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Original article

# Analysis and generalization of the manifestation of different types of force in competitive exercises of the leaders of the world armwrestling weighing over 100 kg

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## Abstract

**Purpose:** approbation of a complex of speed-strength characteristics for monitoring the dynamics of strength exercises of the world's leading armwrestlers weighing over 100 kg.

**Material and Methods.** The study involved the 3 best arm wrestlers in the world weighing over 100 kg (116.00 ± 18.03 kg) in 2017–2020. 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 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; average strength, index of four exercises (FF = 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; time to reach 1 kg force ($t_1$ = $Σt_{0.5F}$ / (0.5×F)), ms/kg; Pearson's correlation analysis; Factor 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 these efforts of dynamic strength, the features of the manifestation of explosive, fast and slow strength of arm wrestlers weighing over 100 kg were established. Determining the relationship between strength and speed-strength indicators using factor analysis made it possible to establish two factors that determine the overall variance of the sample. The first factor with a contribution of 70.9 % to the total sample formed the temporal characteristics of effort in test exercises, such as the time to reach maximum effort (r = 0.979), speed-strength index (r = 0.986), force gradient. (r = 0.986) and the time to reach a force of 1 kg (r = 0.979). The second factor with a factor loading of 29.1 % was the maximum force (r = 0.960), the average test strength (r = 0.961) and the achieved force in 500 ms (r = 0.716). Thus, the results of the correlation and factorial analyzes of the strength and speed-strength indicators of armwrestlers weighing more than 100 kg indicate the priority of the temporal characteristics of efforts over strength in a competitive exercise.

**Conclusions.** The study made it possible to test a complex of speed-strength indicators for monitoring the functional state of the world's leading armwrestlers weighing over 100 kg, an approved system of criteria for time and power characteristics of efforts in competitive exercises allows you to monitor the state of athletes to monitor and predict success in armwrestling. The author's device used in the study made it possible to automate the process of measurements with high mobility, as well as immediately create a database on the power and speed-strength capabilities of armwrestlers with high accuracy.

**Keywords:** armsport, armwrestling, armwrestlers, explosive strength, strength indicators

## Анотація

**Аналіз й узагальнення прояву різних видів сили у змагальних вправах провідних армрестлерів світу вагою понад 100 кг.**
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**Мета дослідження:** апробація комплексу швидкісно-силових показників задля моніторингу динаміки силових вправ провідних армрестлерів світу вагою понад 100 кг.

**Матеріал і методи**. У дослідженні взяли участь 3 кращих армрестлера світу вагою понад 100 кг (116,00 ± 18,03 кг) у 2017–2020 роках. Визначено чотири силові тестові вправи, що забезпечують виконання змагальної дії в армрестлінгу: згинання пальців, розгинання молотом, 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 авторського 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; середня сила, індекс чотирьох вправ (FF = ΣF / 4), кг; градієнт загальної сили чотирьох вправ ($Σt_{0,5F}$), мс; швидкісно-силовий індекс в перші 500 мс ($J_{500}$ = $ΣF_{500}$ / $Σt_{500}$), час досягнення сили 1 кг ($t_1$ = $Σt_{0,5F}$ / (0,5×F)), мс/кг; проведено кореляційний аналіз Пірсона; факторний аналіз.

**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 понад 100 кг. Визначення взаємозв'язків силових і швидкіс-




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но-силових показників із використанням факторного аналізу дозволило встановити два фактора, що визначають загальну дисперсію вибірки. Перший фактор із внеском 70,9 % до загальної вибірки сформовано часовими характеристиками зусиль у тестових вправах, такими як час досягнення максимальних зусиль (r = 0,979), швидкісно-силовий індекс (r = 0,986), градієнт сили (r = 0,986) і час досягнення сили в 1 кг (r = 0,979). Другий фактор із факторним навантаженням 29,1 % склали показники максимальної сили (r = 0,960), середньо тестовий показник сили (r = 0,961) і сила, що досягнута за 500 мс (r = 0,716). Таким чином, результати кореляційного та факторного аналізів силових і швидкісно-силових показників армрестлерів вагою понад 100 кг свідчать, що часові характеристики зусилля у змагальній вправі мають пріоритетне значення.

**Висновки**. Дослідження дало змогу провести апробацію комплексу швидкісно-силових показників задля моніторингу функціонального стану провідних армрестлерів світу вагою понад 100 кг, апробована система критеріїв часових і силових характеристик зусиль у змагальних вправах армрестлерів дозволяє стежити за станом армрестлерів для моніторингу та прогнозування успішності в армрестлінгу. Авторський прилад, що використовувався в дослідженні, надав змогу автоматизувати процес вимірів з високою мобільністю, а також одразу створювати базу даних про силові та швидкісно-силові можливості армрестлерів із високою точністю.

**Ключові слова:** армспорт, армрестлінг, армрестлери, вибухова сила, силові показники.

## Introduction

The training of highly qualified athletes is the main object of research in modern science and sports, in which the task of developing the foundations for the rational organization of the training process is solved. The most important element of such an organization can be a system of complex control of the levels of preparedness of athletes, taking into account all the forming 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-competitive 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 power and speed-strength indicators.

Studying the experience of preparing and participating in competitions of world armwrestling leaders provides unique information, which concentrates the positive experience of an athlete. However, until now, the methodological aspects of building individual training processes of the world's leading armwrestlers have not yet become the object of close attention of researchers. Such works are rare [1, 2, 3], although their significance from both theoretical and practical points of view is beyond doubt.

Armwrestlers weighing over 100 kg is a category of athletes that differs from other weight categories not only in their large weight, but above all in a wide variety of anthropometric indicators, namely: greater or lesser height, large amount of muscle mass, as well as a different ratio of the length and coverage of the hand arms, forearm, upper arm, legs. In this regard, this category of athletes has a greater manifestation of various technical methods of conducting a duel [1].

In most cases, armwrestlers weighing more than 100 kg take part in competitions for absolute superiority at national championships, as well as European and world championships, and international competitions. Therefore, it is this weight category that is given special attention. Taking into account the peculiarities of the external characteristics of the physique of such athletes, their technique and tactics of conducting a duel, it is especially important to determine the most effective and influential characteristics of the manifestation of strength, which ensure the success of the duel in armwrestling [2, 3, 4].

According to the available information from scientific and methodological sources, at present, various types of manifestation of power and time characteristics of efforts during the performance of special and competitive exercises in speed-strength sports are not sufficiently covered.

