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Diagnostic utility of acromioclavicular joint clinical examination tests a systematic review

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ABSTRACT

Background: Several studies reported high sensitivity and/or specificity for clinical tests identifying acromioclavicular joint (ACJ) pathology. However, methodological quality and inconsistent findings limit the confidence in interpreting exam results. Individual tests often lack clinimetric properties to guide clinical decisions but the diagnostic utility of combining ACJ tests in parallel or in series has not been widely reported.

Objectives: The objectives of this systematic review are to assess diagnostic utility of single clinical examination tests and clustering techniques to determine the most clinically relevant combination for ruling in or ruling out shoulder pain of ACJ origin.

Methods: We systematically searched PubMed and Scopus, with search terms related to diagnostics and ACJ pain. We performed statistical analyses for clinimetric properties of tests. Results: The search yielded 798 results. Eleven studies containing 1963 participants provided data for this review. Active compression yielded the highest specificity (0.911) and Paxinos Sign (PxS) resulted in the highest sensitivity (0.850) of any single test. Combining active compression, ACJ tenderness (ACJT), and PxS both in series and in parallel yielded large, often conclusive shifts in the post-test probability that a patient's pain is (positive likelihood ratio, 53.954) or is not (negative likelihood ratio, 0.062) of ACJ origin.

Conclusions: Single ACJ clinical examination tests possess limited diagnostic utility. Combining active compression, ACJT, and PxS either in series or parallel resulted in conclusive shifts in post-test probability for ruling in or out ACJ related pain.

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Introduction

The shoulder is the third most common source of musculoskeletal pain [1,2] and shoulder pain may lead to functional limitation, economic burden, and decreased quality of life [1–8]. The prevalence of shoulder pain has not been fully elucidated; however, estimates suggest a prevalence of 4%–26% [6,9,10]. Other research suggests a one-month prevalence of shoulder pain between 4.7% and 46.7295% [2,3,6,8]. Due to patient specific factors, inaccurate examination, and/or variations in treatment, many individuals who experience new onset shoulder pain will develop chronic pain, thus increasing the associated costs [1,5–8].

The acromioclavicular joint (ACJ) is a common cause of shoulder pain in patients, regardless of demographics [1,4,11–19]. Several ACJ pathologies may lead to pain of ACJ origins, e.g. osteoarthritis, distal osteolysis, and sprains [20]. Regardless of etiology, the ACJ accounts for 10% [6,21,22] of all shoulder pain. The ACJ also constitutes up to 40% [21,23] of contact sports shoulder injuries. Since each shoulder girdle articulation can induce musculoskeletal pain [4,6,21], accurately identifying disorders of each structure is a prerequisite for determining patients' prognosis and treatment [1,11–13,17,19,22].

Numerous clinical examination tests for pain of ACJ origins have been described (e.g. Active Compression Test (ACT), localized ACJ tenderness (ACJT), Hawkins–Kennedy Test (HKT), Paxinos Sign (PxS), and cross-body adduction (CBA)), but the diagnostic utility of these procedures has not been fully elucidated [1,4,11–19].

Individual clinical examination tests typically lack sufficient clinimetric properties to guide clinical decision making [4,13,24–28]. Several studies demonstrating moderate to high sensitivity and/or specificity for ACJ clinical examination tests had questionable methodologies [13,14,16–29]. Moreover, the findings from these studies are inconsistent [11–29]. Prior to accepting clinical examination tests as best practice, tests must be reproducible, reliable, valid, and demonstrate

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sufficient clinimetric properties to guide clinical decisions. Therefore, researchers and clinicians must be diligent when selecting the best clinical examination tests to perform.

Combining tests is a commonly utilized diagnostic tool in physical examinations [24–29]. Testing in series requires all tests to be positive before obtaining an aggregate positive result, increasing the specificity of the combined tests (i.e. the probability of detecting a true positive) [4,25]. When testing in parallel, only one test must be positive to obtain an aggregate positive result. Thus, parallel testing increases the sensitivity of the combined tests (i.e. the probability of detecting a true negative) [4,25]. Based on findings from several studies, aggregating the results of multiple clinical examination tests may augment their clinical utility compared to single tests [4,24–29]. For example, Laslett et al. [27] and Hegedus et al. [29] emphasized conducting composite clinical examination procedures to increase diagnostic utility of commonly used tests to, respectively, identify low back pain of sacroiliac origins and differentiate between shoulder pathologies. However, when multiple tests are performed, the likelihood of obtaining a single false negative or false positive result, within the cluster, increases [25]. Thus, clinicians must exercise caution unless an individual test has been found to have high diagnostic utility, such as has been reported for the Lachman test [30].

