

# The study of functional asymmetry in students and schoolchildren practicing martial arts

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## Abstract

**Purpose:** The study of functional asymmetry in students and schoolchildren practicing martial arts using a computer test.

**Material:** The study involved students and schoolchildren (n = 38) practicing the martial arts (taekwondo, karate). Participants were divided into groups according to the sports' skill level. The first group included experienced athletes (n = 15, age – 19.00 ± 0.45 years). The second group included beginners (n = 23, age - 9.78 ± 0.65 years). The functional asymmetry was determined using «Reaction SM Dual» software for tablets with iOS. Two visual tests were used. The duration of each test was 100 s. Each test was divided into 5 stages. Each stage lasts 20 s. The first test (simple reaction) – the participant pushes against the circles on the screen with two hands. The second test (differentiated reaction) – the participant pushes against the circles of the same color (out of five possible) on the screen. The following indicators were determined: the number of pushes with the right and left hand (abs); reaction time with the right and left hand (s); duration of pushes with the right and left hand (ms). It was estimated the following indicators: total number of pushes; average reaction time; average duration of pushes. Results are estimated using parametric and nonparametric statistical indicators.

**Results:** The number of pushes in the test, the reaction rate, and the duration of pushes were significantly higher in experienced athletes. It was determined the asymmetry due to the lower duration of pushes with the right hand compared to the left hand in beginners. The asymmetry was not confirmed in experienced athletes. The reaction rate for the left hand significantly increased compared to stage 1 in beginners: at stage 2 (t = -2.41), at stage 3 (t = -2.23), at stage 4 (t = -2.30) and at stage 5 (t = -2.68). This dependency was less expressed for the right hand. It was confirmed the increase of the reaction rate in comparison with stage 1: at stage 3 (t = -2.39), at stage 4 (t = -2.00) and at stage 5 (t = -2.32). The differences in the dynamics of the test were more expressed in experienced athletes. It was determined the decrease in the number of pushes compared to stage 1: stage 2 (t = 2.53), stage 4 (t = 2.89) and stage 5 (t = 2.61). For the right hand, this pattern was more expressed. The decrease in the number of pushes was determined compared with stage 1: stage 2 (t = 2.17), stage 3 (t = 2.07), stage 4 (t = 2.39) and stage 5 (t = 2.94). Experienced athletes have confirmed significant changes in the reaction rate with their left hand compared to stage 1: stage 4 (t = -2.33) and stage 5 (t = -2.06). For the right hand, this pattern was confirmed only for the final stage of the test (t = -2.35).

**Conclusions:** It was confirmed the legitimacy of using a special computer test to study functional asymmetry in students and schoolchildren practicing martial arts. The test division into several stages can significantly increase the information content of the results. The applied battery of indicators provides the necessary information for the analysis of asymmetry. It was determined the best functional condition of experienced athletes compared to beginners. Experienced athletes demonstrate the best ability to mobilize and concentrate on extreme conditions. The dynamics of the test also confirms the asymmetry in athletes with less training experience. Performing a test with a differentiated stimulus confirmed the revealed patterns. The lack of asymmetry in experienced athletes confirms optimal training tactics. The asymmetry in beginners stipulates the correction of training. Used computer test can be recommended for martial arts athletes' condition monitoring.

**Keywords:** functional asymmetry, martial arts, computer program, students, schoolchildren.

## Introduction

The asymmetry of body functions is quite common. It is important in physical education and sports. According to many authors' opinion, this is a condition for effective motor action, including motor skills' training. Svetlana et al. [1] investigated the biological phenomenon of a person's functional asymmetry and its correlation with

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sports results. It is concluded that it is necessary to consider the functional asymmetry in the training process. This allows providing the long-term positive dynamics of sports results.

The comprehensive analysis of a person's functional asymmetry was carried out by Khudik et al. [2]. The main types of functional asymmetry are motor, sensory, and psychic. In the course of the review of research results in some sports, the effect of the functional asymmetry on the athletic performance was assessed. There are works

where the same sport is pointed out as having a positive influence of asymmetry by some authors, or as having a negative effect by others. It can be concluded that functional asymmetry is a biological phenomenon due to which it is possible to avoid an early formation of motor skills.

