Article

Not peer-reviewed version

Muscle Activation Differences Between CKCUEST and Modified CKCUEST: An EMG Analysis

Samuel Eloy Gutiérrez-Torre , Miguel Ángel Lozano-Melero * , María Gómez-Jiménez , Daniel Manoso-Hernando

Posted Date: 4 March 2025

doi: 10.20944/preprints202503.0276.v1

Keywords: CKCUEST; EMG; Shoulder.

Article

Muscle Activation Differences Between CKCUEST and Modified CKCUEST: An EMG Analysi

Samuel Eloy Gutiérrez-Torre [1], Miguel Ángel Lozano-Melero [1,*], Maria Gómez-Jiménez [1,2] and Daniel Manoso-Hernando [1,2]

[1] Department of Physiotherapy. Centro Superior de Estudios Universitarios La Salle. Universidad Autónoma de Madrid, 28023, Madrid, Spain.

[2] CranioSPain Research Group, Centro Superior de Estudios Universitarios La Salle, Universidad Autónoma de Madrid, 28023, Madrid, Spain.

* Correspondence: 201008632@campuslasalle.es; Tel.: +34 645737609.

Abstract: Background/Objectives: The validity of shoulder orthopaedic test to establish a diagnosis has been recently challenged. For this reason; functional tests; such as the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) have commenced to be used in clinical settings. The aim of this study is to compare the electromyography (EMG) activity during the CKCUEST and the modified CKCUEST in healthy adult population. **Methods**: Ten male and 10 female participants were recruited from a University setting. Edinburgh Handedness Inventory; the International Physical Activity Questionnaire and the percentage of activation of the maximum voluntary contraction of the infraspinatus; anterior deltoid and upper trapezius; of both upper limbs; throughout the CKCUEST and modified CKCUEST were analysed. **Results**: The percentage of activation of infraspinatus ($p<0.01$); anterior deltoid ($p<0.01$) and upper trapezius ($p<0.01$) in both sides were significantly higher in the CKCUEST compared to the modified CKCUEST. No correlations were observed between laterality and the activation percentage of the infraspinatus ($p>0,05$); anterior deltoid ($p>0,05$) and upper trapezius ($p>0,05$) in both sides during the CKCUEST. **Conclusions**: The results of this research showed a higher percentage of EMG activation during the CKCUEST compared to the modified CKCUEST in all the muscular structures analysed; regardless of the participants' hemibody

Keywords: CKCUEST; EMG; Shoulder

1. Introduction

The shoulder represents the third most prevalent region of musculoskeletal disorders, with an estimated 20% of the population reporting shoulder pain at some stage in their lifetime. Of these cases, 20% to 40% are attributable to pathologies involving the rotator cuff complex, a condition known to cause substantial functional impairment and reduced quality of life [1,2].

Historically, rotator cuff diagnosis has been based on physical examination and imaging. Nevertheless, exclusive reliance on imaging for diagnostic purposes presents significant challenges, as structural abnormalities in the rotator cuff are frequently observed even in asymptomatic individuals [3,4].

In regards to physical examination of the shoulder, about 180 orthopaedic shoulder tests have been described in the literature [5], which leads to great distraction and confusion when naming and referring to the same test [6], even when making diagnostic clusters [7]. However, the validity of these tests based on strong methodological designs, such as meta-analyses, are scarce and therefore they should be considered more as symptom provocation tools rather than diagnostic tests [2,8–10].Mañoso Hernando 20/11/24 7:48

For this reason, functional tests have begun to be used [5,11] such as the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) (ICC = 0.82-0.98) [12], the Upper Limb Rotation Test

 doi:10.20944/preprints202503.0276.v1

(ULRT) (ICC= 0.90-0.99) [13], Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC) (ICC= 0.50-0.93) [14], Y-Balance Test Upper Quarter (YBT-QT) (ICC = 0.91-0.99) [15], or the Seated Medicine Ball Throw (SMBT) ICC = 0.88- 0.99) [16].

The CKCUEST, is a functional and dynamic test used for the functional assessment of the shoulder, usually used in athletes whose sporting activity mainly involves the use of this upper limb [17]. This test consists of placing the participants in a push-up starting position, where they must touch one hand with the opposite hand and then perform the same procedure with the contralateral side [17], for fifteen seconds [12].

Previous studies have shown that this test can serve as a tool for the shoulder assessment in patients with pain, as well as follow-up in a care or even rehabilitation process; achieving higher movement efficiency values of the upper extremity [18,19] .

On the other hand, electromyography (EMG) studies have shown how the shoulder girdle muscles activity participate throughout shoulder movements [20]. In the same direction, Kinsella et al. found lower muscle EMG activity in patients with painful shoulder syndrome [21]. Similarly, other studies have observed differences in upper trapezius, infraspinatus and serratus anterior muscle activation in patients with shoulder pathology versus asymptomatic subjects, measured by EMG in a variety of shoulder functional movements [22,23].

However, although the importance of assessing this musculature is evident in the

scientific literature [21–23] and the assessment of functional tests such as the CKCUEST has been proposed to assess shoulder pathology [24,25] to the authors knowledge, there is no study that assesses EMG activity in the CKCUEST in healthy adults.

