Journal of Orthopedics Research and Rehabilitation

Original Article

DOI: 10.51271/JORR-0058

The relationship between isokinetic muscle strength ratios and clinical measures of shoulder stabilization and segmental power: a preliminary study

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Cite this article as: Karatay GM, Güzel NA. The relationship between isokinetic muscle strength ratios and clinical measures of shoulder stabilization and segmental power: a preliminary study. *J Orthop Res Rehabil.* 2025;3(4):90-94.

Received: 27.07.2025 ◆ **Accepted**: 11.10.2025 ◆ **Published**: 22.10.2025

ABSTRACT

Aims: This study aimed to investigate the relationships between various isokinetic strength ratios-including conventional concentric (CVRC) with separate velocities, conventional eccentric (CVRE), functional deceleration ratio (FDR), and mixed ratios (MR, MR_cross)-and two clinical performance measures; closed kinetic chain upper extremity stability test (CKCUEST) and Unilateral Seated Shot Put Test (USSPT).

Methods: Thirty-two asymptomatic young adults (18-40 years) were assessed using an isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). Seven isokinetic ratios were calculated from peak torque values. CKCUEST and USSPT were used to measure upper extremity stabilization and power, respectively. Normality was tested via Shapiro-Wilk and histogram analysis. Pearson correlation was applied for CKCUEST, and Spearman correlation for USSPT.

Results: No isokinetic ratio was significantly correlated with CKCUEST. For USSPT, CVRC_240 showed the strongest negative correlation (ρ=-0.585, p<0.001), followed by MR_cross (ρ=0.467, p=0.007), CVRC_120 (ρ=-0.422, p=0.016), and CVRC_60 (ρ=-0.378, p=0.033).

Conclusion: CVRC_240 and MR cross ratios demonstrated moderate associations with segmental upper extremity power. These findings support their use as performance markers for ballistic functional tasks, while their lack of correlation with stabilization tests suggests different neuromechanical determinants.

Keywords: Muscle strength, shoulder joint, athletic performance, athletic trainers, athletic injuries

INTRODUCTION

The shoulder is a highly mobile and complex joint system that requires a delicate balance between mobility and stability to ensure functional performance during daily and athletic activities. Among its components, the glenohumeral joint plays a central role in allowing multiplanar movement while relying heavily on dynamic neuromuscular control to maintain stability. Unlike joints with inherent structural congruity, the glenohumeral articulation depends more on surrounding musculature and sensorimotor input to preserve joint centration under load and during high-velocity movements.[1]

Muscle performance balance is critical for functional joint integrity, particularly between the rotator cuff's external and internal rotators. Previous studies have emphasized the importance of the strength ratios between these muscle groups in maintaining joint control and preventing overuse injuries. Isokinetic dynamometry has become a widely accepted method for quantifying this muscle performance, providing objective data across different contraction types (concentric, eccentric) and angular velocities (e.g., 60°/s, 240°/s).[2-4]

Over the years, different muscle strength ratios have been used to interpret shoulder performance and identify potential muscular imbalances. The conventional ratio (ER/IR), usually calculated using peak torques from concentric contractions, is one of the most commonly used indices. However, functional ratios-which compare eccentric external rotator strength to concentric internal rotator strength-may better reflect the demands of overhead and throwing motions. More recently, mixed ratio models, involving different speeds and contraction types, have been proposed to capture the complexity of shoulder function during real-life movement patterns.[2,4-6]

Despite their widespread use, the clinical implications of these isokinetic ratios remain partially understood. While some studies have associated lower ER/IR ratios with

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shoulder dysfunction or increased injury risk, there is limited consensus on which ratios best reflect different clinical domains such as dynamic stabilization capacity or segmental power output.[7,8] Clinical functional tests such as the closed kinetic chain upper extremity stability test (CKCUEST) and the unilateral seated shot put test (USSPT) have been developed to measure these domains in a more task-specific and field-applicable manner. Still, their relationship with isokinetic ratios has not been clearly defined in asymptomatic young adults.[9,10]