The asymmetry studies are often used in sports. Hernandez-Garcia et al. [3] emphasize that asymmetry analysis is a simple, economical and informative tool for the athletes' condition monitoring.

Caraballo et al. [4] studied the asymmetry of morphofunctional indicators in yachtsmen with different skills' levels. It is proposed to use asymmetry indicators as predictors of success.

Teixeira et al. [5] used the study of functional asymmetry in assessing the quality of high-intensity functional training. Gomez Piqueras et al. [6] developed benchmarks to assess the skills' level of professional football players. The asymmetry indicators are included in the list of proposed criteria.

Arede et al. [7] determined the selection criteria of young basketball players. The success predictors include asymmetry indicators. Tabor et al. [8] studied the correlation between the level of functional and dynamic asymmetry and running speed in elite and sub-elite runners. It is concluded that a decrease in asymmetry leads to an increase in running speed results.

Warmenhoven et al. [9] investigated the asymmetry in elite rowers by assessing the symmetry index and functional data analysis. Differences in symmetry are a competition level factor. Elite rowers use the asymmetry of movements to increase the strength and speed of movements.

Thus, the available literature data confirm the relevance of the study of functional asymmetry in athletes practicing the different types of sports.

The *purpose of this work* was to study functional asymmetry in students and schoolchildren practicing martial arts using a computer test.

## Materials and methods

### Participants.

The study involved students and schoolchildren ( $n = 38$ ) practicing martial arts (taekwondo, karate). Participants were divided into groups according to the sports' skill level. The first group included experienced athletes ( $n = 15$ , age -  $19.00 \pm 0.45$  years). The second group included beginners ( $n = 23$ , age -  $9.78 \pm 0.65$  years).

### Research Design

The study design involved the determination of functional asymmetry using «Reaction SM Dual» software. The program is designed for tablets with iOS [10]. Two visual tests were used to assess the functional asymmetry of athletes. Tests are differed in the complexity of the visual stimuli influence on the performer. The first test (simple reaction): the participant must push with the same hands against the same visual signals (blue circles). In performing the second test (differentiated reaction), the participant must push only against the blue circles. The

feature of this task is the stimulus: circles of other colors also appear on the screen with blue circles. Each test was divided into 5 stages. Each stage lasts 20 s. The duration of each test is 100 s.

The following indicators were determined: the number of pushes with the right and left hand (abs); reaction time with the right and left hand (s); duration of pushes with the right and left hand (ms). It was estimated: total number of pushes; average reaction time; average duration of pushes.

It was compared the results of tests in groups, the dynamics of tests, and the results of groups.

### Statistical analysis.

Statistical analysis of the obtained data was carried out using licensed MS Excel. It was determined the following indicators of descriptive statistics: arithmetic mean, standard deviation, and mean error. The significance of differences in the groups was estimated using parametric (Student's test) and nonparametric (Rosenbaum's test) indicators. Differences were considered significant at  $p < 0.05$ .

## Results

The results reflect the simple reaction performance (table 1) and a differentiated reaction (table 2).

The results of table 1 illustrate the significant differences between the groups for all studied indicators. The number of pushes with the left hand was significantly higher in the group of experienced athletes at all stages (respectively, from stage 1 to 5): ( $t = 4.87$ ), ( $t = 6.82$ ), ( $t = 6.06$ ), ( $t = 6.17$ ), ( $t = 7.05$ ). The total number of pushes with the left hand was also differed significantly ( $t = 21.75$ ). Experienced athletes were characterized by the best reaction time with their left hand in performing the test at all stages (stages 1 to 5, respectively): ( $t = 52.38$ ), ( $t = 52.29$ ), ( $t = 52.29$ ), ( $t = 52.28$ ), ( $t = 52.28$ ). Experienced athletes had the best average reaction time ( $t = 52.30$ ). The improvement in reaction time led to a reduction in the duration of push in all stages in experienced athletes (respectively from stage 1 to 5): ( $t = 10.02$ ), ( $t = 9.65$ ), ( $t = 7.91$ ,  $Q = 7$ ), ( $t = 8.65$ ,  $Q = 10$ ), ( $t = 9.18$ ,  $Q = 9$ ) and the average value of the duration of the push ( $t = 10.28$ ).