Therefore, the aim of this study is to compare the percentage of activation of the maximum voluntary isometric contraction (MVIC) of the infraspinatus, anterior deltoid and upper trapezius muscles during the execution of the CKCUEST and the modified CKCUEST in a healthy adult population.

2. Materials and Methods

2.1. Participants

To carry out this observational study we followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [26] which are a series of recommendations for writing up studies to ensure that the necessary information is provided on how the study was conducted, what was found and what was not found [26].

For this pilot study, a total of 20 healthy subjects, 10 male and 10 female participants were recruited through a non-probabilistic consecutive sampling stratified by sex; from the student population of the Centro Superior de Estudios Universitarios de la Salle (CSEULS), where the laterality of the healthy adult participants was determined using the Edinburgh Handedness Inventory (EHI) manual dominance questionnaire [27] ,adapted to Spanish [28].

As inclusion criteria, participants were accepted if they present:

- A healthy state of health.
- An asymptomatic state in the region of the shoulder complex (both right and left).
- Age 18 years or more.

As exclusion criteria, participants were rejected if they present:

- Shoulder pathology (rotator cuff-related shoulder pain, frozen shoulder, severe shoulder osteoarthritis, cervical radiculopathy, shoulder instability, upper limb neuropathy or acromio-clavicular joint pathology).
- Sensory and/or motor deficits.
- Over 65 years of age.
- Shoulder surgery less than 6 months ago.
- Previous steroid injections in the last 3 months.
- Diagnoses related to the cervical spine or upper limbs.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 4 March 2025 doi:10.20944/preprints202503.0276.v1

- Pregnancy.
- Comorbidities such as arthritis rheumatoid arthritis and/or fibromyalgia.
- Systemic diseases such as: diabetes mellitus and/or thyroid diseases.
- Dementia or severe psychiatric illness and any other illness that interferes with understanding and/or participation in the study.
- Refusal to sign informed consent.

2.2. Measuring Instruments

2.2.1. Edinburgh Handedness Inventory (EHI)

The Spanish-validated version of the EHI consists of a 10-item self-report questionnaire on manual dominance or preference of one hand over the other in manual activities [28].

This questionnaire measures the preference of the use of one hand over the other in different activities.

The original EHI ask the participant to mark with the symbol + each item in one of the two columns depending on whether it refers to the right or left hand. If the patient does not use one of the hands at all, they are asked to mark with ++ the hand for which they have a preference. If the patient is indifferent, they are asked to mark + in both columns.

It has been shown that these instructions can lead to misunderstandings, therefore in the Spanish edition, it has been changed to a 5-point scale format as follows (1 = always right, 2 = usually right, 3= both equally, 4= usually left, 5= always left). The laterality quotient (LQ) is estimated on the basis of the following formula:

$LQ = (R-L) / (R+L) * 100$

The LQ classifies the laterality of each participant's hand into left-handed (-100 to -61) ambidextrous (-60 to 60) or right-handed (61 to 100) [28].

2.2.2. International Physical Activity Questionnaire

The International Physical Activity Questionnaire (IPAQ) is a self-reported questionnaire for the measurement of activity in subjects aged 15-69 years, with a long version with 31 items and a short version with 7 items validated in Spanish [29]. This questionnaire assesses the frequency, duration and intensity of physical activity. This questionnaire provides the results of physical activity in metabolic equivalents (METs), in the long version we can also differentiate the total score of each activity divided into different domains (leisure-related, household and gardening, occupational and transport activities). Both categorise physical activity as low, moderate and high and also provide the number of METs minutes/week and thus indicate the amount of physical activity [30].

2.2.3. Electromyography

Surface electromyographic data was collected with a BTS Bioengineering® FreeEMG 300 system.

2.3. Procedure

Following the EHI [28] and IPAQ questionnaires [30], a standardised warm-up consisting of multiplane shoulder movements supervised by the researchers was performed.

Next, prior to the CKCUEST and modified CKCUEST tests, a test was performed to calculate the MVIC for each muscle using manual resistance exerted by the examiner.

Participants performed three MVIC per muscle, all muscles were tested randomly [31]. EMG activity was measured for 5 seconds, taking as reference the central 3 seconds and leaving 1 minute of rest between repetitions [32,33].

For each muscle, the highest level of activity generated during the 3 MVIC assessment positions was used for normalisation [34]. The same researcher was responsible for all MCVI measurements to ensure test consistency.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 4 March 2025 doi:10.20944/preprints202503.0276.v1

The MVIC calculation test for each muscle was performed according to Cools et al, (2020) [35]:

• Anterior Deltoid: Patient seated, both feet supported, elbow at 90° flexion and shoulder in neutral position: Resistance is applied proximal to the elbow in a posterior direction (resisting shoulder flexion).

• Infraspinatus: Patient in seated position, both feet supported, elbow in 90º flexion and man in neutral position: Resistance is applied proximal to the wrist in medial direction (resisting external rotation).

• Upper trapezius: Patient seated, both feet supported, elbow extended and shoulder at 90º of abduction. Resistance is applied proximal to the elbow in a caudal direction (resisting abduction).

Pictures detailing the electrodes position are added in the annexes section as Figure 1.

