

Comparative analysis of goniometric indicators of kettlebell lifting and arm wrestling athletes

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Abstract

Background and Study Aim The examination of athletes' physical condition is an essential component of sports monitoring. Flexibility is a key physical quality in sport, and goniometry is widely used to assess it. However, goniometric indicators are rarely applied to evaluate kettlebell lifting athletes. The aim of this study was to compare the range of movements in the hand joints of kettlebell lifting (KL) and arm wrestling (AW) athletes using goniometric testing.

Material and Methods Thirty-six athletes participated in the study, including 21 KL athletes and 15 AW athletes matched by age and skill level. The range of active movements in the wrist, elbow, and shoulder joints was measured using an IGaging electronic goniometer (USA). Flexion, extension, abduction, and adduction were assessed. For each movement, the maximum value of two or three attempts was recorded. Asymmetry coefficients were calculated, and group differences were analyzed using the Rosenbaum (Q) criterion.

Results KL athletes demonstrated a greater range of movements in most wrist and shoulder joint indicators. AW athletes showed a greater flexion range in the right elbow joint. Significant asymmetry was observed in KL athletes, particularly in wrist extension, wrist adduction, elbow extension, and several shoulder movements. In AW athletes, asymmetry was less pronounced and detected mainly in wrist abduction and adduction.

Conclusions The study established clear differences in joint mobility between kettlebell lifting and arm wrestling athletes. KL athletes exhibited greater joint mobility and more pronounced asymmetry, reflecting the specific demands of kettlebell lifting. AW athletes showed increased elbow flexion associated with arm-wrestling technique. Goniometry is an objective and informative method for assessing athletes' functional condition and may be used as a screening tool for monitoring KL and AW athletes.

Keywords: kettlebell lifting, arm wrestling, amplitude, movements, joints, goniometric, research, asymmetry.

Introduction

Research and analysis of the condition of athletes is a mandatory and important component of sports monitoring. This information allows for the optimization of training, the prediction of athletes' success, and the assessment of their level of preparedness. The main objective of this study is to investigate basic physical qualities, such as strength, endurance, speed, coordination, and flexibility. The qualities selected for assessment depend on the specific impact of the sport on the athlete's body.

Flexibility is one of the most important physical qualities in sports and physical culture. It determines the possibility of achieving success in many sports [1,

2, 3, 4]. It is a criterion for the effectiveness of fitness training [5]. Flexibility also allows for the assessment of recovery and rehabilitation effectiveness [6, 7, 8]. The comparison of flexibility indicators provides information about the functional state of athletes, amateurs, and people undergoing rehabilitation. Goniometry is the leading method for studying flexibility [9, 10, 11]. Goniometric indicators are used to assess the preparedness of athletes and to evaluate the effectiveness of rehabilitation after injuries [6].

In a previous study [12], goniometry was used to assess the functional state of the musculoskeletal system of athletes during a year-long training cycle. Low flexibility and joint mobility reflected insufficient musculoskeletal system elasticity. This indicated overexertion in the bodies of the athletes. Positive dynamics were interpreted as evidence of functional state restoration.

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Flexibility indicators are interrelated with other criteria of the condition of athletes [13, 14]. A previous study [13] examined the relationship between flexibility and injury history when performing strength endurance exercises, such as running, cycling, swimming, and triathlon. Flexibility was assessed using goniometry. Significant correlations were observed. It was concluded that flexibility can influence injury characteristics. This relationship varies depending on the focus of strength training.

A comparative analysis of the morphofunctional characteristics of athletes in various martial arts as factors of success has also been conducted [15, 16]. Goniometric characteristics were assessed as predictors of success in wrestling and striking martial arts. The range of movements reflects the ability to perform an effective grab, strike, or block.

A similar design was used in another study [7]. A set of morphofunctional indicators was applied to assess the recovery of basketball players. Goniometry was used to measure the range of movements of the joints, and muscle testing was used to determine muscle strength. Comparative measurements of muscle parameters and personalized tests adapted for each athlete were performed. An increase in the range of movements in the joints was interpreted as an optimization of the athletes' condition.

