Features of the strength abilities of the world's leading armwrestlers weighing 80-100 kg

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Abstract

Purpose: determination of the main components of power capabilities that ensure the success of the competitive exercise of armwrestlers weighing 80-100 kg.

Material and Methods. The study involved 4 best armwrestlers in the world weighing from 80 to 100 kg (m = 87.50 ± 2.47 kg) in 2017–2020: athlete 1 is a multiple world champion weighing 90 kg (Ukraine), athlete 2 is a multiple champion world champion weighing 82 kg (Ukraine), athlete 3 - multiple world champion weighing 93 kg (Ukraine), athlete 4 - multiple winner of international competitions weighing 85 kg (USA). During the study, strength indicators were determined in 4 competitive exercises. Strength indices in all test exercises were measured in a static mode by an FB5k series electrical tenzodynamometer (Poland) with an accuracy class of up to 100 g, which was mounted on a special armwrestling table using a specially made block device. The created design was called the "ARM1 Device" (patent 43082). During the 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), 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}), hour of reaching a force of 1 kg ($t_{0,5F}/(0,5\times F)$); Pearson correlation analysis.

Results. As a result of the study, the main data on the speed-strength indicators of armwrestlers were obtained and analyzed. In the process of testing, according to the indicators of time periods and given efforts of dynamic strength, the features of the manifestation of the explosive, fast and slow strength of arm wrestlers 80-100 kg were established.

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. This makes it possible to determine the natural ability to manifest dynamic strength, as well as to select and predict the performance of promising athletes, to specify the direction and content of the training process, and to clarify the program of participation in competitions.

Keywords: armsport, armwrestling, armwrestlers, dynamic strength, strength indicators

Анотація

Дмитро Безкоровайний, Олег Камаєв, Максим Мішин, Станіслав Власко, Леонід Плотницький, Сергій Глядя, Андрій Клюка. Особливості прояву силових здібностей провідних армрестлерів світу вагою 80-100 кг

Мета: визначення основних складових силових можливостей, що забезпечують успішність змагальній вправі армрестлерів вагою 80-100 кг.

Матеріал і методи. У дослідженні взяли участь 4 кращих армрестлера світу вагою від 80 до 100 кг (m = 87,50 ± 2,47 кг) у 2017–2020 роках: спортсмен 1 – багаторазовий чемпіон світу вагою 90 кг (Україна), спортсмен 2 – багаторазовий чемпіон світу вагою 82 кг (Україна), спортсмен 3 – багаторазовий чемпіон світу вагою 93 кг (Україна), спортсмен 4 – багаторазовий призер міжнародних змагань вагою 85 кг (США). Визначено чотири силові тестові вправи, що забезпечують виконання змагальної дії в армрестлінгу: згинання пальців, розгинання молотком, гак і згинання кисті. Ці вправи виконувалися лівою і правою руками. Силові показники у всіх тестових вправах вимірювали електротензодинамометром серії FB5k (Польща) з класом точності до 100 г, закріпленим на спеціалізованому столі для армрестлінгу за допомогою спеціально виготовленого блокового приладу – «Прилад ARM1» (патент №43082). У ході статистичного аналізу були розраховані наступні параметри: максимальна та відносна сила, сумарний індекс сили в чотирьох силових вправах (F), час досягнення максимальної сили (t), швидкісно-силовий індекс (F/t), середня сила. індекс чотирьох вправ (F/4), градієнт загальної сили чотирьох вправ ($t_{0,5F}$), індекс сили в перші 100 мс і 500 мс, швидкісно-силовий індекс в перші 500 мс (F_{500} / t_{500}), час досягнення сили 1 кг ($t_{0,5F}$ / (0,5×F)); кореляційний аналіз Пірсона.

Результати. За результатами дослідження отримано та проаналізовано основні дані швидкісно-силових показників армрестлерів. В процесі тестування за показниками часових відрізків і даними зусиль динамічної сили встановлено особливості прояву вибухової, швидкої і повільної сили армрестлерів вагою 80-100 кг.

Висновки. 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. Це дає змогу визначити природну здібність прояву динамічної сили, а також зробити відбір і прогнозування результативності найперспективніших спортсменів, конкретизувати спрямованість і зміст тренувального процесу й уточнити програму участі у змаганнях.

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

Аннотация

Дмитрий Бескоровайный, Олег Камаев, Максим Мишин, Станислав Власко, Леонид Плотницкий, Сергей Глядя, Андрей Клюка. Особенности проявления силовых способностей ведущих армрестлеров мира весом 80-100 кг.

Цель: определение основных составляющих силовых возможностей, обеспечивающих успешность соревновательного упражнения армрестлеров весом 80-100 кг.