In connection with the above, it is especially important to determine the dynamics of the growth of the efforts of armwrestlers for 100, 200, 300, 500 ms. According to researchers [5, 6], in these time intervals (200–300 ms) in speed-strength sports, explosive force is manifested, which is characterized by two components: starting and accelerating forces [7, 8, 9].

Starting strength is a characteristic of the ability of muscles to rapidly develop working effort at the initial moment of their tension. The accelerating force is the ability of the muscles to increase the working force in the conditions of their contraction [10, 11, 12]. In connection with the indicated requests of the theory and practice of speed-strength sports, the determination of the features of the manifestation of various types of power and time characteristics of competitive efforts in the process of performing competitive exercises of arm wrestlers is of particular relevance.

Success in arm wrestling is determined not only by strength indicators, but also by the speed of movement. The first group is sufficiently represented in the literature, as the strength of individual muscle groups, indices of physical development and correlations between them were studied [2, 3, 4]. At the same time, there are virtually no studies of the speed properties of armwrestlers. This is due to the complexity of methodological support and the lack of special equipment.

The peculiarities of this sport necessitate the development and testing of indicators that can be used in monitoring the condition of athletes.

In connection with the above, the purpose of this study was to test a complex of speed-strength indicators for monitoring the dynamics of strength exercises of the world's leading armwrestlers weighing over 100 kg.

## Materials and Methods

*Participants*

The study involved 3 leading arm wrestlers in the world weighing over 100 kg (average weight 116.00 ± 18.03 kg). Athlete 1 (age 32) – multiple world champion weighing 136 kg (Ukraine), athlete 2 (age 28) – multiple world champion weighing 101 kg (Poland), athlete 3 (age 31) – multiple world champion weighing 111 kg (USA).

All participants gave informed consent to participate in the research.

*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 armwres-

tling using an author's specially made block device – "ARM2 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 [13]. All exercises were performed with both left and right hands.

Measurements of strength and speed-strength indicators of each of the athletes were carried out three times within three years, after the end of the main competition of the year (armwrestling championship or world cup). They made three attempts in each movement on the left and right hands, 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 XP, Vista, Windows 7.

*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; average strength, index of four exercises ($\overline{FF}$ = ΣF / 4), kg; total strength gradient of four exercises ($\Sigma t_{0,5F}$), ms; speed-strength index in the first 500 ms ($J_{500}$ = $\Sigma F_{500}$ / $\Sigma t_{500}$), kg/ms; time to reach 1 kg force ($t_1$ = $\Sigma t_{0.5F}$ / (0.5×F)), ms/kg; Wilcoxon-White test; Pearson correlation analysis; Factor analysis.

## Results

An analysis of the results of evaluating the indicators of maximum strength indicates that highly qualified armwrestlers in test exercises demonstrate the features of the manifestation of power capabilities (Table 1).

An analysis of the maximum strength indicators of heavyweight armwrestlers in four test exercises shows that these athletes have relatively high strength indicators in all exercises, due to which the overall results of both the left and right hands are high. They showed especially high results in the hook exercise. So, in athlete 1, the strength indicator of this exercise of both the left and right hands, compared with the average data in other exercises, is better by 19.57 % and 19.43 %, respectively. In athlete 2, the difference between similar indicators was 51.37 % and 37.90 %, and in athlete 3, the hook strength indicator is higher than other results by an average of 54.80 % and 56.00 % (Table 1). These differences between hook strength and other exercises explain the effectiveness of this exercise, which is what most heavyweight athletes do.

Comparison of the average test strength indicators ($F_1$) of the left and right hands proves that the differences between them are fully preserved both in terms of general strength indicators and in terms of the results of the strength of the left and right hands (Table 2). Accordingly, according to the results of statistical analysis, this indicator also had an unreliable difference between the indicators of the strength of the left and right hands (62.47 ± 0.80 kg; 62.47 ± 2.45 kg; $t_{fact}$ 11 > $t_{table}$ 7 with $V_1$ = 2.24 % & $V_2$ = 6.86 %).

A comparative analysis of the weight data and strength indicators of each armwrestler showed that the strength indicators of the hands, despite the large difference in weight, do not differ so significantly. Thus, the difference in the power data of the left hand between athletes 1 and 2 was 1.09 %, and the weight data differed by 36 %. Between athletes 2 and 3, hand strengths differed by 4.4 %, and weights by 11 %. A similar difference between the indicators of athletes 1 and 3, respectively, is 3.27 % and 22.52 %.

The difference between the strength indicators and the weight data of the right hands decreased somewhat, but not significantly. So the difference between athletes 1 and 2 in weight was 36 %, and in strength – 13.31 %, between athletes 2 and 3 – 11 % and 7.46 %, between athletes 1 and 3 – 22.52 % and 5.82 % according. Thus, in arm wrestler 1, despite the high weight, the maximum strength indicators are better, but not so distinctly, than the weight (Table 1).

Moreover, for athlete 1, the total time to achieve the total maximum strength (Σt) is significantly lower compared to the time capabilities of the other two athletes. So, in comparison with the data of athlete 2, the time to reach the maximum strength of the left hand is 2.47 times better (4.9 s versus 12.1 s), and the right one is 2.37 times better (5.1 s versus 12.1 s). In athlete 3, the time indicator is better than the result of athlete 2 by 51.25 % (8.0 s versus 12.1 s) of the left hand, and by 22.07 % (9.6 s versus 12.1 s) of the right indicators compared to athlete 1 are worse by 23.62 % (8.0 s versus 4.9 s) and 88.24 % (9.6 s versus 5.1 s), respectively. Thus, in terms of time to maximum strength, athlete 1, despite the higher weight, shows

**Table 1. Results of measurements of strength indicators of arm wrestlers weighing over 100**

| Indicator | Athlete and his weight (kg) | | | | | |
|---|---|---|---|---|---|---|
| | 1, UA, 136 | | 2, POL, 101 | | 3, USA, 111 | |
| | left arm | right arm | left arm | right arm | left arm | right arm |
| Flexion of fingers (kg) | 54,1 | 59,8 | 42,5 | 38,5 | 43,8 | 50,8 |
| Stretch with a hammer (kg) | 57,9 | 55,8 | 63,8 | 61,2 | 64,8 | 57,6 |
| Hook (kg) | 70,7 | 75,6 | 82,3 | 73,5 | 87,2 | 85,8 |
| Bending the hand (kg) | 65,4 | 74,2 | 56,8 | 60,2 | 60,4 | 56,6 |
| Total strength of the hands (kg) | 248,1 | 265,4 | 245,4 | 233,4 | 256,2 | 250,8 |