Meaningful clinical tests or test clusters should be able to conclusively rule in and/or rule out a disorder, without the need for further medical testing. To initially ensure validity, clinical diagnostic tests must be compared to a gold standard. Various imaging (arthrography, ultrasound [US], magnetic resonance imaging [MRI], radiograph, etc.) and surgical modalities (e.g. diagnostic injections and arthroscopy) are cited in the literature for diagnosing ACJ pathology [1,11–20]. However, a gold standard has yet to be established [1,4,11,18,26,28,31]. The purpose of this review is to determine the most clinically relevant and efficient cluster of clinical examination tests for ruling in and/or ruling out shoulder pain of ACJ origin.

There have been previous studies seeking to investigate the diagnostic utility of clustering clinical examination tests for shoulder pathology. Although Hegedus et al. [29] conducted a systematic review in 2012 on clinical examination tests and test clusters for the shoulder, ACJ related pathology was not included. Additionally, Krill et al. [4] performed a systematic review in 2017 and Cadogan et al. [12] reviewed the previous literature in 2013. However, our study seeks to update the previous findings with additional and more recent research to determine the most clinically useful diagnostic test cluster for ACJ related pain. The objective of this study is to advance the quality of existing literature by thoroughly analyzing it to ensure accurate, inexpensive, and non-invasive means of diagnosis of pain of ACJ origin.

Methods

To appraise diagnostic utility of clinical examination tests for pain of ACJ origins, researchers AR and AS independently searched PubMed and Scopus (10 August 2022) with search terms related to diagnostics, ACJ, and clinical examination tests (Appendix I). The inclusion criteria specified the studies must report data that allows for the calculation of sensitivity and specificity of clinical examination tests for the ACJ. Duplicate records were removed. We excluded studies that were: reviews, systematic reviews, and not available in English. We also excluded studies that did not: examine diagnostic accuracy of clinical examination tests, include diagnostic information regarding the ACJ, or include information needed to perform statistical analyses. Studies were excluded in the order specified by the PRISMA 2020 guidelines [32]. AR, AS, and RS performed a full text review of the remaining articles, then synthesized and analyzed data from the studies. The time frame during which this review process took place was from 10 August 2022 to 30 August 2022.

Data management

We evaluated clinical examination tests that were both diagnostic for pain of ACJ origins and included in at least two of the 11 studies. AR, AS, and RS extracted and aggregated data from each of the studies into Microsoft Excel 2019. We calculated sensitivity, specificity, and likelihood ratios (LRs) for single tests. We used MedCalc software version 20.023 [33] to calculate 95% confidence intervals for sensitivity, specificity, and LRs for single tests. We then combined the data in series and in parallel (Appendix II). We then calculated sensitivity, specificity, and LRs for those amalgamations utilizing the formulae described by Krill et al. [4]. Since the product of two fractions is lower, sensitivity is lower when calculated in series and specificity is lower when calculated in parallel. As this analysis seeks to achieve optimal sensitivity and specificity of the composite examination, use of the product calculations for each is not included in the tables. The positive likelihood ratio (LR+) and negative likelihood ratio (LR−) values were stratified according to the classification system developed by Jaeschke et al. [34], as shown in Appendix III. Researchers AR, AS, RS, and CD qualitatively analyzed the methods of

each study to exclude potentially biased data. Each researcher independently analyzed the methods, using the STARD [35] checklist, then the quality of each study was collectively reviewed to generate a consensus on potential bias for each study (30 August 2022 to 5 November 2022). After reviewing the studies, we determined the variations in study methodologies [14,16–18,20] likely led to bias in the data. Thus, we conducted multiple analyses with different combinations of data.