Материал и методы. В исследовании приняли участие 4 лучших армрестлера мира весом от 80 до 100 кг (m = 87,50 ± 2,47 кг) в 2017–2020 годах: спортсмен 1 – многократный чемпион мира весом 90 кг (Украина), спортсмен 2 – многократный чемпион мира весом 82 кг (Украина), спортсмен 3 – многократный чемпион мира весом 93 кг (Украина), спортсмен 4 – многократный призер международных соревнований весом 85 кг (США). Определены четыре силовых тестовых упражнения, обеспечивающих выполнение соревновательного действия в армрестлинге: сгибание пальцев, разгибание молотком, крюк и сгибание кисти. Эти упражнения выполнялись левой и правой руками. Силовые показатели во всех тестовых упражнениях измерялись электротензодинамометром серии FB5k (Польша) с классом точности до 100 г, закрепленным на специализированном столе для армрестлинга с помощью специально изготовленного блочного устройства – «Прибор ARM1» (патент №43082). В ходе статистического анализа были рассчитаны следующие параметры: максимальная и относительная сила, суммарный индекс силы в четырех силовых упражнениях (F), время достижения максимальной силы (t), скоростно-силовой индекс (F/t), средняя сила. индекс четырех упражнений (F/4), градиент общей силы четырех упражнений ($t_{0,5F}$), индекс силы в первые 100 мс и 500 мс, скоростно-силовой индекс в первые 500 мс (F_{500}/t_{500}), время достижения силы 1 кг ($t_{0,5F}$/ (0,5×F)); корреляционный анализ Пирсона

Результаты. По результатам исследования получены и проанализированы основные данные скоростно-силовых показателей армрестлеров. В процессе тестирования по показателям временных отрезков и данным усилиям динамической силы установлены особенности проявления взрывной, быстрой и медленной силы армрестлеров 80-100 кг.

Выводы. Проведенное исследование позволило установить показатели скоростно-силового индекса, градиента силы, способность проявления динамической силы за первые 500 мс, четко характеризующие скоростно-силовые возможности армрестлеров и позволяющие определить особенности и характер проявления их динамической силы. Это позволяет определить естественную способность проявления динамической силы, а также сделать отбор и прогнозирование результативности перспективных

спортсменов, конкретизировать направленность и содержание тренировочного процесса и уточнить программу участия в соревнованиях.
Ключевые слова: армспорт, армрестлинг, армрестлер, динамическая сила, силовые показатели

Introduction

According to the results of a number of studies, armwrestlers weighing from 80 to 100 kg differ from athletes in other weight categories, including armwrestlers weighing more than 100 kg, by higher strength indicators. According to a study by Mazurenko [1], armwrestlers weighing from 80 to 100 kg in average absolute strength indicators in four test exercises (flexion of fingers, stretch with a hammer, hook and bending the hand) with their left and right arms are stronger than heavyweights (over 100 kg) by 28 %. And according to certain model indicators of the absolute strength of the hands of highly skilled armwrestlers, the indicated difference is 9.27 % (n = 8). In this connection, it is very important to determine the features of the manifestation of the degree of effort in various competitive movements and conditions for performing exercises close to competitive by the indicated athletes.

Under the conditions of competitive wrestling, armwrestling athletes show different types of efforts, including dynamic and static, as well as strength endurance. The magnitude and duration of the manifestation of the listed types of power capabilities depends on the nature of the efforts in overcoming the opponent's resistance [2, 3, 4].

It is known that efforts in speed-strength sports are different: explosive, fast and slow. The explosive nature of efforts or explosive force is manifested when overcoming resistances that do not reach the limit values, but with maximum acceleration [5, 6].

The fast nature of efforts or fast force is manifested when overcoming resistances that do not reach the boundary values, it is performed with an acceleration below the maximum.

The slow nature of the efforts or slow force is manifested when overcoming the limiting load 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 during yielding movements, as well as during their combination; slow strength - during the overcoming or yielding nature of the work of the muscles. With the manifestation of a slow force, the duration of the boundary stresses is longer than with the manifestation of an explosive force. There are also differences in the number of repetitions when performing exercises in one approach. So, for explosive and slow strength, single efforts without repetitions are characteristic, and for fast strength, on the contrary, multi-repetition ones. Moreover, the smaller the value of overcoming resistance and acceleration (relative to the maximum value), the more repetitions can be performed [7, 8, 9, 10].

Since armwrestling refers to sports of a speed-strength nature, determining the features of the manifestation of the above types of strength in strength exercises, which are close to competitive exercises in terms of the nature of efforts and stress, is of particular relevance [11, 12, 13].

Purpose: determination of the main components of power capabilities that ensure the success of the competitive exercise of armwrestlers weighing 80-100 kg.

Materials and methods

Study participants

The study involved of some of the best armwrestling athletes in the world weighing from 80 to 100 kg (m = 87.50 ± 2.47 kg) in 2017–2020: athlete 1 is a multiple world champion weighing 90 kg (Ukraine), athlete 2 is multiple world champion weighing 82 kg (Ukraine), athlete 3 – multiple world champion weighing 93 kg (Ukraine), athlete 4 – multiple winner of international competitions weighing 85 kg (USA).