The similar correlation is confirmed for the right hand. The number of pushes was higher in experienced athletes in all stages (stages 1 to 5, respectively): ( $t = 4.33$ ), ( $t = 5.11$ ), ( $t = 6.12$ ), ( $t = 5.44$ ), ( $t = 6.45$ ), and by the total number of pushes ( $t = 22.27$ ). Experienced athletes had the best reaction rate indicators at all stages of the test (stage 1 to 5, respectively): ( $t = 52.39$ ,  $Q = 7$ ), ( $t = 52.31$ ), ( $t = 52.30$ ), ( $t = 52.31$ ), ( $t = 52.31$ ). This pattern is also confirmed for the average reaction time ( $t = 52.33$ ). The duration of pushes with the right hand in experienced athletes was also significantly lower. This is confirmed by both the Student criterion and the Rosenbaum criterion. Their values were for the test stages (respectively, from stage 1 to 5): ( $t = 8.04$ ), ( $t = 7.80$ ), ( $t = 6.18$ ), ( $t = 7.24$ ,  $Q = 8$ ), ( $t = 7.76$ ,  $Q = 9$ ), for the average duration of pushes ( $t = 8.63$ ,  $Q = 7$ ).

Beginners were characterized by the asymmetry in performing a simple test. This resulted in a lower duration

**Table 1.** Simple reaction performance for functional asymmetry by athletes with different skills' levels.

Indicator	Experienced athletes (n=15)	Beginners (n=23)
The number of pushes with the left hand – 1 stage, abs	41.93±0.64 <sup>1</sup>	35.30±1.11
The number of pushes with the left hand – 2 stage, abs	39.67±0.62 <sup>1</sup>	32.65±1.11
The number of pushes with the left hand – 3 stage, abs	40.40±0.56 <sup>1</sup>	32.87±1.27
The number of pushes with the left hand – 4 stage, abs	39.33±0.63 <sup>1</sup>	32.52±1.31
The number of pushes with the left hand – 5 stage, abs	39.40±0.73 <sup>1</sup>	32.22±1.13
The total number of pushes with the left hand, abs	200.73±2.71 <sup>1</sup>	165.57±5.63
Left hand reaction time – 1 stage, s	0.48±0.01 <sup>1</sup>	0.57±0.02
Left hand reaction time – 2 stage, s	0.50±0.01 <sup>1</sup>	0.63±0.02
Left hand reaction time – 3 stage, s	0.50±0.01 <sup>1</sup>	0.63±0.02
Left hand reaction time – 4 stage, s	0.51±0.01 <sup>1</sup>	0.63±0.03
Left hand reaction time – 5 stage, s	0.51±0.01 <sup>1</sup>	0.64±0.02
The average reaction time with the left hand, s	0.50±0.01 <sup>1</sup>	0.62±0.02
Duration of push with the left hand - 1 stage, ms	55.15±3.27 <sup>1</sup>	70.20±2.71 <sup>2</sup>
Duration of push with the left hand – 2 stage, ms	54.79±3.41 <sup>1</sup>	73.10±3.13 <sup>2</sup>
Duration of push with the left hand – 3 stage, ms	56.11±3.60 <sup>1</sup>	73.76±3.94 <sup>2</sup>
Duration of push with the left hand – 4 stage, ms	56.41±4.05 <sup>1</sup>	73.76±3.80 <sup>2</sup>
Duration of push with the left hand – 5 stage, ms	55.01±4.10 <sup>1</sup>	77.34±3.77 <sup>2</sup>
The average duration of push with the left hand, ms	55.49±3.57 <sup>1</sup>	73.97±3.02 <sup>2</sup>
The number of pushes with the right hand – 1 stage, abs	42.40±0.65 <sup>1</sup>	36.04±1.11
The number of pushes with the right hand – 2 stage, abs	40.33±0.69 <sup>1</sup>	34.00±1.34
The number of pushes with the right hand – 3 stage, abs	40.33±0.58 <sup>1</sup>	33.09±1.21
The number of pushes with the right hand – 4 stage, abs	40.13±0.69 <sup>1</sup>	33.65±1.30
The number of pushes with the right hand – 5 stage, abs	39.73±0.63 <sup>1</sup>	33.26±1.09
Total number of pushes with the right hand, abs	203.20±2.91 <sup>1</sup>	170.04±5.70
Right hand reaction time – 1 stage, s	0.48±0.01 <sup>1</sup>	0.56±0.01
Right hand reaction time – 2 stage, s	0.48±0.01 <sup>1</sup>	0.61±0.02
Right hand reaction time – 3 stage, s	0.50±0.01 <sup>1</sup>	0.62±0.02
Right hand reaction time – 4 stage, s	0.50±0.01 <sup>1</sup>	0.61±0.02
Right hand reaction time – 5 stage, s	0.50±0.01 <sup>1</sup>	0.61±0.02
The average reaction time with the right hand, s	0.49±0.01 <sup>1</sup>	0.60±0.02
Duration of push with the right hand – 1 stage, ms	53.64±2.74 <sup>1</sup>	60.92±2.23
Duration of push with the right hand – 2 stage, ms	52.47±2.83 <sup>1</sup>	60.04±2.18
Duration of push with the right hand – 3 stage, ms	51.31±3.13 <sup>1</sup>	60.73±2.94
Duration of push with the right hand – 4 stage, ms	50.83±3.04 <sup>1</sup>	62.73±2.76
Duration of push with the right hand – 5 stage, ms	49.91±3.09 <sup>1</sup>	60.90±2.31
Average duration of push with the right hand, ms	51.64±2.84 <sup>1</sup>	61.06±2.07

