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Features of the manifestation of strength and speed-strength abilities of elite armwrestlers of different weight categories

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Purpose. To determine the features of the manifestation of strength and speed-strength indicators in the components of the competitive exercise of leading armwrestlers of different weight categories.

Material and Methods. The study involved 3 of the best armwrestlers in the world in different weight categories: athlete 1 (weight 62 kg; age 39 years) - multiple world champion (Ukraine), athlete 2 (weight 90 kg, age 36 years) - multiple world champion (Ukraine) , athlete 3 (weight 136 kg, age 34 years) – multiple world champion (Ukraine). The strength characteristics of athletes were determined in four test exercises that ensure the performance of a competitive action in armwrestling: flexion of the fingers, stretch with a hammer, hook and bending the hand. These exercises were performed with the left and right hands. Strength indicators in all test exercises were measured with an FL1K 0.5N, 1000N electric strain gauge dynamometer, Kern & Sohn GmbH (China) with an accuracy class of up to 50 g, fixed on a specialized armwrestling table using a specially made an author's block device. In the course of statistical analysis, the following parameters were determined and calculated: maximum (F) and relative (F_1 = ΣF / m) strength, kg; total strength index in four strength exercises (ΣF = F1 + F2 + F3 + F4), kg; time to reach maximum strength (Σt = t1 + t2 + t3 + t4), s; speed-strength index (J = ΣF / Σt), kg*ms^{-1}; average strength, index of four exercises (= ΣF / 4), kg; total strength gradient of four exercises ($Σt_{0,5F}$), ms; speed-strength index in the first 500 ms (J_{500} = $ΣF_{500}$ / $Σt_{500}$), kg*ms^{-1}; time to reach 1 kg force (t_1 = $Σt_{0.5F}$ / (0.5×F)), ms*kg^{-1}.

Results. Athlete 1, weighing 62 kg, reached the maximum value of the strength of the left arm, equal to 181.8 kg, in 4.8 s, and in the right – after 4.4 s and reached 170.0 kg. The speed-force index when reaching maximum strength was, respectively, 0.038 kg*ms^{-1} and 0.039 kg*ms^{-1}. For athlete 2, weighing 90 kg, the maximum strength values were determined after 5.3 s with the left hand and after 5.5 s with the right hand and, respectively, amounted to 233.8 kg and 260.5 kg. At the same time, the speed-strength index reached 0.044 kg*ms^{-1} with the left hand, and 0.047 kg*ms^{-1} with the right hand. The achievements of the maximum strength value of the heaviest athlete 3, weighing 136 kg, of both left and right arms were significantly better and reached 248.1 kg and 275.4 kg, respectively. At the same time, the time characteristics for reaching the limiting force values are relatively low and amounted to 4.9 s and 5.1 s. In this regard, noticeably high speed-strength index values are observed: left arm – 0.051 kg*ms^{-1}; right – 0.054 kg*ms^{-1}.

Conclusions. The study made it possible to establish that the heaviest athlete 3 has the highest overall maximum strength, but in the test exercises, which are elements of performing competitive hook and hammer pull movements, the lighter athlete 2 demonstrated a higher result. The lightest athlete 1, whose weight is 62 kg, has a high result in the relative strength indicator. The heaviest athlete 3 has significantly higher levels of explosive, fast, slow and maximum strength and, as a result, a higher speed-strength index, due to which he wins quick victories in competitions. Athletes 1 and 2, who have lower body weight, according to such time characteristics as force gradient, time to reach 1 kg of force, speed-strength indicator at the last second, have respectively better results. This indicates that athletes 1 and 2 achieve their victories in competitions due to these very characteristics.

Key words: armwrestling, armwrestlers, explosive power, strength indicators, timing characteristics, weight category.

Олег Камаєв, Віктор Джим, Андрій Забора, Марина Джим, Людмила Канунова, Олександр Півень.
Особливості прояву сили та швидкісно-силових здібностей елітних армрестлерів різних вагових категорій.

Мета дослідження: визначити особливості прояву сили та швидкісно-силових показників у складових змагальної вправи провідних армрестлерів різних вагових категорій.

Матеріал і методи. В дослідженні взяли участь 3 кращих армрестлери світу в різних вагових категоріях: спортсмен 1 (вага 62 кг; вік 39 років) – багаторазовий чемпіон світу (Україна), спортсмен 2 (вага 90 кг, вік 36 років) – багаторазовий чемпіон світу (Україна), спортсмен 3 (вага 136 кг, вік 34 роки) – багаторазовий чемпіон світу (Україна). Силові характеристики атлетів визначалися в чотирьох тестових вправах, 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 FL 1K 0,5N, 1000N, Kern & Sohn GmbH (Китай) з класом точності до 50 г, закріпленим на спеціалізованому столі для армрестлінгу за допомогою спеціально виготовленого блокового приладу. У ході статистичного аналізу були визначені та розраховані наступні параметри: максимальна (F) та відносна сила (F_1 = ΣF / m) , кг; сумарний індекс сили в чотирьох силових вправах (ΣF = F1 + F2 + F3 + F4), кг; час досягнення максимальної сили (Σt = t1 + t2 + t3 + t4), с; швидкісно-силовий індекс (J = ΣF / Σt), кг*с$^{-1}$; середня сила, індекс чотирьох

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вправ (= ΣF / 4), кг; градієнт загальної сили чотирьох вправ ($\Sigma t_{0,5F}$), мс; швидкісно-силовий індекс в перші 500 мс ($J_{500} = \Sigma F_{500} / \Sigma t_{500}$), час досягнення сили в 1 кг ($t_1 = \Sigma t_{0,5F} / (0,5 \times F)$), мс*кг$^{-1}$.

