motor functional asymmetry holds significant importance in analyzing the motor skills and perceptual-motor capabilities of athletes across diverse sports and proficiency levels. A comparison of functional asymmetry metrics among athletes from three distinct specializations affirmed the similarity in outcomes across all measures. This suggests that elite athletes possess a heightened level of movement coordination and symmetry in their execution between their right and left hands. The advanced level of sports training contributes to the balanced enhancement of intermuscular coordination, further positively impacting visual-motor reaction times.

Keywords: functional asymmetry, martial arts, esports, short track, psychophysiological

Introduction

The study of motor functional asymmetry is a complex area that is considered in many scientific fields. The study of this issue is in the sphere of priorities of disciplines such as sports science, psychology, medicine, sports and medical rehabilitation, etc. In sports science, the study of asymmetry indicators is related to the study of dynamic asymmetry – movements of the upper and lower limbs and body, morphological asymmetry – anthropometric parameters of the right and left sides of the body, and functional asymmetry – visual- and auditory-motor reactions. These parameters are closely related to the functional capabilities of athletes to perform physical work [1]. Dynamic asymmetry also determines the risk of injury in the process of sports activity [2].

A separate area is the study of the state of athletes of different skill levels. Krstulović et al. [3] investigated the differences between elite and subelite athletes in terms of morphological, functional, and dynamic asymmetry. The biggest differences between the right and left sides of the body in all participants were fixed by the variable assessing functional asymmetry. Statistically significant differences in asymmetry coefficients between elite and subelite judo athletes were fixed only by two variables assessing dynamic asymmetry.

In addition to studying the morphological and functional asymmetry value of the upper and lower limbs, Chapelle et al. [4] examined the correlation between muscle mass and functional asymmetry in young tennis players in terms of value and direction.

Rodrigues et al. [5] found that the work of right-handed and left-handed players is characterized by different degrees of hand asymmetry, as left-handed players usually have less asymmetry when performing several tasks simultaneously.

Some studies have been devoted to the study of asymmetry indicators in the age aspect. Read et al.

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[6] studied the influence of the maturation stage on asymmetry indicators in young football players. The authors note that differences in functional capabilities between limbs are determined in early childhood. Therefore, targeted interventions to reduce the value of asymmetry as an injury risk factor should begin in athletes before peak growth rate and be maintained throughout childhood and adolescence to ensure that asymmetry does not increase.

Many studies are aimed at identifying the features of functional asymmetry in athletes of different sports. Lopez-Fernandez et al. [7] conducted a study aimed at investigating morphological, functional, and neuromuscular asymmetries in the lower limbs of futsal players at different competitive levels. The study revealed that elite futsal players do not develop bilateral asymmetries in the studied lower limb parameters. Conversely, sub-elite players are prone to developing morphological and neuromuscular asymmetries between their dominant and non-dominant legs.

Chapman et al. [8] studied the parameters of elite athletes. It was found that functional movement ability, which is associated with the likelihood of future injury, is also associated with the ability to improve long-term performance in competition.

Another study by Warmenhoven et al. [9] examined the asymmetry of the stroke cycle in highly skilled female rowers, considering kinematics and foot strength measurements in laboratory tests. It was found that international athletes were more likely to use an asymmetry strategy with an increase in force from the stroke side (left) at the beginning of the stroke phase and with an increase in force from the bow side (right) in the second half of the stroke. It was also found that the first half of the stroke phase is an adaptive part of the stroke cycle. Thus, asymmetry may play a functional role in the successful execution of movements during rowing.

In addition to cyclic sports, studies of functional asymmetry have been conducted with athletes of different skill levels: football [2, 6, 10], tennis [1, 4], and field hockey [11]. There are also studies of asymmetry indicators in athletes of martial arts of different skill levels: judo [3], taekwondo, karate [12, 13, 14].

A separate sporting area is intellectual sports, in which the success of competitive activity is related to the development of cognitive and psychophysiological functions, speed and correctness of decision-making (chess, checkers, go, poker, bridge, etc.). One of the youngest sports in this area is esports.

Competitive activity in esports is complex and multicomponent, which is not inferior in requirements to the professional qualities of athletes to traditional "motor" sports [15, 16]. Therefore, the study of the peculiarities of this activity, in particular, in relation to the manifestation of psychophysiological properties of athletes, and their comparison with other sports is an important area of scientific research.