NOTE: 1 – differences with beginners are significant, 2 – differences with the right hand are significant.

of pushes with the right hand compared to the left hand. Such a dependency was determined at all stages of the test (stage 1 to 5, respectively): ( $t = 2.65$ ), ( $t = 3.42$ ), ( $t = 2.65$ ), ( $t = 2.72$ ), ( $t = 3.71$ ) and the average value of this indicator ( $t = 3.53$ ).

A comparison of the results in the dynamics of the test also found some differences. The response time for the left hand significantly increased compared to stage 1 in beginners: at stage 2 ( $t = -2.41$ ), at stage 3 ( $t = -2.23$ ), at stage 4 ( $t = -2.30$ ) and at stage 5 ( $t = -2.68$ ). For the right hand, this dependency was less expressed. The increase in the reaction time in comparison with the 1<sup>st</sup> stage was confirmed: at the 3<sup>rd</sup> stage of the test ( $t = -2.39$ ), at the 4<sup>th</sup> stage ( $t = -2.00$ ), and the 5<sup>th</sup> stage ( $t = -2.32$ ).

The differences in the dynamics of the test were more expressed in experienced athletes. The decrease in the number of pushes was determined in comparison with the 1<sup>st</sup> stage of the test: at the 2<sup>nd</sup> stage ( $t = 2.53$ ), the 4<sup>th</sup> stage ( $t = 2.89$ ), and the 5<sup>th</sup> stage ( $t = 2.61$ ). This pattern was more expressed for the right hand. The reduction in the number of pushes was determined in comparison with the first stage of the test: at the second stage ( $t = 2.17$ ), the third stage ( $t = 2.07$ ), the fourth stage ( $t = 2.39$ ), and the fifth stage ( $t = 2.94$ ). The significant changes in the reaction rate with left hand compared to stage 1 were confirmed in experienced athletes: stage 4 ( $t = -2.33$ ) and stage 5 ( $t = -2.06$ ). This pattern was confirmed only for the final stage of the test for the right hand ( $t = -2.35$ ).