Результати. Спортсмен 1, вагою 62 кг, максимального значення сили лівої руки, що дорівнювала 181,8 кг, сягнув через 4,8 с, а правої – через 4,4 с і сягнув 170,0 кг. Швидкісно-силовий індекс під час досягнення максимальної сил склав, відповідно, 0,038 кг*мс$^{-1}$ і 0,039 кг*мс$^{-1}$. У спортсмена 2, вагою 90 кг, межові значення сили визначилися через 5,3 с лівою рукою та через 5,5 с – правою і, відповідно, склали 233,8 кг і 260,5 кг. При цьому швидкісно-силовий індекс сягнув лівою рукою 0,044 кг*мс$^{-1}$, правою – 0,047 кг*мс$^{-1}$. Досягнення максимального значення сили найважчого спортсмена 3, вагою 136 кг, як лівої, так і правої рук були значно кращими та сягнули, відповідно, 248,1 кг і 275,4 кг. При цьому, часові характеристики досягнення межових значень сили порівняно низькі та склали 4,9 с і 5,1 с. У зв'язку з цим, спостерігаються помітно високі показники швидкісно-силового індексу: лівої руки – 0,051 кг*мс$^{-1}$; правої – 0,054 кг*мс$^{-1}$.

Висновки. Дослідження дало змогу встановити, що найважчий спортсмен 3 має найвищий загальний показник максимальної сили, але у тестових вправах, що є засобом виконання змагальних вправ гак і натяжка молотком, легший спортсмен 2 продемонстрував вищий результат. Найвищий результат показника відносної сили має найлегший спортсмен 1, вага якого 62 кг. Найважчий атлет 3 має значно кращі показники вибухової, швидкої, повільної та максимальної сили та, як наслідок, вищий показник швидкісно-силового індексу, за рахунок чого здобуває швидкі перемоги у змаганнях. Атлети 1 і 2 з легшою вагою за такими часовими характеристиками, як градієнт сили, час досягнення сили в 1 кг, швидкісно-силовим індексом на останній секунді, мають відповідно кращі результати, а це вочевидь указує на те, що за рахунок саме цих характеристик вони здобувають свої перемоги у змаганнях.

Ключові слова: армрестлінг, армрестлери, вибухова сила, силові показники, часові характеристики, вагова категорія.

Introduction

The preparation of highly qualified athletes is the main object of research of modern science in sports, during which the problem of developing the foundations for the rational organization of the training process is solved. The most important element of such an organization is a system of comprehensive monitoring of athletes' preparedness levels, taking into account all formative factors. In this regard, there is a need to accurately determine the indicators of the level of sportsmanship of an armwrestler, especially at the stage of preparation for the main start, that is, at the stage of pre-competition specialized training. Since the technical and tactical training of highly qualified athletes is at approximately the same level, special attention must be paid to control over strength and speed-strength indicators [1].

Studying the experience of preparing and performing in competitions of world armwrestling leaders provides unique information that concentrates the positive experience of the athlete. However, to date, the methodological aspects of constructing individual training processes for elite armwrestlers in the world have not yet received sufficient attention from researchers. Such works are rare [2, 3, 4, 5], although their significance from both theoretical and practical points of view is beyond doubt.

Each elite armwrestler who has achieved high sports results has purely individual ("crown") techniques of wrestling [6]. This is based on unique strength, speed-strength and functional abilities, which significantly distinguish him from the average athlete, who, according to the indicated indicators, can even correspond to the model characteristics of a qualified athlete. In this regard, in the process of preparing armwrestlers, timely identification of such unique capabilities of each athlete and their successful development and improvement in the future is of particular importance.

In sports associated with weight categories, each weight category has its own characteristic features of wrestling, technical and tactical actions, strength and speed-strength readiness, manifestation of explosive, fast, slow strength or strength endurance. All these characteristic features of each weight category need to be taken into account when preparing an athlete [8].

According to our preliminary research [3], it has been established that a change in an armwrestler's own weight causes significant changes in his strength and speed-strength capabilities. Thus, an increase in the athlete's weight by 8.8 % (from 125 kg to 136 kg) led to an increase in strength indicators in various test exercises from 8.12 to 22.04 %. At the same time, the speed-force index increased by 36.76 %, the force gradient (time to reach half of the maximum effort) improved by 41.02 %.