Goniometric indicators were included in a set of tests to assess the condition of sport dancers [3]. The authors used the Columbia Adolescent Dancer Screening (CADS). The questionnaire included information about dance injuries, health questionnaires, and tests to assess aerobic capacity, range of movements, strength, balance, and dance technique. The pragmatism, evidence base, and effectiveness of the screening methods used were confirmed.

The correlations among flexibility, muscle strength, and static and dynamic balance were studied by Unuvar et al. [17]. Differences in these indicators were found between athletes and non-athletes. The data were interpreted as the result of the influence of regular physical activity.

A similar design was used in a previous study [11]. Asymmetries and correlations between the strength and flexibility of the knee flexors and extensors in young football players were examined. The existence of dependencies between muscle strength and flexibility was confirmed.

Another study [14] showed that specific loads in handball affect the shoulder joint condition of athletes. Insufficient muscle strength reduces the range of movements and increases the risk of injury. It was concluded that including exercises to strengthen the rotator and adductor muscles in the training plan can improve shoulder health in handball players.

Goniometric studies can be used to assess limb

asymmetry [18, 19, 20, 21]. This is important for analyzing and predicting sports performance and for preventing injuries. Sports asymmetry is defined as bilateral differences in the fitness parameters of athletes. These asymmetries are likely a function of the dominant limb and are intensified by long-term sports experience.

Goniometric indicators are important for achieving success in strength sports. The range of movements in the shoulder, hip, and knee joints of female powerlifters was evaluated in the study by Spence et al. [22]. An increase in the range of movements in the shoulder joint was found compared with female amateurs.

In the study by Podrigalo et al. [23], a goniometric assessment of the range of movements in the joints of the hands of arm wrestling (AW) athletes and amateurs was conducted. The range of movements in the hand joints was examined. The results suggest that the range of movements in the joints is an important factor for AW performance. An increase in the indicators confirms the optimization of flexibility in athletes compared with amateurs. The results also reflect the expansion of the arsenal of technical wrestling techniques. This allows for improved performance.

Analysis of research findings has shown that flexibility and goniometric indicators are informative parameters for assessing the functional state of athletes in various sports. Researchers emphasize that the range of movements in the joints is closely related to physical preparedness, recovery processes, and the risk of injury. At the same time, authors highlight that joint mobility reflects sport-specific demands and can influence technical performance. However, goniometric indicators are practically not used to assess the condition of kettlebell lifting (KL) athletes. Some studies have proposed a set of tests to assess the condition of KL athletes [24]. However, the goniometric method was not used in this battery of tests. These aspects indicate the need for further analysis of joint mobility in strength disciplines and demonstrate the relevance of examining sport-specific movement characteristics.

Research hypothesis

The available results allowed us to develop the following research question: "Will the specifics of kettlebell lifting and arm wrestling training affect the range of movements in the joints of the upper limbs?"

The research hypothesis was to identify differences in the range of movements in the hand joints in KL and AW athletes. The results of the analysis will make it possible to optimize the training of athletes in these sports and to use goniometric studies to monitor their condition.

Based on the above, this study aimed to conduct a comparative analysis of the range of movements in the joints of the hands in kettlebell lifting and

arm wrestling athletes based on the results of goniometric testing.

Materials and Methods

Participants

The study used the test results of 36 kettlebell lifting and arm wrestling athletes. The participants were divided into groups according to the sport. Group 1 included 21 kettlebell lifting athletes with an average age of 21.57 ± 2.11 years and skill levels ranging from beginners to International Masters of Sport. Group 2 included 15 arm wrestling athletes with an average age of 21.80 ± 0.49 years and skill levels from beginners to Masters of Sport. Differences in age were insignificant ($p > 0.05$).

Inclusion/exclusion criteria. The inclusion criteria were no injuries in the last 6 months and no medication intake in the last month. The interval between testing and the last training session was 24 h.