**Table 2.** The differentiated test performance of functional asymmetry by athletes with different skills' levels

Indicator	Experienced athletes (n=15)	Beginners (n=23)
The number of pushes with the left hand – 1 stage, abs	34.93±0.79 <sup>1</sup>	29.59±1.24
The number of pushes with the left hand – 2 stage, abs	33.73±0.64 <sup>1</sup>	26.59±1.36
The number of pushes with the left hand – 3 stage, abs	34.07±0.52 <sup>1</sup>	27.41±1.34
The number of pushes with the left hand – 4 stage, abs	33.73±0.61 <sup>1</sup>	27.50±1.42
The number of pushes with the left hand – 5 stage, abs	34.13±0.56 <sup>1</sup>	27.55±1.33
The total number of pushes with the left hand, abs	170.60±2.67 <sup>1</sup>	138.64±6.55
Left hand reaction time – 1 stage, s	0.58±0.01 <sup>1</sup>	0.71±0.03
Left hand reaction time – 2 stage, s	0.58±0.01 <sup>1</sup>	0.79±0.04
Left hand reaction time – 3 stage, s	0.59±0.01 <sup>1</sup>	0.77±0.04
Left hand reaction time – 4 stage, s	0.59±0.01 <sup>1</sup>	0.77±0.04
Left hand reaction time – 5 stage, s	0.59±0.01 <sup>1</sup>	0.76±0.04
The total number of pushes with the left hand, s	0.59±0.01 <sup>1</sup>	0.76±0.04
Duration of push with the left hand - 1 stage, ms	59.49±3.70 <sup>1</sup>	72.18±2.69 <sup>2</sup>
Duration of push with the left hand – 2 stage, ms	58.69±4.86 <sup>1</sup>	75.64±2.92 <sup>2</sup>
Duration of push with the left hand – 3 stage, ms	59.66±4.55 <sup>1</sup>	74.48±3.39 <sup>2</sup>
Duration of push with the left hand – 4 stage, ms	56.61±4.14 <sup>1</sup>	74.75±3.39 <sup>2</sup>
Duration of push with the left hand – 5 stage, ms	57.20±4.08 <sup>1</sup>	74.23±3.60 <sup>2</sup>
The average duration of push with the left hand, ms	58.32±4.17 <sup>1</sup>	74.25±3.00 <sup>2</sup>
The number of pushes with the right hand – 1 stage, abs	35.27±0.75 <sup>1</sup>	30.32±1.34
The number of pushes with the right hand – 2 stage, abs	34.20±0.64 <sup>1</sup>	27.36±1.37
The number of pushes with the right hand – 3 stage, abs	34.73±0.61 <sup>1</sup>	28.18±1.42
The number of pushes with the right hand – 4 stage, abs	34.47±0.84 <sup>1</sup>	27.91±1.38
The number of pushes with the right hand – 5 stage, abs	34.60±0.85 <sup>1</sup>	28.00±1.34
Total number of pushes with the right hand, abs	173.27±3.26 <sup>1</sup>	141.77±6.70
Right hand reaction time – 1 stage, s	0.58±0.01 <sup>1</sup>	0.70±0.03
Right hand reaction time – 2 stage, s	0.59±0.01 <sup>1</sup>	0.77±0.04
Right hand reaction time – 3 stage, s	0.58±0.01 <sup>1</sup>	0.75±0.04
Right hand reaction time – 4 stage, s	0.58±0.01 <sup>1</sup>	0.75±0.04
Right hand reaction time – 5 stage, s	0.58±0.01 <sup>1</sup>	0.74±0.04
The average reaction time with the right hand, s	0.58±0.01 <sup>1</sup>	0.74±0.04
Duration of push with the right hand – 1 stage, ms	53.73±2.96 <sup>1</sup>	61.62±2.48
Duration of push with the right hand – 2 stage, ms	54.07±3.08 <sup>1</sup>	63.28±2.41
Duration of push with the right hand – 3 stage, ms	53.44±3.04 <sup>1</sup>	61.92±2.81
Duration of push with the right hand – 4 stage, ms	51.70±3.02 <sup>1</sup>	64.00±3.01
Duration of push with the right hand – 5 stage, ms	49.85±2.92 <sup>1</sup>	62.94±3.14
Average duration of push with the right hand, ms	52.56±2.89 <sup>1</sup>	62.76±2.60

NOTE: 1 – differences with beginners are significant, 2 – differences with the right hand are significant.

