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Kinetic chain modifies muscle activation in adults with shoulder pain: a randomized cross-over trial

Mauricio Barramuño-Medina, MD[a], Sofía San Martín-Zurita, MBBS[a], Valentina Silva-Correa, MBBS[a], Thiara Téllez-Camilo, MBBS[a], Pablo Valdés-Badilla, PhD[b,c], Claudio Bascour-Sandoval, PhD[d], Germán Gálvez-García, PhD[e,f,*]

[a]*Kinesiology Program, Faculty of Health Sciences, Universidad Autónoma de Chile, Temuco, Chile*
[b]*Department of Physical Activity Sciences, Faculty of Education Science, Universidad Católica del Maule, Talca, Chile*
[c]*Sport Trainer Program, Education Department, Universidad Viña del Mar, Viña del Mar, Chile*
[d]*Departamento de Ciencias de la Rehabilitación, Facultad de Medicina, Universidad de La Frontera, Temuco, Chile*
[e]*Department of Experimental Psychology, Psychobiology and Behavioral Sciences Methodology, Universidad de Salamanca, Salamanca, Spain*
[f]*Department of Psychology, Universidad de La Frontera, Temuco, Chile*

Background: A kinetic chain approach to shoulder rehabilitation is recommended. This study aimed to compare muscle activity between the isolated external rotation exercise and an exercise incorporating a kinetic chain approach in adults with shoulder pain. It also sought to identify muscle activation differences with the same tasks between asymptomatic adults and those experiencing shoulder pain.
Methods: This is a randomized crossover trial. Twenty-four adults participated; 12 with shoulder pain and 12 without. Both groups performed isolated external rotation and kinetic chain exercises, with the sequence randomly allocated. Shoulder and scapular muscles were measured using surface electromyography. Mixed-effects models were used for the main statistical analysis.
Results: Significant changes in muscle activation levels were observed with the kinetic chain strategy compared to isolated resistance exercise. In the exercise factor, a significant decrease of 8.9% was observed in the maximum activation of the infraspinatus muscle with kinetic chain implementation. Conversely, the latissimus dorsi muscle showed a significant increase of 16.5% in maximal activation with kinetic chain compared to external rotation exercise.
Conclusion: Implementing the kinetic chain approach led to significant changes in muscle activation. It offers potential benefits for shoulder rehabilitation, making it an alternative to isolated external rotation exercises.
Level of evidence: Level II; Randomized Crossover Trial

Keywords: Electromyography; shoulder injuries; pain; exercise therapy; resistance training; rehabilitation

The research protocol for this study received approval from the Research Ethics Committee of Universidad de La Frontera, Chile (approval number: 062_20).

*Reprint requests: Germán Gálvez-García, PhD, Departamento de Psicología Básica, Psicobiología y Metodología de las Ciencias del Comportamiento, Facultad de Psicología, Universidad de Salamanca, Campus Ciudad Jardín, Salamanca 37005, Spain.

E-mail address: germangalvezgarcia@usal.es (G. Gálvez-García).

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Shoulder pain is a common condition with a prevalence between 10.8% and 55.2% of the general population.[15] It generates functional impairment, a significant reduction in shoulder function caused by pain, which limit the ability to perform daily activities and essential tasks.[31] This, in turn, negatively impacts health-related quality of life and work participation.[15,31] Physical therapy is widely used in rehabilitating this condition,[6] highlighting the use of specific exercises to strengthen the rotator cuff muscles and other muscle groups responsible for controlling scapular kinematics. This approach facilitates the restoration of the functionality of the shoulder joint complex.[6,7]

When an impairment or deficit is found from clinical evaluation, rehabilitation programs often include the practice of shoulder external rotation (ER) exercises,[9,34] which is based on the fact that numerous studies have documented strength deficits or abnormal rotator cuff muscle activity in individuals with shoulder injuries.[13,16,21] Shoulder pain is a prevalent symptom in patients with rotator cuff tears or subacromial impingement, with comparative studies between symptomatic and asymptomatic individuals demonstrating a significant reduction in external rotator muscle activation.[4,26] The use of ER exercises is also supported by evidence that activation levels of shoulder external rotator muscles, such as the infraspinatus (IS), may be reduced by shoulder pain, even without structural injury, as shown in studies with experimentally induced subacromial pain via hypertonic saline injection.[8,28]