A characteristic difference between esports and other intellectual sports is the need to quickly make tactical decisions and implement them. This is achieved through various techniques involving the fine motor skills of the muscles of the hands [17]. At the same time, in different esports, technical actions are performed using different devices: a keyboard and/or mouse, joystick, and touchpad. Therefore, a particularly important competence for esports athletes is the ability to simultaneously perform fast movements of different nature with the fingers and hands of the right and left hands, as well as the coordination of these movements. This determined the choice of the direction of our study.

Purpose of the Study. The purpose of the study was to conduct a comparative analysis of indicators of motor functional asymmetry in elite athletes of cyclic sports (on the example of short track), martial arts (on the example of karate and taekwondo), and esports (on the example of CS:GO, which belongs to the genre of first-person shooter).

Materials and Methods

Participants

30 athletes of average age (19±0.64) years, divided into groups according to the sport, took part in the research. Group 1: athletes of impact martial arts, n=10, age (18.9±0.12) years, candidates for master of sports). Group 2: elite players of semi-professional CS:GO teams, n=10, age (19.2±0.50) years. Group 3: short track athletes n=10, age (19±0.09) years, masters of sports.

This study was approved by the Bioethics Committee for Clinical Research and conducted according to the Declaration of Helsinki (protocol of the Commission on Bioethics of the Kharkov State Academy of Physical Culture No. 38).

Research Design

The level and features of manifestation of motor functional asymmetry in athletes of different sports specializations were determined with the help of the computer program "Reaction SM Dual". This program was developed at the Departments of Martial Arts, Informatics, and Biomechanics of Kharkiv State Academy of Physical Culture for iOS tablet [13]. For testing, a test model of 6 stages was chosen, the duration of which was 20 s, and the total time of the test was 120 s. The test consisted of 6 stages. The task of this model (model 5) during the 6 stages is to perform sequential hand actions with both hands under the influence of signals.

At the end of the test, the program offers to fill in information about the test participant and provides the following indicators to characterize

the manifestation of the studied quality (for the left and right hand separately): number of taps at each stage of the test (abs); total number of taps (abs); time of visual-motor reaction for each stage of the test (ms); duration of touching at tapping in each stage of the test (ms); average value of touch duration at tapping in each stage of the test (ms); minimum and maximum value of visual-motor reaction per test (ms); coefficient of variation of reaction time for the whole test (%); touch duration at tapping in each stage per test (ms); average value of duration of touching at tapping per test (ms); differences between hands in the speed of visual-motor reaction (ms); differences between hands in the number of taps (n).

Statistical Analysis

Statistical processing of the research results was carried out with the help of Statistica 13, the following methods were used: descriptive statistics, checking the compliance of the sample distribution with the normal law by the Shapiro-Wilk criterion, testing statistical hypotheses by the Mann-Whitney criterion, and analysis of variance by the Kruskal-Wallis criterion.

Results

It was established that according to the Shapiro-Wilk criterion the distribution of both groups differs from the normal one at the level of α=0.05. The analysis of the results of the study of motor functional asymmetry showed that athletes participated in testing performed movements with the right hand more confidently, as evidenced by the number of taps, reaction time, and duration of taps during the whole test, but these differences are not statistically significant (the hypothesis of reliability of differences was tested by the Kruskal-Wallis criterion, $p>0.05$) (Table 1).

To study the dynamics of functional asymmetry, the results were divided into three cycles of two stages each. The difference between performing the exercise without and under the influence of visual distracting signals was determined.

Analysis of the dynamics of changes shows that the difference in the number of taps during the test decreases.

Thus, the smallest difference in the number of taps was fixed in esports athletes. It was 5.2 times for the left hand and 5.0 times for the right hand in the third cycle. As for the analysis of sensorimotor reaction in this test it is closely related to the number of taps, so the dynamics of changes throughout the exercise is the same (reduction of the difference between the performance of the test exercise without the influence of visual distracting signals and under their influence) (Fig. 1).

The analysis of the duration of taps provides more information about the characteristics of the functional asymmetry features of the studied athletes. We separately analyzed the difference between adjacent stages by the number of taps, reaction time, and duration of taps (Fig. 2).