The increasing complexity of the test conditions due to the introduction of differentiated stimuli led to a decrease in indicators compared with the results of a simple test. However, the previously determined patterns are reserved. Experienced athletes had a significantly higher number of pushes compared to beginners at all stages of performing this test with the left hand (stages 1 to 5, respectively): (t = 4.19, Q = 13), (t = 6.55, Q = 17), (t = 5.91), (t = 5.83, Q = 18), (t = 5.80) and the total number of pushes (t = 81.39). The reaction rate with the left hand was also significantly higher at all stages (respectively from stage 1 to 5): (t = -26.86), (t = -26.79, Q = 14), (t = -26.81), (t = -26.81), (t = -26.82) and according to the average indicator (t = -26.82).

As in a simple test, the duration of push in experienced athletes was significantly lower at all stages of the test (stages 1 to 5, respectively): (t = 29.23), (t = 31.94, Q = 7), (t = 31.04), (t = 31.25, Q = 9), (t = 30.84) and according to the average indicator (t = 30.86, Q = 8).

A similar dependency was determined according to the results of the test with the right hand. The results of athletes of both groups were lower than in a simple test performing. Experienced athletes in all indicators had better results than beginners. They performed more pushes with left hand at all stages (respectively from stages 1 to 5): (t = -3.62), (t = -5.94, Q = 16), (t = -5.30), (t = -5.51, Q = 18), (t = -5.44, Q = 14), had a significantly



higher number of pushes per test ( $t = 83.85$ ,  $Q = 14$ ). The reaction rate with the right hand was better at all stages of the test (respectively from stage 1 to 5): ( $t = -26.87$ ), ( $t = -26.81$ ,  $Q = 14$ ), 3 ( $t = -26.83$ ), ( $t = -26.83$ ,  $Q = 17$ ), ( $t = -26.83$ ,  $Q = 12$ ), and according to the average indicator ( $t = -26.83$ ,  $Q = 14$ ). The duration of pushes with the right hand was also significantly lower at all stages of the test (respectively from stages 1 to 5): ( $t = 20.95$ ), ( $t = 22.25$ ), ( $t = 21.18$ ,  $Q = 7$ ), ( $t = 22.81$ ), ( $t = 21.98$ ,  $Q = 8$ ) and according to the average indicator ( $t = 21.84$ ).

It was determined the expressed asymmetry of indicators in beginners. It is also true in a simple reaction test performing. The results of the duration of pushes were significantly higher with the left hand at all stages of the test (respectively from stage 1 to 5): ( $t = 2.89$ ), ( $t = 3.27$ ,  $Q = 11$ ), ( $t = 2.86$ ,  $Q = 8$ ), ( $t = 2.37$ ), ( $t = 2.37$ ) and according to the average indicator ( $t = 2.89$ ,  $Q = 7$ ). The complication of the task did not lead to the asymmetry in experienced athletes.

No significant differences were determined in the dynamics of the test with a differentiated stimulus.

### Discussion

Visual tracking of a moving target is a sensorimotor function that depends on attention. Many sports require athletes to quickly transform visual information into a targeted motor reaction (visual-motor reaction). Understanding the neural functions that determine working capacity allows improving the athletes' diagnosis; increase productivity by improving training.

Psychophysiological characteristics of athletes reflect the specificity of the influence of the type of martial arts. Podrigalo et al. [11] determined that different types of martial arts are characterized by different predictors of success. The development and optimization of the selected qualities can improve the growth prospects of sports skills.

The importance of functional asymmetry for success in martial arts was confirmed by Nikolaenko et al. [12]. Data about peculiarities of organization of motor control and brain functional asymmetry pattern in highly trained judo wrestlers are presented. It has been shown that in athletes the right hemisphere is predominant in the processing of both speech and visual-spatial information, while high competition results in wrestlers with left-side stand correlate with the prevalence of the left hemisphere in speech perception. It is suggested that high sports results in wrestlers are due to the formation of novel long-term skills, reorganization of motor control, and interhemispheric interaction.