Electromyographic studies reveal that ER exercises mainly activate the IS and teres minor muscles, with activation percentages between 48% and 67% concerning maximum voluntary isometric contraction (MVIC).[2,12,23,24] For its part, there is also a significant contribution from other periscapular and trunk muscles, such as the trapezius, serratus anterior, levator scapulae, rhomboids, pectoralis minor, and latissimus dorsi.[23]

In recent years, researchers[19,25,33] have advocated the incorporation of the kinetic chain (KC) approach as a strategy for rehabilitating shoulder injuries. KC refers to the sequential task-specific activation of body segments during functional movement patterns,[25] which has a potential influence on muscle activation levels.[33] With careful exercise selection and integrating a whole-body approach, multiple joints are used simultaneously, executing movement patterns that emulate the athletic and/or functional activities of daily living.[33] In this context, a group of researchers[19] studied trunk rotation associated with arm elevation, emphasizing that these movements are coupled with activities of daily living. For its part, Yamauchi et al[33] studied the effect of trunk rotation during shoulder exercises on scapular muscle activity. However, to our knowledge, there are no reports on the rotator cuff muscle activation levels during trunk rotation in individuals with shoulder pain. The influence of KC on shoulder muscle activation has been studied due to its potential implications for rehabilitation. These studies have found lower levels of IS activation. However, this influence has only been investigated in subjects without shoulder pain.[20,25,27,30]

Understanding muscle activation patterns of specific exercises in individuals experiencing shoulder pain is essential for customizing effective rehabilitation programs within the context of evidence-based clinical practice. This study aimed to compare muscle activity between the isolated ER exercise and an exercise incorporating a KC approach in adults. It also sought to identify muscle activation differences with the same tasks between asymptomatic adults and those experiencing shoulder pain. Two of the following hypotheses were proposed: (i) muscle activity will be greater during the exercise incorporating a KC approach compared to the traditional isolated ER exercise in adults, and (ii) adults with shoulder pain will exhibit lower muscle activity than asymptomatic adults during both exercises.

Material and methods

Study design

This is a randomized crossover trial, with proportional sampling and homogeneous organized, quantitative methodology. The methodology followed was the extension to randomized crossover trials of Consolidated Standards of Reporting Trials Statement guidelines.[10]

Participants

A total of 24 adults participated in this study. The sample included both males and females, with no restrictions based on sex. Participants were recruited via social networks, specifically through an Instagram announcement poster that had active for 4 months. The advertisement detailed the study's purpose, eligibility criteria, and participation requirements. A convenience sampling method was used to select respondents. The shoulder pain group (SPG) comprised 12 adults (7 males and 5 females; mean age of 26 ± 11 years; mean body mass index (BMI) of 27.2 ± 4.2 kg/m^2), while the no pain group (NPG) consisted of 12 participants (8 males and 4 females; mean age of 22 ± 2 years; mean BMI of 27.6 ± 4.6 kg/m^2). Gpower software (version 3.1.9.7; Franz Faul, Universität Kiel, Kiel, Germany) was used to calculate a minimum sample size of 9 participants per group using data from previous studies of the infraspinatus muscle during ER exercises (SPG: mean 9.22 ± 3.63; NPG: mean 12.60 ± 3.43).[29] An effect size of 0.95 was calculated, with an alpha error probability of 0.05, a power of 80%, and an expected loss of 15% established.

Inclusion criteria for both groups (SPG and NPG) comprised ages between 18 and 65 years and demonstrated a suitable range of shoulder movement for exercise execution (ie, possess at least 45° of external glenohumeral rotation). Additionally, the SPG had to meet the criterion of a history of atraumatic shoulder pain for at least three months, confirmed through at least 2 of 3 orthopedic tests associated with shoulder pain (empty-can test, Hawkins–Kennedy test, modified Neer test).[7] Although these tests are primarily used for rotator cuff pathology and do not cover all types of shoulder pain, they were selected due to their frequent