The results of studies of leading arm wrestlers in the weight category from 80 kg to 100 kg indicate that their performance in test exercises that make up competitive exercises is often better than the achievements of athletes weighing more than 100 kg, for example, during the achievement of maximum strength, relative strength, force gradient [1] .

In connection with the above, the determination and comparison of the strength and speed-strength abilities of elite arm wrestlers of different weight categories acquires both theoretical and practical importance.

The purpose of the study is to determine the characteristics of the manifestation of strength and speed-strength characteristics of efforts in compound competitive exercises of leading arm wrestlers of different weight categories.

Material and Methods

Participants

The study involved 3 leading arm wrestlers in the world of different weight categories: athlete 1 (age 39) – multiple world champion weighing 62 kg (Ukraine), athlete 2 (age 36) – multiple world champion weighing 90 kg (Ukraine), athlete 3 (age 34) – multiple world champion weighing 136 kg (Ukraine).

Procedure

Strength and speed capabilities in test exercises were determined by an electrical tenzodynamometer of the FL1K 0.5N, 1000N series, Kern & Sohn GmbH (China) with an accuracy class of up to 50 g, fixed on a specialized table for armwrestling using an author's specially made block device. The strength and speed capabilities of armwrestlers were determined based on the results of four test exercises covering the main muscle groups that ensure the performance of a competitive action, namely: flexion of fingers, stretch with a hammer, hook and bending the hand. [9, 10]. All exercises were performed with both left and right hands.

Measurements of strength and speed-strength indica-

tors of each of the athletes were carried out one month before the start of the main competition of the year (arm wrestling championship or world cup). Three attempts were made in each movement on the left and right hands, and after measurements the best results were selected.

When measuring the strength of the muscles of the hands and speed-strength indicators, the subject stood facing the table, grabbed the special handles of the device with a brush and squeezed them with maximum force, trying to show maximum force as soon as possible. Flexion of fingers was performed with a special eccentric 3D handle, which the athlete grabbed and pressed with his fingers into the platform, the pressure vector was directed to the chest. Stretch with a hammer was performed with a fabric loop, the pressing vector was directed to the forehead. The hook was performed with a rotating handle with a diameter of 30 mm, which the athlete grabbed and tried to pull up to the chest, simulating a hook fight. The block was located on the left or right sides of the table, respectively. Bending the hand was performed with a rotating handle with a diameter of 45 mm, which the athlete grabbed and tried to bend the hand towards the chest. The distance and angle between the handles of the device was easily changed and selected for each exercise.

The special computer program AFH-FASTFD 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). AFH-FASTFD is compatible with the operating systems Windows.

Statistical analysis

Statistical analysis of the obtained data was carried out using the licensed program STATISTICA 10. The following parameters were determined and calculated: maximum (F) and relative (F_1 = ΣF / m) strength, kg; total strength index in four strength exercises (ΣF = F1 + F2 + F3 + F4), kg; time to reach maximum strength (Σt = t1 + t2 + t3 + t4), s; speed-strength index (J = ΣF / Σt), kg*ms^{-1}; average strength, index of four exercises (= ΣF / 4), kg; total strength gradient of four exercises ($\Sigma t_{0,5F}$), ms; speed-strength index in the first 500 ms (J_{500} = ΣF_{500} / Σt_{500}), kg*ms^{-1}; time to reach 1 kg force (t_1 = $\Sigma t_{0.5F}$ / (0.5×F)), ms*kg^{-1}; speed-strength index at the end of test exercises (J_2), kg*s^{-1}.

Results

A comparison of the difference in the weight of armwrestlers shows that the differences between the closest weight categories were 31.11 % (between 62 kg and 90 kg) and 33.82 % (between 90 and 136 kg), and between the lightest and heaviest – 54.41 % (62 kg – 136 kg). At the same time, the differences in the difference in effort in the manifestation of maximum force are noticeably lower. Thus, the difference between athletes 2 and 3 in terms of strength of the left hand was 5.27 % (233.8 kg versus 248.1 kg), the right – 4.17 % (263.9 kg versus 275.4 kg). Between athletes 1 and 2, this difference was respectively 22.24 % (181.8 kg versus 233.8 kg) and 35.58 % (170.0 kg versus 263.9 kg) (Table 1).

The differences between the performance of athletes 1 and 3 (62 kg and 136 kg) in all test exercises range from 20.64% (in bending the hand – 51.9 kg versus 65.4 kg) to 43.98 % (in flexion of fingers – 33.5 kg versus 59.8 kg). Between athletes 1 and 2, the difference in maximum strength in test exercises ranged from 15.47 % (in bending the hand – 51.9 kg versus 61.4 kg) to 43.91 % (in hook – 46.8 kg versus 83.5 kg) (Table 1).