**Table 2. Estimated hand strength indicators for armwrestling athletes weighing over 100 kg**

| Athlete | Arm | ΣF, kg | FF, kg | Σt, s | J, kg/s | $F_1$, kg/kg | $Σt_{0,5F}$, ms | $ΣF_{500}$, kg | $J_{500}$, kg/ms | $t_1$, ms/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1, UA, 136 kg | left | 248,1 | 62,02 | 4,9 | 50,63 | 1,82 | 1175 | 217,5 | 108,75 | 9,47 |
| | right | 265,4 | 66,35 | 5,1 | 52,04 | 1,95 | 1130 | 210,2 | 105,1 | 8,52 |
| 2, POL, 101 kg | left | 245,4 | 61,35 | 12,1 | 20,28 | 2,45 | 3245 | 118,4 | 59,2 | 26,44 |
| | right | 233,4 | 58,35 | 12,1 | 19,29 | 2,33 | 3190 | 69,0 | 34,5 | 27,33 |
| 3, USA, 111 kg | left | 256,2 | 64,05 | 8,0 | 32,03 | 2,31 | 1840 | 120,8 | 60,4 | 14,36 |
| | right | 250,8 | 62,70 | 9,6 | 26,13 | 2,26 | 2225 | 96,8 | 48,4 | 17,74 |

a significantly faster time to reach maximum strength.

At the same time, the average statistical indicators of the time to reach the maximum strength of the left and right hands, respectively, are 8.33 ± 2.09 s and 8.93 ± 2.03 s, which does not differ in the reliability of differences ($t_{fact}$ 9,5 > $t_{table}$ 7). Due to the large difference in this indicator between each athlete, the coefficient of variation is noticeably high, so the variability of the totality of the left hand is 43.3 %, and that of the right hand is 38.7 %.

The calculation of the speed-strength index (J) clearly confirmed the results of the temporary opportunities for achieving maximum strength. The results of the speed-strength index of athlete 1 according to the indications of the left hand are 2.5 times higher than the results of athlete 2 (50.63 kg/s versus 20.28 kg/s), and compared with the results of athlete 3 by 58.07 %. (50.63 kg/s versus 32.03 kg/s); the speed-strength index of the right hand of athlete 1 is 2.7 times higher than that of athlete 2 (52.04 kg/s versus 19.29 kg/s), and compared to athlete 3 it is 99.16 % higher (52.04 kg/s versus 26.13 kg/s). The achievement of athlete 3 is better than 2, respectively, of the left hand by 62.87 % (32.03 kg/s versus 20.28 kg/s), and the right one – by 35.46 % (26.13 kg/s versus 19, 25 kg/s) (Table 2).

Taking into account such dynamics of changes in the speed-strength index of armwrestlers, it can be seen that the result of this indicator almost directly depends on the time to reach maximum strength in test exercises.

In this regard, the statistical analysis carried out confirmed these data. The indicators of the speed-strength index of athletes of the left and right hands did not differ in reliability of differences, namely – 34,31 ± 8,03 kg/s and 34,49 ± 9,93 kg/s respectively ( $t_{fact}$ 11 > $t_{table}$ 7 with $V_1$ = 40,05 % & $V_2$ = 50,02 %).

An analysis of the characteristics of relative strength indicates that this indicator inversely depends on the weight of the athlete. So, heavyweight athlete 1 has both the left and right hands the lowest result, respectively 1.82 kg/kg and 1.95 kg/kg. Athlete 2 with the lowest weight showed the highest results: the left one – 2.45 kg/kg, the right one – 2.33 kg/kg. Athlete 3, respectively, the relative strength was: the left one – 2.31 kg/kg, right – 2.26 kg/kg.

The strength gradient indicator convincingly characterizes the speed-strength capabilities of armwrestlers. This is confirmed by the fact that the heaviest athlete 1 showed the shortest time to reach half the maximum force, equal to 1175 ms with the left hand and 1130 ms with the right. Athlete 2 spent 3245 ms in this exercise with his left hand, which is 2.76 times of athlete 1, and 3190 ms with his right hand, which exceeds the result of the first by 2.82 times. The difference between the results of athletes 1 and 3 reached 56.6 % (1175 ms versus 1840 ms) and 96.9 % (1130 ms versus 2225 ms), respectively. The results of athlete 2 are worse than the data of the third left hand by 76.60 % (3245 ms versus 2225 ms), the right one – by 43.37 % (3190 ms versus 2225 ms).

Thus, the indicators of the strength gradient of armwrestlers have a very large difference between themselves, this is especially noticeable in the data of the left hand. In this regard, the coefficient of variation of the left hand is 54.00%, and that of the right hand is 25.00%. Such data prove that there can be no significant difference between the achievements of the left (2047 ± 641 ms) and right hands (2223 ± 559 ms) ($t_{fact}$ 10 > $t_{table}$ 7).

Analyzing the power capabilities of arm wrestlers for 500 ms ($ΣF_{500}$), it was found that athlete 1 achieved the highest results during this time. In the process of testing with his left hand, he demonstrated 217.5 kg, which amounted to 87.67% of the maximum strength, and with his right hand – 79.21 % of the maximum indicator, which corresponds to 210.2 kg. Athlete 2 in this test showed a significantly lower result, so that his speed-strength capabilities allowed him to show 118.4 kg with his left hand, and only 69.0 kg with his right hand, which, respectively, amounted to 48.25 % and 29.57 % of his maximum . Athlete 3 in this test reached 47.15 % and 38.60 % of his maximum, respectively, which corresponded to 120.8 kg and 98.8 kg.

Comparison of the results of the left and right hands of armwrestlers in this test indicates that the speed-strength capabilities of the right hand differ in large differences, as evidenced by a large coefficient of variation equal to 59 %. The indicator of the left hand is much lower and amounts to 37 %. With such indicators of variation in the results the average results cannot differ significantly, therefore $t_{fact}$ 8 > $t_{table}$ 7, with the data of the left hand 152.2 ± 32.6 kg, the right hand – 125.3 ± 43.2 kg.

The dynamics of the digital values of the speed-strength index for the first 500 ms completely coincides with the results of the efforts achieved during this time. But this indicator clearly gives a temporal characteristic of the manifestation of the athlete's strength. According to this indicator, athlete 1 practically shows results that are several times higher than the same results of the other two athletes. So, his left hand, he showed a 1.84 times better result than athlete 2 (108.75 kg/s versus 59.20 kg/s) and 1.8 times higher than athlete 3 (108.75 kg/s versus 60.40 kg/s). And the achievements of his right hand are 3.05 times higher than the results of athlete 2 and 2.17 times better than those of athlete 3 (Table 2; Fig. 1).