The CKCUEST was performed in a push-up position, keeping the back straight parallel to the floor, hands spaced 91.44cm (36 inches) apart and both upper limbs perpendicular to the floor and over the hands [25]. The exercise will start with 5 seconds rest, then 3 seconds with the left hand touching the right hand, 3 seconds rest and 3 seconds with the right hand touching the left hand, controlled by a metronome at 60 Hertz. In total, 5 repetitions were performed, eliminating the first and last for analysis [35,36]

The mean for the EMG peak activity of each muscle, during the closed kinetic chain phase, was obtained for the three consecutive repetitions. The mean obtained was then expressed as a percentage of the MVIC.

The modified CKCUEST was performed in a push-up position with knees flat on the floor, keeping the back straight and parallel to the floor, hands spaced 91.44cm (36 inches) apart and both upper limbs perpendicular to the floor and over the hands [25,37]. The task consists of the same phases as the CKUEST, which were also controlled by a metronome by redoing 5 repetitions of which the first and the last were eliminated in the same way [35,36].

All participants performed the CKCUEST and the modified CKCUEST, which were randonmly ordered by flipping a coin, a two-minute rest was taken between the performance of each test.

Equally to the CKCUEST analysis, the mean for the EMG peak activity of each muscle, during the closed kinetic chain phase, was obtained for the three consecutive repetitions throughout the modified CKCUEST. The mean obtained was then expressed as a percentage of the MVIC.

2.4. Statistical Analysis

Statistical Package of Social Sciences (SPSS) software, version 24.0 (IBM; Armonk-NY; IBM-Corp) was used for statistical analysis. A P-value < 0.05 for a 95% confidence interval (CI) was determined as statistically significant, using an alpha-type error of 0.05.

The Shapiro Wilk test was used to determine the normality distribution of the data values obtained. Data with a parametric distribution were represented by mean, standard deviation and upper and lower limits of the CI (and minimum-maximum range) at 95%. As statistical tests for the parametric data, Student's t-test for related samples was used to perform the comparison analysis between the CKCUEST test and the modified CKCUEST test, and Student's t-test for independent samples to compare sex, as well as to compare the percentage of activation of the infraspinatus, anterior deltoid and upper trapezius muscles according to the laterality of the participants in the present study.

On the other hand, for the description of the non-parametric data we used the median, the interquartile range and the upper and lower limits of the confidence interval (CI) (and minimum-maximum range) at 95%, while for their analysis we used the Wilcoxon test for related samples for the analysis of comparison between the CKCUEST test and the modified CKCUEST test and the Wilcoxon Mann- Whitney U test for the analysis of sex, as well as to compare the percentage of activation of the infraspinatus, anterior deltoid and upper trapezius muscles as a function of the laterality of the participants in the present study.

Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

3. Results

A total of 20 participants were recruited. Ten men and 10 women met our inclusión criteria. A description of participants is found in Table 1. The variables weight, height, body max index (BMI) and IPAQ showed a normal distribution, hence a Students t-test for independ samples was used to assess differences between the two groups. On the other hand, EHI and age did not follow a distribution according to normality, therefore the Wilcoxon Mann Whitney U test was employed to assess differences between the two groups.

Table 1. Socio-demografic variables, EHD e IPAQ.

	Men (n=10)	**Women (n=10)**	***P–value***
EHD (r,l,a)	18,60±8,656[a]	13,50±11[c]	.462[d]
Age (years)	26,604,789±4,789[a]	24,20±6[c]	.250[d]
Weight (kg)	74,50±9,914[a]	57,60±6,818[a]	**.000[b]**
Height (cm)	179,90±7,089[a]	165,40±6,041[a]	**.000[b]**
BMI (kg/m²)	22,94±1,72[a]	21,05±2,16[a]	**.049[b]**
***IPAQ* (mets)**	3532,00±1291,606[a]	4160,80±1637,022[a]	.353[b]

Abbreviations: EHD, Edinburg Handedness Inventory (measured in: r, right handed; l, left handed; a, ambidextrous); BMI, Body Mass Index; IPAQ, International Physical Activity Questionnaire. a Data with parametric distribution represented as mean standard deviation and 95% confidence interval. b Student's t-test for independent simples. c D Data with nonparametric distribution represented as median interquartile range and 95% confidence interval. d Wilcoxon Mann Whitney U-test.

The percentage of activation of insfraspinatus, anterior deltoid and upper trapezius in both sides were significantly higher in the CKCUEST compared to the modified CKCUEST (p<0.01), as it shown in Table 2.

Table 2. Correlations in the percentage of activation of the infraspinatus, anterior deltoid and upper trapezius muscles between the CKCUEST and modified CKCUEST tests.