The strength indicators of athlete 2 (weighing 90 kg) turned out to be better in a number of test exercises than the achievements of athlete 3 (weighing 136 kg). Such results were obtained in exercises that are means of performing a competitive exercise. Thus, in stretch with a hammer with the right hand, athlete 2 demonstrated 62.3 kg versus 55.8 kg for athlete 3 (the difference was 11.61 %). In the left-hand hook exercise, the difference was 2.12 % (72.2 kg versus 70.7 kg). In the same exercise, the data of the right hand of athlete 2 was better by 10.45 % (83.5 kg versus 75. kg) compared to the achievements of athlete 3. In other exercises, athlete 3 showed better results. The difference in strength capabilities ranged from 0.35 % in stretch with a hammer exercise with the left hand (57.9 kg versus 57.7 kg) to 24.08 % in flexion of fingers with the left hand (59.8 kg versus 45.4 kg).

The average test strength of armwrestlers from one to the next weight category gradually increases in full accordance with the indicators of maximum strength.

An analysis of the indicators of the relative strength of armwrestlers shows that this indicator mostly depends on the athlete's own weight. Thus, the data of the left hand of the lightest athlete 1 is 13.13 % higher than the result of athlete 2, respectively 2.93 kg versus 2.59 kg. And the data of the right hand of athlete 2 are better by 5.47 % (2.89 kg versus 2.74 kg) compared to athlete 2 (Table 2).

A comparison of the relative strength of athlete 1 with the results of athlete 3 indicates that his achievements of both the left and right hands are significantly high and, accordingly, were: the left hand was higher by 60.99 % (2.93 kg versus 1.82 kg), and the right – by 35.64 % (2.74 kg versus 2.02 kg).

At the same time, the relative strength of both hands of athlete 2 is also better than that of athlete 3, namely, respectively, the left hand by 42.31 % (2.59 kg versus 1.82 kg), the right – by 43.07 % (2.89 kg versus 2.02 kg) (Table 2).

Analyzing the results of the manifestation of maximum strength by highly qualified armwrestlers of different weights, it should be noted that high body weight, even of elite athletes, is not always accompanied by high indicators of maximum strength compared to athletes weighing up to 100 kg [4].

Table 1. Maximum strength indicators of elite armwrestlers of different weight categories

Indicator	Athlete 1		Athlete 2		Athlete 3	
	left arm	right arm	left arm	right arm	left arm	right arm
Flexion of fingers (kg)	36,0	33,5	42,6	45,4	54,1	59,8
Stretch with a hammer (kg)	44,5	41,9	57,6	62,3	57,9	55,8
Hook (kg)	49,4	46,8	72,2	83,5	70,7	75,6
Bending the hand (kg)	51,9	47,8	61,4	72,7	65,4	84,2
Total strength of the hands (kg)	181,8	170,0	23,8	263,9	248,1	275,4

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Table 2. Strength and speed-strength characteristics of armwrestlers of different weight categories

The athlete and his weight	Arm	ΣF, kg	$\bar{F}$, kg	Σt, s	J, $kg*s^{-1}$	F_1, $kg*kg^{-1}$	$\Sigma t_{0,5F}$, ms	ΣF_{500}, kg	J_{500}, $kg*s^{-1}$	t_1, $mc*kg^{-1}$	J_2, $kg*s^{-1}$
1, 62 kg	left	181,8	45,45	4,8	37,87	2,93	1105	143,8	69,35	26,40	15,39
	right	170,0	42,50	4,4	38,63	2,74	995	140,6	68,90	25,88	12,58
2, 90 kg	left	233,8	58,45	5,3	44,11	2,59	910	195,9	97,95	22,67	10,82
	right	263,9	65,97	5,5	47,98	2,89	1410	204,9	102,45	20,84	12,36
3, 136 kg	left	248,1	62,02	4,9	57,63	1,82	1057	217,5	108,75	19,75	10,55
	right	275,4	68,85	5,1	54,00	2,02	1256	210,2	105,10	18,52	17,81

Determination of the force gradient (time to reach half of the maximum force) made it possible to establish high speed-strength capabilities of athletes. In this connection, for all three athletes this indicator is noticeably better on the hand, which differs from the other in terms of the time characteristics of strength, than the result of the strength characteristics of the manifestation of efforts. So, for athlete 1, the result of the left hand is 10.56 % better than the result of the right (995 ms versus 1105 ms), for athlete 2, the right hand is 54.94 % better than the left (910 ms versus 1410 ms), and for athlete 3, the right the hand is also better than the left by 18.83 % (1057 ms versus 1256 ms). Thus, the force gradient of the left hand of athlete 2 is the best and amounts to 910 ms (Table 2).

The dynamics of the strength indicator over 500 ms allows us to clearly state that this indicator in highly qualified armwrestlers depends on the weight of the athlete. In this case, heavy athlete 3 demonstrated a better result with his left hand compared to athlete 2 by 11.01 % (217.50 kg versus 195.92 kg), and compared to athlete 1 by 51.25 % (217.50 kg versus 204, 90 kg). The achievements of his right hand were higher by 2.59 % (210.20 kg versus 204.90 kg) and 49.50 % (210.20 kg versus 140.62 kg), respectively.

