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ANALYSIS AND EVALUATION OF THE FEATURES OF THE MANIFESTATION OF DYNAMIC POWER IN LEADERS OF THE WORLD ARMWRESTLING

The article reveals the definition of the features of the manifestation of the dynamic strength of the world's leading armwrestlers. The study involved 3 of the world's best armwrestlers weighing from 62 to 74 kg: athlete 1 – multiple world champion (m = 62 kg); athlete 2 – multiple US champion, winner of international competitions (m = 62 kg); athlete 3 – champion of Ukraine, winner of international competitions (m = 74 kg). Four power test exercises have been identified that ensure the performance of a competitive action in arm wrestling: flexion of the fingers, stretch with a hammer, hook and bending the hand. These exercises were performed with the left and right hands. Strength indices in all test exercises were measured with an FB5k series electrical tenzodynamometer (Poland) with an accuracy class of up to 100 g, fixed on a specialized armwrestling table using a specially made block device – "ARM1 Device" (patent #43082). In the course of statistical analysis, the following parameters were calculated: maximum and relative strength, total strength index in four strength exercises (F), time to reach maximum strength (t), speed-strength index (F / t), average strength index of four exercises (F / 4), the gradient of the total strength of the four exercises (t0.5F), the strength index in the first 100 ms and 500 ms, the speed-strength index in the first 500 ms (F500 / t500), the time to reach a force of 1 kg (t0.5F / (0.5×F)); Pearson correlation analysis. The study made it possible to establish indicators of the speed-strength index, strength gradient, the ability to manifest dynamic strength in the first 500 ms, clearly characterizing the speed-strength capabilities of armwrestlers and allowing to determine the features and nature of the manifestation of their dynamic strength. These indicators make it possible to determine the natural ability to manifest one or another type of dynamic force; clarify the direction and content of the training process; to conduct an effective selection of armwrestlers at different stages of a long-term training process; predict the expected sports result; determine the tactics of competitive activity of each athlete.

Keywords: armsport, armwrestling, armwrestlers, dynamic power, power indicators.

Безкоровайний Д. О., Камаєв О. І., Мулик К. В., Літовцев Е. А., Звягінцева І. М,. Плотницький Л. М. Глядя С. О., Кравчук Є. В. Аналіз й оцінка особливостей прояву динамічної сили у провідних армрестлерів світу

У статті визначено особливості прояву динамічної сили провідних армрестлерів світу. В дослідженні прийняло участь 3 кращих армрестлери світу вагою від 62 до 74 кг: спортсмен 1 – багаторазовий чемпіон світу (m = 62 кг); спортсмен 2 – багаторазовий чемпіон США, переможець міжнародних змагань (m = 62 кг); спортсмен 3 – чемпіон України, переможець міжнародних змагань (m = 74 кг). Визначено чотири силові тестові вправи, що забезпечують виконання змагальної дії в армрестлінгу: згинання пальців рук, натяжка молотком, гак і згинання кисті. Ці вправи виконувалися лівою та правою руками. Силові можливості в тестових вправах визначалися електротензодинамометром серії FBk (Польща) з класом точності до 100 г, що був закріплений на спеціалізованому столі для армспорту за допомогою спеціально виготовленого блочного пристрою – «Прибор ARM1» (патент № 43082). Під час статистичного аналізу були розраховані такі параметри: максимальна і відносна сила, сумарний силовий показник у чотирьох силових вправах (F), час досягнення максимальної сили (t), швидкісно-силовий індекс (F /

t), середній силовий показник чотирьох вправ (F / 4), градієнт сумарної сили чотирьох вправ ($t_{0,5F}$), силовий показник у перші 100 мс і 500 мс, швидкісно-силовий індекс у перші 500 мс (F_{500} / t_{500}), час досягнення сили в 1 кг ($t_{0,5F}$ / (0,5 × F)); проведено кореляційний аналіз критерію Пірсона. Проведене дослідження дало змогу встановити показники швидкісно-силового індексу, градієнту сили, здібність прояву динамічної сили за перші 500 мс, які чітко характеризують швидкісно-силові можливості армрестлерів і дозволяють визначити особливості та характер прояву їхньої динамічної сили. Ці показники дають змогу визначити природну здібність прояву одного або іншого виду динамічної сили; уточнити спрямованість і зміст тренувального процесу; провести ефективний відбір армспортсменів на різних етапах багаторічного тренувального процесу; спрогнозувати очікуваний спортивний результат; визначити тактику змагальної діяльності кожного спортсмена.