The study program and design were discussed and approved at a meeting of the Bioethics Committee of the Kharkiv State Academy of Physical Culture (Protocol No. 14 of September 16, 2025). All participants or their legal guardians provided written informed consent in accordance with the Declaration of Helsinki. Participant data were stored anonymously in a database to ensure confidentiality.

Study Design

The amplitudes of active movements were determined using an IGaging electronic goniometer (USA) in the wrist, elbow, and shoulder joints of the arms. The results were expressed in angular degrees. Flexion, extension, abduction, and adduction at the wrist and shoulder joints were assessed. Flexion and extension at the elbow joints were also assessed. Two or three measurements of the same movement were taken, and the maximum values were recorded. The measurements posed minimal risk and were non-invasive to health.

Testing Procedure. All measurements were performed in a standardized standing position with the arms relaxed along the body. The right arm was tested first, followed by the left arm. Each joint movement was assessed in the anatomical plane corresponding to the direction of motion, while compensatory movements of adjacent joints were visually controlled and minimized. Participants were given one adaptation trial before the measurements to familiarize themselves with the procedure. No warm-up exercises were permitted to avoid artificially increasing joint mobility. All tests were conducted indoors under identical environmental conditions. Two or three repeated measurements were obtained for each movement, and the maximum value was used for analysis. All assessments were performed by the same specialist

with experience in goniometric testing to ensure consistency of the measurements.

Equipment. A digital IGaging electronic goniometer (USA) was used for all measurements. The device has a measurement range from 0 to 360 degrees and a digital display with a resolution of 0.1 degrees. The goniometer was calibrated according to the manufacturer's recommendations before each testing session. The measurement accuracy and stability of the device have been confirmed in previous studies [15, 23], allowing its use for research tasks requiring objective joint mobility assessment.

Examiner Qualifications. All goniometric measurements were performed by the same examiner. The examiner had specialized training and practical experience in conducting joint mobility assessments in athletes. The use of a single qualified examiner minimized measurement variability and ensured procedural consistency throughout the study. Prior to the study, the examiner completed additional practice sessions to standardize measurement technique and adherence to testing protocol.

Participant Characteristics. All athletes reported right-hand dominance. The determination of limb dominance was based on self-report and confirmed through sport-specific tasks. The assessment of dominance was required to correctly interpret joint asymmetries and to ensure consistency during testing. The training experience of the participants was recorded. Kettlebell lifting athletes had an average training experience of 3 to 7 years, depending on their qualification level. Arm wrestling athletes demonstrated a similar range of training experience. All participants were actively training and participating in competitions at the time of the study. Their training routine included at least three structured training sessions per week. These characteristics were considered important for interpreting joint mobility and asymmetry patterns, as training experience and limb dominance influence the development of flexibility and strength adaptations in both sports.

Standardization of Testing Conditions. All measurements were conducted under standardized conditions. Testing took place indoors in a quiet laboratory environment at a controlled room temperature of 21–23°C. The measurements for all participants were performed at the same time of day, in the afternoon hours, to minimize the influence of circadian variability on joint mobility. Participants were instructed to refrain from intensive physical activity for 24 hours before testing. They were also asked to avoid consuming stimulants, such as caffeine, on the day of testing. Compliance with these requirements was verified verbally prior to the assessment. Before the measurements, participants remained seated for 5 minutes to stabilize physiological parameters. No additional

stretching or warm-up procedures were allowed, as these could artificially increase joint mobility. All conditions were identical for both groups to ensure methodological consistency.

Statistical analysis

Data analysis was performed using licensed MS Excel 2019 version 2506. The nature of the distribution and the size of the groups determined the use of the median and the first (25 percent) and third (75 percent) quartiles. The nonparametric Rosenbaum (Q) criterion was used to assess differences between groups, with differences considered significant at $p < 0.05$. The asymmetry coefficients for the movements studied were calculated using the following formula [25]:

$$SI = \frac{X_r - X_l}{0.5 \times (X_r + X_l)} \times 100\%$$

In this formula, X_r represents the value for the right side, and X_l represents the value for the left side. A value of zero indicates perfect symmetry in the analyzed joints. A positive SI value means that X_r is greater than X_l , while a negative value indicates that X_r is lower than X_l [26]. Asymmetry is considered present when the SI exceeds 10 percent [27].

