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Upper extremity isokinetic strength characteristics in elite male handball players: Dominant–non-dominant peak tork comparison and relationship with peak torque angle

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Abstract

The aim of the study was to compare the isokinetic upper extremity (shoulder) strength of elite male handball players on their dominant (Ds) and non-dominant (Nds) sides and to determine its relationship with peak torque angle (PTangle) values. Thirty male volunteers who actively played handball (age: 22.40 ± 2.06 years; height: 185.50 ± 5.01 cm; body weight: 83.52 ± 9.29 kg; BMI: 24.21 ± 1.89 kg/m²) participated in the study. The study had a cross-sectional design. To determine participants' upper extremity isokinetic strength, concentric/concentric shoulder internal rotation (IR) and external rotation (ER) tests were performed at angular velocities of 60 and 180°/sec, and participants' peak torque (PT) and PTangle values were recorded. Participants' Ds and Nds shoulder isokinetic strength values in the IR and ER phases were significantly different at all angular velocities ($p < 0.05$); however, unilateral and bilateral strength asymmetry ratios were within the normal range. Additionally, no significant correlation was found between PT and PTangle values ($p > 0.05$). Strength adaptations were observed in the dominant shoulder due to repetitive and high-torque movements in handball. Furthermore, the angular parameters involved in maximum torque production may provide specific information about the neuromuscular dynamics of athletes.

Keywords: Handball, isokinetic strength, shoulder, peak torque angle

Introduction

Handball is an olympic sport that involves defensive actions, requires frequent physical contact, and consists of two 30-minute periods with fast-paced attacks [1]. The game includes short-term and high-intensity actions such as sudden position, direction changes, jumping, lateral sliding, throwing, and repeated sprints [2,3]. For this reason, athletes must be physically prepared to maintain the intensity and tempo of the game during competition [4]. In particular, the ability to perform offensive actions effectively depends on strength and power potential [5]. During these activities, overuse can cause one side of the body to dominate the other, placing excessive strain on the body and leading to upper and lower extremity problems [6]. If athletes are unable to compensate for this situation, muscle imbalances or strength asymmetries may occur, which can result in serious injuries [7].

Strength asymmetry is the production of strength by muscles on the dominant (Ds) and non-dominant (Nds) sides at ratios other than specific ones [8,9]. One study in the literature reports that the risk of shoulder injury is 2.57 times higher in handball players with strength asymmetry [10], while another study indicates that the risk of injury is higher in athletes with bilateral strength asymmetry greater than 10-15% [11]. The effects of muscle asymmetry on athletic performance manifest at two levels: both in terms of direct strength production and movement coordination. While asymmetry at certain levels can contribute to the athlete gaining a technical advantage, strength imbalances that arise above certain thresholds disrupt movement economy, increase energy expenditure, and elevate the risk of injury [11,12]. Furthermore, it has been determined that bilateral strength asymmetry may cause a decrease in athletes' biomechanical parameters during training or competition [13].

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Therefore, monitoring bilateral and unilateral asymmetric strength ratios is critical for identifying potential injury risks and planning preventive intervention periods, particularly for handball players and the entire athletic population [14].

Currently, isokinetic dynamometers are the most valid and reliable method for measuring lower and upper extremity strength and power potential [15]. This method not only determines athletes' strength and power potential, but also identifies strength asymmetries that lead to performance differences and injury risk [16]. It is also unique in that it can determine the angle at which the shoulder can produce the highest torque (PTangle) during internal (IR) and external rotation (ER) movements [15]. PT angles can play an important role in preventing shoulder injuries and reducing the risk of injury when taken into account in training programs to optimize handball players' shoulder strength and performance [15].

Studies on isokinetic parameters for handball players are quite limited in the literature. Therefore, the present study, which compares unilateral and bilateral upper extremity strength and power potential—which are crucial for defensive and offensive actions in elite handball players—and examines the movement angles at which participants reach their peak torque values, is very important. In light of this information, the aim of the study was to: a) compare the isokinetic strength of the upper extremities (shoulders) of elite male handball players on the Ds and Nds sides, b) examine the relationship between peak torque angles and peak torque values.

The hypotheses of the study;

H1: Elite male handball players have significantly better Ds isokinetic shoulder strength than Nds, but this difference does not cause unilateral and bilateral strength asymmetry.

H2: The relationship between PTangle and PT values obtained at all angular velocities is not significant.