Ключові слова: армспорт, армрестлінг, армрестлери, динамічна сила, силові показники.

Formulation of the problem. According to the analysis of the performance of competitive exercises, arm wrestling belongs to the group of sports of a speed-strength nature. The structure of competitive movements and the magnitude of overcoming the resistance of the opponent indicate the need for maximum dynamic, and with an increase in resistance from the opponent, static efforts [1, 10].

An analysis of the structure of the competitive movement and the amount of resistance overcome in arm wrestling indicates that at the beginning of the fight, arm wrestlers use dynamic effort, and with significant resistance from the opponent, they use the static method of effort. At the end of the competitive movement, the muscles perform work in a dynamic mode [5]. In this regard, the determination of the features of the manifestation of the above types of force in strength exercises, which are close to competitive exercises in terms of the nature of efforts and stresses, acquires particular relevance.

Analysis of literary sources. In the dynamic mode, the strength of the muscles is manifested when their length decreases (prevailing mode of operation) or increases (yielding mode of operation). Varieties of dynamic muscle work have their own specifics related to the magnitude and nature of force manifestation [18].

The nature of dynamic efforts when overcoming resistance can be different – explosive, fast, slow. Explosive force is characterized by the fact that overcoming resistances that do not reach maximum values is performed with maximum acceleration. The rapid nature of efforts, or rapid strength, is manifested when overcoming resistances that do not reach the limit values with acceleration below the maximum. The slow nature of efforts or slow force is manifested when overcoming boundary resistances at a constant speed. It is important to note that explosive strength is manifested only during the overcoming nature of muscle work; fast strength – both during overcoming and yielding movements, as well as during their combination; slow strength manifests itself during the overcoming or yielding nature of muscle work [16, 17, 21, 26].

There are also differences in the number of repetitions of exercises during one approach. So, for explosive and slow strength, single efforts without repetitions are characteristic, and for fast strength, on the contrary, they are multi-repeated. Moreover, the smaller the value of overcoming resistance and acceleration (relative to the maximum values), the more efforts can be repeated [12]. Under the conditions of competitive wrestling, arm wrestlers show different types of efforts, including dynamic and static, as well as strength endurance. The magnitude and duration of manifestation of the listed types of power capabilities depends on the nature of the efforts in overcoming the opponent's resistance [3].

The purpose of the study is to determine the features of the manifestation of the dynamic strength of highly qualified armwrestlers.

Materials and methods. *Participants.* The study involved 3 of the world's best armwrestlers weighing from 62 to 74 kg: 1 – multiple world champion (m = 62 kg); 2 – multiple US champion, winner of international competitions (m = 62 kg); 3 – champion of Ukraine, winner of international competitions (m = 74 kg).

Methods. Measurements of strength indicators were carried out in the study group of participants a week after the end of the competition. Within 4 days, one competitive movement of each athlete was measured.

Strength indices in all test exercises were measured with an FB5k series electrical tenzodynamometer (Poland) with an accuracy class of up to 100 g, which was fixed on a specialized armwrestling table using a specially made block device. The created design was called the "ARM1 Device" (patent #43082).

During the measurement of the strength of the muscles of the hands, the subject became facing the table, grabbed the device holders with his hand and squeezed them with maximum force, without tearing the elbow of the working arm from the table. The distance between the holders of the device easily changed and was selected individually for each subject.

The special computer program AXIS FM made it possible to process the measurement data in real time (on-line) and the previously collected data from the memory of the electrical tenzodynamometer (of-line). AXIS FM is compatible with the operating systems Windows XP, Vista, Windows 7.

Statistical analysis of the obtained data was carried out using the licensed program STATISTICA 10. Statistical analysis calculated the following parameters: maximum and relative strength, total strength index in four strength exercises (F), time to reach maximum strength (t), speed-strength index (F / t), average strength index of four exercises (F / 4), gradient of the total strength of four exercises ($t_{0,5F}$), strength index in the first 100 ms and 500 ms, speed-strength index in the first 500 ms (F_{500} / t_{500}), time to reach a force of 1 kg ($t_{0,5F}$ / (0,5 × F)); Pearson correlation analysis.