Thus, it was found that the difference in the duration of taps between the performance of the exercise without the influence of visual signals and

Table 1. Results of motor functional asymmetry testing

Indicator	Hand	Martial arts, n=10	Esports, n=10	Short track, n=10
		$\bar{X} \pm m$		
Total taps (whole test)	left	216.67±5.99	224.33±5.60	220.20±5.50
	right	218.33±5.91	224.67±5.83	222.90±6.18
Visual-motor reaction time (ms)	left	557.89±15.70	536.67±13.02	548.30±13.37
	right	553.56±15.20	536.00±13.46	542.30±15.24
Time variation coefficient, %	left	20.74±2.01	15.13±1.43	20.42±1.42
	right	20.17±2.16	15.80±1.50	21.14±2.62
Minimum value of reaction time (ms)	left	40.00±1.00	39.00±3.00	36.00±3.00
	right	40.00±1.00	40.00±1.00	39.00±1.00
Maximum value of reaction time (ms)	left	128.00±8.00	98.00±6.00	113.00±6.00
	right	125.00±11.00	106.00±7.00	129.00±24.00
Touch duration (ms)	left	55.56±2.94	54.68±2.92	56.12±3.88
	right	51.06±2.66	50.47±3.45	48.51±4.75

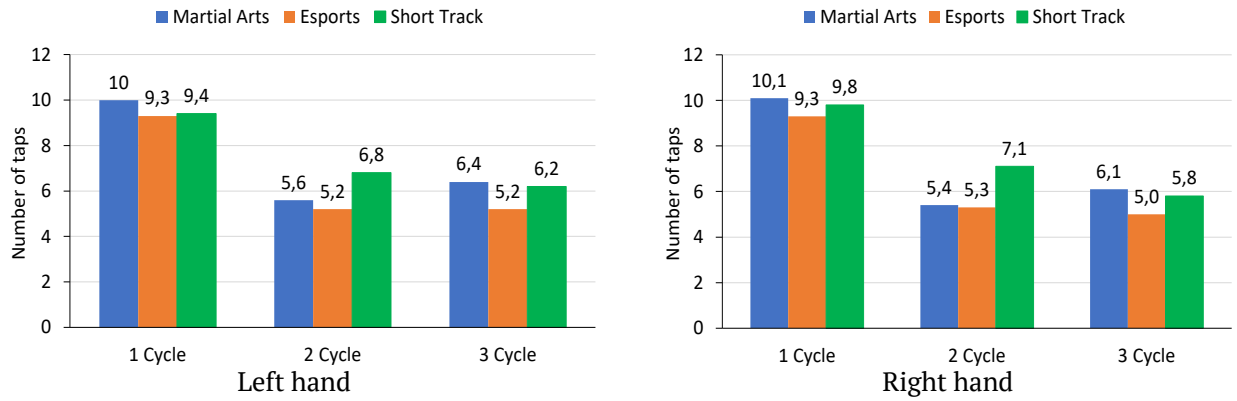

Figure 1. The difference in the number of taps between the exercise without and with the influence of visual distracting signals

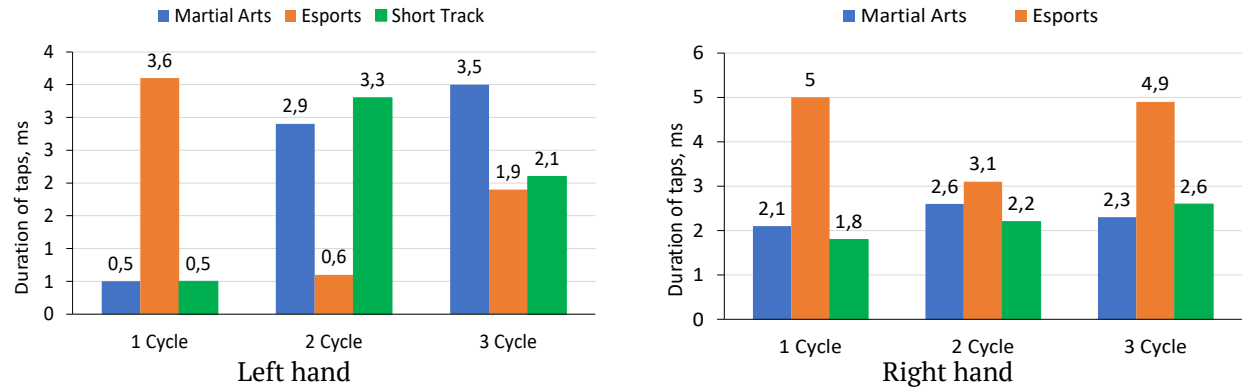

Figure 2. Difference in the duration of taps (ms) between performing the exercise without the influence of visual distracting signals and under their influence