Procedure

The power capabilities of armwrestlers were determined by the results of four test exercises covering the main muscle groups that ensure the performance of competitive movements, namely: flexion of fingers, stretch with a hammer, hook and bending the hand. All exercises were performed with both left and right hands [14, 15].

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 holder 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

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}), hour of reaching a force of 1 kg ($t_{0,5F}$ / (0,5×F); Pearson correlation analysis.

Results

The analysis of the results of the assessment of the maximum strength indicators indicates that highly qualified armwrestlers in these exercises demonstrate their own characteristics of the manifestation of strength capabilities (Table 1).

Table 1

The results of measurements of the strength indicators of arm wrestlers weighing 80-100 kg.

Indicator	Athlete and his weight (kg)							
	1, UA, 90		2, UA, 82		3, UA, 93		4, USA, 85	
	left arm	right arm	left arm	right arm	left arm	right arm	left arm	right arm
Flexion of fingers (kg)	42,6	45,4	41,4	38,2	40,2	43,8	36,4	43,2
Stretch with a hammer (kg)	57,6	62,3	101,2	47,0	61,5	67,4	56,6	51,2
Hook (kg)	72,2	80,1	106,4	46,1	81,8	91,3	57,7	67,0
Bending the hand (kg)	61,4	72,7	77,5	42,0	52,6	51,6	39,6	40,8
$\bar{x} \pm m$	58,45 ± 12,24	65,12 ± 15,04	81,63 ± 29,62	43,33 ± 4,05	59,03 ± 17,52	63,53 ± 20,96	47,58 ± 11,14	50,55 ± 11,83
Student's t-test	t = 3,37; P < 0,05		t = 2,98; P > 0,05		t = 2,05; P > 0,05		t = 0,91; P > 0,05	
Total strength of the hands (kg)	233,8	260,5	326,5	173,3	236,1	251,4	190,0	202,2
$\bar{x} \pm m$	left arm 246,60 ± 57,33				right arm 221,85 ± 41,27			
Student's t-test	t = 0,70; P > 0,05							

The total indicator of the maximum strength of the left hand ranges from 190 kg to 326.5 kg, the difference is 71.84 %. The difference in power capabilities of the right hand was 50.32 % (173.3 kg versus 260.5 kg). The difference between the absolute values of the left and right hands was not significant, Student's t-test ranged from 0.33 to 2.98 (P > 0.05), and total indicators (t = 0.70; P > 0.05). Only athlete 1 showed a significant difference between flexion of fingers and stretch with a hammer (t = 3.37; P < 0.05).

A particularly large difference between each athlete is observed in exercises close in biomechanical characteristics to competitive exercises, namely: in stretch with a hammer and a hook, where the difference ranges from 78.81 % to 98.05 %. In the bending the hand exercise, there are also high differences – from 78.20 % to 95.70 %, and in the finger flexion exercise, this indicator ranges from 17.00 % to 18.85 %.

A particularly high indicator of strength was manifested in athlete 2 the left hand – 326.5 kg, and the right hand – the lowest result of 173.3 kg. He had the highest achievements in the exercises stretch with a hammer and hook, respectively 101.2 kg and 106.4 kg. Moreover, the difference between the indicators of the strength of the left and right hands reaches 88.4 %, which allows him to achieve a winning result with his left hand. In other athletes, the difference between the left and right hands was: 1 – 11.42 %, 3 – 7.62 %, 4 – 6.4 % (Table 1).

A comparative analysis of the time to reach the maximum strength of athletes (Σt) made it possible to establish that a higher indicator of strength in all four athletes is achieved over a longer time. Determining the reliability of the difference in time indicators between the left and right hands indicates an unreliable difference in this indicator (left hand - 5.56 ± 0.67 s; right hand – 6.45 ± 0.98 s; t = 0.70; P > 0, 05) (Table 2).

The determination of the speed-strength index (F/t) of armwrestlers weighing 80-100 kg indicates that this indicator in most cases coincides with the time to reach maximum strength – the shorter the time, the higher the speed-strength index, however, in addition to the data of an athlete 2. He has a low result of the speed-strength index of the right hand (F/t = 35.41 kg/s) despite one of the best indicators of the time to reach maximum strength (t = 4.9 s), which is associated with low level of maximum strength (F = 173.5 kg) (Table 2).