The indicators of the speed-strength index of the left and right hands for the first 500 ms completely coincide with the re-

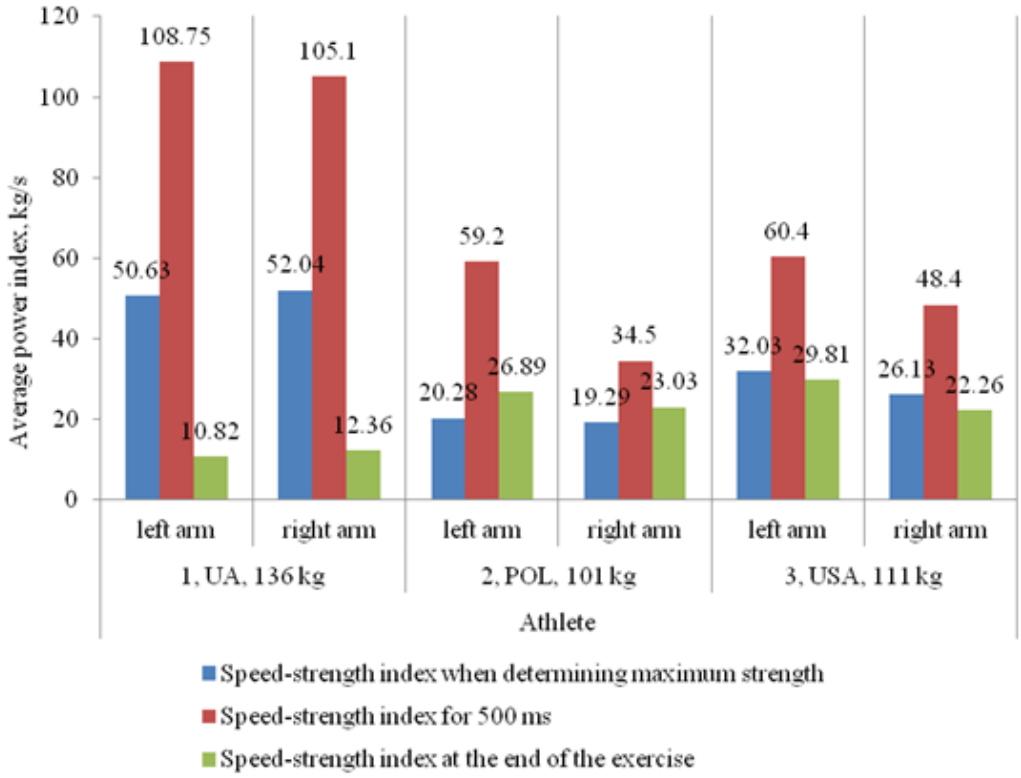


**Figure 1.** *Dynamics of changes in the speed-power index of armwrestlers*

sults of power capabilities for 500 ms, which is associated with the time criterion for the manifestation of efforts. In this regard, this indicator also has a large coefficient of variation and large values of errors in the representativeness of the mean sample. Such data prove that the difference in the indices of the speed-strength hand index will not be significant. Therefore, the results of the left hand were 76.12 ± 16.33 kg/s, and those of the right hand were 62.66 ± 21.62 kg/s ($t_{fact}$ 8 > $t_{table}$ 7; $V_1$ = 37,10 % & $V_2$ = 59,70 %).

The determination of the speed-strength index during the manifestation of maximum effort and the strength index for 500 ms allowed us to establish the level of this index in the last seconds of performing strength exercises. Comparative analysis of the features of the manifestation of these three characteristics of strength training in the process of testing made it possible to determine the strongest and most advantageous aspects of the genetically determined abilities of each armwrestler and the direction of his strength training. Thus, an athlete has 1 speed-strength index of the left hand for 500 ms more than this indicator when determining the maximum strength by 115.19 % (108.75 kg/s versus 50.63 kg/s), and the right – by 101.96 % (105.10 kg/s versus 52.04 kg/s). At the same time, this athlete has an index of the left hand at the end of the exercise less than the data for 500 ms by 10.31 times (10.55 kg/s versus 108.75 kg/s), the right hand – by 5.91 times ( 17.81 kg/s versus 105.10 kg/s) (Fig. 1).

For the other two athletes, these indicators differ significantly from the results of the heaviest athlete 1. The speed-strength index of the left hand in athlete 2 for 500 ms is 2.92 times higher than the data during the maximum strength test (59.20 kg/s versus 20.28 kg/s), while the right hand is 1.79 times better (34.50 kg/s versus 19.29 kg/s). At the end of the exercise, the difference was: the left hand – 4.71 times less than the data for 500 ms (12.57 kg/s versus 59.20 kg/s), the right hand – 2.12 times worse (34.50 kg/s versus 16.27 kg/s). Athlete 3 in the test for 500 ms increased the speed-strength index of left hand by 1.89 times (60.40 kg/s versus 32.04 kg/s), the right one – 1.85 times higher (48.40 kg/s versus 26.13 kg/s). At the end of the exercise, this athlete showed the best result in relation to the first two athletes. So, his left hand index was 22.57 kg/s, which is 2.68 times lower than the data for 500 ms (60.40 kg/s), and 20.26 kg/s for the right hand, which is also worse than the result for 500 ms (48.40 kg/s) by 2.37 times (Fig. 1).

Analyzing and comparing the indicators of the speed-strength index when determining the maximum strength, power capabilities for 500 ms and at the end of testing, it can be stated with great confidence that the armwrestler has high speed-strength abilities and his training methodology is successfully aimed at maintaining and developing this characteristic of power capabilities.

At the same time, according to the speed-strength index, at the end of testing, it should be noted that arm wrestler 1 had a low level of strength endurance, especially of the left hand (Fig. 1). The remaining two athletes, unlike the first one, have low speed-strength abilities, but they have higher strength endurance. Obviously, such power capabilities allow them to successfully compete in national and international competitions. As for armwrestler 1, it should be emphasized that he is a world-class leader in his weight category.

The calculation of the time to achieve a force of 1 kg ($t_1$) quite convincingly emphasizes the individual speed-strength abilities that are inherent in each of the studied armwrestlers. The highest results of this indicator are observed in athlete 1. With his left hand he showed 9.47 ms, and with his right hand – 8.52 ms, the achievements of athlete 2 are much worse, namely: with the left - 2.79 times (26.44 ms against 9 .49 ms), with his right – by 3.21 times (27.33 ms versus 8.52 ms). In athlete 3, this indicator is somewhat better, but worse than in athlete 1. With his left hand, he showed 14.36 ms, which is worse by

34.05% the results of the first one, and with his right hand, by 51.97% lower (17.74 ms versus 8, 52 ms) (Table 2).