Figure 1 shows an example of recording changes in effort during one exercise performed by one of the studied athletes with the left hand for three attempts.
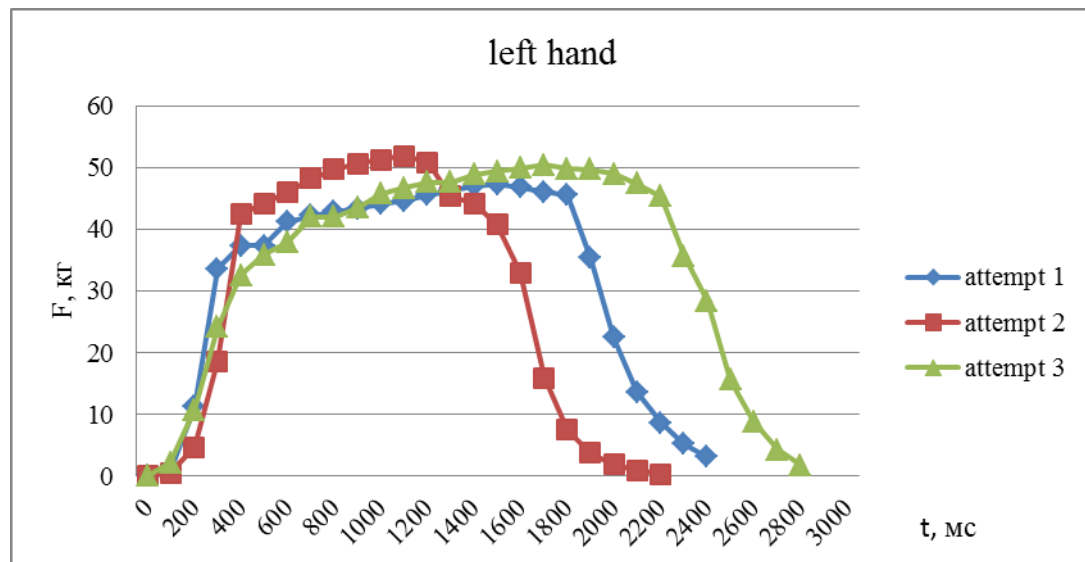
Figure 1. An example of recording changes in effort during the performance of the studied exercise

Presenting main material. A comparative analysis of the test results shows that in athletes of different weight categories of 62 kg and 74 kg, the difference in body weight is 19.35%. General strength indicators vary significantly. So, in athlete 1, the power capabilities of the left hand are less than in athlete 3 by 16.09 %, of the right hand by 42.44%. In athletes 2 and 3, the difference is 56.79 % and 37.69 %, respectively (Table 1).

The difference in strength indicators between the left and right hands for each of the athletes is not so significant, so for athlete 1 the left hand is stronger than the right by 7.40 %, for athlete 2 the right hand is stronger than the left by 2.53 %, and for athlete 3 the left hand is stronger by 10.99 % (Table 1).

Table 1 – The results of measurements of strength indicators of armwrestlers

Indicator	Athlete and his weight					
	1, UA, 62 kg		2, USA, 62 kg		3, UA, 74 rg	
	left arm	right arm	left arm	right arm	left arm	right arm
Flexion of fingers (kg)	36,0	33,5	30,2	32,6	42,7	43,9
Stretch with a hammer (kg)	44,5	41,9	39,8	39,4	86,0	81,4
Hook (kg)	49,4	45,8	60,8	62,6	64,9	47,3
Bending the hand (kg)	51,9	46,8	38,6	40,2	72,0	66,7
Total strength of the hands (kg)	181,8	168,0	169,4	178,8	256,6	239,3

The average strength indicators of the left and right hands (F / 4) differed in athlete 1 by 8.22 % (45.45 kg versus 42.00 kg), in athlete 2 by 2.59 % (42.35 kg versus 43.45), in 3 – by 10.78 % (66.47 kg versus 60.00 kg). Differences in the relative strength of the athletes' arms range from 2.71 kg to 3.59 kg; in percent, the difference was 8.11 % for the first, 2.56 % for the second, and 10.8 % for the third, respectively (Table 2).