The indicators of the speed-strength index for 500 ms almost completely coincide with the dynamics of strength characteristics for the specified period of time.

In connection with such temporal characteristics of the efforts of arm wrestlers, all athletes demonstrated an increased result of the speed-strength index corresponding to their own weight (Table 2; Fig. 1). Thus, for athlete 1, this indicator for both the left and right hands turned out to be the lowest: 37.87 $kg*s^{-1}$ for the left, which is 16.51 % lower than for the second athlete (44.11 $kg*s^{-1}$) and 52.23 % lower than that of the third athlete (57.63 $kg*s^{-1}$); 38.63 $kg*s^{-1}$ – right, and this is 24.24 % worse than the second (47.98 $kg*s^{-1}$) and 38.91 % worse than the third (54.00 $kg*s^{-1}$). The strongest indicator was demonstrated by athlete 3, and the difference between athletes 2 and 3 was: 30.70 % with the left hand (57.63 $kg*s^{-1}$ versus 44.11 $kg*s^{-1}$), 12.52 % with the right hand (54.00 $kg*s^{-1}$ versus 47.98 $kg*s^{-1}$).

Analysis of the time it takes athletes to achieve a force of 1 kg during the testing process indicates that armwrestlers with a large body weight achieve noticeably better time characteristics of the force. Thus, heavy athlete 3 demonstrated 19.75 ms/kg with his left hand, athlete 2 spent 22.67 $ms*kg^{-1}$ on this, which is 14.78 % worse, and athlete 1 generally spends 26.40 $ms*kg^{-1}$ (by 33.67 % worse). The right hand performance in this test between athletes 2 and 3 differed by 12.53 % (18.52 $ms*kg^{-1}$ versus 20.84 $ms*kg^{-1}$), and between athletes 3 and 1 the difference was 39.74 % (18.52 $ms*kg^{-1}$ versus 25.88 $ms*kg^{-1}$). Between athletes 2 and 1, this difference was respectively 16.45 % (22.67 $ms*kg^{-1}$ versus 26.40 $ms*kg^{-1}$) and 24.18 % (20.84 $ms*kg^{-1}$ versus 25.88 $ms*kg^{-1}$) (Table .2).

Determining the speed-strength index in the last second of the test made it possible to establish that this indicator for each arm wrestler depends on his maximum strength indicator. Moreover, each athlete has purely individual achievements that do not depend on their own weight. It should also be noted that this indicator allows us to determine the degree of success of arm wrestlers' performances at high-level competitions. So, the lightest athlete 1 was particularly effective in the speed-strength

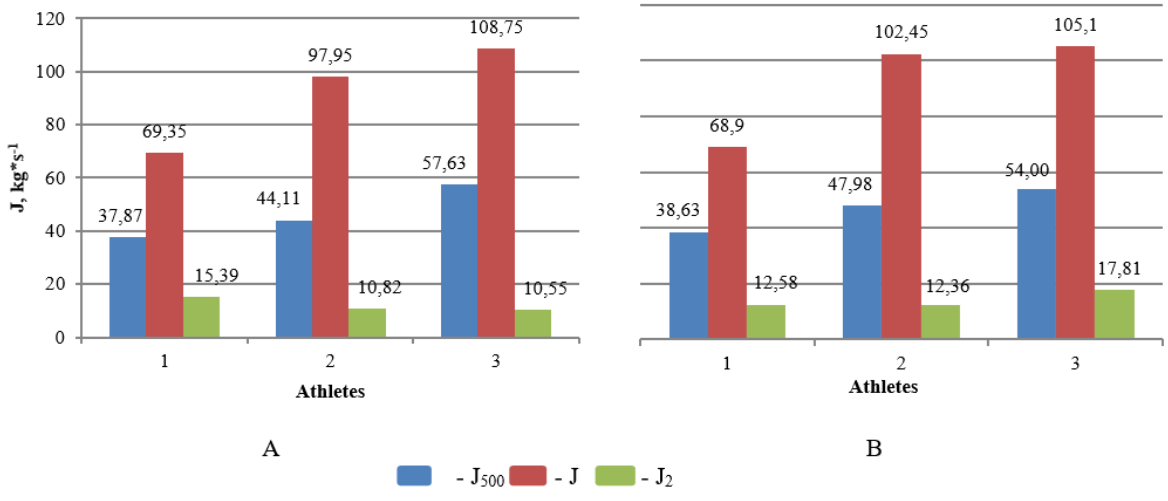

Figure 1. Dynamics of changes in the speed-strength index during testing of armwrestlers: A – left hand, B – right hand

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index in the last second of his left hand with a result of 15.39 kg*s^{-1}, which ensured his high performance with his left hand. Athlete 3, with a result of this indicator of 17.81 kg*s^{-1} with his right hand, also won most of his victories with his right hand. Athlete 2, with indicators in this test with the left hand of 10.82 kg*s^{-1}, and with the right hand – 12.36 kg*s^{-1}, the number of victories between the left and right hands did not differ significantly (Table 2; Fig. 1).