Table 2

Estimated hand strength indicators for armwrestling athletes weighing 80-100 kg

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} / 500, kg/s	$t_{0,5F}$ / (0,5×F), ms/kg
1, UA, 90 kg	left	233.8	58.45	5.3	44.11	2.59	910	195.9	97.95	7.73
	right	260.5	65.12	6.5	40.08	2.89	1410	204.9	102.45	10.82
2, UA, 82 kg	left	326.5	81.62	6.6	49.47	3.98	2046	202.8	101.40	12.53
	right	173.5	43.87	4.9	35.41	2.12	1935	106.7	53.35	22.31
3, UA, 93 kg	left	236.1	59.02	4.8	34.72	2.54	1500	93.0	46.50	12.71
	right	254.1	63.52	9.3	27.62	2.73	2750	93.8	46.90	21.64
4, USA, 85 kg	left	190.0	47.80	3.9	48.72	2.24	670	156.0	78.00	7.05
	right	202.2	50.55	5.2	38.88	2.38	905	156.0	78.00	7.96

In the case of Athlete 4, who has relatively weak maximal strength indices (190.0 kg and 202.2 kg), the high result of the speed-strength index (48.72 kg/s and 38.88 kg/s) clearly coincides with the low indices the time to reach the greatest force (3.9 s and 5.2 s). In connection with such data, his speed-strength capabilities, compared with the average results of other athletes, are better by 13.97 % with his left hand, and by 11.69 % with his right hand.

Thus, the ability to achieve maximum strength is the key to a high result in the speed-strength index of armwrestlers in this weight category. But at the same time, the difference in the speed-strength index between the left (44.25 ± 3.39 kg/s) and right (35.50 ± 2.82 kg/s) hands is unreliable (t = 1.98; P > 0.05).

The relative strength index (F / m) of armwrestlers weighing 80-100 kg mainly ranges from 2.12 kg/kg to 2.88 kg/kg, in percentage terms this fluctuation reaches an average of 29.02 %. Only athlete 2 reaches 3.98 kg/kg, which is the result of the high maximum strength (326.5 kg) of his left arm. The indicators of relative strength between the left (2.84 ± 0.23 kg/kg) and right (2.53 ± 0.17 kg/kg) hands do not differ in reliability (t = 1.98; P > 0.05).

Analysis of the results of determining the force gradient (the time to reach half of the maximum force ($t_{0,5F}$) allows us to state that this indicator fully depends on the value of the time to reach the maximum force, and also quite clearly characterizes the differences in the power capabilities of the left and right hands. Athlete 1 this figure is 54.94 % (910 ms versus 1410 ms), in athlete 2 it is only 5.71 % (2046 ms versus 1935 ms), in athlete 3 it reaches 83.3 % (1500 ms versus 2750 ms), in athlete 4 – 20.15 % (670 ms versus 805 ms). Statistical comparison of this indicator between the left (1281.50 ± 308.78 ms) and right (1725.00 ± 412.38 ms) hands also indicates the unreliability of the difference (t = 0.86; P > 0.05).

An analysis of the achievement of arm strength in the first 500 ms showed that this indicator has a special manifestation in the process of many years of training. So, athlete 1, who successfully competed with both hands, has a high indicator of the strength of both hands: the left – 195.9 kg, the right – 204.9 kg, while the difference between them is 4.59 %. Athlete 2 had high achievements during the competition with his left hand, and the right hand was weaker than the left by 90.06 % (202.8 kg versus 106.7 kg). Athlete 3 competed quite successfully with both hands; on testing he showed almost the same results with both left and right hands: 93.0 kg versus 93.8 kg. Athlete 4 also had the same results of both left and right hands, equal to 56.0 kg (Table 2).

A comparative analysis of the listed strength indicators with the achieved maximum results gives a clear idea of the speed-strength capabilities of each athlete. At the same time, two athletes demonstrated sufficiently high results of power characteristics for 500 ms. Athlete 1 reproduced with his left hand 84.95 %, with his right hand – 78.66 % of the maximum indicator, respectively, 195.9 kg versus 233.8 kg and 204.9 kg versus 260.5 kg. Athlete 4 reached 82.11 % (156.0 kg vs. 190.0 kg) with his left hand in 500 ms, and 77.15 % (156.0 kg vs. 202.2 kg) with his left hand.

The rest of the athletes reproduced weaker results. Thus, in 500 ms, athlete 2 reached 62.11 % of the maximum strength with the left hand, which amounted to 202.8 kg against 326.5 kg, and with the right hand – 61.49 %, respectively, 106.7 kg against 173.5 kg. An even lower result was obtained from athlete 3: with the left hand 39.4 % (93.0 kg vs. 236.1 kg), with the right hand – 36.91 % (93.8 kg vs. 254.1 kg) Fig. 1.

With such a large difference between the strength indicators for 500 ms of the left and right hands, it is natural that this difference is not significant ($t = 0.6$; $P > 0.05$): left hand – 161.90 ± 25.35 kg; right – 140.35 ± 25.35 kg.