Results

The obtained results are presented in Tables 1 and 2.

Table 1 confirms the differences in the range of movements in the athletes' hand joints. An increased range of movements was found in kettlebell lifting athletes in the right ($Q=20$, $p < 0.01$) and left ($Q=17$, $p < 0.01$) wrist joints. The range of movements in the right elbow joint was greater in AW athletes ($Q=7$,

Table 1. Amplitude of movements in hand joints of kettlebell lifting and arm wrestling athletes (All values are presented in degrees)

Indicators	1 Group			2 Group		
	1st quartile	Median	3rd quartile	1st quartile	Median	3rd quartile
Right wrist joint						
Flexion	66.8	69.4	77.6	67.0	72.0	73.5
Extension	49.0	60.72	67.3	48.0	52.0	56.5
Abduction	39.1	43.52	49.8	40.5	42.02	49.5
Adduction	38.7	47.61	55.9	26.5	33.02	36.5
Right elbow joint						
Flexion	115.8	124.91	130.6	119.0	125.02	132.5
Extension	20.9	23.42	26.9	17.0	19.02	24.0
Right shoulder joint						
Flexion	192.0	195.91	203.0	153.5	159.0	170.0
Extension	69.8	80.21	87.6	45.0	55.0	60.5
Abduction	182.9	200.61	206.9	139.0	148.0	162.0
Adduction	30.3	38.82	45.2	16.5	20.0	27.5
Left wrist joint						
Flexion	64.3	69.3	81.9	65.0	69.0	72.0
Extension	61.1	66.8	73.7	54.5	59.0	62.5
Abduction	42.3	51.3	59.5	39.0	41.0	53.0
Adduction	40.4	54.11	67.0	29.5	33.0	37.0
Left elbow joint						
Flexion	125.3	137.0	156.2	124.0	129.0	133.0
Extension	25.1	27.71	35.1	18.0	20.0	23.0
Left shoulder joint						
Flexion	162.8	176.8	184.3	155.0	163.0	170.5
Extension	65.9	76.81	84.9	48.5	54.0	60.5
Abduction	164.4	178.1	187.6	143	148.0	158.0
Adduction	35.2	44.1	47.5	20	24.0	25.5

Note. 1 – differences between groups are significant ($p < 0.05$), 2 – differences with the left hand are significant ($p < 0.05$).

Table 2. Coefficients of asymmetry of the range of movements in the hand joints of kettlebell lifting and arm wrestling athletes.

Indicators	1 Group			2 Group		
	1st quartile	Median	3rd quartile	1st quartile	Median	3rd quartile
Wrist joint						
Flexion, %	-11.93	-1.32	11.34	-1.41	4.26	9.94
Extension, %	-26.70	-13.42	-3.07	-12.68	-8.40	-6.85
Abduction, %	-20.22	-8.68	-3.64	-8.66	-2.30	8.70
Adduction, %	-26.49	-16.67	1.62	-21.98	-6.45	2.78
Elbow joint						
Flexion, %	-22.82	-8.66	4.38	-2.28	0.74	1.62
Extension, %	-43.14	-19.91	-7.41	-8.31	0.00	6.06
Shoulder joint						
Flexion, %	4.43	12.89	16.11	-1.18	0.00	0.64
Extension, %	-22.17	1.11	19.12	-6.10	-3.03	2.00
Abduction, %	7.98	11.06	18.87	-3.64	2.31	4.91
Adduction, %	-27.43	-13.72	9.36	-26.61	0.00	4.60