Thus, based on the analysis of the power and time characteristics of the competitive efforts of elite arm wrestlers of various weights, it was established:

– indicators of maximum strength, speed-strength index during testing, strength achievements in 500 ms depend on the armwrestler's own weight;

– indicators of relative strength and time to achieve strength of 1 kg are inversely proportional to the athletes' own weight;

– indicators of the force gradient and speed-strength in-

Table 3. Dynamics of strength and speed-strength index of armwrestlers of different weights over time

t, ms	Indicator	Athlete 1		Athlete 2		Athlete 3	
		left arm	right arm	left arm	right arm	left arm	right arm
100	ΣF_{100}, kg	21,5	39,3	53,7	36,0	36,1	5,9
	J_{100}, kg*ms^{-1}	0,215	0,393	0,537	0,360	0,361	0,059
200	ΣF_{200}, kg	58,3	76,4	125,4	119,7	174,8	168,1
	J_{200}, kg*ms^{-1}	0,291	0,382	0,627	0,598	0,874	0,840
300	ΣF_{300}, kg	94,4	83,1	161,9	174,3	199,8	189,3
	J_{300}, kg*ms^{-1}	0,321	0,277	0,540	0,581	0,666	0,631
500	ΣF_{500}, kg	143,8	140,6	195,9	204,9	217,5	210,2
	J_{500}, kg*ms^{-1}	0,288	0,281	0,392	0,409	0,435	0,420
Σt	ΣF, kg	181,8	170,0	233,8	260,5	248,1	275,4
	Σt, ms	4800	4400	5300	5500	4900	5100
	J, kg*ms^{-1}	0,038	0,039	0,044	0,047	0,051	0,054

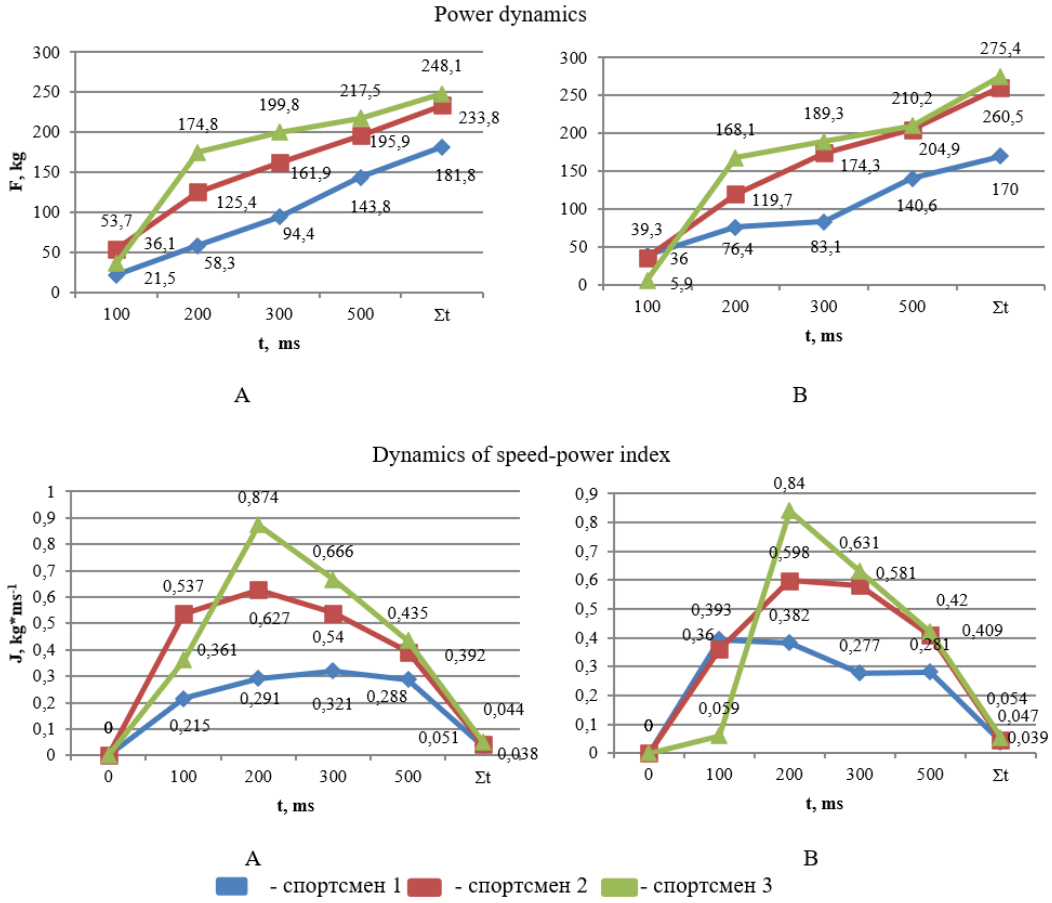

Figure 2. Dynamics of changes in effort and speed-strength index of armwrestlers of different weights over time: A – left hand; B – right hand

dex at the last second do not depend on the armwrestlers' own weight.