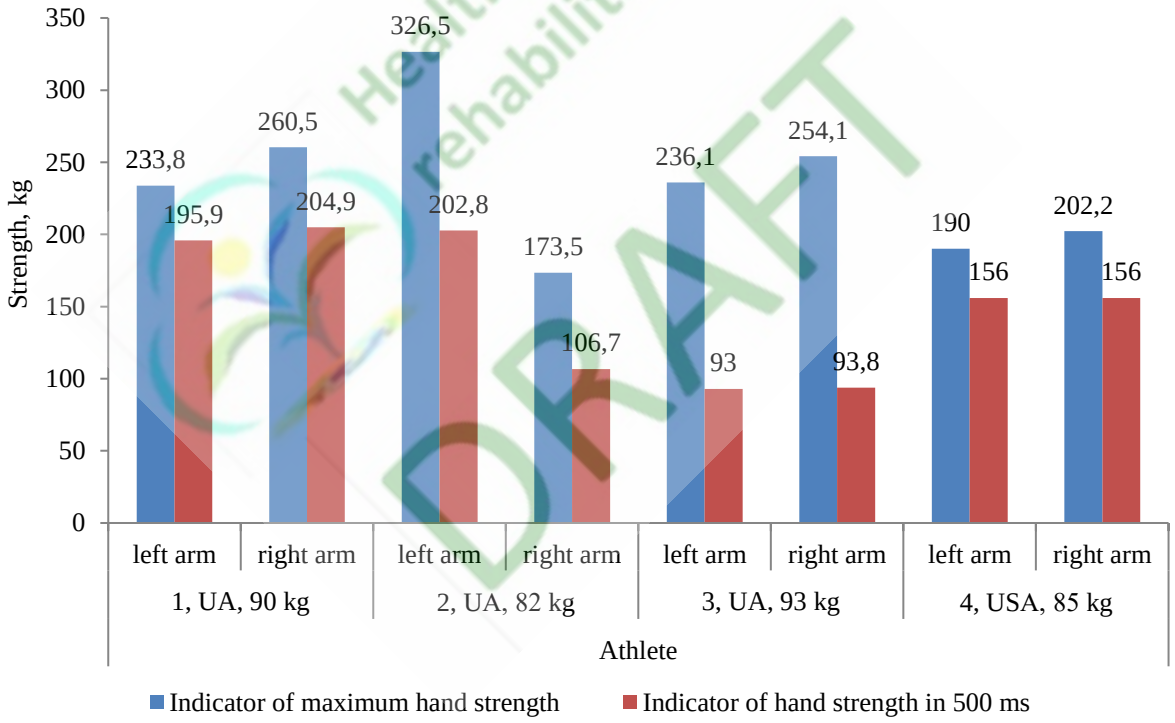

Fig. 1. The ratio of the maximum strength of the arms of armwrestlers and the strength of the hands in 500 ms

The level of the speed-strength index of armwrestlers for 500 ms fully depends on the result achieved during this time and is equal to half of it. This is due to the fact that the time for determining this indicator is limited to two seconds (4 exercises of 0.5 s). In this regard, the dynamics of changes in the force index for 500 ms completely coincides with the results of the manifestation of force for these 0.5 s, which is described above in Table 2.

The determination of the speed-strength index during the manifestation of maximum strength and the strength index for 500 ms made it possible to establish the level of this index at the end of the strength exercises. A comparative analysis of the features of the manifestation of these three characteristics of strength training in the testing process made it possible to determine the strongest and preferred sides of the natural abilities and orientation of the strength training of each armwrestler.

So, in an athlete 1 speed-strength index of the left hand for 500 ms is more than the same indicator when determining the maximum strength by 133.6 % (97.95 kg/s versus 41.93 kg/s), and the right hand – by 155.6 % (102.45 kg/s versus 40.08 kg/s). At the same time, this athlete's left hand index at the end of the exercise is 9.88 times less than the data for 500 ms (97.95 kg/s versus 9.91 kg/s), and the right hand is 8.29 times lower (102.45 kg/s versus 12.36 kg/s) Fig. 2.