$p < 0.05$). The range of movements in the left elbow joint was greater in kettlebell lifting athletes ($Q=12$, $p < 0.01$). The range of movements in the shoulder joints was significantly greater in kettlebell lifting athletes ($p < 0.01$). This was confirmed for flexion ($Q=25$), extension ($Q=25$), and abduction ($Q=24$) of the right joint, and for extension ($Q=20$), abduction ($Q=15$), and adduction ($Q=15$) of the left joint. Asymmetry in the range of movements of the hand joints was observed in kettlebell lifting athletes. The range of extension in the wrist joint was smaller in the right hand ($Q=9$, $p < 0.05$). The range of adduction in the wrist joint was greater in the left hand ($Q=7$, $p < 0.05$). Asymmetry was also confirmed in the elbow joint for extension. The range of this movement was greater in the left hand ($Q=10$, $p < 0.01$). The amplitudes of flexion and abduction were greater in the right shoulder joint, with $Q=8$ ($p < 0.05$) and $Q=9$ ($p < 0.05$). The adduction amplitude was greater in the left shoulder joint ($Q=7$, $p < 0.05$). The asymmetry of the range of movements in the arm joints was less pronounced in the arm wrestling athletes. The ranges of abduction and adduction of the wrist joint were smaller in the right hand in both cases ($Q=6$, $p < 0.05$).

Table 2 shows the coefficients of asymmetry of the range of movements. Table shows that the left joint range of movements is greater in kettlebell lifting athletes. This is confirmed by the negative values of all asymmetry coefficients, except for the shoulder joint extension indicator. Significant asymmetry was observed when the coefficient exceeded 10 percent in 6 of 10 cases. These include extension and adduction of the wrist joint, elbow joint extension, and shoulder joint flexion, abduction, and adduction. The asymmetry coefficient confirms the results obtained using the Rosenbaum index. In AW

athletes, the asymmetry coefficient did not exceed 10 percent for any movement. This indicates that the range of movements in the joints of the hands is close to symmetry. The asymmetry coefficients for abduction and adduction of the wrist joint were the highest, although they did not exceed 10 percent. Asymmetry in these movements was confirmed using the Rosenbaum index.

Discussion

The purpose of this study was to compare the range of movements in the hand joints of kettlebell lifting and arm wrestling athletes based on goniometric testing. The results showed clear differences between the groups. Kettlebell lifting athletes demonstrated a greater range of movements in most joints, including the wrist, elbow, and shoulder joints. Arm wrestling athletes showed a greater flexion range only in the right elbow joint. The analysis also revealed pronounced asymmetry in kettlebell lifting athletes, while in arm wrestling athletes the range of movements was closer to symmetry.

These findings should be considered in the broader context of sports science and the functional demands of different strength disciplines. A comparative analysis of the physical qualities of athletes in different sports allows us to establish the specific effects of sports loads on the bodies of athletes [9]. This is very important for optimizing sports training, predicting success, and understanding the dynamics of athletic skill.

The choice of the range of movements as the study object reflects the specific impact of sports on the bodies of athletes. The range of movements in the hand joints should be assessed as a predictor

of KL success. Sufficient flexibility combined with strength allows the kettlebell to be lifted along the optimal trajectory. This ensures the functionality of KL athletes and increases their performance. The range of movements is also important in AW, as optimal arm movement allows the athlete to win a fight, and sufficient flexibility allows participation under various technical conditions.

Goniometry was selected as the research tool. It is widely used in sports, fitness, and rehabilitation. The advantages of this method include objectivity, simplicity, clarity, and ease of practical application [9, 10, 11]. The instrument used, a digital goniometer from IGaging (USA), allows for quick and objective assessment of the range of movements in the joints. Its effectiveness has been confirmed in previous studies [15, 23].

A significant advantage of goniometry is its ability to assess the impact of specific loads on the bodies of athletes. The tasks of athletes in KL and AW differ, which determined the differences established in the joint range of movements. This agrees with the available literature. The effect of baseball throws on the range of movements in the shoulder joint was evaluated in the study by Reinold et al. [28]. A significant increase in external shoulder rotation was observed immediately after throwing weighted balls. This effect increased as the weight of the balls increased.