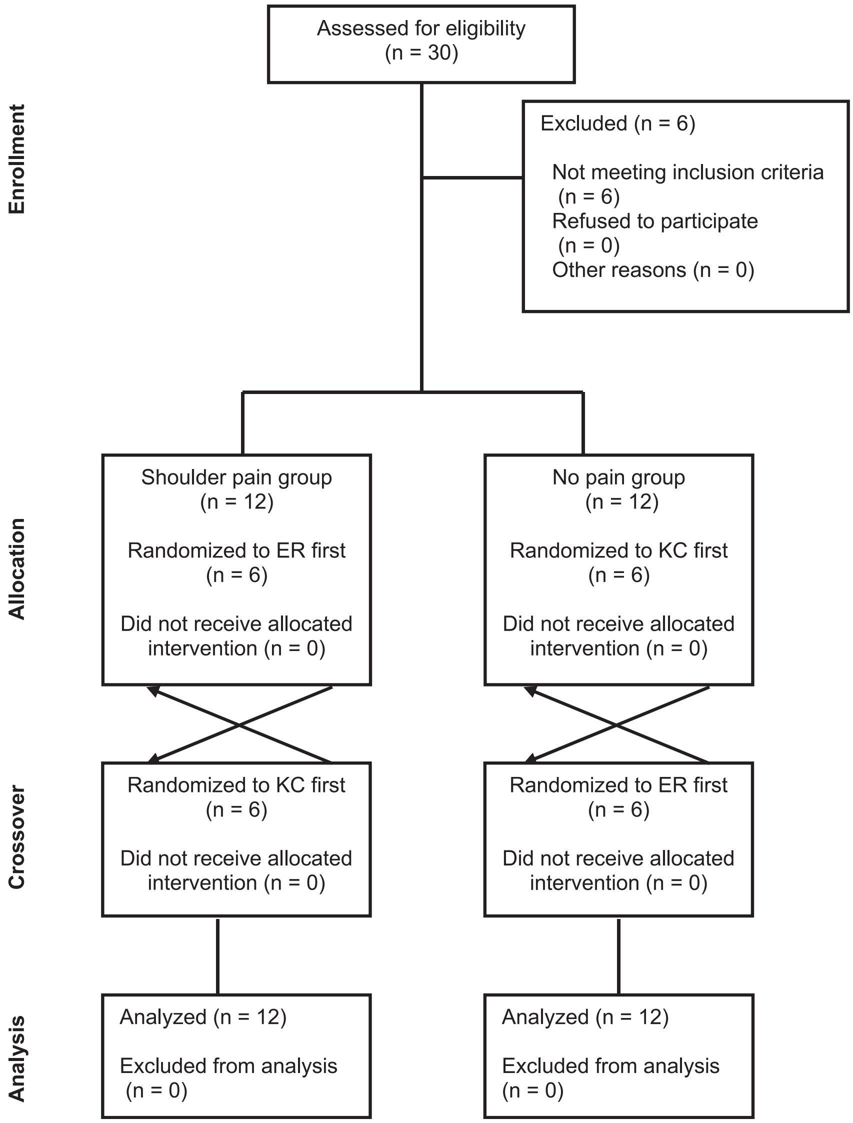

Figure 1 Study flowchart, based on CONSORT. *ER*, external rotation exercise; *KC*, kinetic chain exercise.

association with shoulder dysfunction. SPG had to present a score between 20 and 50 mm on the Visual Analogue Scale in a resting or static condition.

The exclusion criterion common to both groups (SPG and NPG) was as follows: (i) the presence of systemic diseases that may influence shoulder movement or muscle activation (eg, diabetes mellitus, rheumatoid arthritis, hypothyroidism, neuromuscular diseases). For the SPG, the following additional exclusion criteria were included: (i) history of shoulder fracture; (ii) history of shoulder surgery; (iii) previous corticosteroid injection involving upper extremity, and (iv) reported feeling of shoulder instability. For NPG, a history of shoulder pain in the last year was also considered an exclusion criterion. The recruitment process to obtain the final sample size is presented in Fig. 1.