	Activation % *CKCUEST* (N=20)	**Activation % modified-*CKCUEST* (N=20)**	***P-value***
Right hemibody			
- Infraespinatus	39,347±15,020[a] (32,317 – 46,376)	15,730±20,22[b] (15,976 – 24,333)	**.000 ǂ**
- Anterior deltoid	61,949±24,408[a] (52,398 – 71,500)	24,699±15,752[a] (17,326 – 32,072)	**.000***
- Upper trapezius	11,075±15,63[b] (10,840 – 25,609)	6,335±7,07[b] (5,558 – 11,981)	**.000ǂ**
Left hemibody			
- Infraespinatus	38,497±16,625[a] (30,716 – 46,278)	15,350±8,33[b] (11,299 – 25,859)	**.000ǂ**
- Anterior deltoid	62,833±21,513[a] (52,764 – 72,901)	28,844±19,657[a] (19,644 – 38,044)	**.000***
- Upper trapezius	15,270±22,72[b] (14,660 – 37,514)	10,595±16,79[b] (7,522 – 24,880)	**.000ǂ**

Abbreviations: CKCUEST, Closed Kinetic Chain Upper Extremity Stability Test. a: Data with parametric distribution represented as mean standard deviation and 95% confidence interval. b: Data with nonparametric distribution represented as median interquartile range and 95% confidence interval. *: Student's t-test for related

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 4 March 2025 doi:10.20944/preprints202503.0276.v1

samples. †: Wilcoxon test for related samples. Correlation between laterality and the percentage of activation of the infraspinatus, anterior deltoid and upper trapezius muscles in the CKCUEST test are shown in Table 3.

Table 3. Correlation between laterality and the activation percentage of the infraspinatus, anterior deltoid and upper trapezius muscles in the CKCUEST test.

Activation percentage in *CKCUEST*	Right handed (%) (n=10)	Ambidextrous(%) (n=10)	Left handed (%) (n=0)	*P-value*
Right hemibody				
- Infraespinatus	30,659±16,507[a] (26,850 – 50,467)	40,035±14,238[a] (29,849 – 50,220)	-	.844*
- Anterior deltoid	65,491±17,894[a] (52,689 – 78,292)	50,408±23,047[a] (41,921 – 74,894)	-	.453*
- Upper trapezius	15,655±28,19[b] (10,221 – 36,740)	9,245±6,95[b] (5,114 – 20,823)	-	.082†
Left hemibody				
- Infraespinatus	35,845±18,20[b] (27,668 – 54,389)	35,961±14,854[a] (25,334 – 46,587)	-	.623†
- Anterior deltoid	59,310±36,73[b] (52,892 – 81,067)	58,686±23,475[a] (41,892 – 75,479)	-	.364†
- Upper trapezius	34,569±27,495[a] (14,889 – 54,238)	15,605±9,595[a] (8,740 – 22,499)	-	.054*

Abbreviations: CKCUEST, Closed Kinetic Chain Upper Extremity Stability Test. a: Data with parametric distribution represented as mean standard deviation and 95% confidence interval. b: Data with nonparametric distribution represented as median interquartile range and 95% confidence interval. *: Student's t-test for independent samples. †: Wilcoxon Mann Whitney U-test.

4. Discussion

This study has identified significant muscle activation percentage differences in the infraspinatus, anterior deltoid and upper trapezius muscle during the performance of the CKCUEST and the modified CKCUEST in healthy participants. No statistical differences in the percentage of activation in the muscles studied were shown between men and women and between right-handed and ambidextrous subjects.

According to our results, the EMG activity of the infraspinatus, anterior deltoid and upper trapezius muscles bilaterally, observed during the performance of the CKCUEST, are higher than the activation percentages obtained during the performance of the modified CKCUEST in the same muscle regions in a healthy adult population, this could be explained as throughout the CKCUEST, the push-up position demands higher muscle activity to stabilise the shoulder complex than during the modified CKCUEST, as in the latter, the participants were in cuadrupedia with knees flat on the floor, hence, the muscle activity to stabilise the shoulder is less demanding [38].

To the authors knowldege, this is the first study to compare EMG activity of the shoulder during the performance of such dynamic tests in a healthy adult population.

Shoulder pain assessment based on shoulder range of motion, strength, mapping pain and shoulder functional tests has been proposed in the literature [24,39,40] as statistical differences have been found in recent studies [41]. Hence, the CKCUEST seems an ideal tool for the functional shoulder assessment and according to our results, the modified CKCUEST might be more optimal for shoulder pain patients as a decreased EMG activity in all muscles studied was showed compared to the CKCUEST, as it was proposed by Tucci et al (2014) [25]. An exercise progression to the CKCUEST seems logical to increase loading capacity throughout the conservative treatment, as loading progression has been proposed as a key factor in shoulder pain management [42,43]. In this line, an association between the CKCUEST and shoulder strength has been established [44]. Also, a moderate correlation has been observed between the ULRT and CKCUEST scores (r range= 0.505-

0.589) as it showed that CKCUEST can account for 30.6% to 37.8% of the variance in the ULRT performances. The ULRT was designed to promote weight bearing, requiring shoulder motor control and stability and involving the entire kinetic chain in a more complex shoulder position of 90º of abduction and 90º of external rotation [13].

The CKCUEST should be considered as an assessment tool in those patients whose pain severity and irritability allow them to perform the functional test as well as in healthy subjects [25]. However, as only healthy participants were included in the study, further studies are needed to evaluate both, the CKCUEST and the modified CKCUEST in shoulder pain patients.

In line with our findings, Gorman et al (2012) found no differences in EMG activity between sex and hand dominance during the performance of the UQY-BT [15]. However, Tucci et al (2014) found that healthy females performed a higher number of touches throughout the CKCUEST than healthy males [25], possibly due to anthropometric variables such as the wingspan differences between sex, hence, even though healthy women seem to perform more number of touches than men during the CKCUEST, the EMG activation in the infraspinatus, upper trapezius and anterior deltoid appears not to be different between groups.