Analysis of the results shows that according to this indicator, there are also large differences between the speed-strength capabilities of athletes. In this regard, a comparison of the average statistical data of the time to achieve a force of 1 kg proves that there will be no significant difference between the results of the left and right hands, this is confirmed by their results: data of the left hand – 16.44 ± 5.28 ms; right – 18.18 ± 5.16 ms ($t_{fact}$ 9 > $t_{table}$ 7; $V_1$ = 55,00 % & $V_2$ = 49,00 %).

Thus, the results of the study of the features of the manifestation of power and speed-strength capabilities of the leading armwrestlers weighing over 100 kg fully characterize their genetically determined abilities and their level of physical fitness for competitive activity. The data obtained allow us to explain the predominant speed or power capabilities of each armwrestler in general, supported by their sporting achievements. So, athlete 1 is a multiple world champion (Ukraine), athlete 2 is a world champion (Poland), athlete 3 is a multiple world champion (USA).

The conducted correlation analysis between the studied strength and speed-strength indicators of armwrestlers made it possible to establish the degree of interdependence of the strength and temporal characteristics of the features of the manifestation of efforts in test exercises, which are elements of competitive movements. Thus, the indicator of time to achieve strength of 1 kg has a very strong relationship with the speed-strength index (r = 0.986), and with the other eight indicators it has a stronger and very strong relationship with the modulus of the correlation coefficient from 0.828 to 0.943. The same level of connection is observed in the speed-strength index. The strength gradient indicator showed a very high level of correlation with the speed-strength index (r = 0.943), with the time to reach a force of 1 kg (r = 0.943) and the time to reach maximum strength (r = 0.928), and with the other five indicators - a strong level equal to r = 0.771–0.886. Other types of strength characteristics (maximum strength, average test strength, time to reach maximum strength, relative strength and strength in 500 ms) have medium (r = 0.5-0.7) and strong (r = 0.7–0.9 ) correlation coefficient with all indicators (Table 3).

Thus, the results of the correlation analysis indicate that the temporal characteristics of the manifestation of efforts (time to achieve a force of 1 kg, maximum strength, speed-strength index) demonstrate high levels of connection with the strength characteristics of the manifestation of efforts in test exercises.

Determining the relationship between strength and speed-strength indicators using factor analysis made it possible to establish two factors that determine the overall variance of the sample. The first factor with a contribution of 70.9 % to the total sample was formed by temporal characteristics of efforts in test exercises, such as the time to achieve maximum effort (r = 0.979), speed-strength index (r = 0.986), force gradient (r = 0.986) and time achieving a force of 1 kg (r=0.979). The second factor with a factor loading of 29.1 % was maximal strength (r = 0.960), average test strength (r = 0.961), and achieved strength in 500 ms (r = 0.716).

Thus, the results of the correlation and factorial analyzes of the strength and speed-strength indicators of armwrestlers weighing more than 100 kg indicate the priority importance of the temporal characteristics of effort in a competitive exercise. It is the power properties of the effort that determine the secondary importance of the action in the process of performing competitive exercises.

In connection with the above, it is especially important to determine the dynamics of the growth of the efforts of armwrestlers for 100, 200, 300 ms. According to researchers [10], during these time intervals (200–300 ms) in speed-strength sports, explosive power is manifested, which is characterized by two components: starting and accelerating forces [8].

According to the results of this study, the starting force appears in the first 200 ms. It fully manifests itself at 200 ms, therefore, for 100 ms, the studied athletes have many zero indicators, however, except for athlete 1, his left hand in this time period in the flexion of fingers exercise reached 35.2 kg of effort, and the right – 1.5 kg. In other exercises, both the left and right hands showed efforts ranging from 0.4 kg to 2.7 kg, and as a result, the left – 36.1 kg, the right – 5.9 kg (Table 4).

In athlete 2, the left hand did not react for 100 ms, only zero values were registered. The right hand reacted only in the flexion of the fingers and showed 10.7 kg.

Athlete 3 with his left hand in all exercises for 100 ms showed strength from 2.2 to 6.8 kg, and the total strength indicator was 14.4 kg. The right hand registered zero reaction.

For 200 ms, all three athletes significantly increased their strength indicators, but athlete 1 demonstrated a 2-fold better result in almost all test exercises compared to two athletes. So his strength indicators with his left hand range from 33.2 kg to 50.5 kg, and the final result was 166.8 kg. The power

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

| Indicator | ΣF, kg | $\overline{FF}$, kg | Σt, s | J, kg/s | $F_1$, kg/kg | $\Sigma t_{0,5F}$, ms | $\Sigma F_{500}$, kg | $J_{500}$, kg/mc | $t_1$, ms/kg |
|---|---|---|---|---|---|---|---|---|---|
| ΣF, kg | 1,000 | 0,968 | -0,717 | 0,828 | 0,828 | -0,757 | 0,627 | 0,627 | -0,793 |
| $\overline{FF}$, kg | 0,968 | 1,000 | -0,717 | 0,828 | 0,828 | -0,757 | 0,627 | 0,627 | -0,793 |
| Σt, s | -0,717 | -0,717 | 1,000 | 0,980 | 0,914 | 0,991 | -0,903 | -0,903 | 0,985 |
| J, kg/s | 0,828 | 0,828 | 0,980 | 1,000 | -0,942 | -0,949 | 0,955 | 0,995 | -0,939 |
| $F_1$, kg/kg | 0,414 | 0,434 | 0,914 | -0,942 | 1,000 | 0,875 | 0,886 | -0,886 | 0,847 |
| $\Sigma t_{0,5F}$, ms | -0,757 | -0,757 | 0,991 | -0,949 | 0,875 | 1,000 | -0,847 | -0,847 | 0,998 |
| $\Sigma F_{500}$, kg | 0,627 | 0,627 | -0,903 | 0,955 | 0,886 | -0,847 | 1,000 | 1,000 | -0,842 |
| $J_{500}$, kg/ms | 0,627 | 0,627 | -0,903 | 0,995 | -0,886 | -0,847 | 1,000 | 1,000 | -0,842 |
| $t_1$, ms/kg | -0,793 | -0,793 | 0,985 | -0,939 | 0,847 | 0,998 | -0,842 | -0,842 | 1,000 |