All participants involved were required to endorse the criteria governing the utilization and management of data by formally acknowledging their consent through signing an informed consent document, granting permission to use their information for scientific purposes. The research protocol received approval from the Research Ethics Committee of Universidad de La Frontera, Chile (approval number: 062_20) and was conducted following the principles outlined in the Declaration of Helsinki on research involving human subjects.

Primary outcome (surface electromyography)

The electromyographic signals were recorded using the BTS-FEREEMG1000 wireless system surface electromyograph (BTS Bioengineering, Italy), equipped with 8 channels. The sampling frequency was set at 1000 Hz for each channel, with a resolution of 16 bits. A gain of 1000 was applied during the acquisition. The SMART Capture acquisition software (BTS Bioengineering, Italy) was used for data collection. Wireless probes were employed and connected to disposable bipolar Ag/AgCl electrodes to capture the signals. These electrodes were strategically placed following the guidelines outlined by Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM).[11] The skin was

Figure 2 EMG sensor location and exercises. (**A**) EMG sensor location; (**B**) Initial position of both exercises; (**C**) Final position of external rotation exercise; and (**D**) Final position of kinetic chain exercise. *EMG*, electromyography.

prepared by shaving and cleaning with alcohol before attaching the electrodes. They were aligned with the muscle fibers, avoiding motor points and maintaining a 2 cm distance between electrodes. The muscles evaluated were anterior deltoid, medial deltoid, posterior deltoid, infraspinatus (IS), latissimus dorsi (LD), medial trapezius (MT), lower trapezius (LT), and upper trapezius (UT; Fig. 2). The electromyographic assessment involved conducting the MVIC for each studied muscle in the dominant arm, following the exercises and normalization signal recommendations outlined by Boettcher et al,[3] performing 5 seconds of isometric contraction, 3 repetitions and 30 seconds of rest.

Secondary outcomes

In addition, control variables were collected as secondary outcomes. Apart from personal data, a 13-item pain catastrophic scale was provided to the SPG.[1] Subsequently, measurements for bipedal height, body weight, and BMI were conducted under the guidelines of the International Society for Advances in Kinanthropometry.[17] The glenohumeral joint range of motion was assessed with a goniometer,[22] and pain during exercise was measured with the visual analogue scale.[32]

Intervention

The intervention was administered to the SPG and NPG. The assessments and interventions occurred in a single session with a duration of 60 min. After warm-up and adaptation, both groups performed 2 exercises (ER and KC). Two exercise sequences, ER/KC or KC/ER, were allocated in a ratio of 1:1, randomized (https://www.randomizer.org), and balanced. The dependent variable was the maximum electromyographic activation of the concentric phase of each muscle studied. The secondary assessments were body weight, bipedal height, BMI, range of motion, pain and catastrophizing.

The warm-up procedure started with a 5-minute warm-up comprising 2 sets of 20 repetitions of low-amplitude circumduction movements. This involved the participant making small circles with their hand, starting with minor movements and gradually increasing the size of the circles as pain permitted. This was followed by 10 repetitions of free active external shoulder rotation, with one minute of rest between each set. Subsequently, participants performed 5 practice repetitions of ER and KC exercises to ensure proper form and engagement. Finally, a 5-minute rest period was provided. Both groups performed 2 exercise sequences that were allocated in a 1:1 ratio (randomized and balanced) and were measured using surface electromyography.

The isolated ER exercise was performed in a bipedal position, upright, looking straight ahead, with the dominant arm, shoulder in a neutral position, elbow flexed at 90°, and forearm and wrist in a neutral position. Resistance was introduced using a red elastic band (Thera-band). One end of the band was secured while the other was held in the participant's hand, maintaining an initial tension set at 25% of the band's length. The OMNI Resistance Exercise Scale of perceived exertion was used to record perceived intensity.[5] An intensity range of 2-5 was chosen on the OMNI-Resistance Exercise Scale to standardize subject performance, ensuring exercises were neither too easy nor too challenging. Participants engaged in external rotation, commencing from a 0° position and concluding at approximately 45° of glenohumeral ER (refer to Fig. 2 *B* and *C*). The concentric phase lasted 2 seconds, the isometric phase 1 second, and the eccentric phase 2 seconds.[33]