Results

The search of PubMed and Scopus databases ($N = 2$) yielded 798 results (Figure 1). Duplicate records were removed ($N = 8$). Before screening, 399 records were removed by utilizing database automation tools. Our initial search ($N = 386$) was then reduced to $N = 45$ ($\kappa = 1$) through abstract and title screening (Figure 1). Additional articles ($N = 34$) were excluded following full-text review ($\kappa = 1$) (Figure 1). The eleven ($N = 11$) remaining eligible studies were then charted in a STARD checklist and the data were extracted and reviewed (Appendix STARD) [35]. The eleven studies providing data for this review had a total participant pool of $N = 2301$, 1963 of which were included in the analyses. Reference standards, clinical examination tests, and total participants for each of the studies are described in Appendix IV.

STARD assessment

We examined study methodology by using the STARD [35] checklist for the reporting of studies of diagnostic accuracy. All but two studies described the rationale for utilizing the reference standard [13,20]. Three studies did not include methods for calculating or comparing measures of diagnostic accuracy [16,18,20]. Four studies described blinding of assessors [1,12,16,19]. Four studies did not describe the definition of and rationale for the units, cutoffs and/or categories of the results of the index tests and the reference standard [13,17,19,20]. Only four studies described the number, training, and expertise of the testers [1,12,15,17]. None of the studies reported test reproducibility [1,11–19,20]. Eight studies [11,13,14,16–19,20] did not report how indeterminate results, missing responses, and outliers were handled. Four studies reported estimates of both diagnostic accuracy and measures of statistical uncertainty [11,12,15,19].

Strategies of data aggregation and exclusion

Several studies [14,17,18,20] did not describe blinding procedures. Multiple studies [14,16,17,20] enrolled samples that had confirmed ACJ pathology, thus introducing a possible source of bias in the data.

O'Brien et al. [16] included 50 participants without complaints of shoulder pain, which increased the average weighted specificity for the ACT. Thus, including participants with no shoulder pain may introduce a source of bias into the data and limits the study's applicability. Additionally, the investigators made tentative diagnoses prior to performing the reference standard with no explanation of their rationale [16]. These prior diagnoses may indicate a source of confirmation bias.

Without explanation, Ulaşlı et al. [17] added a 'mild' response to testing outcomes. Without blinding, the mild response could lead to further bias in the data. We dichotomized these data by analyzing the 'mild' responses, separately, as both a positive and negative test result.

To be included in their study, van Riet and Bell [18] required participants to have radiographically diagnosed ACJ pathology, a positive clinical examination test, and ten negative clinical examination tests after receiving a localized anesthetic and corticosteroid injection. Requiring all these inclusion criteria may indicate a source of selection, inclusion, and confirmation bias. These potential sources of bias may inflate sensitivity values for clinical examination tests, as there is a much greater chance of detecting true positives. Additionally, requiring these criteria may also lead to a population not representative of the general population.

After receiving written, photographic, and verbal instructions, participants in the Frigg et al. study [14] conducted the clinical examination tests on themselves. Participant self-examination may have also introduced potential bias in the data, as patients were given test 'equivalents' [14]. As clinicians did not perform the tests, these data are less likely to be clinically relevant.

Gürbüz et al. [20] did not fully explain why they diagnosed individuals with ACJ pathology prior to performing clinical examination tests, nor did they describe who performed the tests. Additionally, Gürbüz et al. [20] omitted some of their results for ACJ clinical examination tests. These factors could lead to several sources of bias within the data.

The methodologies of these studies[14,16–18,20] could lead to bias in the data. To account for bias while still analyzing all available data related to ACJ clinical examination tests, we only included data from these studies [14,16–18,20] in Appendices V and VI. To reflect the most clinically relevant test combinations, data from studies with methodologies that have the potential to generate bias [14,16–18,20] will be excluded from the conclusion. The results and conclusion of this systematic review

