A study of the individual kinematic-dynamic and speed-strength parameters of elite female weightlifters

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Abstract

Objective: To determine the morphological, kinematic-dynamic, and speed-strength parameters of elite female weightlifters and to evaluate their correlation with athletic performance.

Methods: Analysis and synthesis of scientific and methodological literature, pedagogical observation, pedagogical testing, anthropometric measurements, accelerometry and assessment of kinematic-dynamic parameters, and methods of mathematical and statistical analysis.

Results: Body mass, as well as arm and thigh circumference, demonstrate a high positive correlation with athletic performance (r = 0.58–0.75). Analysis of the kinematic-dynamic parameters of the snatch showed that the velocity in the explosive effort phase reaches its peak values (1.85±0.22 m/s). The barbell squat exercise shows the highest correlation with the 1RM (one-repetition maximum) indicator (r = 0.82–0.85).

Conclusions: The results of anthropometric studies showed that among highly skilled female weightlifters, indicators such as height, body weight, and shoulder and thigh circumferences naturally increase with a rise in weight class. As the weight class increases, the time to reach maximum barbell speed increases, while the speed during the explosive effort phase decreases.

Keywords: weightlifting, female weightlifters, individualization, kinematic-dynamic parameters, speed-strength training, correlation analysis.

Introduction

Weightlifting is one of the leading disciplines in modern Olympic sports, and in recent years, it has been developing rapidly in the women's sector. Although women's weightlifting only entered the international arena in the last quarter of the 20th century, today women's competitions are firmly established in the program of the Olympic Games, as well as in world and continental championships. The growth of athletic performance and increased competition place new demands on the organization of the training process (3). Alongside the development of women's weightlifting on the global stage, there is a growing need to build a training system that considers the physiological characteristics of the female body, gender differences, and the individual morphofunctional characteristics of athletes (4).

Current scientific research and practical developments are focused primarily on training male athletes, and there is a noticeable lack of scientifically-based methodologies for women's weightlifting (1, 2, 5, 7). Many methodological recommendations are formulated by adapting programs designed for men, which fails to fully account for the anatomical and physiological characteristics of the female body and its hormonal fluctuations. The potential for "universal" training programs to ensure performance growth in elite athletes is limited; therefore, developing approaches that consider the individual characteristics of each athlete is an important scientific and practical task (4). In this regard, a comprehensive study of the relationship between morphological characteristics, speed-strength capabilities, and biomechanical indicators of elite female weightlifters is particularly relevant.

The individualization of sports training for weightlifters is a widely studied problem. Previous studies have examined the fundamentals of managing the training process in women's weightlifting, considering athletes' age and skill level. A model for individualizing the training of qualified weightlifters has been proposed, along with the boundaries for training load volume and intensity in weightlifting (1, 3, 5, 6, 8). At the same time, existing research is predominantly general in nature, and there is a lack of studies aimed at a comprehensive examination of the relationship between morphological indicators, speed-strength capabilities, and movement biomechanics in elite female weightlifters.

The aim of the study is to determine the morphological, kinematic-dynamic, and speed-strength parameters of elite female weightlifters and to evaluate their relationship with sports performance.

To achieve this aim, the following objectives must be met:

1. Analyze the main anthropometric indicators of female weightlifters according to their weight category and determine their correlation with sports performance.

2. Study the kinematic-dynamic parame-

ters of movements in the snatch and clean and jerk exercises, and determine their differences based on weight category.

3. Assess the athletes' levels of maximum and explosive strength, as well as strength endurance, and determine the relationship between these indicators and sports performance.

Methods

The study involved 30 elite female weightlifters (aged 18–27, with 5–12 years of experience in the sport). A set of research methods was used, namely analysis and synthesis of scientific and methodological literature, pedagogical observation, pedagogical testing, anthropometric measurements, accelerometry, and assessment of kinematic and dynamic parameters, as well as methods of mathematical and statistical analysis.

Results and discussion

According to the results of the anthropometric measurements, all anthropometric indicators showed a consistent increase with higher weight categories (Table 1). The average difference in height between athletes in the lightest (48 kg) and heaviest (77 kg) weight categories was 18.8 cm, while the difference in body mass was 26.2 kg.