Analysis of power and time characteristics during testing of leading armwrestlers with different body weights made it possible to establish that explosive force, determined by the starting and accelerating forces, is formed differently in each athlete. Thus, for athlete 1, the starting force at 100 ms was 21.5 kg with the left hand with a corresponding speed-strength index of 0.215 kg*ms^{-1}, and the right hand during this time reached 39.3 kg with a speed-strength index of 0.393 kg*ms^{-1}. Over the next 100 ms, i.e. at 200 ms, the accelerating force increased and formed an explosive force, which on the left hand with a speed-strength indicator of 0.291 kg*ms^{-1} reached 58.3 kg, and on the right hand – 76.4 kg with a speed-strength indicator of 0.382 kg*ms^{-1} (Table 3; Fig. 2).

In athlete 2, the starting force of the left hand in 100 ms reached 53.7 kg with a corresponding speed-strength index of 0.537 kg*ms^{-1}, and his right hand demonstrated a starting force of 36.0 kg with a speed-strength index of 0.360 kg*ms^{-1}. The accelerating force, manifested in the next 100 ms, brought the explosive force of the left hand to 125.4 kg with a speed-strength index of 0.627 kg*ms^{-1}, and of the right hand to 119.7 kg*ms^{-1} with a speed-strength index of 0.598 kg*ms^{-1} (Table 3, Fig.2).

The heaviest athlete 3, in 100 ms, showed a starting force of 36.1 kg with his left hand, and only 5.9 kg with his right hand, with corresponding speed-strength indices of 0.361 kg*ms^{-1} and 0.059 kg*ms^{-1}. But his accelerating force in the next 100 ms made it possible to sharply increase the level of explosive force of the left hand to 174.8 kg with a speed-strength index of 0.874 kg*ms^{-1}, and of the right hand to 168.1 kg with a speed-strength index of 0.840 kg*ms^{-1} (Table 3, Fig. 2).

In the time interval from 200 to 300 ms, athlete 1's speed-strength index of the left hand, against the background of an increase in the strength indicator, reaches 0.321 kg*ms^{-1}, which is obviously associated with the continued formation of the explosive force of the left hand (Fig. 2). The speed-strength index of the right hand of both athlete 1 and the other two athletes over this period of time has a clear tendency to gradually decrease.

This dynamics of changes in the speed-strength index is accompanied by a gradual increase in the strength index. The rate of increase in the strength indicator after an intensive increase in 200 ms for all athletes slows down over the next 100 ms (by 300 ms), but still grows noticeably and takes on the character of fast strength when the resistance does not reach the limit value, and acceleration (speed-strength index) below the maximum values (Fig. 2).

Subsequently, the strength index for all athletes continues to gradually increase until maximum values are reached, and the speed-strength index decreases at a constant rate, which is typical for the manifestation of slow strength.

Athlete 1 reached the maximum value of the left arm strength equal to 181.8 kg in 4.8 s, and the right arm reached 170.0 kg in 4.4 s. The speed-force index when reaching maximum strength was 0.038 kg*ms^{-1} and 0.039 kg*ms^{-1}, respectively.

For athlete 2, the maximum force values were determined after 5.3 s with the left hand and after 5.5 s with the right hand and, accordingly, amounted to 233.8 kg and 260.5 kg. At the same time, the speed-strength index decreased and reached 0.044 kg*ms^{-1} with the left hand, and 0.047 kg*ms^{-1} with the right hand.

The achievements of the maximum strength value of the heaviest athlete 3 of both left and right arms were significantly better and reached 248.1 kg and 275.4 kg, respectively. At the same time, the time characteristics for achieving maximum force values are relatively low and amounted to 4.9 s and 5.1 s. In this regard, noticeably high speed-strength index values are observed.

Discussion

High achievements in modern armwrestling mostly depend on the quality of strength and speed-strength preparedness of athletes, since the technical and tactical training of highly qualified armwrestlers is at the highest level in all weight categories [10, 11].

It should also be noted that in armwrestling there are many examples when light weight armwrestlers take part in competitions with a weight category 10 kg higher and even for absolute championship at national and international championships. Athletes with less body weight often defeated heavyweights weighing 20–50 kg more. Such high performance of lightweights attracts special attention from spectators, fans, athletes, coaches and, of course, researchers [12, 13, 14]. All this causes great interest in determining the strongest athlete of the tournament, country, continent and even the world, not only in weight categories, but also in the absolute championship. Taking into account the peculiarities of the external characteristics of the physique of such athletes, their techniques and tactics of conducting a fight, it is especially important to determine the most effective and significant characteristics of the manifestation of strength that ensure the success of a fight in armwrestling, and also to find out due to strength or speed-strength indicators lighter athletes win.

The study was carried out over three years, as stated above, the athletes took part in international competitions and received prizes, and from the three athletes studied, their best indicators of both strength and speed-strength capabilities were selected, which was also confirmed by their results of participation in competitions.