Table 2 – Calculated characteristics of arm strength of armwrestlers

Athlete	arm	F, kg	F /4, kg	t, s	F/t, kg/s	F/m, kg/kg	$t_{0,5F}$, ms	F_{500}, kg	F_{500} / t_{500}, g/mc	$t_{0,5F}$ / (0,5 × F), ms/kg
1, UA, 62 kg	left	181,8	45,45	4,8	37,87	2,93	1105	138,7	277	12,16
	right	168,0	42,00	4,4	38,18	2,71	995	137,8	276	11,84
2, USA, 62 kg	left	169,4	42,35	11,2	15,12	2,73	1320	106,2	212	15,58
	right	173,8	43,45	10,4	16,71	2,80	1000	137,4	275	11,51
3, UA, 74 kg	left	265,6	66,47	8,0	33,24	3,59	1770	165,7	331	13,30
	right	239,3	60,00	8,1	29,63	3,24	2020	100,7	201	16,88

The time to reach maximum strength (t) for each athlete, regardless of body weight, is significantly different. For example, for 1, this indicator is 4.8 with the left hand, and the right – 4.4 s. At the same time, for 2, this indicator is 11.2 s and 10.4 s, respectively. When comparing the data between 1 and 2 athletes, the difference in the ratio is 133.3 % and 136.4 %, it

can be stated that the result of 2 is worse by 2.33 and 2.36 times.

In athlete 3, the time to reach maximum strength with the left hand was 8.0 s, and with the right hand – 8.1 s, which in turn is worse than that of athlete 1 by 1.67 and 1.84 times. Moreover, the differences between the left and right hands of all three athletes are insignificant and range from 0.1 s to 0.8 s (Table 2).

The definition of the speed-strength index (F / t) indicates that this indicator does not depend on the athlete's body weight, but obviously has an individual origin. According to the digital results, athlete 1 has a significant advantage, his results in this test exceed the data of the left hand of athlete 2 by 133.3% (37.78 kg / s versus 15.12 kg / s), the right – by 128.44% (38.80 kg/s versus 16.71 kg/s). The ratio of results between athletes 1 and 2 indicates the best performance from first: 13.93% (37.87 kg/s versus 33.24 kg/s) the left and 28.8% (38.18 kg/s versus 29, 63 kg/s) with right hands (Table 2; Fig. 2).
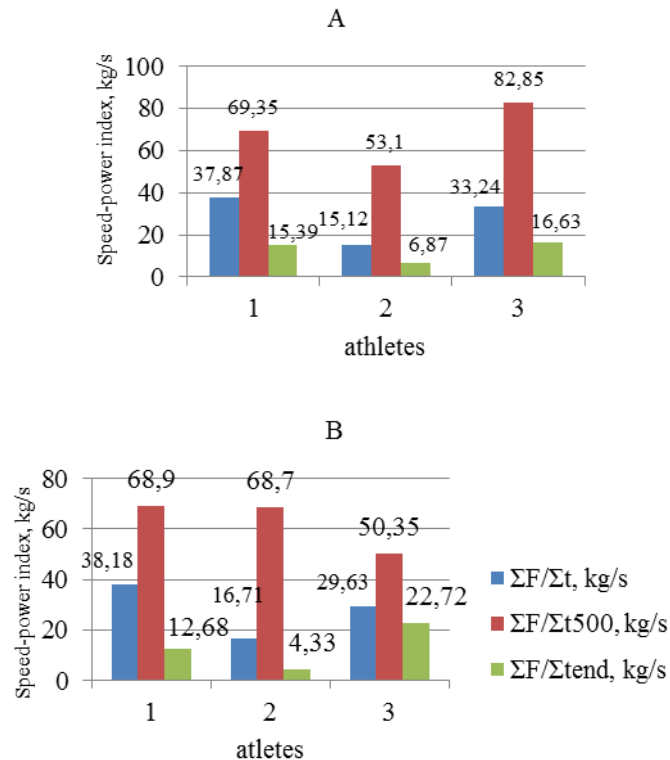
Figure 2. Dynamics of changes in the speed-strength index during testing of armwrestlers (kg/s):
A – left hand, B – right hand

Analysis of the dynamics of changes in this indicator during the performance of test exercises showed that the speed-strength index in the first 500 ms increases sharply in all athletes according to both hands. Compared with the results of this indicator, when determining the achievement of maximum strength, the greatest increase is observed in athlete 3 and reaches 82.85 kg/s, which is 2.49 times higher than his general test indicator (33.24 kg/s) (Fig. 2).