Material and Methods

Study Design

The study had a cross-sectional study design. Participants visited the laboratory twice. During their first visit, participants were shown examples of the tests that would be used in the study. Height and weight measurements were taken from participants who volunteered for the study after signing an Informed Consent Form. During the second visit, isokinetic shoulder IR and ER strength tests were performed at angular velocities of 60°/sec and 180°/sec (Figure 1). Subjects rested for at least 20 minutes between angular velocity changes. Warm-up and cool-down protocols consisted of 10-15 minutes of dynamic stretching for the upper extremities prior to measurements, including shoulder rotations, arm swings, and arm stretches, with 3-5 minutes of rest between angular velocity changes. Subjects were instructed not to exercise during the study period. All measurements were performed at the same time of day (14.00-16.00) and under similar environmental conditions (temperature ranging from 19 to 22°C and humidity from 52 to 60 percent).

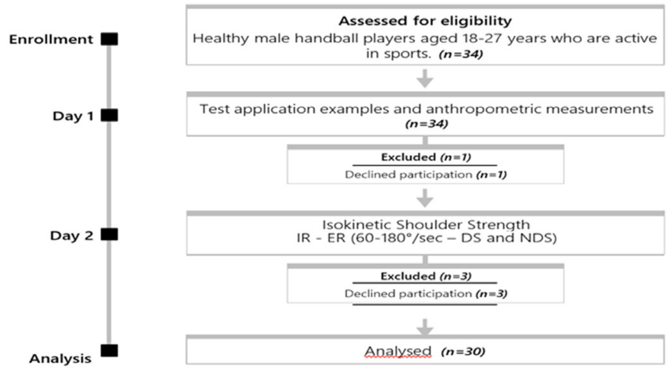

Figure 1. Flowchart

This study was conducted in compliance with the ethical principles stated in the Declaration of Helsinki. Ethics committee approval was obtained from Ondokuz Mayıs University Clinical Research Ethics Committee (No: 2025/403, Date: 23.07.2025).

Participants

The study included 30 well-trained male handball players who actively played handball (age: 22.40 ± 2.06 years; height: 185.5 ± 5.01 cm; body weight: 83.52 ± 9.29 kg; BMI: 24.21 ± 1.89 kg/m²) participated in the study (Table 1). The participants were individuals who actively played handball at the league level. The sample size of the study was determined by G*Power (version 3.1.9.6, Germany) analysis (d=0.8; α=0.05; 1-β=0.8) and the minimum number of subjects was 26. The inclusion criteria for participants were: no health problems, having played handball actively for at least 5 years, and no history of serious shoulder injuries in the last 6 months. Volunteers who did not meet the inclusion criteria were excluded from the study. Descriptive information about the participants is presented in Table 1.

Table 1. Descriptive statistics of participants (n=30)

Variables	Mean	SD	Min.	Max.
Age (years)	22.40	2.06	18.00	27.00
Height (cm)	185.50	5.01	174.00	201.00
Weight (kg)	83.52	9.29	64.00	120.00
BMI (kg/m²)	24.21	1.89	18.70	30.42

BMI: Body Mass Index, SD: Standart Deviation, Min: Minimum, Max: Maximum

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Evaluation Tools

Anthropometric Measurements

Participants' body weights were measured with a body composition analyzer (Jawon Body Composition Analyzer Model X-Scanplus II, Seoul, Korea) with an accuracy of 0.1 kg. Height measurements were taken with a stadiometer (Holtain Ltd., Crymych, UK) with an accuracy of 0.1 cm. Both measurements were performed barefoot and in an anatomical standing position [17]. Body mass index (BMI) was calculated using the formula 'body weight (kg) / height (m)2' from the obtained body weight and height data.

Upper Extremity Isokinetic Strength Tests

In the study, a computer-controlled isokinetic dynamometer (Cybex Humac Norm Test and Rehabilitation System, CSMI) was used to measure the upper extremity isokinetic strength of the subjects. For upper extremity strength, the angular velocities of the PT in the IR and ER phases were set at 60°/sec and 180°/sec. The dynamometer was calibrated before each test and adjusted according to the test protocols to be performed. To prevent errors in the measurements, the subject's arm was placed in a horizontal position before the measurement to determine the torque value produced by the arm in a free state, and the effect of gravity was eliminated [18]. The tests began with a warm-up protocol [19], and after a 2-minute rest period, measurements in the shoulder IR and ER phases were applied respectively at angular velocities of 60°/s (5 repetitions) and 180°/s (5 repetitions) with Con/Con contractions. Shoulder isokinetic measurements were performed in the supine position, with approximately 90° abduction in the scapular plane, and with the torso stabilized using straps. Con/Con contractions are preferred in sports that require explosive movements such as handball in order to increase muscle strength and speed because these contractions enable players to be more effective in dynamic movements such as throwing the ball with force, jumping and changing direction. PT values obtained in the test results were recorded in Nm. Based on the results, the bilateral strength ratios of Ds and Nds were found to be IR/IR and ER/ER and the ipsilateral strength ratios were found to be ER/IR and recorded as percentage values. Additionally, the joint angle at which participants reached their PT value (PTangle) was recorded. For each data point, the PTangle value corresponds to the best performance observed across the test repetitions [20].