**Table 4. Dynamics of changes in the explosive force of arm wrestlers in 300 ms (kg)**

| t, ms | Athlete | Flexion of fingers | | Stretch with a hammer | | Hook | | Bending the hand | | Total indicator | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | left arm | right arm | left arm | right arm | left arm | right arm | left arm | right arm | left arm | right arm |
| 100 | 1 | 35,2 | 1,5 | 0 | 0 | 0,4 | 1,7 | 0,5 | 2,7 | 36,1 | 5,9 |
| | 2 | 0 | 10,7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10,7 |
| | 3 | 3,6 | 0 | 5,4 | 0 | 6,8 | 0 | 2,2 | 0 | 14,4 | 0 |
| 200 | 1 | 38,4 | 40,7 | 33,2 | 45,7 | 50,5 | 36,2 | 44,7 | 37,5 | 166,8 | 160,1 |
| | 2 | 19,8 | 11,9 | 26,8 | 12,6 | 23,9 | 20,9 | 17,3 | 9,6 | 87,8 | 55,0 |
| | 3 | 21,3 | 10,8 | 18,7 | 10,3 | 29,8 | 26,1 | 18,7 | 19,5 | 88,5 | 66,7 |
| 300 | 1 | 45,9 | 47,8 | 45,7 | 49,5 | 54,8 | 48,7 | 50,4 | 42,3 | 195,8 | 188,3 |
| | 2 | 24,1 | 13,3 | 30,4 | 14,3 | 31,7 | 23,8 | 20,7 | 10,4 | 106,9 | 61,8 |
| | 3 | 25,6 | 12,4 | 23,3 | 13,8 | 36,5 | 33,6 | 21,6 | 24,3 | 107,0 | 84,1 |

**Table 5. Dynamics of strength and speed-strength index of arm wrestlers over time**

| t, ms | Indicator | Athlete 1 | | Athlete 2 | | Athlete 3 | |
|---|---|---|---|---|---|---|---|
| | | left arm | right arm | left arm | right arm | left arm | right arm |
| 100 | $\Sigma F_{100}$, kg | 36,1 | 5,9 | 0 | 10,7 | 14,1 | 0 |
| | $J_{100}$, kg/ms | 0,361 | 0,059 | 0 | 0,107 | 0,141 | 0 |
| 200 | $\Sigma F_{200}$, kg | 166,8 | 160,1 | 87,8 | 55,0 | 88,5 | 66,7 |
| | $J_{200}$, kg/ms | 0,834 | 0,800 | 0,730 | 0,275 | 0,442 | 0,333 |
| 300 | $\Sigma F_{300}$, kg | 195,8 | 188,3 | 106,9 | 61,8 | 107,0 | 84,1 |
| | $J_{300}$, kg/ms | 0,653 | 0,628 | 0,356 | 0,206 | 0,357 | 0,280 |
| 500 | $\Sigma F_{500}$, kg | 217,5 | 210,2 | 118,4 | 69,0 | 120,8 | 96,8 |
| | $J_{500}$, kg/ms | 0,435 | 0,420 | 0,237 | 0,138 | 0,242 | 0,194 |
| | $\Sigma F$, kg | 248,1 | 265,1 | 245,4 | 233,4 | 256,2 | 250,8 |
| | $\Sigma t$, ms | 4900 | 5100 | 12100 | 12100 | 8000 | 9600 |
| | J, kg/ms | 0,051 | 0,052 | 0,021 | 0,019 | 0,031 | 0,026 |

indicators of the right hand reached from 36.2 kg to 45.7 kg, and the final ones – 160.1 kg. During this time, athlete 2 demonstrated the final result of 87.8 kg with his left hand, and 55.0 kg with his right hand; athlete 3: left hand - 88.5 kg, right – 66.7 kg. Thus, there is a very large difference in starting strength between athlete 1 and the other two athletes, which ranges from 1.9 to 2.91 times.

The dynamics of the increase in force between 200 ms and 300 ms, which corresponds to the time of formation of the accelerating force, was also noticeably different for each arm-wrestler. So, in athlete 1, the strength indicator of the left hand increased by 29 kg, the right hand – by 28.2 kg; in athlete 2, the increase was 19.1 kg and 6.8 kg, respectively, and in athlete 3, by 18.5 kg and 17.4 kg, respectively. In general, in 300 ms, the explosive strength of athlete 1 reached 195.8 kg of left hand, 188.3 kg of right arm, athlete 2: 106.9 kg and 61.8 kg, respectively, athlete 3: 107.0 kg and 84 ,1 kg. Such data indicate that the magnitude of the explosive force is determined mainly by the starting force. So, for all three athletes, the starting strength in percentage terms is from 75 % to 92 % of the explosive strength and, accordingly, the accelerating strength adds 18 % and 25 % to the final explosive strength.

The process of formation of explosive force is accompanied by the corresponding indicators of the speed-strength index. So, for 20 ms during the development of starting strength, each arm wrestler under study showed the highest result of the speed-strength index. In athlete 1, this indicator, as well as the strength characteristic, is almost twice as high as in the other two athletes, namely, 0.834 kg/ms of the right hand and 0.800 kg/ms of the left hand against respectively athlete 2 – 0.430 kg/ms and 0.270 kg/ms; athlete 3 – 0.42 kg/ms and 0.333 kg/ms. During the manifestation of the accelerating force between 200 and 300 ms, the speed-force index decreases from 15.23 % to 23.70 % and ranges from 0.653 kg/ms to 0.206 kg/ms (Table 5)

Such a decrease in this indicator is obviously due to the beginning of a gradual decrease in the acceleration of the efforts of athletes.

In the time intervals between 300 ms and 500 ms, the force indicator takes on the character of a fast force, since overcoming the resistance with effort does not yet reach the limit values, and the acceleration of the force is already significantly lower than the maximum, as evidenced by the decrease in the speed-force index ranging from 30.71 % to 33.41 %, and the strength indicator for the same time increases by 10.76–15.10 %.

In the future, the force continues to gradually increase until reaching the boundary value. The effort of athletes in the process of overcoming resistance increases significantly and the strength at this time takes on the character of a slow force. The strength indicator reaches its maximum value, the acceleration continues to decrease, which is associated with a decrease in the speed-strength potential. The time to reach the limit indicator, as well as the magnitude of the maximum effort for each arm wrestler, are purely individual, as described above.

The process of growth of strength to the greatest abilities of armwrestlers is accompanied by a significant decrease in the value of the speed-strength index. So, during testing, the indicator of this index of the left hand of athlete 1 decreases from 0.834 kg/ms to 0.051 kg/ms, for athlete 2 – from 0.442 kg/ms to 0.032 kg/ms, and for athlete 3 from 0.430 kg/ms to 0.020 kg/ms.