In athlete 2, the speed-strength index of the right hand increased by 4.11 times (68.7 kg/s versus 16.71 kg/s). Such data indicate that these athletes, in particular athlete 2, have the majority of victories with their right hand, and athlete 3 with their left. The results of both arms of athlete 1 increased evenly and amounted to 69.35 kg/s on the left and 68.90 kg/s on the right. Accordingly, the increase was 1.83 times and 1.80 times (Fig. 2). Given the relatively high test scores (37.07 kg/s and 38.18 kg/s), the data obtained confirms that athlete 1 performs well with both hands.

At the end of the test exercise, the indicator of the speed-strength index naturally decreases, but the magnitude of its decrease is quite different. So, in athlete 3, the calculated indices of the left and right hands, compared with the general test result, decreased by 1.99 times and 1.33 times. For other athletes, this figure ranges from 2.46 to 3.86 times. Such dynamics indicates that arm wrestler 3 has higher strength endurance.

The process of growth of power indicators for the first 500 ms is characterized by specific features, emphasizing the features of the ratio of speed-power capabilities of the left and right hands. So, for athlete 1, this difference was only 0.65 % (137.8 kg versus 138.7 kg), athlete 2, the strength of the right hand is 29.38 % more than the left one (134.7 kg versus 106.2 kg), and in athlete 3, the right hand is stronger than the left by 64.55 % (165.7 kg versus 100.7 kg). A similar dynamics of changes is preserved in the indicators of the speed-strength index for the first 500 ms (Table 2; Fig. 2).

A comparative analysis of the indicators of maximum strength and power capabilities in all athletes for the first 500 ms allows us to assert that this result is clearly individual. So, in athlete 1, the strength of the left and right hands in 500 ms, respectively, reaches 76.29 % and 81.35 % of the maximum power capabilities (Fig. 3).
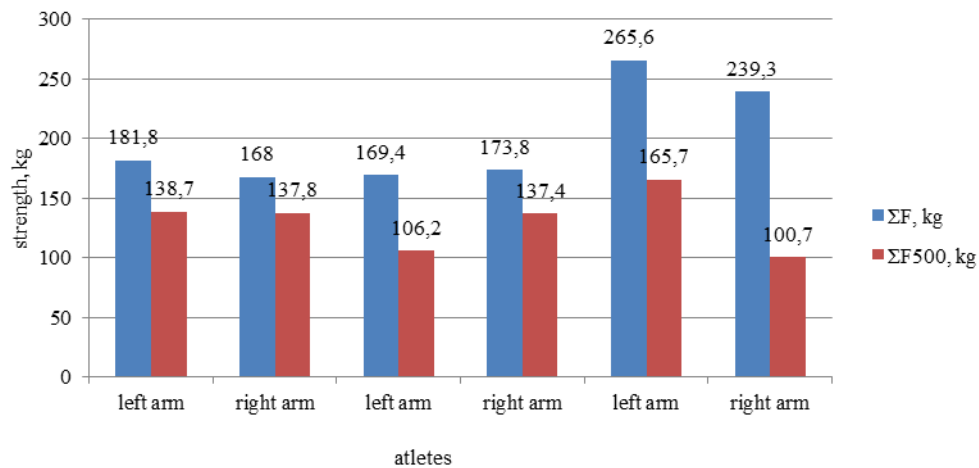
Figure 3. Indicators of the total strength of armwrestlers

In athlete 2, this figure was 62.69 % and 72.06 %, respectively, of the maximum. In arm wrestler 3, the magnitude of strength in the first 500 ms reached only 62.39 % and 42.08 % of his maximum possibilities of manifestation of strength. The given result indicates that armwrestler 1 has higher speed-strength capabilities of both hands.