Statistical Analysis

The SPSS statistical analysis package (SPSS version 25.0, Chicago, IL) was used for statistical analysis. Mean values and standard deviation were used for descriptive data. The normality of the data and equality of variance were assessed using the Shapiro-Wilk, Q-Q plot, and Levene tests, respectively. Normality tests revealed that the data followed a normal distribution. The Paired Sample T-Test was used to compare the PT values produced by the subjects in the IR and ER phases on the Ds and Nds sides of the upper extremity and the bilateral (IR/IR-ER/ER) and unilateral (ER/IR) strength ratios. To investigate the magnitude of the difference between variables, effect size (Cohen's d) was analyzed. Thresholds for Cohen's d statistics are interpreted as small (0.10–0.29), moderate (0.30–0.49), and large effect (≥0.50) [21]. The Pearson Correlation Test was used in the correlation analysis between PT and PTangle values. In the correlation analysis, >0.30 was defined as weak correlation, 0.3-0.6 as moderate, 0.6-0.8 as strong, and 0.8-1.0 as perfect correlation [22]. Statistical results were evaluated at a significance level of $p<0.05$.

Results

Comparisons of the upper extremity isokinetic strengths of the subjects on the Ds and Nds sides showed that the Ds side was significantly higher than the Nds side at all angular velocities in the IR and ER phases ($p<0.05$) (Figure 2).

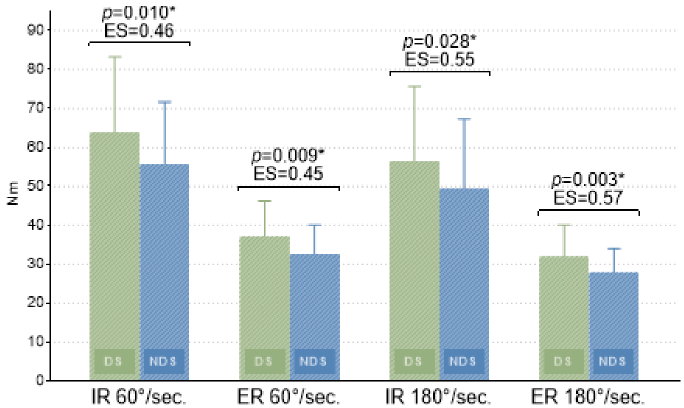

Figure 2. Comparison of isokinetic shoulder strength (PT) with Ds and Nds. *p<0.05; ES: Cohen's effect size; IR: internal rotation; ER: external rotation

It was determined that there was no significant difference in the unilateral and bilateral strength ratios obtained from the upper extremity isokinetic strength of the subjects ($p>0.05$) and that the strength ratios obtained were within the normal range (% ±10-15) (Figure 3).

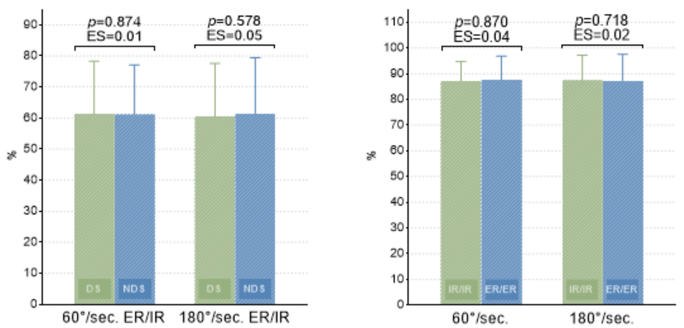

Figure 3. Comparison of unilateral (H/Q-ER/IR) and bilateral (H/H-Q/Q-ER/ER-IR/IR) strength ratios of subject. *p<0.05; ES: Cohen's effect size; IR: internal rotation; ER: external rotation

In the correlation analysis between the PT value of the subjects' upper extremity isokinetic strengths and the PTangle metrics, no statistically significant relationship was found between PT and PTangle at all angular velocities in the IR and ER phases (p>0.05) (Figure 4).