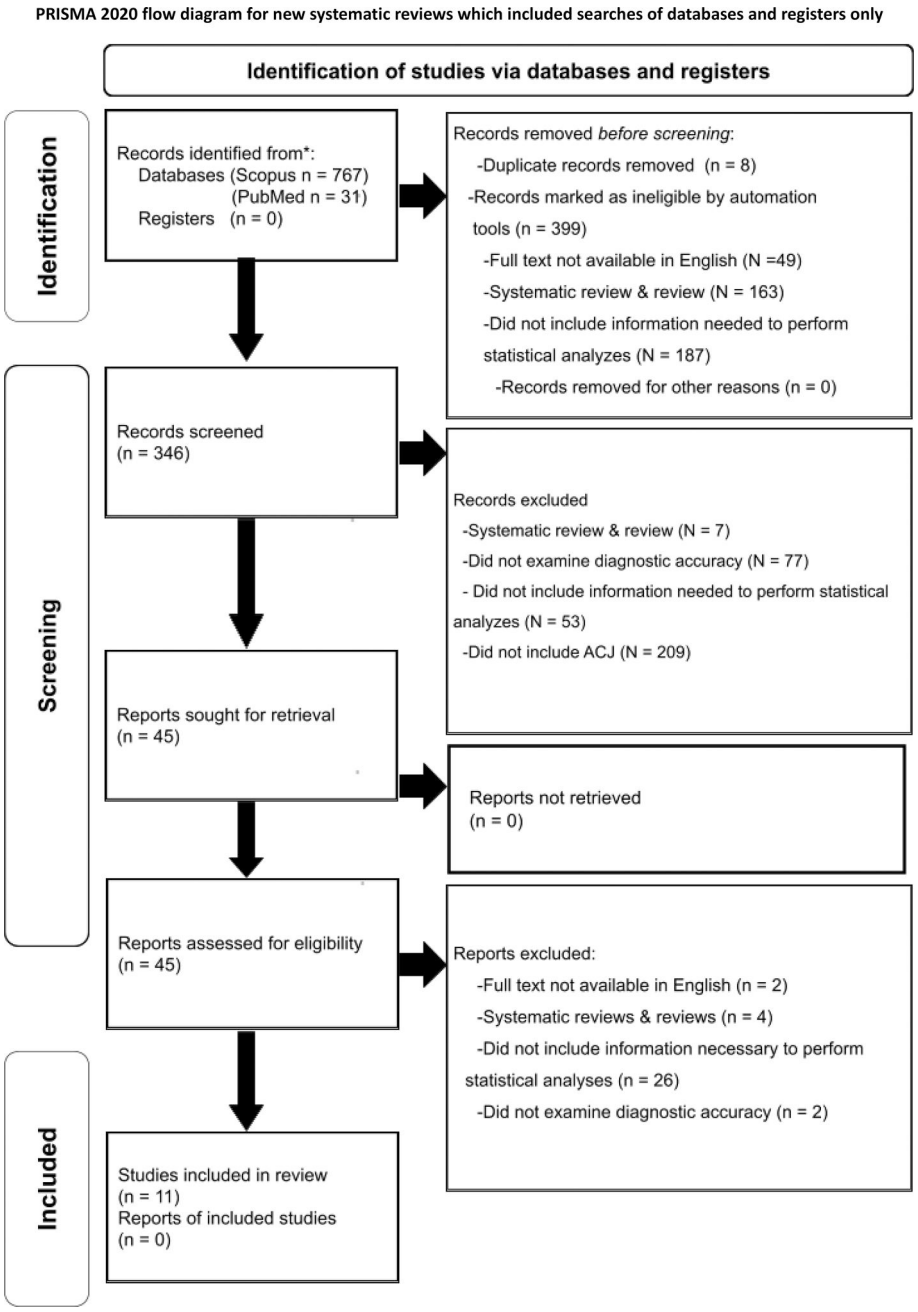

Figure 1. The initial search of the PubMed and Scopus databases. The initial search yielded 798 results. Following the Prisma 2020 guidelines, the figure reveals that 346 results were screened. 45 reports were retrieved and assessed for eligibility. A total of 11 studies were included.

reflect findings from studies [1,11–13,15,19], due to their higher methodical quality.

Data analysis

We analyzed data from studies that investigated the CBA test [1,11–15,17,18,20], HKT [12,13,17], ACJT [10,12,14,15,18,19], PxS [11,18,19], and ACT [11–13,16,18,19]. The number of patients evaluated with each ACJ test is summarized in Table 1. Analyses of data sensitivity, specificity, and LRs (Table 2) were weighted based on the number of patients represented in each test.