Our results have implications for clinical practice and future studies. The CKCUEST has been proposed within the physical examination in patient suffering shoulder pain as a functional test [25] and to evaluate shoulder performance in athletes [45], however, subjects with low physical activity levels and patiens with shoulder dysfunction might find the CKCUEST difficult to be properly performed [25]. Our results found that as the modified CKCUEST showed significant diminished EMG activity in the infraspintatus, anterior deltoid and upper trapezius muscle than the CKCUEST, the modified CKCUEST might be an optimal choice for either physical functional examination in patients with shoulder pain or subjects with low physical activity levels. Equally, a progression from the modified CKCUEST and the CKCUEST may be considerd in shoulder rehabilitation in order to enhance tissue loading capacities, as this test has shown correlation with shoulder strength [44].

Therefore, future investigation should evaluate the difference in EMG activity between patients with shoulder pain and asymptomatic, as well as whether the inclusion of a CKCUEST progression within a shoulder rehabilitiation process improves variables such as pain and function in patients with shoulder pain.

Limitations

At present, this research is a pilot study, where the sample size calculated for the main variable has not been reached. For this reason, the results of this research should be taken with caution, reducing the external validity of the data and therefore its interpretation. Therefore, it would be interesting to reach the full sample size in order to be able to see the effects of the intervention.

Another limitation to be taken into account is the design of the tests themselves, which does not take into account the size of the upper limbs of the participants, which could influence changes in the activation of the regions analysed or other future variables to be measured. Therefore, it would be interesting to evaluate muscle activity taking into account the participants' wingspan, as well as the design of the functional test itself. Another of the limitations of this research is its design, a cross-sectional observational study; where the greatest limitation is given by the follow-up of the participants or the application of these tests as possible future interventions in other methodological designs. In this case, it would be interesting to be able to evaluate muscle activity during the execution of these dynamic tests in other types of methodologies, both evaluative and interventional.

The CKCUEST consist of assessing the maximun number of touches throughout fifteen seconds in a determined position, however, and due to EMG limitations to accurately pin down the precise peak muscle activity during the test performance, we proceded to analyse the data as it has been previously proposed in the literature, starting with 5 seconds rest, then 3 seconds with the left hand touching the right hand, 3 seconds rest and 3 seconds with the right hand touching the left hand, controlled by a metronome at 60 Hertz. In total, 5 repetitions were performed, eliminating the first

 doi:10.20944/preprints202503.0276.v1

and last for analysis and obtaining the mean for the EMG peak activity of each muscle, during the closed kinetic chain phase [35,36].

Finally, given the nature of the pilot study and the type of sampling stratified by sex, it was not possible to collect participants, verified by the EHI questionnaire, with upper limb dominance characteristics with values defined as left-handed. This has compromised the analysis of these variables and thus one of the secondary objectives of the study. Therefore, it would be interesting to carry out a stratified sampling by type of upper limb dominance in order to be able to draw more solid conclusions.

5. Conclusions

The results of this research showed a higher percentage of EMG activation during the CKCUEST compared to the modified CKCUEST in all the muscular structures analyzed, regardless of the participants' hemibody.

Supplementary Material: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

Author Contributions: Conceptualization, D.H.M. and M.G.J.; methodology, D.H.M. and M.G.J.; software, M.G.J.; validation, S.E.G.T., M.A.L.M., D.H.M. and M.G.J.; formal analysis, D.H.M. and M.G.J.; investigation, S.E.G.T. and M.A.L.M.; resources, D.H.M. and M.G.J.; data curation, D.H.M.; writing—original draft preparation, S.E.G.T., M.A.L.M., D.H.M. and M.G.J.; writing—review and editing, S.E.G.T., M.A.L.M., D.H.M. and M.G.J.; visualization, S.E.G.T., M.A.L.M., D.H.M. and M.G.J.; supervision, D.M.H.; project administration, D.H.M. and M.G.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of CEI Centro Superior de Estudios Universitarios La Salle de Madrid (CSEULS) (protocol code CSEULS-PI-002/2024 18th of January 2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

a	**ambidextrous**
BMI	body max index
CI	confidence interval
CKCUEST	Closed Kinetic Chain Upper Extremity Stability Test
CSEULS	Centro Superior de Estudios Universitarios de la Salle
EHI	Edinburgh Handedness Inventory
EMG	electromyography
ICC	Intraclass Correlation Coefficient
IPAQ	International Physical Activity Questionnaire
KJOC	Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score
L	left handed
LQ	laterality quotient
METs	metabolic equivalents
MVIC	maximum voluntary isometric contraction
R	right handed
SMBT	Seated Medicine Ball Throw
SPSS	Statistical Package of Social Sciences
ULRT	Upper Limb Rotation Test
YBT-QT	Y-Balance Test Upper Quarter