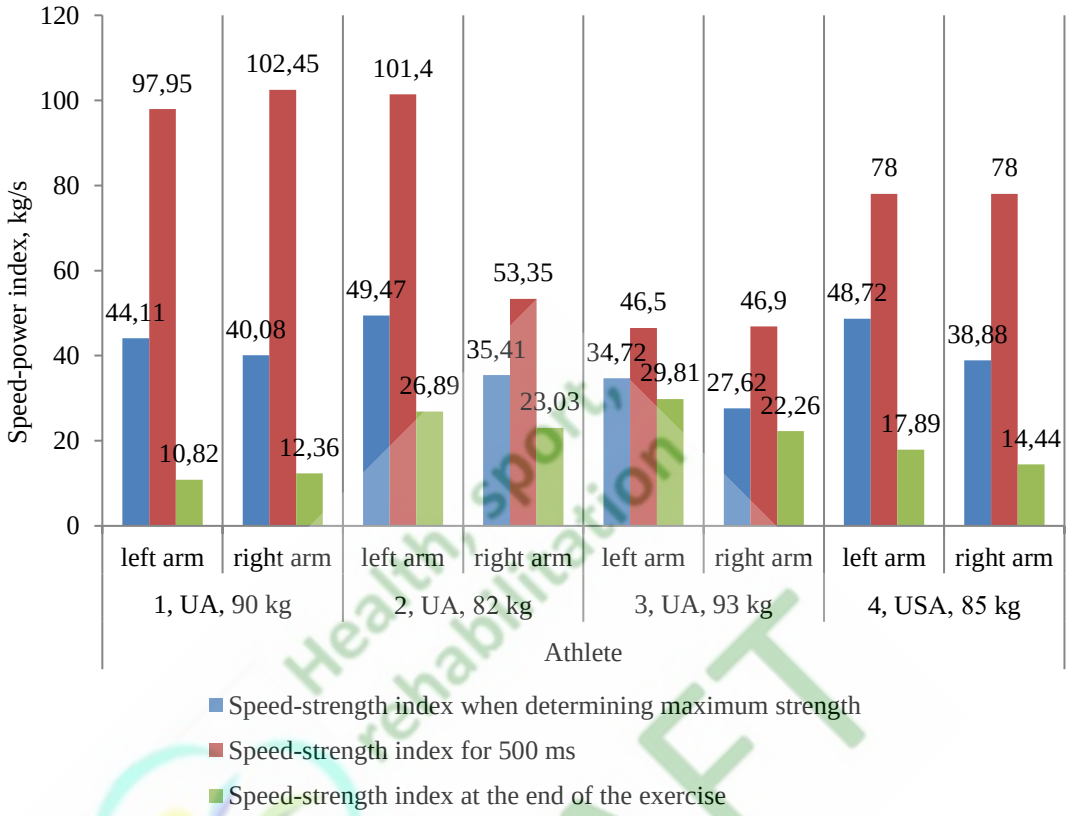

Fig. 2. Dynamics of changes in the speed-strength index in the process of testing armwrestlers

In athlete 4, the trend of changes in the studied indicator is similar. The speed-strength index of the left hand for 500 ms is higher than the data when testing the maximum force by 60.1 % (78.00 kg/s versus 48.72 kg/s), and the right hand – by 100.62 % (78.00 kg/s versus 38.88 kg/s). At the end of the exercise testing, his difference was: the left hand was 4.36 times less (17.89 kg/s vs. 78.00 kg/s), the right hand was 5.40 times less (14.44 kg/s vs. 78.00 kg/s).

In athlete 3, these indicators are less pronounced and have a different focus. His speed-strength index of the left hand for 500 ms is better than the index when determining the maximum force by 104.97 % (101.40 kg/s versus 49.47 kg/s), and the right hand is also higher by 50.66 % (53, 35 kg/s versus 35.46 kg/s). The index, determined at the end of testing, is much higher compared to the two previous athletes. So, for athlete 1 and 4, the index ranged from 10.81 kg/s to 17.89 kg/s, and for athlete 2, respectively, it was 26.89 kg/s with the left hand, and 23.03 kg/s with the right, but these results are lower than the indices reached by the athlete 2 for 500 ms, with the left hand by 207.1 % (101.40 kg/s versus 26.89 kg/s), and with the right hand by 131.6 % (53.35 kg/s). s versus 23.03 kg/s).

The same dynamics of changes in the speed-strength index was observed in athlete 3, in whom, for 500 ms with the left hand, the index is higher than when determining the maximum effort by 33.39 % (46.50 kg / s versus 34.72 kg / s), and the right one – by 69.80 % (46.90 kg/s versus 22.26 kg/s). This athlete's speed-strength index at the end of the test also remains quite high: 29.81 kg/s for the left hand, 22.26 kg/s for the right hand. The difference between these indicators was: with the left hand 55.98 %, with the right hand – 110.69 %. But, at the same time, the difference between these indicators is not significant ($t = 1.98$; $P > 0.05$). Data of the left hand – 44.25 ± 3.39 kg/s; right – 35.50 ± 2.82 kg/s.

Thus, athletes 1 and 4 showed low speed-strength index at the end of the test exercises, and athletes 2 and 3 showed a relatively increased speed-strength index.

The calculation of the time required for an athlete to achieve a strength of 1 kg ($t_{0,5F}$ / (0,5×F) clearly emphasizes the individual speed-strength abilities of each armwrestler. Especially high results of this indicator are observed in two armwrestling athletes. Athlete 1 with his left hand demonstrated 7.33 ms/kg,

and the right one - 10.82 ms/kg, athlete 4, respectively – 7.05 ms/kg and 7.96 ms/kg. left hands are on average weaker by 70.77 %, and right – by 134.02 %, the available digital data are as follows: athlete 2 – left hand 12.53 ms/kg, right – 22.31 ms/kg, athlete 2 respectively 12.71 ms/kg and 21.64 ms/kg.