Synthesizing data from the studies with higher methodical quality [1,11–13,15,19], the PxS resulted in the highest sensitivity and the lowest LR − of any single test (Table 2). Utilizing data from the studies [1,11–13,15,19], the best LR+s and LR − s from single ACJ tests meet the threshold to indicate moderate, but usually important shifts in post-test probability.

Conducting two clinical examination tests in series yielded different results than single diagnostic tests alone (Table 3). Using data from the studies with higher methodical quality [1,11–13,15,19], ACT combined with either ACJT or PxS yielded similar values for specificity (Table 3). However, PxS and ACT produced the greatest LR+ (Table 3). Additionally, ACT combined with ACJT, PxS, or the CBA test all demonstrated large, often conclusive shifts in probability of pain of ACJ origins

(Table 3). The other combinations of tests demonstrated a range from very small to moderate LR+s. Appendix V includes all of the data, regardless of potential bias, when testing in series [1,11–20].

Parallel testing two clinical examination tests (Table 4) generated different results than single diagnostic tests. Analyzing data from the studies with higher methodical quality [1,11–13,15,19], PxS combined with ACJT resulted in the highest sensitivity and the lowest LR− of all other combinations (Table 4). PxS combined with CBA, HKT, or ACT all yielded moderate, but usually important LR−s (Table 4). Using the same data [1,11–13,15,19], parallel testing all other amalgamations of two tests resulted in LR−s with small, sometimes important or very small, usually unimportant, impacts on the probability of pain of ACJ origin (Table 4). Appendix VI includes all of the data, regardless of potential bias, when testing in parallel [1,11–20].

Conducting three clinical examination tests in series yielded larger shifts in post-test probability than two tests in series (Table 5). Utilizing data from the studies with higher methodical quality [1,11–13,15,19], ACT combined in series with both

Table 1. Participants per test.

Test [data sources]	TP	FN	TN	FP	*N*
CBA [1,11–13,15]	315	267	556	214	1352
CBA^{PF} [1,11–15,17,18,20]	453	384	556	214	1607
CBA^{NF} [1,11–15,17,18,20]	405	432	556	214	1607
CBA^{PB} [1,11–15,17,18,20]	437	400	556	214	1607
CBA^{NB} [1,11–15,17,18,20]	389	448	556	214	1607
ACT [11–13,19]	81	87	451	44	663
ACT [11–13,16,18,19]	184	97	707	51	1039
HKT [12,13]	22	15	187	253	477
HKT^{P} [12,13,17]	80	19	187	253	539
HKT^{N} [12,13,17]	26	73	187	253	539
ACJT [1,12,15,19]	265	209	170	44	688
ACJT^{B} [1,12,14,15,18,19]	333	313	170	44	860
ACJT^{F} [1,12,14,15,18,19]	339	307	170	44	860
PxS [1,12,14,15,18,19]	102	18	53	16	189
PxS [11,18,19]	109	69	53	16	247

The test [data sources] column indicates each test that was used and the referenced sources that contributed to the data. The superscript letters within that column denote how the data for a test were stratified.
N: Mild data counts as a negative response [17].
P: Mild data counts as a positive response [17].
B: Baseline data [14].
F: Follow up data [14].
ACJ: acromioclavicular joint; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy test; PxS: Paxinos Sign; TP: true positives; TN: true negatives; FP: false positives; FN: false negatives

Table 3. Specificity and positive likelihood ratios of two combined physical ACJ tests in series.

Test 1 [data sources]	Test 2 [data sources]	Specificity	LR+
CBA [1,11–13,15]	HKT [12,13]	0.840	2.014^{s}
CBA [1,11–13,15]	ACT [11–13,19]	0.975	10.563^{L}
CBA [1,11–13,15]	ACJT [1,12,15,19]	0.943	5.295^{m}
CBA [1,11–13,15]	PxS [11,19]	0.936	7.139^{m}
HKT [12,13]	ACT [11–13,19]	0.949	5.609^{m}
HKT [12,13]	ACJT [1,12,15,19]	0.882	2.812^{s}
HKT [12,13]	PxS [11,19]	0.867	3.791^{s}
ACT [11–13,19]	ACJT [1,12,15,19]	0.982	14.749^{L}
ACT [11–13,19]	PxS [11,19]	0.979	19.883^{L}
ACJT [1,12,15,19]	PxS [11,19]	0.952	9.967^{m}