 doi:10.20944/preprints202503.0276.v1

References

1. Hinsley, H.; Ganderton, C.; Arden, N.K.; Carr, A.J. Prevalence of Rotator Cuff Tendon Tears and Symptoms in a Chingford General Population Cohort, and the Resultant Impact on UK Health Services: A Cross-Sectional Observational Study. BMJ Open 2022, 12. https://doi.org/10.1136/BMJOPEN-2021-059175.
2. Lewis, J.S. Rotator Cuff Tendinopathy. Br. J. Sports Med. 2009, 43, 236–241. https://doi.org/10.1136/bjsm.2008.052175.
3. Minagawa, H.; Yamamoto, N.; Abe, H.; Fukuda, M.; Seki, N.; Kikuchi, K.; Kijima, H.; Itoi, E. Prevalence of Symptomatic and Asymptomatic Rotator Cuff Tears in the General Population: From Mass-Screening in One Village. J. Orthop. 2013, 10, 8–12. https://doi.org/10.1016/J.JOR.2013.01.008.
4. Teunis, T.; Lubberts, B.; Reilly, B.T.; Ring, D. A Systematic Review and Pooled Analysis of the Prevalence of Rotator Cuff Disease with Increasing Age. J. Shoulder Elb. Surg. 2014, 23, 1913–1921. https://doi.org/10.1016/j.jse.2014.08.001.
5. McFarland, E.G..; Kim, T.K. Examination of the Shoulder : The Complete Guide. 2006, 282.
6. May, S.; Chance-Larsen, K.; Littlewood, C.; Lomas, D.; Saad, M. Reliability of Physical Examination Tests Used in the Assessment of Patients with Shoulder Problems: A Systematic Review. Physiotherapy 2010, 96, 179–190. https://doi.org/10.1016/J.PHYSIO.2009.12.002.
7. Hermans, J.; Luime, J.J.; Meuffels, D.E.; Reijman, M.; Simel, D.L.; Bierma-Zeinstra, S.M.A. Does This Patient with Shoulder Pain Have Rotator Cuff Disease?: The Rational Clinical Examination Systematic Review. JAMA 2013, 310, 837–847. https://doi.org/10.1001/JAMA.2013.276187.
8. Hegedus, E.J.; Goode, A.P.; Cook, C.E.; Michener, L.; Myer, C.A.; Myer, D.M.; Wright, A.A. Which Physical Examination Tests Provide Clinicians with the Most Value When Examining the Shoulder? Update of a Systematic Review with Meta-Analysis of Individual Tests. Br. J. Sports Med. 2012, 46, 964–978. https://doi.org/10.1136/BJSPORTS-2012-091066.
9. Hegedus, E.J.; Goode, A.; Campbell, S.; Morin, A.; Tamaddoni, M.; Moorman, C.T.; Cook, C. Physical Examination Tests of the Shoulder: A Systematic Review with Meta-Analysis of Individual Tests. Br. J. Sports Med. 2008, 42, 80–92. https://doi.org/10.1136/BJSM.2007.038406.
10. Salamh, P.; Lewis, J. It Is Time to Put Special Tests for Rotator Cuff-Related Shoulder Pain out to Pasture. J. Orthop. Sports Phys. Ther. 2020, 50, 222–225. https://doi.org/10.2519/JOSPT.2020.0606.
11. Sciascia, A.; Uhl, T. RELIABILITY OF STRENGTH AND PERFORMANCE TESTING MEASURES AND THEIR ABILITY TO DIFFERENTIATE PERSONS WITH AND WITHOUT SHOULDER SYMPTOMS. Int. J. Sports Phys. Ther. 2015, 10, 655.
12. Goldbeck, T.G.; Davies, G.J. Test-Retest Reliability of the Closed Kinetic Chain Upper Extremity Stability Test: A Clinical Field Test. J. Sport Rehabil. 2000, 9, 35–45. https://doi.org/10.1123/JSR.9.1.35.
13. Decleve, P.; Attar, T.; Benameur, T.; Gaspar, V.; Van Cant, J.; Cools, A.M. The "Upper Limb Rotation Test": Reliability and Validity Study of a New Upper Extremity Physical Performance Test. Phys. Ther. Sport 2020, 42, 118–123. https://doi.org/10.1016/J.PTSP.2020.01.009.
14. Kraeutler, M.J.; Ciccotti, M.G.; Dodson, C.C.; Frederick, R.W.; Cammarota, B.; Cohen, S.B. Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Scores in Asymptomatic Professional Baseball Pitchers. J. shoulder Elb. Surg. 2013, 22, 329–332. https://doi.org/10.1016/J.JSE.2012.02.010.
15. Gorman, P.P.; Butler, R.J.; Plisky, P.J.; Kiesel, K.B. Upper Quarter Y Balance Test: Reliability and Performance Comparison between Genders in Active Adults. J. strength Cond. Res. 2012, 26, 3043–3048. https://doi.org/10.1519/JSC.0B013E3182472FDB.
16. Harris, C.; Wattles, A.P.; Debeliso, M.; Sevene-Adams, P.G.; Berning, J.M.; Adams, K.J. The Seated Medicine Ball Throw as a Test of Upper Body Power in Older Adults. J. strength Cond. Res. 2011, 25, 2344–2348. https://doi.org/10.1519/JSC.0B013E3181ECD27B.
17. Roush Pt, J.R.; Kitamura, J.; Waits, M.C. Reference Values for the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) for Collegiate Baseball Players. N. Am. J. Sports Phys. Ther. 2007, 2, 159.
18. Richardson, E.; Lewis, J.S.; Gibson, J.; Morgan, C.; Halaki, M.; Ginn, K.; Yeowell, G. Role of the Kinetic Chain in Shoulder Rehabilitation: Does Incorporating the Trunk and Lower Limb into Shoulder Exercise Regimes Influence Shoulder Muscle Recruitment Patterns? Systematic Review of Electromyography Studies. BMJ Open Sport Exerc. Med. 2020, 6, 683. https://doi.org/10.1136/BMJSEM-2019-000683.