Wrist and thigh circumference also increased—from 23.4 to 29.4 cm and from 50.1 to 61.0 cm, respectively—indicating significantly greater muscle mass in the heavier weight classes.

BMI values ranged from 20.7±0.6 to 25.3±1.0 kg/m2, which reflects a natural change in the athletes' body proportions depending on weight class and the absence of obesity in the surveyed group. The data obtained show a relatively small variation in anthropometric indicators across weight classes, suggesting that the athletes belong to a single somatotype (predominantly mesomorphic).

At the same time, the sharp increase in absolute indicators such as wrist and thigh circumference with the transition to heavier weight classes confirms that muscle mass and strength potential are key factors for success in weightlifting. The differences in these anthropometric characteristics among athletes of different weight classes underscore the need to account for them when planning the training process—particularly in individualizing training loads and selecting sports equipment—as these parameters directly influence an athlete's strength capabilities and movement biomechanics.

According to the results of the correlation analysis (Table 2), absolute anthropometric indicators such as body weight, as well as wrist and thigh circumference, have a high to moderate positive correlation with athletic performance ($r=0.58–0.75$; $p<0.01$). The skinfold thickness measurement shows no significant correlation with athletic performance ($r=0.19–0.21$; $p>0.05$). This confirms a close relationship between strength capabilities and parameters such as muscle mass and body size in weightlifting.

According to the data in Table 2, body weight has the highest positive correlation with the snatch result ($r=0.72$; $p<0.01$) and an even higher one with the clean and jerk result ($r=0.75$). Wrist circumference also demonstrates a high correlation with the results in both lifts ($r=0.68–0.71$), which is an important metric that serves as an indirect indicator of muscle mass. Height and thigh circumference also showed an above-average correlation with athletic performance ($r=0.58–0.69$). These findings suggest that absolute anthropometric indicators—particularly those related to muscle mass—are key factors in achieving high results in weightlifting. All statistically significant correlations presented in the table are at the $p<0.01$ level, which indicates the high reliability of the identified relationships.

The correlation between subcutaneous fat fold thickness and athletic performance was found to be insignificant ($r=0.19–0.21$; $p>0.05$), which strongly suggests that the volume of fat tissue does not directly influence success in weightlifting—only muscle mass and physique are of decisive importance. These findings substantiate the need to focus on the proportion of muscle mass, rather than the thickness of the fat layer, when assessing an athlete's body composition. These results allow coaches to correctly define selection criteria for elite athletes and to emphasize the development of strength abilities when planning the training process.

Figure 1 graphically illustrates the correlation between anthropometric indicators and competitive exercise results in elite female weightlifters.

Based on the data presented in Figure 1, a clear correlation can be seen between anthropometric indicators and performance in the snatch and the clean and jerk. Body mass shows the

Table 1. Key anthropometric indicators of elite female weightlifters by weight category (M±σ)

Weight category, kg	n	Height, cm	Body mass, kg	BMI, kg/m2	Wrist circumference cm	Thigh circumference, cm
48	4	153.2±2.1	47.6±0.8	20.7±0.6	23.4±0.9	50.1±1.2
53	6	157.5±2.4	52.3±0.9	21.9±0.7	24.8±0.8	52.6±1.4
58	7	161.8±2.6	57.7±0.7	22.4±0.8	25.9±0.7	54.3±1.5
63	7	165.2±2.8	62.2±0.9	23.1±0.9	27.1±0.9	56.7±1.6
69	4	169.5±3.0	68.1±1.1	24.4±0.9	28.5±1.0	59.2±1.8
77	2	172.0±2.5	74.8±1.2	25.3±1.0	29.4±0.8	61.0±1.5

highest correlation with the results in both lifts (r=0.72 for the snatch; r=0.75 for the clean and jerk), which clearly demonstrates the defining influence of this factor on athletic performance in weightlifting. A high degree of positive correlation is also characteristic of arm and thigh circumferences (r=0.68–0.71 and r=0.65–0.69, respectively), confirming the significance of muscle mass as an evaluation criterion. Height and body mass index (BMI) show a moderate correlation with athletic performance (r=0.49–0.61), and their influence is relatively insignificant.