A control check of the reliability between the listed indicators of the left and right hand according to the Wilcoxon rank test for unrelated samples showed that this difference in all data is unreliable t-calculated more than t-tabular, namely t-calculated from 13 to 21 against 11 t-tabular.

The correlation analysis of the results of the study made it possible to establish the degree of correlation between nine different characteristics of the power capabilities of the world's leading armwrestlers. Thus, it was confirmed that out of 36 modules of the correlation coefficient 63.89 % (23 modules) indicate a high level of correlation between the digital values of the manifestation of the strength capabilities of athletes. A weak level of correlation is observed between 33.33 % (12 cases) of correlation coefficients (Table 3).

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} /500, kg/s	$t_{0,5F}$ / (0,5×F), ms/kg
F, kg	1.000	0.968	0.714	-0.238	0.968	0.714	0.251	0.351	0.443
F/4, kg	0.968	1.000	0.714	-0.238	0.968	0.714	0.718	0.351	0.714
t, s	0.714	0.714	1.000	-0.833	0.714	0.828	0.718	0.451	0.818
F/t, kg/s	-0.238	-0.238	-0.833	1.000	-0.238	-0.714	0.828	0.586	0.802
F/m, kg/kg	0.968	0.968	0.714	-0.238	1.000	0.714	0.238	0.351	0.238
$t_{0,5F}$, ms	0.714	0.714	0.828	-0.714	0.714	1.000	-0.731	-0.443	0.766
F_{500}, kg	0.251	0.718	0.718	0.828	0.238	-0.731	1.000	0.758	0.714
F_{500} / 500, kg/s	0.351	0.351	0.451	0.586	0.351	-0.443	0.758	1.000	0.802
$t_{0,5F}$ / (0,5×F), ms/kg	0.443	0.714	0.818	0.802	0.238	0.766	0.714	0.802	1.000

The highest correlation level (r > 0.9) was established in three cases: between the maximum strength indicators (F) and the average test strength characteristic (F/4). The same level of correlation was found between relative strength and average test strength.

The largest number (7 cases) of a strong correlation (r > 0.7–0.9) was established by the indicator of the time to reach the maximum force (t) and the force gradient ($t_{0.5F}$). So, the time to reach maximum strength is closely related to maximum strength (F), with the average test indicator (F / 4), speed-strength index (F / t), relative strength (F / m), force gradient ($t_{0,5F}$) , with 500 ms force (F_{500}) and 1 kg force attainment time ($t_{0,5F}$ / (0,5F)) The force gradient has a strong correlation (r = 0.714–0.857) with maximum force, average test force, with the time to achieve maximum strength, speed-strength index, relative strength, strength index for 500 ms and with the time to achieve a force of 1 kg (Table 3).

The strength index for 500 ms has a close relationship (r = 0.714–0.825) with six strength characteristics, namely: with the average test strength index, the time to reach maximum strength, the speed-strength index, the force gradient, the 500 ms speed-strength index, and time to reach a force of 1 kg. In turn, the time to achieve a force of 1 kg also has 6 connections of a strong level (r = 0.714–0.818): with the average test strength indicator, the time to reach maximum strength, the force gradient, the strength indicator for 500 ms and the speed-strength index of 500 ms. In addition, 4 strong connection coefficients each have a speed-strength index and an average test strength indicator. Other registered correlations are at weak (r = 0.3–0.49) and very weak (r ≤ 0.29) levels.

Thus, the most influential on the strength and speed-strength characteristics of armwrestlers weighing 80–100 kg are the time to reach maximum strength, the strength index for 500 ms, the force gradient and the time to reach a force of 1 kg.

Additionally, the analysis of the factorial structure of the speed-strength indicators of the strongest armwrestlers weighing from 80 to 100 kg was carried out, which showed that the indicators of the temporal

characteristics of the manifestation of strength showed the greatest severity of the factors, namely: the time to reach maximum strength – 0.976; force gradient – 0.874; speed-strength index – 0.837; these figures generally accounted for the majority of the total sample variance of 52.2%. The second group in terms of the factor load was strength indicators of strength for 500 ms – 0.886; relative strength – 0.807; the maximum strength was 0.729, and their contribution to the total sample variance was 44.5%.

Discussion

Considering that the strength capabilities in most cases are higher for athletes weighing more than 100 kg than for armwrestlers weighing 80-100 kg, athletes weighing up to 100 kg often became winners in competitions to determine the absolute champion without taking into account the weight of the athlete [16, 17, 18, 19]. In this regard, it is especially important to determine what characteristics of strength training is the basis for high sports achievements of armwrestlers weighing 80-100 kg. Hypothetically, it was assumed that this is a large force, explosive or fast, or possibly slow, which ensures success in armwrestlers' competitive exercises.