This knowledge gap highlights the need to explore how specific isokinetic strength ratios correlate with clinical tests of stabilization and power, particularly in populations with no evident shoulder pathology. Such information could improve screening practices, inform rehabilitation programs, and provide normative data for performance optimization in overhead athletes and general populations.[7,11,12]

Therefore, this preliminary study aimed to investigate the relationships between selected isokinetic shoulder strength ratios-namely, conventional, functional, and mixed ratios- and two clinically relevant functional outcomes: CKCUEST and USSPT. We hypothesized that specific isokinetic ratios would demonstrate significant correlations with these performance measures, reflecting their potential as biomechanical markers for shoulder function assessment.

METHODS

Study Design and Participants

To maintain consistency in assessment, only the dominant upper limb of each participant was evaluated. Dominance was determined based on the arm preferred for writing and throwing tasks. The principles of the Declaration of Helsinki were followed in this study. Ethical approval was obtained from the Gazi University Ethics Committee (Date: 24.05.2022, Decision No: 2022-933) before data collection, and all participants provided written informed consent.

This preliminary observational study included data from 32 asymptomatic adults aged 18 to 40. All participants were free of upper extremity injury, surgery, or pain within the past six months and had not participated in structured shoulder rehabilitation or overhead throwing programs. Participants were required to be physically able to complete high-demand upper extremity tasks.

Isokinetic Testing and Strength Ratio Calculations

Isokinetic strength testing used an isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). Participants were positioned supine with the shoulder in the frontal plane at 90° abduction and the elbow at 90° flexion. The range of motion was set from 50° internal to 40° external rotation.[5,8,13,14]

Each participant completed isokinetic testing for concentric contractions at 60°/s, 120°/s, and 240°/s, and eccentric contractions at 60°/s only. Each contraction type was performed for five repetitions at 60°/s and 120°/s, and 20 repetitions at 240°/s, as per the standard testing protocol. Peak torque values (Nm) were recorded for each test condition.

Based on these values, seven isokinetic strength ratios were calculated:

- Concentric external rotation/concentric internal rotation at 60 degrees per second (CVRC_60)
- Concentric external rotation/concentric internal rotation at 120 degrees per second (CVRC_120)
- Concentric external rotation/concentric internal rotation at 240 degrees per second (CVRC_240)
- Eccentric external rotation/eccentric internal rotation at 60 degrees per second (CVRE_60)
- Eccentric external rotation/concentric internal rotation at 60 degrees per second (FDR_60)
- Eccentric external rotation at 60 degrees per second/ concentric internal rotation at 240 degrees per second (MR)
- Eccentric internal rotation at 60 degrees per second/ concentric external rotation at 240 degrees per second (MR_cross)

All ratio calculations were performed after screening for outliers and missing values.

Clinical Performance Tests

CKCUEST: Participants were positioned in a modified push-up stance with hands placed 36 inches (91.4 cm) apart. They were instructed to alternately touch the opposite hand as many times as possible within 15 seconds. The total number of touches was recorded and used as the stability score.

By standard sex-specific procedures, the test was performed in a modified push-up position (knees on the ground) for female participants, and in a standard push-up position for male participants.[15-17]

One-arm seated medicine ball throw test (USSPT): Participants were seated with their backs supported and instructed to throw a 3-kg medicine ball using a single arm, in a forward direction, with maximal effort. Each participant completed three trials, and the farthest distance (in centimeters) was used as the final score. This test served as a measure of unilateral upper extremity segmental power.[18,19]

Statistical Analysis

All data analyses were performed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test, skewness–kurtosis values, and visual inspection of histograms and Q-Q plots.

USSPT scores were found to be non-normally distributed. All isokinetic strength ratios and CKCUEST scores followed normal distribution.

As a result:

- Pearson correlation was used to explore the relationship between strength ratios and CKCUEST scores.
- Spearman correlation was applied to compare the involvement of USSPT.

Statistical significance was set at $p<0.05$ for all analyses.