Table 2. Correlations between anthropometric indicators and athletic performance (n=30)

Anthropometric Indicators	Snatch Result, r	Clean and Jerk Result, r
Body Weight	0.72**	0.75**
Height	0.58**	0.61**
Wrist Circumference	0.68**	0.71**
Thigh Circumference	0.65**	0.69**
Subcutaneous Fat Layer	0.21	0.19

Note: BMI – Body Mass Index; * – significant at p<0.05; ** – significant at p<0.01.

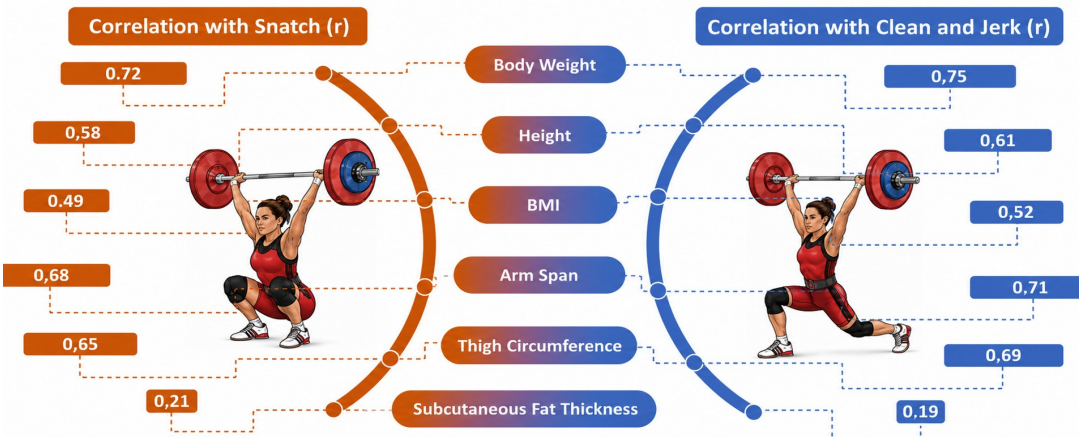
The most important point shown in the figure is that the skinfold thickness indicator shows a weak correlation with performance results in both lifts (r=0.21 for the snatch and r=0.19 for the clean and jerk). This indicates that the amount of adipose tissue does not have a direct impact on athletic performance.

Furthermore, the correlation coefficients for all anthropometric indicators are somewhat higher for the clean and jerk than for the snatch. This is because the clean and jerk requires greater overall strength and significant body mass. Overall, the data presented in the figure clearly demonstrate that in weightlifting, it is necessary to rely primarily on absolute anthropometric indicators related to muscle mass (body mass, arm and thigh circumference), whereas indicators such as skinfold thickness are of secondary importance when evaluating athletic performance.

Table 3 below presents the mean, minimum, and maximum values obtained for the main phases of the snatch exercise: the first pull, the second pull, and the unsupported squat phase. These data allow for the assessment of the female athletes' technical and speed capabilities.

The average barbell lifting speed during the preliminary acceleration phase is 1.42 m/s, and in the final acceleration phase, this figure increases to 1.85 m/s, which indicates a high level of explosive strength development in the athletes. The time to reach maximum barbell

Fig 1. Correlation between anthropometric indicators and competitive exercise results in elite female weightlifters



speed is approximately 0.38 s, with the speed of the final acceleration (1.68 m/s) being significantly higher than that of the preliminary acceleration phase. This confirms that the primary speed-strength potential is realized specifically in the final acceleration phase, and the effectiveness of the technique depends on the execution of this phase (Table 3).

ing various phases of the exercise can vary depending on the athlete's weight category and strength level. Consequently, these parameters serve as key criteria in the development of individualized technical and strength training programs.