The total force gradient indicator (the time to reach half of the total maximum force ($t_{0.5F}$) quite clearly defines the difference between the hands. So, for athlete 1, the sum of the force gradients ($t_{0.5F}$) of the right hand was 995 ms , and the left – 1105 ms, which corresponds to 11.05% of the difference in 14.12% (Table 2).

The determination of the time taken to achieve a force of 1 kg ($t_{0.5F}$ / (0.5 × F)) made it possible to establish that this indicator is purely personal and does not depend on the characteristics of training and participation in competitions with any hand. In athlete 1, this indicator of the left hand reached 12.06 ms/kg, the right hand - 11.74 ms/kg, respectively, the difference between the indicators is insignificant, only 2.70 %. In other athletes, this difference is noticeably higher, for example, in athlete 2 it is 30.81 % (15.58 ms/kg versus 11.91 ms/kg), and in athlete 3 it is 26.60 % (13.33 ms/kg versus 16.88 ms/kg (Table 2).

Analysis of the correlations between the studied indicators made it possible to establish that the total maximum strength (F) of all test exercises correlates too strongly with the average strength indicator (0.965), has a high correlation with the strength gradient (0.809), and a weak relationship is registered with the relative strength indicator -0.428. The average strength indicator (F / 4) repeats all connections of maximum strength.

The time to reach maximum strength has a high level of connection with the speed-strength index, but in a negative direction (-0.965). The same direction of the connection is observed between the strength indicators and the speed-strength index for 500 ms, but the average strength of the connection (-0.546).

The indicator of the speed-strength index (F / t), in addition to a high negative correlation (-0.965) with the time to reach maximum strength, also has a high negative correlation with the force gradient (-0.748); a high level of connection (0.748) was registered between the strength indicators for 500 ms (F500) and the speed-strength index (F_{500} / t_{500}).

The force gradient ($t_{0.5F}$) has a high level of correlation with the total absolute force (F) and the average force (F / 4), which is equal to 0.809. Also, a high correlation is observed with the speed-strength index, but with a negative direction (-0.748). The force gradient has a low level of negative relationship (-0.428) with the force index for the first 500 ms and the speed-force index for 500 ms. The last indicators (F_{500} and F_{500} / t_{500}) in addition to the above relationships (with t – r = -0.548; F / t – r = 0.742) has an average level of relationship with relative strength (0.667) and a weak negative relationship with the gradient (-0.428). There is a very high correlation between these two indicators, equal to 0.986.

Table 3 – The results of the correlation analysis between the strength and time indicators of the efforts of armwrestlers

Indicator	F, kg	F/4, kg	t, s	F/t, kg/s	F/m, kg/kg	$t_{0.5F}$, ms	F_{500}, kg	F_{500}/t_{500}, g/ms
F, kg	1,0000	0,9865	-0,0714	0,0714	0,4285	0,1428	-0,0952	-0,0952
F/4, kg	0,9865	1,0000	-0,0714	0,0714	0,4285	0,1428	-0,0952	-0,0952
t, s	-0,0714	-0,0714	1,0000	-0,9685	-0,2619	0,1428	-0,5476	-0,5476
F/t, kg/s	0,0714	0,0714	-0,9685	1,0000	0,2619	-0,7428	0,5476	0,5476
F/m, kg/kg	0,4285	0,1428	-0,2619	0,2619	1,0000	0,1428	0,6666	0,6666
$t_{0.5F}$, ms	0,8095	0,8095	0,1428	-0,7428	0,1428	1,0000	-0,4285	-0,4285
F_{500}, kg	-0,0952	-0,0952	-0,5476	0,5476	0,6666	-0,4285	1,0000	0,9865
F_{500}/t_{500}, g/ms	-0,0952	-0,0952	-0,5476	0,5476	0,6666	-0,4285	0,9865	1,0000

The relative strength index (F /m), in addition to those indicated above, has weak correlation (0.428) with the maximum and average (F; F / 4) strength (Table 3).

The scientific and methodological information covered in the modern information space mainly analyzes and compares various methods for developing strength abilities [16], examines the biomechanical characteristics of competitive movements [7] or the functional capabilities of athletes [26] contributing to the improvement of their power indicators and sports results. But specialists and researchers pay very little attention to the characteristics of dynamic (high-speed, explosive and slow) forces.