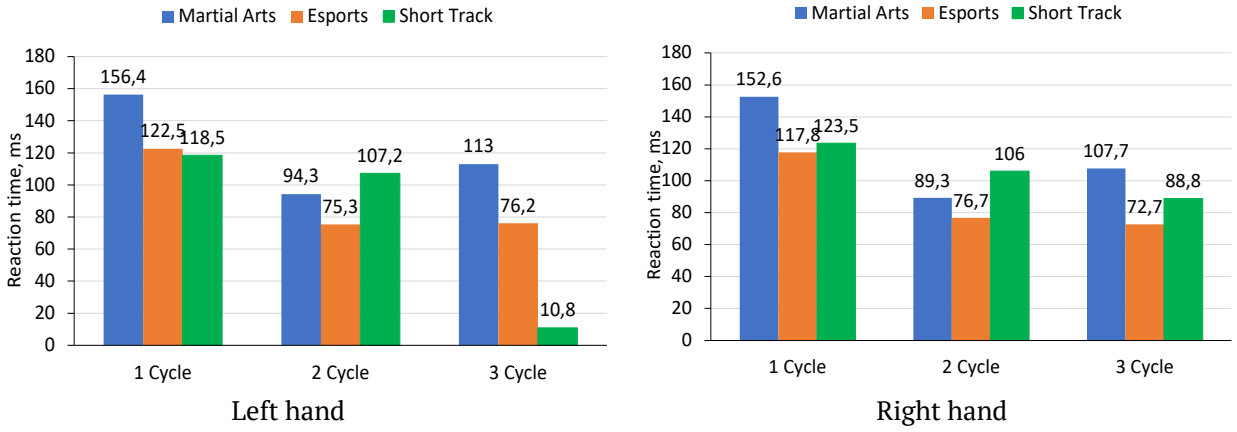

Figure 3. Difference in reaction time (ms) between performing the exercise without and with the influence of visual distracting signals

under their influence in esports athletes on the right hand is more than in martial art and short track athletes throughout the test, although the left hand has lower values in the second and third cycles. The difference in reaction time between the performance of the exercise without the influence of visual signals and under their influence in esports athletes on the left hand is less than in martial art and short track athletes throughout the test, although on the right hand in the first cycle they are inferior to speed skaters (Fig. 3).

The difference between the numbers of taps at all stages of the test, as an indicator of asymmetry was determined. The athletes of all three specializations have a higher frequency of movements with the right hand, except for the group of esports athletes at the 4th stage. It is established that esports athletes from the first to the third stage have an asymmetry was equal to 0, the average difference for 6 stages was equal to 0.11 taps and was the smallest compared

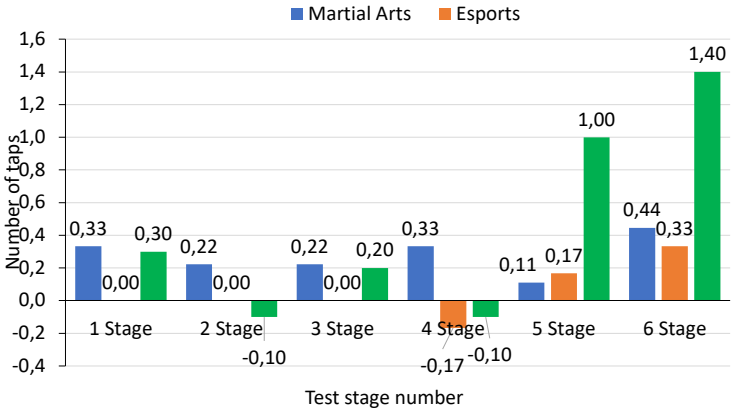

Figure 4. The difference between the number of taps with the left and right hand at different stages of the test (number of taps)