According to the correlation analysis results presented in Table 4, all strength ability

Table 3. Kinematic parameters of the snatch exercise by phase in elite female weightlifters (n=30, M±σ)

Parameter	Mean	Minimum	Maximum
Barbell speed during the first pull (m/s)	1.42±0.18	1.12	1.78
Time to reach maximum barbell speed (s)	0.38±0.05	0.30	0.49
Maximum barbell speed (second pull) (m/s)	1.68±0.21	1.35	2.10
Barbell speed at turnover (m/s)	1.85±0.22	1.50	2.28
Execution time of the unsupported squat phase (s)	0.52±0.06	0.42	0.65
Total execution time of the snatch (s)	1.78±0.15	1.52	2.10
Maximum barbell lift height (cm)	112.4±8.5	95.0	130.0

The average maximum barbell lift height was 112.4 cm (range of values – from 95.0 to 130.0 cm), which indicates significant anthropometric and technical differences between the athletes. The total time to perform the movement was approximately 1.78 s, and its increase was closely related to the duration of the unsupported squat phase (0.52 s).

The difference between the minimum and maximum values of kinematic parameters (e.g., explosive speed in the range of 1.50–2.28 m/s) indicates the individual technical characteristics of each athlete and the need to account for them in the training process. Furthermore, the results confirm that speed and time characteristics dur-

indicators have a positive and statistically significant relationship with athletic performance (in the snatch and clean and jerk). The correlation coefficients range from 0.45 to 0.85. This confirms the direct influence of strength abilities on athletic performance in weightlifting. However, the significance of each strength indicator is not uniform, which requires a differentiated approach to them during the training process.

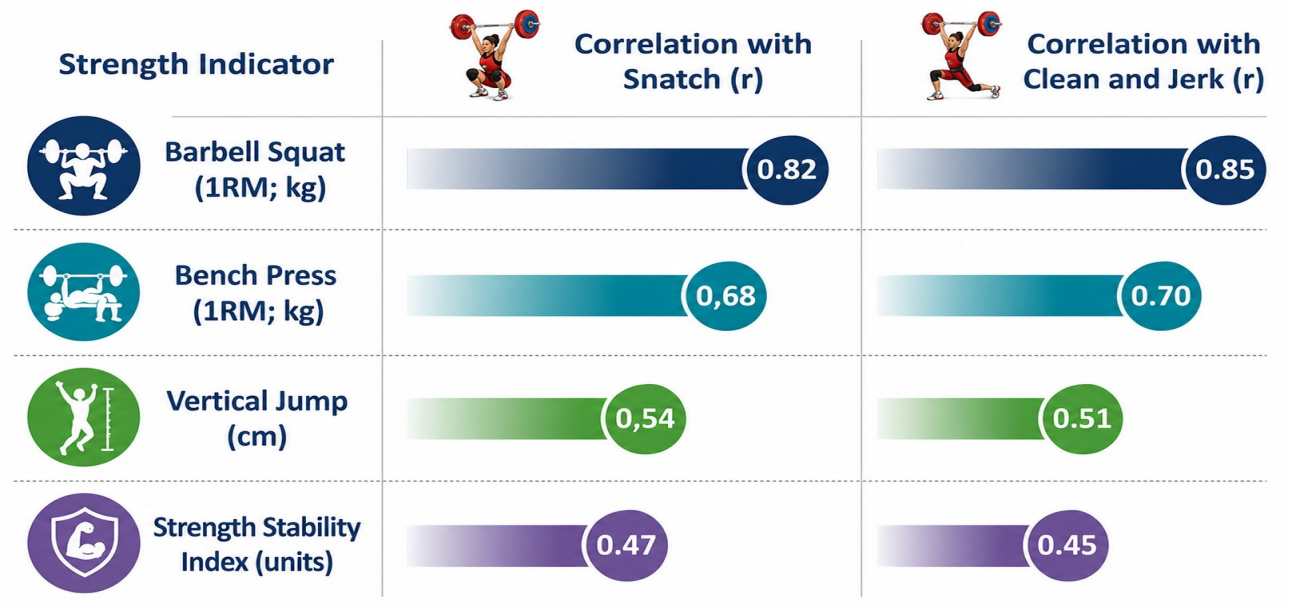
The highest correlation was found with the squat (one-repetition maximum – 1RM): $r = 0.82$ for the snatch and $r = 0.85$ for the clean and jerk ($p<0.01$). This finding clearly demonstrates that the maximum strength capabilities of