The used design involved a comparison of athletes practicing the same sport, differing in the sports' skill level. This allows evaluating the importance of asymmetry to achieve a high skill level.

A similar design was used by Rovnaya et al. [13]. The comparison of the functional condition of synchronized swimming athletes of different skill levels made it possible to distinguish the qualities related to success predictors.

Krstulovic et al. [14] determined the differences

between elite and sub-elite female judo athletes by the level of morphological, functional, and dynamic asymmetry. The criterion for dividing into groups was the level of competitive success. The highest asymmetry of the hands' development was determined using the Edinburgh Handedness Inventory (EHI).

The study of functional asymmetry requires the use of various and functional tests. The functional movement screen (FMS) is used to determine the asymmetry. This is a battery of functional tests simulating various movements. Lewis et al. [15] indicate that it is an affordable and non-invasive tool for identifying weakness and asymmetry during specific exercises. FMS is used as a screening method for athletes in many sports. So Zhu J. [16] used it to study the causes of sports injuries and creating a model for predicting sports injuries in badminton.

Marques et al. [17] used the FMS test battery in young football players from Top League. It was confirmed the presence of functional disorders and a high prevalence of asymmetry between the right and left parts of the body.

de Oliveira et al. [18] used FMS to compare the biomechanical characteristics of runners. The special asymmetry index (IS) was used for analysis. The indicator was calculated as the ratio of the average score of a non-dominant hand to the average score of a dominant hand, multiplied by 100.

A review by Whittaker et al. [19] is indicated that the Functional Movement Screen, a battery of 7 motor tests, is most often used to assess functional asymmetry. This does not allow providing a qualitative morphofunctional assessment of the athletes' condition. The authors point to the need for using other tools for functional asymmetry analyzing.

The test we used contained two options (models). It allows reducing the testing time, the level of errors due to the influence of test loads on the athlete.

Wieczorek [20] used the following indicators to evaluate asymmetry: 8 tests determining the dominance of the eyes and hands; 5 tests evaluating the static balance, strength, accuracy, and speed of hands' movement, muscle strength of the fingers flexors. Studies have shown that the speed of learning a complex motor skill substantially depends on the determined direction and profile of functional asymmetry and motor skills.

Another test used to study asymmetry is tensiomyography. In a review by Garcia-Garcia et al. [21] emphasizes its significance for elite athletes' condition analyzing. The authors point out the lack of clear criteria for asymmetry. Arboix-Alio et al. [22] evaluated the effectiveness of various neuromuscular tests for assessing asymmetry in roller hockey. A large number of tests increases the significance of the results. Burmistrov et al. [23] used video analysis of movements and determination of many biomechanical indicators for the analysis of functional asymmetry in speed skating. Krzykala et al. [24] suggested using a goniometric study to analyze the asymmetry in field hockey players. The athletes confirmed the expressed asymmetry of morphological and functional indicators. The results are evaluated as a

factor of the musculoskeletal system injuries.

The choice of a special computer test for asymmetry analysis is quite widespread in sports. Akinina et al. [25] used the Sports Psychophysiological computer program to analyze the psychomotor development indicators of children who practiced karate. The effectiveness of using a computer program to assess the quality of training in martial arts has been confirmed. Hromcik et al. [26] used a similar research design to assess the speed of the sensorimotor reaction in badminton athletes. Participants performed a special computer test. The reaction rate was tested in various tasks with changing conditions for representing the target.

The computer program "Reaction SM Dual" has several advantages that allow recommending it for use [10]. These include efficiency, mobility, painlessness, and visibility of the results. Dividing the test into several stages can significantly increase the information content of the results. A similar technique was used by Podrigalo et al. [27] in the analysis of the psychophysiological condition of water and game sports athletes. Repetition of the same tests by participants allows indirectly to judge their ability to mobilize and concentrate in extreme conditions. The duration of the used tests is minimal and does not cause fatigue. Differences in the results allow assessing the stability and balance of the nervous system of the participants.