For the KC exercise, each participant was in the same starting position as the ER exercise using a red elastic band (Thera-band). One end of the band was secured, while the other end was held in the participant's hand, maintaining an initial tension set at 25% of the band's length. The OMNI Resistance Exercise Scale of perceived exertion was used to record perceived intensity.[5] Participants engaged in external rotation, commencing from a 0° position and concluding at approximately 45° of glenohumeral external rotation, simultaneously integrating maximum ipsilateral trunk rotation (refer to Fig. 2 *B* and *D*). The concentric phase lasted 2 seconds, the isometric phase 1 second, and the eccentric phase 2 seconds.[33]

Data processing

The acquired signal underwent digital processing using an algorithm implemented in MatlabR2016a software (MathWorks Inc., Natick, MA, USA). Initially, the signal underwent offset subtraction through a detrending function. Subsequently, fourth-order low-pass and high-pass Butterworth filters were applied, featuring cut-off frequencies of 10 Hz and 450 Hz, respectively. Following this, the signal's root mean square was computed using a sliding window method with a width of 20 samples and a displacement of one sample. The amplitude was normalized relative to the MVIC, and each electromyographic burst was isolated to calculate the maximum amplitudes of the signal for each corresponding muscle.

Statistical analysis

We conducted our analyses using RStudio (version 2023.06.2, Public Benefit Corporation, Boston, MA, USA). The Shapiro–Wilk test of normality was applied to assess the normal distribution of the dependent variables. Initially, we compared group equality of age, body weight, bipedal height and BMI through independent samples t-tests. Subsequently, to enhance statistical power, we employed mixed-effects models. All models incorporated participants as a random effect, with "group" (SPG vs. NPG) and "exercise" (ER vs. KC) as fixed effects. Nested models were compared using likelihood ratio tests. The exponential of the difference between Akaike information criterion values (AICRL = exp(ΔAIC/2)) was calculated to evaluate the relative likelihood of a given model. We also determined the difference between Bayesian information criterion (ΔBIC) values for nested models. Marginal and conditional R^2 were estimated to quantify the proportion of variance explained by fixed effects (R^2m) and both fixed and random effects (R^2c), respectively. A posthoc Tukey test with Bonferroni adjustment was performed for multiple comparisons. For correlation tests, either the Pearson or Spearman test was chosen based on the normality of the data. The level of statistical significance was set at $P < .05$.

Results

The details of the participants in this study who met the selection criteria and reached the analysis phase are shown in Fig. 1. Individuals in both groups were similar regarding age, weight, height, and BMI (Table I). All participants reported low to moderate perceived exertion (2-5 on the OMNI-Resistance Exercise Scale). In the NPG, all participants exhibited what we defined as a full range of motion, with values falling within the following ranges: abduction (170°-180°), adduction (40°-50°), flexion (160°-180°), extension (45°-60°), internal rotation (70°-90°), and external rotation (80°-90°). In the SPG, the average shoulder motion was as follows: abduction 174°, adduction 47°, flexion 163°, extension 46°, internal rotation 77°, and external rotation 80°. In the SPG, the average pain at rest was 32 mm on the visual analogue scale. In comparison, pain experienced while executing the experimental movement reached 60 mm on the visual analogue scale. Additionally, participants in the SPG reported a mean of 26.83 out of 52 points on the Pain Catastrophizing Scale.

The summary statistics and outcomes of the primary analyses are presented in Table II. Regarding the exercise main factor, a significant decrease ($F_{(1,0)} = 7.718$; $R^2c = 0.684$; $P = .010$) of 8.9% was observed in the maximum activation of the IS muscle when implementing the KC. Even though this was not substantiated by the Tukey multiple comparisons test: SPG ER (59.3; CI 95%: [46.6-77.8]) vs. SPG KC (57.2; CI 95%: [41.6-72.8]), t(26.2) = 0.343, $P = .985$; NPG ER (62.2; CI 95%: [46.6-77.8]) vs. NPG KC (46.5; CI 95%: [30.9-62.1]), t(26.2) = 2.660, $P = .059$.