Thus, the analysis of the temporal and power characteristics of the manifestation of force in the process of reaching the boundary resistance (maximum force) allows us to clearly establish the genetically determined speed and power abili-

ties for the manifestation of explosive, fast and slow power of heavyweight armwrestlers.

## Discussion

Most armwrestlers weighing over 100 kg take part in competitions for absolute superiority at national championships, as well as European and world championships, international competitions, which attracts special attention of spectators, fans, athletes, coaches and, of course, researchers [12, 14]. All of the listed persons show a special interest in determining the strongest athlete of the tournament, country, continent and even the world. It should also be noted that there is no permanent absolute leader of the competition, and every year a new absolute winner is determined. Therefore, it is this weight category that is given special attention, and it was she who became the object of our study. Taking into account the peculiarities of the external characteristics of the physique of such athletes, their technique and tactics of conducting a duel, it is especially important to determine the most effective and influential characteristics of the manifestation of strength, ensuring the success of a duel in armwrestling.

The study was conducted for three years, and since there was no permanent leader in the absolute weight category, the best indicators of both strength and speed-strength capabilities were selected from the three studied athletes, after confirming the performance in competitions. After testing, the best indicators were selected.

For the study, an author's device was used to measure both power and time indicators of the development of dynamic strength. This device differed from others [16, 17] used in research by its great mobility, ease of transportation and assembly, as well as the accuracy of measuring force up to 50 g and time up to 100-110 ms. Other researchers determined absolute strength indicators, as well as indicators of static endurance, which were measured using conventional dynamometers and stopwatches. The author's device allowed you to automate measurements, as well as create a database of power and speed-strength capabilities of armwrestlers.

A feature of the competitive activity of arm wrestlers weighing over 100 kg is that athletes in this weight category, according to the rules of the competition, are not limited by weight as in other weight categories, where the difference in weight between rivals is only a few kilograms [14, 15, 16]. Athletes participating in competitions in the absolute weight category can differ from each other by a large difference in weight, ranging from a few to 100 or more kilograms. In this connection, there are large differences in anthropomorphological indicators - height, body and muscle mass, arm length, shoulder, forearm, hand size and other indicators.

Considering that the listed factors have a direct impact on the result of competitive activity, it is of particular importance to determine the degree of their influence on the strength abilities of athletes and the characteristics of muscle efforts that most affect the sporting achievements of heavy weight armwrestlers.

Hypothetically, it was assumed that this could be a large indicator of the maximum strength inherent in athletes of this weight group, or other strength capabilities, such as explosive strength, strength endurance, in addition, it was important to establish the degree of influence of large weight on the ability to display great fast strength and strength endurance. [17, 18].

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, therefore, the search for an answer to determining the features of the manifestation of various characteristics of the manifestation of the dynamic efforts of armwrestlers is of particular importance both for the theory and for the practice of sports.

It was also assumed that the absolute indicators of the strength of armwrestlers are not decisive in the effectiveness of a competitive duel. Thus, in the works of Mazurenko [1] it was noted that athletes with weaker strength indicators emerged as winners in competitions. Therefore, our study was aimed at studying both strength and speed-strength indicators, that is, the phased development of different types of strength over time. The hypothesis turned out to be correct, which was confirmed by the results of factor analysis, which established two factors that determine the total sample variance. The first factor with a contribution of 70.9 % to the total sample was formed by temporal characteristics of effort in test exercises, such as the time to reach maximum effort (r = 0.979), speed-strength index (r = 0.986), force gradient (r = 0.986) and time achieving a force of 1 kg (r=0.979). The second factor with a factor load of 29.1 % was maximal strength (r = 0.960), average test strength (r = 0.961), and achieved strength in 500 ms (r = 0.716). That is, the temporal characteristics of effort in a competitive exercise have priority over power ones.

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 forces [19, 20]. It has also been found that the explosive force is characterized by two components: starting and accelerating forces [21, 22]. The starting force manifests itself from 100 to 200 ms and ensures the speed of development of the working force at the initial moment of muscle tension. The accelerating force allows you to quickly increase the working force in the conditions of the onset of muscle contraction.

The process of formation of starting strength is accompanied by a rapid increase in the speed-strength index, but each athlete has an individual rate of increase and a maximum level, with which the power capabilities of armwrestlers are clearly connected. So, in athlete 1, the speed-strength index of the left hand for 200 ms reached 0.834 kg/ms, and the right hand – 0.800 kg/ms. During the same time, the starting strength of his left hand reached 166.8 kg, and the right hand – 160.1 kg. In other athletes 2 and 3, the speed-strength index reached 0.442 kg/ms and 0.333 kg/ms, respectively; 0.430 kg/ms and 0.270 kg/ms. The starting strength of athlete 2 reached the level of 88.5 kg with the left hand and 66.7 kg with the right, athlete 3, these figures were 87.8 kg and 55.0 kg, respectively.

The 500 ms force data obtained from the study are consistent with those of Coletta et al. (2022) [22].

Based on the results obtained, it can be argued that in order to achieve convincing victories in arm wrestling, it is important to have high starting strength, which manifests itself in 200 ms of wrestling, a strength gradient, a speed-strength index, which manifests itself after 500 ms, and the time to reach maximum strength.

## Conclusions

1. The study made it possible to test a complex of speed-strength indicators for monitoring the functional state of the world's leading armwrestlers weighing over 100 kg, to establish indicators of the speed-strength index, strength gradient, the ability to manifest dynamic strength, which clearly characterize the speed-strength features and the nature of the manifestation

of dynamic the strength of the athletes.

2. It has been proven that the approved system of criteria for time and power characteristics of efforts in competitive exercises can be used when monitoring the state of armwrestlers to monitor and predict success in armwrestling.

3. The author's device used in the study made it possible to automate the process of measurements with high mobility, as well as to immediately create a database on the power and speed-strength capabilities of armwrestlers with high accuracy.

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**Conflict of interest**

The authors declare no conflict of interest.