19. Tarara, D.T.; Fogaca, L.K.; Taylor, J.B.; Hegedus, E.J. Clinician-Friendly Physical Performance Tests in Athletes Part 3: A Systematic Review of Measurement Properties and Correlations to Injury for Tests in the Upper Extremity. Br. J. Sports Med. 2016, 50, 545–551. https://doi.org/10.1136/BJSPORTS-2015-095198.
20. Ludewig, P.M.; Cook, T.M.; Nawoczenski, D.A. Three-Dimensional Scapular Orientation and Muscle Activity at Selected Positions of Humeral Elevation. J. Orthop. Sports Phys. Ther. 1996, 24, 57–65. https://doi.org/10.2519/JOSPT.1996.24.2.57.
21. Kinsella, R.; Pizzari, T. Electromyographic Activity of the Shoulder Muscles during Rehabilitation Exercises in Subjects with and without Subacromial Pain Syndrome: A Systematic Review. Shoulder Elb. 2017, 9, 112–126. https://doi.org/10.1177/1758573216660038.
22. Chester, R.; Smith, T.O.; Hooper, L.; Dixon, J. The Impact of Subacromial Impingement Syndrome on Muscle Activity Patterns of the Shoulder Complex: A Systematic Review of Electromyographic Studies. BMC Musculoskelet. Disord. 2010, 11, 1–12. https://doi.org/10.1186/1471-2474-11-45/FIGURES/2.
23. Kwon, H.J.; Park, C.B.; Kim, Y.; Lee, K.S.; Chae, S.; Park, H.S. Comparative Analysis of Muscle Synergy between Patients with Shoulder Impingement Syndrome and Healthy Controls: A Preliminary Study. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. IEEE Eng. Med. Biol. Soc. Annu. Int. Conf. 2023, 2023. https://doi.org/10.1109/EMBC40787.2023.10340061.
24. Lewis, J. Rotator Cuff Related Shoulder Pain: Assessment, Management and Uncertainties. Man. Ther. 2015, 23, 57–68. https://doi.org/10.1016/j.math.2016.03.009.
25. Tucci, H.T.; Martins, J.; Sposito, G.D.C.; Camarini, P.M.F.; De Oliveira, A.S. Closed Kinetic Chain Upper Extremity Stability Test (CKCUES Test): A Reliability Study in Persons with and without Shoulder Impingement Syndrome. BMC Musculoskelet. Disord. 2014, 15. https://doi.org/10.1186/1471-2474-15-1.
26. Vandenbroucke, J.P.; Von Elm, E.; Altman, D.G.; Gøtzsche, P.C.; Mulrow, C.D.; Pocock, S.J.; Poole, C.; Schlesselman, J.J.; Egger, M. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): Explanation and Elaboration. Epidemiology 2007, 18, 805–835. https://doi.org/10.1097/EDE.0B013E3181577511.
27. Oldfield, R.C. The Assessment and Analysis of Handedness: The Edinburgh Inventory. Neuropsychologia 1971, 9, 97–113. https://doi.org/10.1016/0028-3932(71)90067-4.
28. Albayay, J.; Villarroel-Gruner, P.; Bascour-Sandoval, C.; Parma, V.; Gálvez-García, G. Psychometric Properties of the Spanish Version of the Edinburgh Handedness Inventory in a Sample of Chilean Undergraduates. Brain Cogn. 2019, 137. https://doi.org/10.1016/J.BANDC.2019.103618.
29. Román Viñas, B.; Ribas Barba, L.; Ngo, J.; Serra Majem, L. [Validity of the International Physical Activity Questionnaire in the Catalan Population (Spain)]. Gac. Sanit. 2013, 27, 254–257. https://doi.org/10.1016/J.GACETA.2012.05.013.
30. Gauthier, A.P.; Lariviere, M.; Young, N. Psychometric Properties of the IPAQ: A Validation Study in a Sample of Northern Franco-Ontarians. J. Phys. Act. Health 2009, 6 Suppl 1. https://doi.org/10.1123/JPAH.6.S1.S54.
31. Ekstrom, R.A.; Donatelli, R.A.; Carp, K.C. Electromyographic Analysis of Core Trunk, Hip, and Thigh Muscles during 9 Rehabilitation Exercises. J. Orthop. Sports Phys. Ther. 2007, 37, 754–762. https://doi.org/10.2519/JOSPT.2007.2471.
32. Hibbs, A.E.; Thompson, K.G.; French, D.N.; Hodgson, D.; Spears, I.R. Peak and Average Rectified EMG Measures: Which Method of Data Reduction Should Be Used for Assessing Core Training Exercises? J. Electromyogr. Kinesiol. 2011, 21, 102–111. https://doi.org/10.1016/J.JELEKIN.2010.06.001.
33. Youdas, J.W.; Budach, B.D.; Ellerbusch, J. V.; Stucky, C.M.; Wait, K.R.; Hollman, J.H. Comparison of Muscle-Activation Patterns during the Conventional Push-up and Perfect· PushupTM Exercises. J. strength Cond. Res. 2010, 24, 3352–3362. https://doi.org/10.1519/JSC.0B013E3181CC23B0.
34. Castelein, B.; Cools, A.; Bostyn, E.; Delemarre, J.; Lemahieu, T.; Cagnie, B. Analysis of Scapular Muscle EMG Activity in Patients with Idiopathic Neck Pain: A Systematic Review. J. Electromyogr. Kinesiol. 2015, 25, 371–386. https://doi.org/10.1016/J.JELEKIN.2015.01.006.
35. Cools, A.M.; Tongel, A. Van; Berckmans, K.; Spanhove, V.; Plaetevoet, T.; Rosseel, J.; Soen, J.; Levy, O.; Maenhout, A. Electromyographic Analysis of Selected Shoulder Muscles during a Series of Exercises