According to Mazurenko [18], performance in arm wrestling competitions directly depends on the level of strength training, in particular, the development of arm strength. It has been confirmed that the main predictors of success in hand wrestling include muscle development, physical strength and the value of conditional moments of limb segment strength [14]. Strength training in many sports is used as a criterion for assessing the physical fitness of athletes [15, 27]. In arm wrestling, according to Voronkov et al. [29], for highly qualified athletes in competitive exercises, the strength component is crucial.

Confirmed data based on the use of ergonomic approaches by Podrigalo et al. [26] that armwrestlers of a high level of skill have a significantly higher indicator of hand strength, hand flexion strength, forearm muscle strength, pronation and supination of the hands. Kamaev et al. [12] studied the model indicators of highly qualified arm wrestlers in three weight categories: up to 80 kg, from 80 to 100 kg and over 100 kg. So, in qualified armwrestlers in the weight category from 80 to 100 kg, the power indicators of the right hand, compared with the data of the left hand, are identical with those of highly qualified ones, namely, better, but less distinctly. Thus, for highly qualified armwrestlers, the difference was 12.47 %, and in the group of armwrestlers studied by us, only 7.16 %. The results of the analysis of speed-strength indicators confirm the data of Coletta et al. [17], indicating that the explosive power of armwrestlers manifests itself already in the first 100-200 ms of dynamic effort. Analyzing the time intervals and features of the manifestation of dynamic strength in these time periods, the quantitative characteristics of the manifestation of the dynamic strength of the leading armwrestlers weighing 62 kg and 74 kg were determined. So, the highest indicator of this strength was in athlete 2 (m = 62 kg) with the right hand F100 = 46, kg; athlete 1 (m = 62 kg) with the left hand – 29.3 kg; athlete 3 (m = 74 kg) with the left hand – 16.9 kg.

No data were found on how speed strength develops during competitive movement armwrestlers. For the first time, data on strength were obtained on 500 ms, where athletes have not yet been able to show maximum effort, but acceleration decreases compared to the time of manifestation of explosive strength. Moreover, the heavier athlete 3 achieved a higher speed-strength index than the lighter ones (82.85 kg/s versus 69.35 kg/s). The continuation of the test required maximum effort at constant acceleration, but at this time, a slow force appeared which ensured the achievement of maximum force. At this stage, the speed-strength index significantly decreased in all athletes and ranged from 4.33 kg/s to 22.72 kg/s. Thus, the indicators of the speed-strength index, the strength gradient, the ability to manifest dynamic strength in the first 500 ms quite clearly characterize the speed-strength capabilities of armwrestlers and allow you to determine the features and nature of the manifestation of dynamic strength, as well as determine the expected sports result of each athlete.

The results of the study are clearly supported by the sporting achievements of the armwrestlers who participated in the research process. So, athlete 1 won victories with his left hand at the European Championships 14 times, at the World Championships 10 times, and with his right hand 8 and 3 times, respectively. Athlete 2 predominantly participated in international competitions only with his right hand and, accordingly, has the majority of victories with his right hand. The athlete 3 achieved similar results only with his left hand. The results of the study, confirmed by the real sports achievements of armwrestlers, allow us to determine the natural ability to display explosive and fast strength, as well as the tendency to display strength endurance; select the most promising athletes; to specify the direction and content of the training process; to predict the expected sports result of each athlete's activity depending on the natural abilities of one of the types of dynamic force manifestation.

Conclusions. The study made it possible to establish indicators of the speed-strength index, strength gradient, the ability to manifest dynamic strength in the first 500 ms, clearly characterizing the speed-strength capabilities of armwrestlers and allowing to determine the features and nature of the manifestation of their dynamic strength. These indicators make it possible to determine the natural ability to manifest one or another type of dynamic force; clarify the direction and content of the training process; to conduct an effective selection of armwrestlers at different stages of a long-term training process; predict the expected sports result; determine the tactics of competitive activity of each athlete. The results of the study indicate the importance of determining the features of the manifestation of the strength abilities of armwrestlers of the highest weight categories, as well as the impact of pre-competitive weight loss on various strength abilities of athletes.

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