However, despite the higher qualifications of the athletes who participated in the study, it must be recognized that the number of armwrestlers who won world-class competitions is limited by the small size of the specialized sample. To date, studies have been conducted on winners of world and European competitions weighing 60-80 kg [2, 4, 7], 80-100 kg [4, 10] and athletes weighing more than 100 kg [1, 3, 7]. It should also be noted that the small sample is due to the small number of highly qualified athletes of this level of preparedness who agreed to conduct research with them.

But, in our opinion, the value of the results obtained lies in the fact that they coincide with the data obtained in the study of highly qualified athletes in the weight categories of 60-80 kg, 80-100 kg and more than 100 kg [3, 4, 10].

According to our preliminary studies [1, 2, 3, 6], it was found that armwrestlers, according to their genetic predisposition, can be divided into those who have a tendency to quickly perform competitive exercises, and those who have the ability for strength endurance. Based on this, both strength and speed-strength abilities were determined in the studied athletes.

Considering that the listed factors have a direct impact on the result of competitive activity, it was important to determine the degree of their influence on the strength abilities of athletes and the characteristics of muscle efforts that most influence the sporting achievements of armwrestlers of various weights [15, 16, 17].

Hypothetically, it was assumed that this might not be

the highest indicator of maximum strength, but other strength and speed-strength capabilities, such as explosive strength, strength endurance; in addition, it was important to establish the degree of influence of these qualities on the ability to display great quick strength and strength endurance [18, 19].

There is very little research in this direction in speed-strength sports. In addition, the listed problems are not sufficiently covered in the available sources of information, so the search for an answer regarding the determination of the characteristics of the manifestation of various characteristics of the manifestation of dynamic efforts of armwrestlers is of particular importance for both of the theory and practice of sports.

It was also assumed that the absolute strength indicators of armwrestlers are not decisive in the effectiveness of a competitive match. Thus, in the works of Mazurenko [4], it was noted that athletes with weaker strength indicators emerged victorious in competitions. Therefore, our study was aimed at studying both strength and speed-strength indicators, that is, the gradual development of different types of strength over time.

According to publications and the results of our research, dynamic force in the process of overcoming resistance manifests itself in the form of explosive, fast and slow force [20, 21, 22]. It has also been established that explosive force is characterized by two components: starting and accelerating force [20, 22, 23]. The starting force manifests itself from 100 ms to 200 ms and provides the speed of development of the working force at the initial moment of muscle tension [24, 25, 26], confirming our data. Thus, in all the athletes we studied, the speed-strength index appears at 200 ms of effort, regardless of the level of genetically determined abilities.

A comparison of the strength and time characteristics of the efforts of elite armwrestlers with different body weights showed that an athlete with a large body weight at all time intervals of testing has significantly higher indicators of maximum, explosive, fast strength, as well as speed-strength indicators. According to other indicators, namely relative strength, time to reach 1 kg of strength and speed-strength index at the last second, lighter athletes has slightly better achievements.

Armwrestlers with predominant indicators of strength endurance are characterized by a higher indicator of maximum and relative strength and a correspondingly longer time to achieve maximum strength, as well as significantly higher strength indicators and speed-strength index in the last second of effort.

Separately, it can be noted that athlete 2 with high speed-strength characteristics of effort is more titled and has more harmonious results with both left and right hands.

However, it must be emphasized that due to the small size of the specialized sample, there is a risk of over-interpretation of the study results. It is important to note that while the results are relevant and have potential value for understanding the performance of elite armwrestlers, they may not be generalizable to the broader population or armwrestlers of varying fitness levels.

Conclusions

1. The study made it possible to establish that the heaviest athlete 3 has the greatest total maximum strength, however, in test exercises, which are a means of performing competitive exercises such as hook and stretch with a hammer, the lighter athlete 2 demonstrated higher total maximum strength result.

2. The lightest athlete 1, whose weight is 62 kg, has a high result in terms of relative strength.

3. The heaviest athlete 3 has significantly better explosive, fast, slow and maximum strength indicators and, as a result, a higher speed-strength indicator, thanks to which he wins quick victories in competitions. Athletes 1 and 2 with lower weight according to such time characteristics as force gradient, time to reach 1 kg of force, speed-strength indicator at the last second, have respectively better results, and this obviously indicates that due to these characteristics they win in competitions.

4. The level of development of strength and speed-strength indicators of elite armwrestlers indicates that in the process of selecting young armwrestlers at the stages of long-term training, special attention should be paid to the ability to display starting strength, speed-strength index, force gradient and speed-strength index at the last second of effort, which will increase the effectiveness of individualization of the training process.

Further research will be aimed at experimentally substantiating the methodology for developing speed-strength capabilities (starting, explosive, fast, slow strength) for training from initial training groups to groups of maximum capabilities, to which it is planned to attract a larger number of participants by age, weight and level of preparedness.

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Conflict of interest.

The authors declare no conflict of interest.

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