doi:10.20944/preprints202503.0276.v1

Commonly Used in Patients with Symptomatic Degenerative Rotator Cuff Tears. J. Shoulder Elb. Surg. 2020, 29, e361–e373. https://doi.org/10.1016/j.jse.2020.03.019.
36. Dickie, J.A.; Faulkner, J.A.; Barnes, M.J.; Lark, S.D. Electromyographic Analysis of Muscle Activation during Pull-up Variations. J. Electromyogr. Kinesiol. 2017, 32, 30–36. https://doi.org/10.1016/J.JELEKIN.2016.11.004.
37. Schilling, D.T.; Elazzazi, A.M. Shoulder Strength and Closed Kinetic Chain Upper Extremity Stability Test Performance in Division III Collegiate Baseball and Softball Players. Int. J. Sports Phys. Ther. 2021, 16, 844. https://doi.org/10.26603/001C.24244.
38. Ebben, W.P.; Wurm, B.; Vanderzanden, T.L.; Spadavecchia, M.L.; Durocher, J.J.; Bickham, C.T.; Petushek, E.J. Kinetic Analysis of Several Variations of Push-Ups. J. strength Cond. Res. 2011, 25, 2891–2894. https://doi.org/10.1519/JSC.0B013E31820C8587.
39. Littlewood, C.; Bateman, M.; Connor, C.; Gibson, J.; Horsley, I.; Jaggi, A.; Jones, V.; Meakins, A.; Scott, M. Physiotherapists' Recommendations for Examination and Treatment of Rotator Cuff Related Shoulder Pain: A Consensus Exercise. Physiother. Pract. Res. 2019, 40, 87–94. https://doi.org/10.3233/PPR-190129.
40. Requejo-Salinas, N.; Lewis, J.; Michener, L.A.; La Touche, R.; Fernández-Matías, R.; Tercero-Lucas, J.; Camargo, P.R.; Bateman, M.; Struyf, F.; Roy, J.S.; et al. International Physical Therapists Consensus on Clinical Descriptors for Diagnosing Rotator Cuff Related Shoulder Pain: A Delphi Study. Brazilian J. Phys. Ther. 2022, 26, 100395. https://doi.org/10.1016/J.BJPT.2022.100395.
41. Manoso-Hernando, D.; Bailón-Cerezo, J.; Angulo-Díaz-Parreño, S.; Reina-Varona, Á.; Elizagaray-García, I.; Gil-Martínez, A. Shoulder Mobility and Strength Impairments in Patients with Rotator Cuff Related Shoulder Pain: A Systematic Review and Meta Analysis. PeerJ 2024, 12. https://doi.org/10.7717/PEERJ.17604.
42. Powell, J.K.; Schram, B.; Lewis, J.; Hing, W. "You Have (Rotator Cuff Related) Shoulder Pain, and to Treat It, I Recommend Exercise." A Scoping Review of the Possible Mechanisms Underpinning Exercise Therapy. Musculoskelet. Sci. Pract. 2022, 62. https://doi.org/10.1016/J.MSKSP.2022.102646.
43. POWELL, J.K.; LEWIS, J.S. Rotator Cuff-Related Shoulder Pain: Is It Time to Reframe the Advice, "You Need to Strengthen Your Shoulder"? J. Orthop. Sports Phys. Ther. 2021, 51, 156–159. https://doi.org/10.2519/JOSPT.2021.10199.
44. Silva, E.R.; Maffulli, N.; Migliorini, F.; Santos, G.M.; de Menezes, F.S.; Okubo, R. Function, Strength, and Muscle Activation of the Shoulder Complex in Crossfit Practitioners with and without Pain: A Cross-Sectional Observational Study. J. Orthop. Surg. Res. 2022, 17. https://doi.org/10.1186/S13018-022-02915-X.
45. Lust, K.R.; Sandrey, M.A.; Bulger, S.M.; Wilder, N. The Effects of 6-Week Training Programs on Throwing Accuracy, Proprioception, and Core Endurance in Baseball. J. Sport Rehabil. 2009, 18, 407–426. https://doi.org/10.1123/JSR.18.3.407.