In contrast, the LD muscle exhibited a significant increase ($F_{(1,0)} = 6.450$; $R^2c = 0.435$; $P = .017$) of 16.5% in maximal activation favoring KC. Multiple comparisons revealed significant differences in favor of KC only within the SPG: SPG ER (28.5; CI 95%: [15.0-42.0]) vs. SPG KC (47.8; CI 95%: [34.3-61.3]), t(26.2) = −3.411, $P = .010$; NPG ER (32.1; CI 95%: [18.6-45.6]) vs. NPG KC (45.8; CI 95%: [32.3-59.3]), t(26.2) = −2.432, $P = .095$.

In the exercise main factor, the other muscles studied do not present significant differences: AD ($P = .128$), MD ($P = .361$), PD ($P = .544$), LT ($P = .197$), MT ($P = .635$), and UT ($P = .418$). No significant differences were identified concerning the group's main factor: AD ($P = .189$), MD ($P = .288$), PD ($P = .165$), IS ($P = .684$), LD ($P = .924$), LT ($P = .637$), MT ($P = .908$), and UT ($P = .275$). Regarding the interaction between group and exercise, noteworthy differences were solely observed for the MT muscle ($P = .026$). However, the Tukey multiple comparisons test did not corroborate this: NPG ($P = .613$), KC ($P = .235$). No significant correlation was found between the covariates of weight ($P = .524$), height ($P = .198$), and BMI ($P = .429$) and the electromyographic variables.

Discussion

This study aimed to compare muscle activity between the isolated ER exercise and an exercise incorporating a KC approach in adults. It also sought to identify muscle activation differences with the same tasks between asymptomatic adults and those experiencing shoulder pain. The primary outcomes obtained in our study confirm significant changes in muscle activation levels when implementing the KC strategy compared to isolated ER resistance exercise. In this context, KC refers specifically to the potential influence of trunk movement on shoulder muscle activation.

Table I General characteristics of shoulder pain group and no pain group

Assessments	SPG (n = 12) Mean ± SD	NPG (n = 12) Mean ± SD	*P* value	95% CI
Age (yr)	24.66 ± 11.23	22.66 ± 2.26	.845	−6.34 to 7.67
Body weight (Kg)	72.51 ± 9.70	75.05 ± 7.58	.519	−10.54 to 5.47
Bipedal height (m)	1.66 ± 0.09	1.62 ± 0.02	.259	−0.11 to 0.03
BMI (kg/m^2)	27.30 ± 4.23	27.55 ± 4.46	.250	−3.52 to 4.02

SPG, shoulder pain group; *NPG*, no pain group; *BMI*, body mass index; *SD*, standard deviation; *CI*, confidence interval.

Furthermore, no significant differences were found between the groups during the 2 exercises studied.

The maximum electromyographic activity of the IS during ER exercise was similar to that reported in previous studies.[12,23,24] In our results, implementing the KC strategy of ipsilateral trunk rotation had a slight tendency to reduce its activation; however, it was not significant. This finding is consistent with Miyakoshi et al,[18] who assessed this muscle's activity during glenohumeral ER with and without trunk rotation but did not observe any differences. Their findings were obtained under conditions involving a relative shoulder abduction position of 90°. For our findings, the slight reduction in IS activation during the KC strategy may be due to the increased difficulty in stabilizing the shoulder in more challenging positions, which could shift some of the efforts to other stabilizing muscles.

For the SPG, LD showed a significant increase in favor of KC, while for the NPG, although the same trend was maintained, it was not significant. The activation of this muscle is likely necessary to provide stability and generate force during rotation. Following Overbeek et al,[21] we hypothesize that individuals with shoulder pain who exhibit symptoms consistent with subacromial impingement may benefit from the mechanical unloading of subacromial tissues during abduction. However, it is important to acknowledge that the presence of rotator cuff pain in our subjects is an assumption that should be considered with caution. This unloading mechanism is likely facilitated by the active engagement of shoulder muscles that serve as depressors of the humeral head, such as the LD. Besides, the LD can contribute to scapular stabilization through its insertion on the scapula. A stable scapula is crucial for a properly functioning shoulder joint, as it provides a solid foundation for arm movements.[14,23,25] While our study did not directly assess scapular stability, the exercises focusing on the LD and other shoulder muscles may have potential effects on scapular function. Our results are consistent with the findings reported by Yamauchi et al,[33] who observed that maximal ipsilateral trunk rotation during ER did not yield significant changes in the activation of the MT and UT muscles. Still, they differ in finding differences in the LT muscle. Although our data show a tendency to increase the activation of this muscle, this difference is not significant. Similarly, Nagai et al[19] also reported no differences in the activation of the AD, LT, and UT muscles when incorporating ipsilateral trunk rotation. In a systematic review, Richardson et al[25] suggested that KC exercises involving weight transfer maneuvres may effectively modify muscle activity. It's possible that combining trunk rotation with weight transfer could maximize the impact on muscle activity.