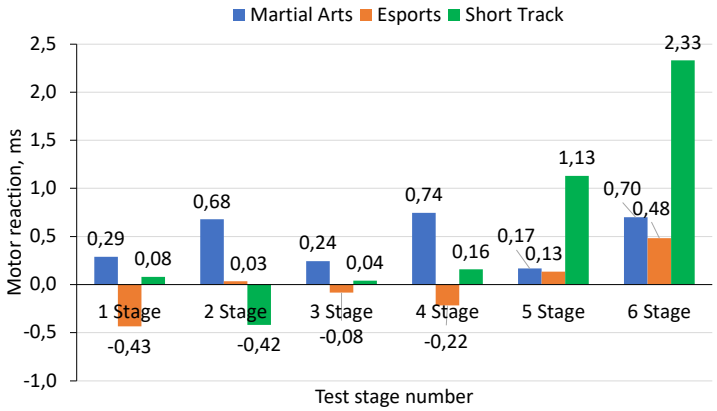

Figure 5. Difference between the time of the motor reaction of the right and left hand at different stages of the test (ms)

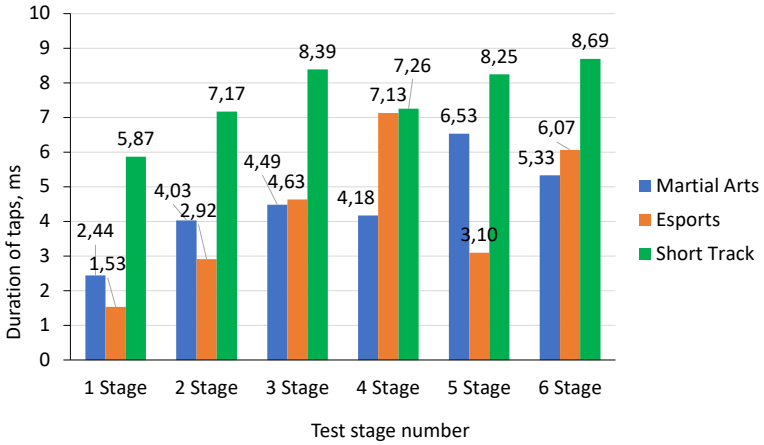

Figure 6. The difference between the duration of taps by the right and left hand at different stages of the test (ms)

with martial arts and short track athletes (Fig. 4). The biggest difference was in short track athletes – 0.52 taps, in martial arts athletes – 0.28 taps.

When determining the difference between the reaction time with the right and left hands at the stages of the test, it was found that martial art and short track athletes tend to have a longer reaction time with the left hand, the largest difference was found in short track athletes, 0.69 ms; in martial artists, the average difference was 0.47 ms. At the 1st, 3rd, and 4th stages, esports athletes had a shorter reaction time on the left hand, the average difference was 0.23 ms (Fig. 5).

The athletes of all three specializations have a tendency to more duration of taps with the right hand. The less difference in the duration of taps at the stages of the test was found in esports athletes, in the range of 1.53-6.07 ms, the average duration was 4.23 ms; in martial art athletes – in the range of 2.44-5.33 ms, the average duration was 4.50 ms; in short track athletes – in the range of 8.87-8.69 ms, the average duration was 7.61 ms (Fig. 6).

The test of the hypothesis about reliability of a difference between groups by the Kruskal-Wallis criterion showed that there are no significant differences between results of athletes of three specializations by the number and duration of taps, reaction time at different stages of the test ($p>0.05$).

Discussion

The present study continues a range of works on the determination of features of manifestation of psychomotor qualities of athletes of cyclic sports, martial arts, and esports [19]. Elite athletes took part in the study, which enable to develop certain regularities regarding the impact of sports specialization on the state of their bodies.

Comparison of the characteristics of athletes of different sports as a variant of scientific research design is widely used in sports science [7, 20, 21]. The study of the psychophysiological characteristics of athletes allows us to identify the most important factors that affect the effectiveness of the competitive activity. The results certainly reflect the specific impact of the sport on the state of the athletes' body [7, 21].