RESULTS

Descriptive Statistics and Normality Testing

The sample included 32 asymptomatic adults (16 females and 16 males; mean age: 24.9±3.5 years). All assessments were conducted on the dominant side, determined by self-reported writing and throwing preference.

Normality testing was performed for each variable using a combination of the Shapiro-Wilk test, skewness-kurtosis indices, histogram distributions, and Q-Q plots. The USSPT was found to be non-normally distributed (p=0.000), while CKCUEST scores and all isokinetic strength ratios exhibited normal distribution characteristics (p>0.05).

Correlational Analysis: CKCUEST and Isokinetic Ratios

Given the normal distribution of CKCUEST scores, Pearson's correlation analysis was conducted between CKCUEST and the isokinetic strength ratios, as shown in Table 1.

Table 1. Pearson's correlation analysis results between CKCUEST and isokinetic strength ratios

Isokinetic ratio	r (Pearson)	p-value	Interpretation
CVRC_60	-0.254	0.161	No significant correlation
CVRC_120	-0.284	0.115	No significant correlation
CVRC_240	-0.190	0.299	No significant correlation
CVRE_60	-0.149	0.416	No significant correlation
FDR_60	-0.233	0.200	No significant correlation
MR	-0.109	0.553	No significant correlation
MR_cross	0.134	0.465	No significant correlation

CVRC_60: Concentric external rotation/concentric internal rotation at 60 degrees per second, CVRC_120: Concentric external rotation/concentric internal rotation at 120 degrees per second, CVRC_240: Concentric external rotation/concentric internal rotation at 240 degrees per second, CVRE_60: Eccentric external rotation/eccentric internal rotation at 60 degrees per second, FDR_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, MR: Eccentric external rotation at 60 degrees per second/concentric internal rotation at 240 degrees per second, MR_cross: Eccentric internal rotation at 60 degrees per second/concentric external rotation at 240 degrees per second

These results indicate that none of the isokinetic ratios were significantly associated with shoulder stabilization performance as measured by the CKCUEST.

Correlational Analysis: USSPT and Isokinetic Ratios

Due to the non-normal distribution of USSPT data, Spearman's rho correlation analysis was used. The results are presented in Table 2.

Table 2. Spearman's rho correlation analysis results between USSPT and isokinetic strength ratios

Isokinetic ratio	ρ (Spearman)	p-value	Interpretation
CVRC_60	-0.378	0.033	Significant, moderate negative
CVRC_120	-0.422	0.016	Significant, moderate negative
CVRC_240	-0.585	0.000	Significant, strong negative
CVRE_60	-0.276	0.127	No significant correlation
FDR_60	-0.316	0.078	No significant correlation
MR	-0.255	0.158	No significant correlation
MR_cross	0.467	0.007	Significant, moderate positive

CVRC_60: Concentric external rotation/concentric internal rotation at 60 degrees per second, CVRC_120: Concentric external rotation/concentric internal rotation at 120 degrees per second, CVRC_240: Concentric external rotation/concentric internal rotation at 240 degrees per second, CVRE_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, FDR_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, MR: Eccentric external rotation at 60 degrees per second/concentric internal rotation at 240 degrees per second, MR_cross: Eccentric internal rotation at 60 degrees per second/concentric external rotation at 240 degrees per second

The strongest correlation was observed between USSPT scores and the CVRC_240 ratio (ρ=-0.585, p<0.001), followed by MR_cross (ρ=0.467, p=0.007). CVRC_60 and CVRC_120 also demonstrated moderate negative correlations with segmental power output.

Interpretation of Results

The findings revealed that concentric strength imbalances, particularly at high angular velocities (240°/s), were significantly associated with segmental power output, while eccentric and mixed ratios showed weaker or no associations. No meaningful relationships were observed between stabilization performance and any of the isokinetic ratios. These results suggest that isokinetic strength ratios may provide greater insight into segmental power capacity than dynamic stabilization ability in asymptomatic populations.

DISCUSSION

This preliminary investigation aimed to explore the relationship between various isokinetic shoulder strength ratios-including conventional (CVRC_60, CVRC_120, CVRC_240), eccentric (CVRE_60), functional deceleration (FDR_60), and mixed ratios (MR, MR_cross)-and clinical measures of shoulder stabilization and segmental power as assessed by CKCUEST and USSPT, respectively.