Concerning the differences between the groups in both studied exercises, our findings align partially with those presented by Overbeek et al.[21] They, too, observed no significant differences in the activation levels of the LD. Still, they did note variations in the co-contraction levels of the AD muscle. To our knowledge, no other studies have assessed the impact of trunk rotation on electromyographic activity during RE in people with shoulder pain.

Study limitations include, using a single load (a single-color elastic band) can be considered. This singular resistance load, provided by the elastic band, represents various percentages of the maximum force exerted by each subject. Light to moderate loads were chosen to simulate a clinical setting where pain management is crucial. This approach, using the OMNI Resistance Exercise Scale of perceived exertion between easy and moderate, better reflects clinical conditions and patient capabilities. It must also be considered that the presence of fatigue or under conditions of increased pain may result in a muscular behavior distinct from that reported in the current study. Additionally, electromyographic data can be affected by artifacts resulting from arm movements. Each signal underwent a manual inspection before analysis to ensure the absence of artifacts. It is essential to consider crosstalk, which indicates the activity of neighboring muscles. Another aspect to consider is that this study did not assess trunk rotation angles. Although participants were instructed to rotate their trunk maximally, achieving an appropriate degree of rotation may be necessary to optimize muscle activation. The chosen combination of trunk rotation with external rotation at 0° abduction was intended to isolate shoulder muscles and assess the impact of trunk movement. However, this position is not a typical functional task, and the observed changes in muscle activity may also be influenced by factors within the shoulder components, beyond the KC contribution (ie, the potential influence of trunk movement on shoulder muscle activation). The study's primary strengths included the randomization of exercises, which minimized intrasubject variability. Additionally, all