Table 4. Correlations between strength indicators and athletic performance (n=30)

Strength indicator	Snatch results, r	Clean and jerk results, r
Barbell Squat (1RM; kg)	0.82**	0.85**
Bench Press (1RM; kg)	0.68**	0.70**
Vertical Jump (cm)	0.54**	0.51**
Strength Stability Index (units)	0.47*	0.45*

the leg and trunk muscles are a determining factor in athletic performance. Bench press results also show a high correlation (r=0.68 for the snatch, r=0.70 for the clean and jerk; p<0.01), but it is lower than that of the squat. This is because in weightlifting, the leg muscles play a more dominant role than the arm muscles. The one-repetition maximum (1RM) in the squat is the most important criterion for assessing an athlete's overall strength potential. Therefore, during the training process, special attention should be paid to exercises that develop the leg muscles (Table 4 and Fig. 2).

Fig 2. Correlation between strength indicators and competitive lift results in elite female weightlifters



The vertical jump test is used to assess explosive power and demonstrates a moderate correlation with athletic performance (r=0.54 for the snatch and r=0.51 for the clean and jerk; p<0.01). The strength endurance index also demonstrated a moderate correlation (r=0.47 and r=0.45; p<0.05) (Table 4 and Fig. 2). Although the correlation of these indicators is lower than that of squat results, they still have a significant impact on athletic performance. Athletes with high levels of explosive power and strength endurance are able to effectively perform technically complex movements. Accordingly, developing these qualities should also be an important component of the training program.

Overall, maximal strength (especially leg strength) is the primary factor determining athletic performance, while explosive power and strength endurance are of secondary importance. The individualized training process must take into account each athlete's strength profile.

Study results. Analysis of the anthropometric indicators of elite female weightlifters showed that body mass, as well as shoulder and thigh circumference, have a high positive correlation with athletic performance (r = 0.58–0.75), whereas the correlation with subcutaneous skinfold thickness is statistically insignificant. Ac-

cording to kinematic characteristics, the velocity during the explosive effort phase of the snatch is 1.85±0.22 m/s. However, as the weight category increases, this indicator decreases, while the time to perform the lift increases. In strength tests, the highest correlation with athletic performance (r=0.82–0.85) is observed for the one-repetition maximum (1RM) in the barbell squat.

The identified correlations between kinematic and strength indicators, as well as the individual variability of movement parameters, confirm the need to differentiate between the technical and strength training of athletes. The data obtained make it possible to consider the morphological and kinematic characteristics of each athlete when planning the training process. This creates a scientific basis for developing individualized training programs and improving athletic performance.

Conclusion

1. Anthropometric studies have shown that among elite female weightlifters, indicators such as height, body mass, and shoulder and thigh circumferences naturally increase with the weight category. Body mass and shoulder and thigh circumferences demonstrate a high degree of positive correlation with athletic performance (r=0.58–0.75; p<0.01). In contrast, skinfold thickness shows no significant correlation with athletic performance (r=0.19–0.21; p>0.05).

2. Analysis of the kinematic and dynamic parameters of the snatch and the clean and jerk showed that barbell velocity reaches its highest values during the explosive effort phase (1.85±0.22 m/s in the snatch, 1.72±0.20 m/s in the clean and jerk). As the weight category increases, the time to reach maximum barbell velocity increases, while the velocity in the explosive effort phase decreases.

3. Based on the assessment of strength indicators, the highest correlation with athletic performance is observed for the back squat (1RM) (r=0.82–0.85; p<0.01). The vertical jump and the strength endurance index demonstrate a moderate correlation with athletic performance (r=0.45–0.54).

4. A comparison of athletes across various weight classes showed that as they move into heavier classes, their absolute strength increases, while their relative strength and explosive power decrease. Athletes in lighter weight classes have an advantage in speed-strength qualities and relative strength, whereas those in heavier classes surpass them in absolute strength. These differences justify the need to individualize the training process, taking into account the specific characteristics of each weight class.

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