The most notable finding was the significant moderate negative correlation between CVRC_240 and USSPT (r_s=-0.460, p<0.01), suggesting that increased strength imbalance at higher angular velocities may negatively influence segmental power output. This observation aligns with prior evidence indicating that muscle imbalances at high velocities could compromise performance in explosive tasks requiring rapid force production and neuromuscular efficiency.[20,21]

Additionally, MR_cross, which involves cross-mode and cross-velocity comparison (eccentric IR at 60°/s over concentric ER at 240°/s), showed a moderate positive correlation with USSPT (r_s=0.404, p<0.05). This highlights the potential relevance of eccentric IR capacity in conjunction with high-speed concentric ER during ballistic throwing-like movements. Similar mixed-mode models have been proposed in the literature to better approximate functional joint demands.[5,22,23]

Contrary to expectations, none of the strength ratios correlated significantly with the CKCUEST performance. While previous research has demonstrated moderate associations between rotator cuff strength and closed-chain functional stability tests,[24,25] the absence of correlation in the present study may be explained by the broader involvement of trunk and scapular musculature in CKCUEST, reducing its sensitivity to isolated glenohumeral rotation strength. Moreover, the push-up-based task may rely more heavily on stabilization and endurance of proximal stabilizers than segmental torque ratios.[26,27]

Regarding the functional deceleration ratio (FDR_60), no significant association was observed with either USSPT or CKCUEST. While functional ratios are conceptually meaningful, their applicability may depend on the task's movement specificity and angular velocity demands.[5,28,29] The FDR_60 calculation-based on eccentric ER and concentric IR at 60°/-may not adequately reflect the dynamic shoulder control mechanisms required in the tests used.

Interestingly, both CVRC_60 and CVRC_120 failed to demonstrate significant relationships with either performance test, suggesting that conventional strength ratios at lower speeds may have limited predictive utility for functional capacity in healthy young adults. This aligns with prior findings emphasizing the contextual relevance of strength assessment protocols, particularly in asymptomatic populations.[30,31]

The results suggest that high-velocity and mixed-mode strength ratios, particularly CVRC_240 and MR_cross, may offer greater functional relevance in predicting segmental power outcomes, as measured by unilateral medicine ball throwing. However, their lack of association with stabilization performance indicates that different neuromechanical properties underlie these constructs.

Limitations

This preliminary study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small and limited to asymptomatic young adults, which may restrict the generalizability of the results to clinical populations. Second, only the dominant shoulder of each participant was assessed, preventing bilateral comparisons. Third, the analysis was cross-sectional, based solely on pretest isokinetic strength data, and therefore does not reflect longitudinal adaptations. Moreover, the study included only two clinical performance tests (CKCUEST and USSPT), which may not capture the full spectrum of shoulder function, particularly proprioceptive or scapular control components. Future studies with larger and more diverse samples, as well as additional functional assessments, are recommended.

CONCLUSION

This preliminary study demonstrated that among various isokinetic shoulder strength ratios, the high-velocity concentric conventional ratio (CVRC_240) and the cross-mode mixed ratio (MR_cross) were moderately associated with segmental upper extremity power, as assessed by the USSPT. These findings suggest that strength asymmetries may influence dynamic force output during functional unilateral tasks, particularly at higher speeds and across contraction types. In contrast, no meaningful associations were observed between the ratios and stabilization performance measured by CKCUEST, indicating a potential divergence between torque production and closed-chain stability capacity. These results highlight the selective predictive value of specific isokinetic ratios in assessing shoulder performance in asymptomatic young adults. Future studies involving symptomatic populations and task-specific strength assessments may further clarify the clinical utility of such indices in performance monitoring and rehabilitation planning.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Gazi University Ethics Committee (Date: 24.05.2022, Decision No: 2022-933).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

Acknowledgments

The authors acknowledge the participants for their valuable contributions to the study.

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