The design used in this study, which compares athletes from different sports, is common in scientific research [1, 2, 4, 6]. For example, the flexibility indicators of tennis players and athletes from other sports were compared in the study by Chandler et al. [1]. The results confirmed the specific influence of the sport on the bodies of athletes. Tennis players had a higher external rotation of the shoulder joints. This was due to the nature of their movements. The differences in flexibility indicate adaptation to the musculoskeletal requirements of the sport.

The participants represented sports with a pronounced focus on strength. However, flexibility indicators are important in both sports. The nature of physical activity influenced the flexibility of the athletes. The activity of KL athletes is aerobic, with weights being lifted for 10 minutes. This causes a significant increase in the load on the musculoskeletal system. AW is characterized by predominantly anaerobic exercise, with a bout duration not exceeding 1 minute. The nature of the effort is mixed, combining static and dynamic components.

A similar study design was used in the study by Podrigalo et al. [15]. That study aimed to conduct a comparative goniometric analysis of the range of movements in the hand joints of martial art athletes. The differences reflected the specificity of the martial arts studied. The ranges of abduction

and adduction in the right wrist joint and the range of abduction in the left wrist joint were greater in wrestlers. This was interpreted as a reflection of the effective grip required to perform the technique. Strike martial artists had greater left wrist joint extension, right elbow joint flexion, and right shoulder joint extension and abduction. These characteristics demonstrate the ability to deliver strikes.

A similar approach was used in the present study. Differences in the range of movements of KL and AW athletes were assessed considering the specific characteristics of each sport. In KL, kettlebells are lifted with active participation of the wrist joint. Movements in this joint allow the athlete to choose a comfortable position for placing the kettlebell at all stages of the lift. This contributes to an increase in the range of movements.

Hand-to-hand combat requires the initial fixation of the hand position. The position of the wrist joint is one of the most important factors for achieving victory in combat. Rigid fixation of this joint allows the athlete to impose their tactics on the opponent, which increases the likelihood of success. These features result in smaller ranges of movements in the wrist joint in AW athletes.

Differences in the range of movements in the elbow joint also illustrate the characteristics of movements in KL and AW. The left elbow joint had a greater range of extension in KL athletes. This is due to the peculiarities of weightlifting. This movement requires maximal joint extension and stable fixation.

The elbow joint performs an important function in AW. Hand movements are mainly performed by bending the arm. AW athletes use this movement to the maximum during a fight. Therefore, the range of flexion is significantly greater in AW athletes.

The most pronounced differences were found in the shoulder joint movements. Studying the range of movements in this joint is important in many sports. In team sports, these indicators determine the ability to throw a ball. The range of movements in the shoulder joints of handball and volleyball athletes was evaluated in comparison with a control group in the study by Benda et al. [2]. An increase in the range of movements of the dominant arm in extension, horizontal adduction, and external rotation was confirmed in game sport athletes. Asymmetry in shoulder joint extension and external rotation was also found in volleyball and handball athletes.

Another study [4] compared the shoulder range of movements in volleyball, handball, swimmer, and judoka athletes. It was concluded that increasing training volume affects performance, increases the risk of disorders, and can lead to injuries.

Raising the arms above the head is an important technical element in many sports. This increases the requirements for the range of movements

in the shoulder joint. Assessing its amplitude allows analysis of the adaptation characteristics of athletes. This approach was used in a previous study [29] to examine the condition of beach volleyball athletes. The absence of asymmetry in shoulder joint movements and the presence of moderate adaptation to exercise loads were demonstrated.

The results obtained confirm the existing literature data. The range of movements in the shoulder joint was significantly greater in kettlebell lifting athletes. This is due to the biomechanics of movement in KL. Lifting kettlebells requires active participation of the shoulder joints. The maximum load is placed on these joints during the jerk exercise.

During a bout in AW, the shoulder joint is more fixed. Athletes perform the movement with their entire body and try to press the opponent's arm against the table. Therefore, the range of movements in the shoulder joints differs significantly between KL and AW athletes. For kettlebell lifting athletes, maximal range is required to provide the optimal trajectory of the lift. For AW athletes, sufficiently rigid fixation of the joint is needed to form a stable kinesthetic chain.