Identification of asymmetry is most optimal when performing any type of activity simultaneously with both hands. A similar design was used by Rodrigues et al. [28]. Participants performed the coincidence-anticipation task test both separately with right and left hands, and with both hands simultaneously. The results improved the asymmetry analysis.

The best results of a simple and differentiated test performing by experienced athletes reflect the best level of their functional condition. Experienced athletes complete the task faster. Therefore, they increase the number of pushes, improves the reaction time to the stimulus. The best mobilization rate is reflected in the reduction of the time for pushing the screen of the device. That is, experienced athletes win according to all test indicators.

Similar results are reported by Surina-Marysheva et al. [29]. The authors studied the features of sensorimotor integration and coordination of movements in elite hockey players using NS-PsychoTest software and hardware. Compared with peers, hockey players aged 15-16 years have a higher level of functional indicators in conditions of interference ( $p < 0.05$  in all cases) and a better indicator of the excitation concentration. It is concluded that the specific conditions of the competitive activity of hockey players increase the efficiency of the central nervous system. This occurs due to an increase in the excitation concentration in conditions of interference. The sensorimotor integration of players of this age is also characterized by better predictive accuracy in reactions to a moving object.

The determined asymmetry of indicators in athletes' beginners confirms the adequacy and information content

of the used test. These results allow judging the level of athletes' skills. In the process of martial arts athletes' training, they are trained to act equally with both hands, throw punch both the right and left hands. Experienced trainers pay attention to the asymmetry, trying to minimize it as much as possible. This gives athletes an additional advantage since throw punch from two sides significantly increases the probability of victory. In this context, the lack of asymmetry should be assessed as a success factor. In turn, the asymmetry in beginners is proof of an insufficient level of training and requires the training process correction.

An analysis of the test performing dynamics for a simple reaction in beginners suggests the difficulty of constantly maintaining the required functional level. This is evidenced by slowing down the reaction rate; decrease in the number of pushes; a sufficiently large number of stages at which these changes are confirmed. Such factors are less expressed on the right hand, which is the lead. An analysis of the results in the dynamics of the test also confirms the functional asymmetry in athletes with less training experience. Experienced athletes had differences in the manifestation of this pattern. Changes in the reaction rate were expressed only at the final stages of the test.

A decrease in the test performance of the with a differentiated stimulus was determined compared with a simple test. This illustrates the complexity of the task that participants have to complete. In this case, the decision-making process is complicated by the need to choose the right reaction object. In a simple reaction, the response algorithm consists of two stages: the appearance of the object - the reaction to it. In the second case, it lengthens the appearance of an object - its recognition - reaction. Naturally, this leads to significant changes in all studied indicators.

The increase in stress during the performance of a complicated test led to more expressed manifestations of already determined patterns. In this context, conducting two test variants allows us to assess the tendency to change, which is not manifested in the case of a simple reaction test.

For athletes with less training experience, the complexity of the task increases the asymmetry. This is confirmed by the results of the duration of pushes at all stages of the test. For experienced athletes, the complication of the task did not lead to the asymmetry. This can be evaluated as a significant level of significance, sufficient potential for controlling neuromuscular mechanisms.

### Conclusions

The obtained results confirm the legitimacy of using a special computer test to study functional asymmetry in students and schoolchildren practicing martial arts. Dividing the test into several stages can significantly increase the information content of the results. The applied set of indicators provides the necessary information for the asymmetry analysis. It was defined as the best functional condition of experienced martial

arts athletes in comparison with beginners has been determined. Experienced athletes demonstrate the best ability to mobilize and concentrate on extreme conditions. The dynamics of the test also confirms the asymmetry of athletes with short training experience. Performing a test with a differentiated stimulus confirmed the patterns identified. The lack of asymmetry in experienced athletes

confirms optimal training tactics. The presence of asymmetry in beginners necessitates the correction of training. Used computer tests can be recommended for monitoring the condition of martial arts athletes.

### Conflicts of Interest

The authors declare no conflict of interest.

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