Table II Descriptive statistics and results of the mixed-effects modelling

Dependent variable	Independent variable		Mean ± SD	Likelihood ratio test	*P* value	AICRL	ΔBIC	R^2m	R^2c
Max AD (%MVIC)	Group (n = 24)	SPG (n = 12)	7.59 ± 7.32	χ^2 (1) = 1.718	.189	0.868	−2.152	0.055	0.580
		NPG (n = 12)	4.71 ± 4.62						
	Exercise (n = 24)	ER (n = 12)	5.30 ± 5.14	χ^2 (1) = 2.315	.128	1.170	−1.555	0.019	0.619
		KC (n = 12)	7.01 ± 7.16						
	Interaction			χ^2 (1) = 2.643	.104	1.379	−1.228	0.095	0.659
Max MD (%MVIC)	Group (n = 24)	SPG (n = 12)	12.70 ± 19.30	χ^2 (1) = 1.127	.288	0.646	−2.743	0.045	0.940
		NPG (n = 12)	6.84 ± 3.93						
	Exercise (n = 24)	ER (n = 12)	9.33 ± 12.10	χ^2 (1) = 0.834	.361	0.558	−3.037	0.001	0.942
		KC (n = 12)	10.20 ± 16.10						
	Interaction			χ^2 (1) = 1.086	.292	0.633	−2.784	0.047	0.944
Max PD (%MVIC)	Group (n = 24)	SPG (n = 12)	27.40 ± 25.60	χ^2 (1) = 1.926	.165	0.963	−1.944	0.072	0.850
		NPG (n = 12)	15.70 ± 16.60						
	Exercise (n = 24)	ER (n = 12)	22.30 ± 23.00	χ^2 (1) = 0.367	.544	0.442	−3.503	0.001	0.852
		KC (n = 12)	20.80 ± 21.70						
	Interaction			χ^2 (1) = 2.556	.109	1.320	−1.314	0.081	0.867
Max IS (%MVIC)	Group (n = 24)	SPG (n = 12)	58.20 ± 29.50	χ^2 (1) = 0.165	.684	0.399	−3.705	0.005	0.627
		NPG (n = 12)	54.30 ± 23.50						
	Exercise (n = 24)	ER (n = 12)	60.70 ± 28.80	χ^2 (1) = 4.026	**.044***	2.754	0.154	0.029	0.684
		KC (n = 12)	51.80 ± 25.90						
	Interaction			χ^2 (1) = 2.762	.096	1.464	−1.108	0.052	0.719
Max LD (%MVIC)	Group (n = 24)	SPG (n = 12)	38.20 ± 20.80	χ^2 (1) = 0.008	.924	0.369	−3.862	0.124	0.679
		NPG (n = 12)	38.90 ± 27.70						
	Exercise (n = 24)	ER (n = 12)	30.30 ± 15.10	χ^2 (1) = 13.558	**.000*****	323.483	9.687	0.000	0.435
		KC (n = 12)	46.80 ± 28.10						
	Interaction			χ^2 (1) = 0.517	.471	0.476	−3.353	0.127	0.686
Max LT (%MVIC)	Group (n = 24)	SPG (n = 12)	48.60 ± 22.60	χ^2 (1) = 0.222	.637	0.411	−3.648	0.000	0.591
		NPG (n = 12)	52.70 ± 25.30						
	Exercise (n = 24)	ER (n = 12)	47.90 ± 20.80	χ^2 (1) = 1.663	.197	0.845	−2.207	0.013	0.618
		KC (n = 12)	53.40 ± 26.70						
	Interaction			χ^2 (1) = 1.314	.251	0.709	−2.556	0.031	0.639
Max MT (%MVIC)	Group (n = 24)	SPG (n = 12)	36.70 ± 20.70	χ^2 (1) = 0.013	.908	0.370	−3.857	0.000	0.778
		NPG (n = 12)	37.80 ± 27.50						
	Exercise (n = 24)	ER (n = 12)	36.50 ± 12.40	χ^2 (1) = 0.224	.635	0.411	−3.646	0.001	0.780
		KC (n = 12)	38.80 ± 26.90						
	Interaction			χ^2 (1) = 4.951	**.026***	4.373	1.079	0.022	0.821

Max UT (%MVIC)	Group (n = 24)	SPG (n = 12)	15.40 ± 24.20	χ^2 (1) = 1.191	.275	0.667	−2.680	0.000	0.964
		NPG (n = 12)	7.72 ± 5.00						
	Exercise (n = 24)	ER (n = 12)	11.20 ± 16.30	χ^2 (1) = 0.655	.418	0.510	−3.215	0.000	0.963
		KC (n = 12)	11.90 ± 19.40						
	Interaction			χ^2 (1) = 0.294	.587	0.426	−3.577	0.049	0.965

MVIC, maximum voluntary isometric contraction; *SPG*, shoulder pain group; *NPG*, no pain group; *SD*, standard deviation; *AICRL*, Exponential of the difference between Akaike information criterion; *ΔBIC*, Bayesian Information Criterion; R^2m, marginal determination coefficient; R^2c, conditional determination coefficient; *ER*, external rotation; *KC*, Kinetic chain.
Bold values $^*P < .05$; $^{***}P < .001$.

participants engaged in both exercises, eliminating selection bias associated with individual characteristics that could impact group assignment.

In a practical context, our findings may be helpful in the development of shoulder rehabilitation plans. If the therapeutic objective is to optimize the activation of the stabilizing muscles of the glenohumeral joint, particularly the IS, isolated ER exercises are recommended over the KC strategy. Conversely, suppose the goal of treatment is to improve synergy between the IS as a stabilizer and the humeral depressor muscles while promoting scapular stability. In that case, the KC strategy is preferable as it leads to more substantial activation of the LD.

Conclusion

Implementing the KC approach led to significant changes in muscle activation, offering potential benefits for shoulder rehabilitation, making it an alternative to isolated external rotation exercises. Additionally, no significant differences were found between the groups in the exercises studied. This could be considered in shoulder rehabilitation plans.

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