	IR 60°/sec. Ds	IR 60°/sec. Nds	ER 60°/sec. Ds	ER 60°/sec. Nds	IR 180°/sec. Ds	IR 180°/sec. Nds	ER 180°/sec. Ds	ER 180°/sec. Nds
IR 60°/sec. Ds	0.040	0.055	-0.043	0.018	-0.052	-0.066	-0.093	-0.182
IR 60°/sec. Nds	0.100	0.065	-0.114	-0.018	0.025	0.045	-0.173	-0.146
ER 60°/sec. Ds	-0.129	-0.075	-0.156	-0.060	-0.032	0.022	-0.142	-0.086
ER 60°/sec. Nds	-0.227	-0.142	-0.022	-0.059	-0.111	-0.058	0.072	0.087
IR 180°/sec. Ds	0.025	0.003	-0.129	-0.116	0.055	0.036	-0.131	-0.146
IR 180°/sec. Nds	0.270	0.256	0.047	0.057	0.191	0.168	-0.009	-0.073
ER 180°/sec. Ds	0.026	0.132	-0.082	-0.034	0.013	0.090	0.038	0.083
ER 180°/sec. Nds	-0.247	-0.264	-0.170	-0.180	-0.259	-0.233	-0.261	-0.310

r= -1.0 -0.5 0 0.5 1.0

Figure 4. The correlation between the PTangle and PT values of the subjects. IR: internal rotation; ER: external rotation; r: Pearson's correlation coefficient: * The vertical columns in the figure show PTangle values, while the horizontal columns show PT values

Discussion

In this cross-sectional study, the PT values of the upper extremity (shoulder) isokinetic strength of elite male handball players were compared on the Ds and Nds sides, and their correlation with PTangle metrics was examined. The results showed that the participants' shoulder isokinetic PT values in the IR and ER phases on the Ds side were higher than those on the Nds side at all angular velocities. However, the detected unilateral and bilateral strength asymmetry ratios were within the normal range. Furthermore, no significance was detected in the correlation analyses between the participants' PT and PTangle values.

Handball is a sport characterized by short duration and high intensity skills, where passing and shooting actions critical to victory are predominantly performed with the arm on the Ds side [23]. Therefore, the load generated during repeated shooting and passing actions can significantly enhance the development of the internal and external rotator muscles on the Ds side compared to the Nds side, and this situation provides the DS side with isokinetic force superiority [24]. A study conducted on elite handball players similarly found that the Ds shoulder rotator cuffs were superior to the Nds [25]. Our current study also obtained results supporting this thesis, demonstrating that the isokinetic strength outputs of the internal and external rotator muscles on the dominant (Ds) side were significantly superior to those on the non-dominant (Nds) side at all tested angular velocities. Importantly, the observed effect sizes ranged from 0.46 to 0.57, indicating a moderate magnitude of difference. This suggests that the superiority of the Ds side is not only statistically significant but also practically meaningful, highlighting a noteworthy asymmetry in rotator muscle strength that could have implications for training design, performance optimization, and injury prevention strategies. This is a neuromuscular adaptation that provides a significant performance advantage in the athletic population by increasing both shooting speed and passing accuracy. Strength differences observed in the dominant shoulder may be related to neuromuscular adaptations and asymmetric usage patterns created by repetitive sports-specific loads through motor learning. Therefore, monitoring unilateral and bilateral strength asymmetries is critical for the customization of training programs and the optimization of performance, as studies in the literature suggest that asymmetries beyond certain thresholds may be associated with performance outcomes in athletic populations, highlighting the importance of their regular sassessment [13]. Additionally, the increased rotator cuff muscle strength on the Ds side contributes to shoulder joint stabilization, supporting the maintenance of glenohumeral control during the deceleration phase after throwing. Such adaptations are frequently reported in the literature [26-28]. On the other hand, this adaptation may cause imbalances in the strength ratios between the internal and external rotators (especially ER/IR) in unilateral movements and between similar muscle groups (IR/IR-ER/ER) in bilateral movements. This situation negatively affects the stabilization mechanism in the glenohumeral joint, leading to microtraumas and overuse pathologies in repetitive actions [27,29]. There are systematic reviews in the literature reporting that asymmetric strength ratios in the shoulder region cause an increase in injury incidence among handball players [16,30]. However, in the present study, the unilateral and bilateral strength ratios determined by formulating the obtained PT values are within normal ranges (±10-15%). This result showed that participants had no risk of injury under normal conditions (no-contact). In a cohort study involving 296 overhead athletes, including handball players, researchers found a significant difference in strength output between the Ds and Nds sides of the participants, but determined that the strength asymmetries were within the normal range [31]. These results support the current study and suggest that participants' performance-focused strength and stability trainings have developed agonist and antagonist muscles in unilateral exercises and similar muscle groups in bilateral exercises in a balanced manner [32]. Monitoring unilateral and bilateral strength asymmetries is critical for the customization of training programs and the optimization of performance, as studies in the literature suggest that asymmetries beyond certain thresholds may be associated with performance outcomes in athletic populations, highlighting the importance of their regular assessment.