A comparison of the ranges of movements in the right and left joints was performed to identify asymmetry. This parameter is important for assessing the condition of athletes [25, 27, 30, 31]. Asymmetry can lead to dysfunction of the entire body, including the main joints. Goniometric measurements serve as diagnostic and analytical tools. Improved movement symmetry in the joints may indicate the restoration of joint neutrality. Anatomical alignment increases neuromechanical efficiency and kinesthetic control of multidirectional movements. This is necessary to improve athletic performance.

Bilateral measurements of the range of movements in the hand joints were used to assess asymmetry. This approach is consistent with the available literature. The review by Bishop et al. [32] summarizes data on asymmetry assessment in athletes. It is recommended that bilateral tests be used. An important aspect of such studies is the standardization of methodology and analysis to optimize the interpretation of the results obtained.

The results presented in Tables 1 and 2 confirm the presence of asymmetry in the range of movements in the hand joints. This condition was significantly more pronounced in KL athletes. Asymmetry of movement in the shoulder joints of kettlebell lifting athletes was found in 3 of 4 movements. This further confirms the importance of these joints for kettlebell lifting.

The study of asymmetry is an important area of sports science. Different points of view exist regarding the influence of asymmetry on the condition of athletes. The review by Gao et al. [18] examined the features of bilateral asymmetry in competitive sports and the possibility of using

asymmetry to assess performance and rehabilitation effectiveness after injuries. Asymmetry can have a positive effect on physical performance in sports where the primary load is placed on the upper limbs.

Other studies [19, 20] have provided data indicating the negative impact of asymmetry. Asymmetry in strength indicators negatively affected the results of change-of-direction performance, sprinting, kicking, and cycling tests [19]. Further research is needed to better understand the influence of strength and power asymmetry on athletic performance. The use of sport-specific tests is particularly important.

Morphological asymmetry can also affect athletic performance [20]. It can cause adverse functional changes that increase the risk of injury and overuse. The authors emphasize the importance of maintaining individual symmetry during training and monitoring asymmetry. This approach may improve athletic performance and reduce injury risk.

Another study analyzed the relationship between asymmetry and athletic fitness [21]. Athletic asymmetry does not appear to have a clear impact on performance indicators. The weaker limb has greater potential for adaptation than the stronger limb and may demonstrate higher responsiveness to training.

The obtained data confirm this conclusion. The skill level of the participants ranged from beginners to elite athletes. However, it was not possible to establish differences in the severity of asymmetry depending on skill level.

KL athletes had a smaller range of motion in the right hand. Previous studies have confirmed that the right hand demonstrates higher strength indicators [33]. Increased strength is combined with reduced flexibility, which is consistent with the available literature and suggests greater effectiveness of the right hand in weightlifting.

Limitations of this study

The small sample size should be noted as a limitation of this study. This reduces the possibilities of statistical analysis and limits the ability to establish dependencies between indicators. The joint analysis of data from athletes with different skill levels also reduces the ability to identify the most important indicators for success.

The research quality can be improved by integrating goniometric indicators with morphological and psychophysiological parameters. This will allow for a comprehensive analysis of the morphofunctional status of kettlebell lifting and arm wrestling athletes.

Conclusions

Differences in the range of movements in the hand joints of kettlebell lifting and arm wrestling

athletes have been established. Kettlebell lifting athletes had a greater range of movements in the wrist joints, the left elbow joint, the right shoulder joint (flexion, extension, and abduction), and the left shoulder joint (extension, abduction, and adduction). The flexion range of the right elbow joint was greater in arm wrestling athletes. These results illustrate the specific characteristics of kettlebell lifting and arm wrestling. Asymmetry was also significantly more pronounced in kettlebell lifting athletes. This reflects the specific demands

of these sports. Goniometry is an objective, visual, and informative tool for assessing the condition of athletes. It can be used as a screening test for selecting and monitoring kettlebell lifting and arm wrestling athletes. The introduction of goniometric testing into practice may increase the effectiveness of athlete training.

Conflict of Interest

The authors declare no potential conflicts of interest.

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