There is very little research in this direction in speed-strength sports, as well as in other sports. In general, these problems are not sufficiently covered in open sources, so the search for a solution to these issues is very important both for the theory and for the practice of sports [19, 20, 21].

In view of the fact that explosive, fast and slow efforts are distinguished in speed-strength sports, it is important to pay special attention to these characteristics of the strength capabilities of athletes when conducting a study. Data from open sources indicate that the explosive force manifests itself for 200–300 ms of effort and is characterized by two components: starting and accelerating forces [22, 23, 24].

According to the results of our study, the starting force manifests itself within 100-200 ms, since zero data were observed in 100 ms in almost all test exercises. Athlete 4 showed especially increased starting strength, so, in bending his fingers, his effort reached 27.2 kg, pulling with a hammer – 51.6 kg, hook – 38.4 kg, bending the hand – 27.4 kg. In athlete 1, these figures are much lower and, respectively, amounted to 7.7 kg, 5.2 kg, 6.5 kg, 33.2 kg. The other two athletes recorded only zero scores.

At 200 ms, the starting force increased significantly in athletes 1 and 4, the starting force compared to the maximum force, respectively, was 53.64 % (125.4 kg) and 62.95 % (119.6 kg) with the left hands, right – 45.95 % (119.7 kg) and 68.00 % (137.5 kg). For the other two athletes 2 and 3, these results were respectively 33.60 % (109.7 kg) and 31.58 % (54.8 kg) the left hands, 21.90 % (51.7 kg) and 19.05 % (48.4 kg) the right hands.

At 300 ms, when the effort takes on an accelerating character, the explosive strength increased significantly compared to the maximum strength of athlete 1 and amounted to 70.66 % (165.2 kg) with the left hand, 66.91 % (174.3 kg) with the right hand. Other athletes showed the following indicators, respectively: athlete 2 – 47.04 % (153.6 kg) and 46.08 % (81.2 kg); athlete 3 – 33.33 % (78.7 kg) and 26.58 % (67.8 kg); athlete 4 – 73.42 % (139.5 kg) and 74.88 % (151.4 kg).

Thus, athletes 1 and 4 showed rather high explosive strength compared to athletes 2 and 3.

With further development of the force, for 400–500 ms, the force takes on the character of a fast force, when resistance is overcome, which does not reach the boundary values, and the acceleration becomes lower than the maximum. Rapid strength was reflected in the 500 ms strength indicators, as noted above, that this indicator, compared with the data of maximum strength, correlation analysis and practical achievements, is especially important in the performance of a competitive exercise. The 500 ms force data from the study are consistent with those from Diffrient DS [15], Matyushenko et al. [16, 17], Nikulin et al. [18].

The growth rate of the fast force within 300–500 ms has its own characteristics. In athletes 2 and 3 it is much higher. So, in athlete 2, the indicator of the left hand increased by 33.03 % (202.8 kg vs. 153.6 kg), the right hand – by 31.40 % (106.7 kg vs. 81.2 kg); in athlete 3, respectively, by 18.70 % (93.0 kg versus 78.7 kg) and 38.35 % (93.8 kg versus 67.8 kg). In two other armwrestlers, these changes were respectively: athlete 1 – 18.55 % (195.9 kg versus 165.2 kg) and 17.56 % (204.9 kg versus 174.3 kg); athlete 4 – 11.82 % (156.0 kg versus 139.5 kg) and 3.04 % (156.0 kg versus 151.4 kg). For these two armwrestlers, the growth rate has significantly decreased, but in general, their strength indicators for 500 ms, as noted earlier, are significantly closer to the maximum strength data. In this regard, it can be argued that the rate of explosive strength build-up is of the highest importance for competitive activity. At the same time, it should be mentioned that athletes 2 and 3 have increased strength endurance compared to athletes 1 and 4.

According to the results of the data obtained, it can be argued that in order to achieve victories in arm wrestling, it is important to have high explosive strength, force gradient, force achieved in 500 ms, optimal maximum strength, time to reach maximum strength , and time to reach 1 kg of force.

Conclusions

1. 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.
2. The obtained data on the speed-strength indicators of armwrestlers weighing 80–100 kg allow:
   – clarify the theoretical data on the dynamics of the development of explosive, fast and slow strength in speed-strength sports;
   – determine the genetically inherited strength abilities of athletes;
   – conduct an effective selection of promising athletes at different stages of a long-term training process;
   – predict the expected sports result;
   – individualize the direction, content, means and methods of the athlete's training process;
   – determine the tactics of competitive activity for each athlete;
   – to complete the optimal sports team for participation in responsible competitions.

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Conflict of interest

The authors declare no conflict of interest.

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