The detection of functional asymmetry is most optimal when performing any type of activity simultaneously with both hands. A similar design was used by Rodrigues et al. [5]. The subjects performed the matching expectation task test both separately with the right and left hands and simultaneously with both hands. In our study, we used the program "Reaction SM Dual" for tablets, which is a common tool for assessing motor functional asymmetry of the upper limbs without reference to the specifics of the athlete's motor activity. This program has some advantages that allow us to recommend it for use [14]. These include efficiency, mobility, painlessness, and visibility of results. Dividing the test into several stages can significantly increase the informativeness of the results obtained.

Comparison of indicators of functional asymmetry of sportsmen of three specializations showed that there are no significant differences between their results by all indicators. In our opinion, this indicates that elite athletes have a high level of coordination of movements and symmetry of their performance with the right and left hands. A high level of sports training, in our opinion, contributes to the harmonious development of intermuscular coordination, which also has a positive effect on the time of visual-motor reactions.

However, the analysis of the obtained results enabled to determine the existence of certain regularities in the test performance by esports athletes. The decrease in the difference between the performance of the test exercise without the influence of visual distracting signals and under their influence is associated with the adaptation of the sensorimotor mechanism of athletes to the action of such signals.

The decrease in the difference between the number of taps in esports athletes in the third cycle may be an evidence of the peculiarities of their competitive activity where the load on the work of visual analysers occurs for a rather long time (the duration of the game can reach 60 min) compared to martial arts where the duration of the round can be 2-3 min.

Differences in the duration of taps in esports athletes without and with the influence of distracting signals may be due to the fact that the specificity of esports athletes' activity is that they need to perform movements with the right hand using a computer mouse, and this requires the inclusion of more muscles than the left (tap several keys). The dynamics of changes in the duration of taps for martial art athletes and short track athletes do not differ significantly.

Esports athletes tend to perform more movements both on average and steadily at all stages of the test with their right and left hands. At the same time, they demonstrate better reaction time compared to other specializations. In our opinion, the competitive activity in esports is characterized as one that requires the harmonious development of fast and accurate hand and finger movements. Moreover, the athletes who participated in the study specialize in CS:GO, in which techniques are implemented by simultaneous work with the right (mouse control) and left (tapping mainly several individual keys on the keyboard) hands. Therefore, this specific activity, which occurs during many hours of daily training, can contribute to the development of more symmetry of movements in these athletes.

This was partially confirmed by Pluss et al. [22]. The authors studied the perceptual-motor abilities of esports athletes according to their level of experience using a battery of tests: hand dexterity, speed-accuracy ratio, and reaction time. Fine motor skills and hand-eye coordination were assessed using a grooved pegboard (Lafayette Instrument, Lafayette, Indiana, USA), with the dominant and non-dominant hand analyzed separately. Professional esports athletes were less susceptible to speed-accuracy compromises compared with amateurs and the control group. In addition, professional esports athletes demonstrated faster response time to a choice of two options. They were also better at using or ignoring information preceding the stimulus to inform the subsequent action compared with the control group. Thus, some perceptual-motor abilities may underlie esports experience but their ability to distinguish professional players from amateurs is limited.

The duration of professional esports training in athletes correlates with cortical volume in the right

superior frontal gyrus, right superior parietal gyrus, and right precentral gyrus in functional magnetic resonance imaging (fMRI) studies [23]. The brain receives signals through perception and processes them to transmit them to the muscles to perform the corresponding movements. Thus, playing video games, in particular e-sports, can involve various parts of the brain related to perceptual and motor skills.

The results of martial art and short track athletes do not differ significantly from those of esports athletes, although they have a slightly lower number of taps and a longer reaction time. In martial arts, athletes usually have a preference or habit for a right-handed or left-handed stance in a fight and when practicing punches. Such practice over time forms an athlete's preference for a certain position and contributes to the more development of movements and motor response with the right or left limbs. Experienced coaches plan training in such a way that athletes practice both body positions to gain an advantage over their opponents and strive to minimize the asymmetry factor [19].

In this context, the peculiarities of short track technique and competitive activity occupy an intermediate position among the three sports specializations. The starting reaction in cyclic sports, especially in highly skilled athletes, is of particular importance and makes a significant contribution to the result of overcoming the distance. At the starting position, athletes take a starting position with the right or left foot and the position of the arms accordingly. This feature may slightly influence the predominance of the right or left side of the body in terms of greater comfort or mastery of a particular starting position. After the start, when performing cyclic movements, athletes usually do not feel the predominance of the right or left side, but this situation can change on the track turns.