On the other hand, isokinetic dynamometers have the capacity to determine the angle at which the peak torque value produced during IR and ER movements of the shoulder is generated (PTangle) [16]. There are quite conflicting study results in the literature regarding the PTangle value. One study has argued that the PTangle value is as important as the PT value in assessing the shoulder rotator cuff muscles and is particularly critical in determining injury incidence and rehabilitation processes [31]. However, another study has argued that the test-retest reliability of the PTangle value is quite low and that examining torque production throughout the entire range of motion may be more meaningful and consistent than using a single-angle torque value [33]. In the present study, we aimed to address this gap, and the findings showed that the correlations with the PT value were not significant. In other words, we found that PTangle values do not predict PT values at all angular velocities and in all IR-ER phases. This result suggested that the PTangle value, although a sensitive indicator of muscle function, is particularly limited in terms of data related to the PT value. The absence of a significant relationship between PT and PTangle in shoulder isokinetic strength measurements indicates inter-individual variability in neuromuscular control strategies and motor output. While peak torque reflects the muscle's maximal force-generating capacity, the peak torque angle represents the joint position within the range of motion at which this force is produced. The independence of these two variables suggests that maximal force production is not confined to a single "optimal" joint angle, but rather can occur at different angular positions depending on individual neuromuscular characteristics. A study supported this conclusion, and researchers found that the daily test-retest reliability of the PTangle estimate they worked with from seven different angles was quite low [34-36]. In light of these findings, inter-individual variability in peak torque angle indicates that the joint range of motion at which peak torque is achieved is person-specific, suggesting that strength assessment, exercise selection, and rehabilitation processes should be individualized rather than based on uniform approaches for coaches and physiotherapists.

Limitations

Although the current study makes an important contribution to the literature on the isokinetic strength profiles of elite male handball players, it appears that the study has some limitations. The fact that the participants in the study were only elite male handball players weakens the generalizability of the study results. Therefore, increasing the sample size and diversifying the participants in future studies will increase the generalizability of the results to the entire handball player population. On the other hand, the current study focuses on PT and PTangle data during Con/Con contractions. Therefore, if Con/Con contractions are considered to only increase the concentric force production capacity of the muscles, the importance of eccentric contractions is overlooked; however, eccentric contractions play a critical role in injury prevention and strength control. Moreover, such contractions may not fully mimic the complex movements in multi-dimensional sports such as handball. Additionally, there are seven different playing positions in handball, and the athletic performance parameters required for each position and the somatotype structures of the players vary. Therefore, more specific results can be obtained by conducting analyses based on playing positions. Finally, due to the cross-sectional design of this study, it is not possible to draw a causal inference that the observed force asymmetries directly cause injury risk; however, the findings reflect potential patterns that may be related to injury risk indicators reported in the literature.

Conclusion

This study has provided critical insights into the relationship between the peak torque values detected in the isokinetic strength profiles of elite male handball players' Ds and Nds shoulders and the PTangle. The results showed that strength adaptations occurred in the shoulder due to repetitive and high-torque actions characteristic of handball (such as passing and shooting). Additionally, it is understood that regular training loads and in-season strengthening programs maintain unilateral and bilateral strength asymmetries at acceptable levels and limit potential injury risks. On the other hand, the insignificant relationship in the angular parameters related to torque production has demonstrated that the joint angle movement strategy and neuromuscular control are athlete-specific dynamics. Therefore, since peak torque occurs at individual-specific joint angles, coaches and physiotherapists should adopt personalized approaches in strength assessment, exercise prescription, and rehabilitation.

Ethical Approval

Approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (No: 2025/403, Date: 23.07.2025)

Patient Consent

Written informed consent was obtained from all participants prior to inclusion in the study, and participation was voluntary.

Conflict of Interest

The authors declare no conflict of interest.

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