## References

1. Mazurenko I. Analysis of strength performance of highly qualified arm athletes at the stage of pre-competition training. *Slobozhanskiy scientific and sports newsletter*. 2019; 4: 44-49. https://doi.org/10.15391/snsv.2019-6.029
2. Podrihalo OO, Podrigalo LV, Kiprych SV, Galashko MI, Alekseev AF, Tropin YM, Deineko AKh, Marchenkov MK, Nasonkina OYu. The comparative analysis of morphological and functional indicators of armwrestling and street workout athletes. *Pedagogy of Physical Culture and Sports*. 2021; 25(3): 188-193. https://doi.org/10.15561/26649837.2021.0307
3. Bezkorovainyi D, Kamayev O, Vlasko S, Plotnytskyi L, Sadovska I. Determination of Model Characteristics and Evaluation Criteria for Strength Training of Qualified Armwrestling Student-Athletes. *Teoriâ ta Metodika Fìzičnogo Vihovannâ*. 2022; 22(2): 282-287. https://doi.org/10.17309/tmfv.2022.2.20
4. Bezkorovainyi D, Mazurenko I, Zvyagintseva I. Analysis of the methodology for preparing the 13-time world champion in arm wrestling. *Martial arts*. 2019; 4(14): 15–25.
5. Ahamed N, Sundaraj K, Ahmad B, Rahman M, Ali A, Islam A. Effects of anthropometric variables and electrode placement on the SEMG activity of the biceps brachii muscle during submaximal isometric contraction in arm wrestling. *Biomedizinische Techni.* 2013; 58(5): 475-488. https://doi.org/10.1515/bmt-2013-0005
6. Akpina S, Zileli R, Senyüzlü E, Tunca S. Anthropological and Perceptual Predictors Affecting the Ranking in Arm Wrestling Competition. *Int J Morphol*. 2013; 31: 832-844. https://doi.org/10.4067/S0717-95022013000300009.
7. Burdukiewicz A, Pietraszewska J, Stachoń A, Andrzejewska J. Anthropometric profile of combat athletes via multivariate analysis. *J Sports Med Phys Fitness*. 2018; 58. https://doi.org/10.23736/S0022-4707.17.07999-3
8. Kholodov J, Kuznetsov V. Theory and methodology of physical culture and sports. 2014.
9. Ogawa K, Yoshida A, Matsumura N, Inokuchi W. Fracture-Separation of the Medial Humeral Epicondyle Caused by Arm Wrestling: A Systematic Review. *Orthopaedic Journal of Sports Medicine*. 2022; 10(5). doi:10.1177/23259671221087606
10. Hirai H, Miyahara S, Otuka A. Physical factors affecting the strength of arm wrestling. *International Journal of Medical Science and Clinical Invention*. 2021; 8(11): 5816–5821. http://doi.org/10.18535/ijmsci/v8i11.010.
11. Kamayev O, Bezkorovainyi D, Mazurenko I, Vlasko S, Zvyagintseva I. Theoretical and methodological foundations for the use of innovative simulators of locally directed impact during the training process of highly qualified armwrestling athletes. *Journal of Physical Education and Sport*. 2020; 20(6); Art 488: 3622-3628. https://doi.org/10.7752/jpes.2020.06488.
12. Zixiang Tong, Xinxing Shao, Zhenning Chen, Xiaoyuan He. Optimization of the forearm angle for arm wrestling using multi-camera stereo digital image correlation: A preliminary study. *Theoretical and Applied Mechanics Letters*. 2021; 11(6): 100287. https://doi.org/10.1016/j.taml.2021.100287
13. Kamayev O, Bezkorovainyi D, Mulik V, Mazurenko I, Gradusov V, Zvyagintseva I, Plotnytskyi L. Model indicators and evaluation criteria of strength readiness of highly qualified arm-wrestlers. *Traektoriâ Nauki = Path of Science*. 2021; 7(3): 2001-2007. http://doi.org/10.22178/pos.68-1
14. Min Kyung-hyun, Yoo, Seong-jin & Choi, Young-lae. Exploring the Subcultural Characteristics of Arm Wrestling Participants. *Journal of Sport and Leisure Studies*. 2018; 74: 397-408. https://doi.org/10.51979/KSSLS.2018.11.74.397.
15. Diffrient DS. (Arm) Wrestling with Masculinity: Television, Toughness, and the Touch of Another Man's Hand. *Men and Masculinities*. 2019; 22(5): 821-849. https://doi.org/10.1177/1097184X17730385.
16. Silva DC de O, Silva Z, Sousa G da C, Silva LFG e, Marques K do V, Soares AB, … Bérzin F. Electromyographic evaluation of upper limb muscles involved in armwrestling sport simulation during dynamic and static conditions. *Journal of Electromyography and Kinesiology*. 2009; 19(6). https://doi.org/10.1016/j.jelekin.2008.09.014.
17. Vlasko S, & Dzhym V. Dynamics of indicators of general physical fitness of qualified arm sportsmen. *Yedynoborstva*. 2023; 1(27): 14–23. https://doi.org/10.15391/ed.2023-1.02
18. Harčarik G. Isokinetic Equipment In The Strength Training Of Armwrestlers. *Masaryk University Press*. 2020; 333–340. https://doi.org/10.5817/cz.muni.p210-9631-2020-43
19. Podrigalo L, Galashko M, Iermakov S, Rovnaya O, Bulashev A. Prognostication of successfulness in armwrestling on the base of morphological functional indicators' analysis. *Physical Education of Students*. 2017; 21: 46. https://doi.org/10.15561/20755279.2017.0108
20. Podrihalo O, Podrigalo L, Bezkorovainyi D, Halashko O, Nikulin I, Kadutskaya L, et al. The analysis of handgrip strength and somatotype features in arm wrestling athletes with different skill levels. *Physical education of students*. 2020; 24(2): 120-126. https://doi.org/10.15561/20755279.2020.0208
21. Rovnaya O, Podrigalo L, Iermakov S, Yermakova T, Potop V. The Application of the Index Method to Assess the Condition of Armwrestling Athletes with Different Levels of Sports Mastery. *Revista Romaneasca pentru Educatie Multidimensionala*. 2019; 11(4Supl.1): 242-256. https://doi.org/10.18662/rrem/187
22. Coletta F, Cesanelli L, Conte D . Biceps brachii morpho-mechanical properties and performance differences between strength-trained athletes and professional arm-wrestlers. *15th Conference Of Baltic Society Of Sport Sciences "Challenges And Solutions In Sport Science"*. 2022; 57.
23. Mao J-T, Chang H-W, Lin T-L, Lin I-H, Lin C-Y, Hsu C-J. Clinical Outcomes of Single Versus Double Plating in Distal-

Third Humeral Fractures Caused by Arm Wrestling: A Retrospective Analysis. *Medicina*. 2022; *58*: 1654. https://doi.org/10.3390/medicina58111654

24. Chang-Yk Lee, Hyuk-Min Kwon, Han-Bit Kim. Olecranon Fracture Sustained during Arm Wrestling in Middle-Aged Male. *J Korean Orthop Assoc*. 2022; 57(6): 520-524. https://doi.org/10.4055/jkoa.2022.57.6.520

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