According to experts, the importance of studying asymmetry indicators is closely related to injuries in sports. Chapelle et al. [1] studied tennis players and noted that body asymmetry negatively affects sports performance and requires individual monitoring of asymmetry. Keith et al. [2] showed that asymmetry in the neuromuscular control of the lower limb leads to asymmetric landing patterns, which can increase the risk of anterior cruciate ligament damage. The authors emphasize the need for reliable and effective screening methods to help identify those who may be at the biggest risk of anterior cruciate ligament injury. A systematic review by Helme et al. [24] summarized the current understanding of the risks of functional asymmetry of the lower body in injuries in athletes. After analyzing 31 articles on this issue, the authors note that 33% of them provide strong evidence of a correlation between functional asymmetry of the lower limbs and the risk of injury.

Researchers of functional asymmetry in athletes also offer different methods for its diagnostics. For example, the review by Parkinson et al. [25] conducted a systematic review of the methods of calculation, thresholds, and reporting of interlimb strength asymmetry. The authors note that the magnitude of interlimb strength asymmetry varies from approximate symmetry to asymmetry of more than 15%. However, there are conflicting data on the magnitude of asymmetry in similar groups of participants and the subsequent impact of asymmetry on injury and performance. Different results can also be explained by differences in methodology, including the calculation of asymmetry and the application of thresholds. Scientists suggest an individual approach to asymmetry that considers the use of thresholds specific to the sample and individual variability [25].

Research in cyclic sports, in particular rowing, has led to the definition of the symmetry index (SI) and functional data analysis (FDA). The asymmetry of the rowing cycle was assessed considering the kinematics and measurement of foot strength in laboratory tests. A new approach to assessing both global and local asymmetry in the whole movement was used to evaluate the constant role of asymmetry and its change depending on the level of competitive representation [9].

The difficulty in comparing the results of different studies is the lack of standardized approaches to measuring asymmetry. Thus, in a systematic review, Helme et al. [24] point to the need to improve the quality of research, including the use of standardized methodologies for measuring indicators. It should also be noted that a significant number of the analyzed studies investigated indicators of functional asymmetry of the lower limbs [1, 2, 6, 26].

The limitation of this study is the lack of possibility to analyze the correlation between indicators of functional asymmetry and the results of motor tests specific for each sport. This task is the next stage of current scientific research.

Conclusions

The study of motor functional asymmetry is of great importance in the analysis of motor skills and perceptive-motor abilities of athletes with different sports and skill levels. A higher level of symmetry of movements and motor reactions, as well as the ability to maintain this level for a certain period of time, is a marker of a high level of fitness of athletes. Determination of indicators of body asymmetry with anthropometric methods and motor tests can contribute to the prevention of injuries and parameters of professional orientation and selection of athletes for a particular sport.

To assess motor functional asymmetry, it is advisable to use modern computerized methods

with a high level of reliability and informativeness.

To study the motor functional asymmetry of the upper limbs of qualified athletes, the program "Reaction SM Dual" for tablets was used, which is a common tool for evaluation without reference to the specifics of the athlete's motor activity.

When comparing the indicators of motor functional asymmetry in elite athletes of martial arts, short track, and e-sports, certain trends in the peculiarities of their body condition were established, but no significant difference was found between them. There is a decrease in the difference between the performance of the test exercise without the influence of visual distracting signals and that of athletes with three specializations.

It is established that esports athletes tend to have more number of taps in the test per unit of time, shorter reaction time and shorter duration of taps with the right and left hands.

The difference between the right and left hands in the number of taps, reaction time, and duration of taps at each of the 6 stages of the test was considered as an indicator of asymmetry. The athletes of all three specializations have insignificant values of asymmetry by these indicators: the difference in the number of taps was within 0-1.40 times, in reaction time – 0-2.33 ms, in duration of taps – 1.53-8.69 ms. It testifies to a high level of symmetry of motor reactions of these athletes and also confirms a high-level of their qualification and motor giftedness.

Conflict of interests

The authors declare that there is no conflict of interests.

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