The Test 1 [data sources] and Test 2 [data sources] columns indicate each test that was used and the referenced sources that contributed to the data. Table 3 describes the mean clinimetric properties of combined physical ACJ tests in series.
ACJ: acromioclavicular joint; LR+: positive likelihood ratio; LR−: negative likelihood ratio; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy test; PxS: Paxinos Sign
Likelihood ratio interpretations:
v: very small, usually unimportant.
s: small, sometimes important.
m: moderate, usually important.
L: large, often conclusive.

Table 2. Sensitivity, specificity, and likelihood ratios of single physical ACJ tests.

Test [data sources]	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR− (95% CI)
CBA [1,11–13,15]	0.541 (0.500, 0.582)	0.722 (0.689, 0.754)	1.947^{v} (1.70, 2.23)	0.635^{v} (0.58, 0.70)
CBA^{PF} [1,11–15,17,18,20]	0.541 (0.507, 0.575)	0.722 (0.689, 0.754)	1.947^{v} (1.71, 2.22)	0.635^{v} (0.58, 0.69)
CBA^{NF} [1,11–15,17,18,20]	0.484 (0.450, 0.518)	0.722 (0.689, 0.754)	1.741^{v} (1.52, 1.99)	0.715^{v} (0.66, 0.77)
CBA^{PB} [1,11–15,17,18,20]	0.522 (0.488, 0.556)	0.722 (0.689, 0.754)	1.879^{v} (1.65, 2.14)	0.662^{v} (0.61, 0.72)
CBA^{NB} [1,11–15,17,18,20]	0.465 (0.431, 0.499)	0.722 (0.689, 0.754)	1.672^{v} (1.46, 1.91)	0.741^{v} (0.69, 0.80)
ACT [11–13,19]	0.482 (0.405, 0.560)	0.911 (0.883, 0.935)	5.424^{m} (3.93, 7.49)	0.568^{v} (0.49, 0.66)
ACT [11–13,16,18,19]	0.655 (0.596, 0.710)	0.933 (0.913, 0.950)	9.732^{m} (7.37, 12.86)	0.370^{s} (0.31, 0.44)
HKT [12,13]	0.595 (0.421, 0.753)	0.425 (0.378, 0.473)	1.034^{v} (0.78, 1.37)	0.954^{v} (0.64, 1.43)
HKT^{P} [12,13,17]	0.808 (0.717, 0.880)	0.425 (0.378, 0.473)	1.405^{v} (1.24, 1.59)	0.452^{s} (0.30, 0.69)
HKT^{N} [12,13,17]	0.263 (0.179, 0.361)	0.425 (0.378, 0.473)	0.457^{v} (0.33, 0.64)	1.735^{v} (1.48, 2.04)
ACJT [1,12,15,19]	0.559 (0.513, 0.604)	0.794 (0.734, 0.847)	2.719^{s} (2.06, 3.58)	0.555^{v} (0.49, 0.63)
ACJ T^{B} [1,12,14,15,18,19]	0.515 (0.476, 0.555)	0.794 (0.734, 0.847)	2.507^{s} (1.91, 3.30)	0.610^{v} (0.55, 0.68)
ACJT ^{F} [1,12,14,15,18,19]	0.525 (0.485, 0.564)	0.794 (0.734, 0.847)	2.552^{s} (1.94, 3.35)	0.598^{v} (0.54, 0.67)
PxS [11,19]	0.850 (0.773, 0.909)	0.768 (0.651, 0.861)	3.666^{s} (2.37, 5.67)	0.195^{m} (0.13, 0.30)
PxS [11,18,19]	0.612 (0.537, 0.684)	0.768 (0.651, 0.861)	2.641^{s} (1.69, 4.12)	0.505^{v} (0.40, 0.63)

The test [data sources] column indicates each test that was used and the referenced sources that contributed to the data. The superscript letters within that column denote how the data for a test were stratified. Table 2 describes the mean clinimetric properties of single ACJ tests. The numbers within parentheses indicate the 95% confidence interval for each clinimetric property.
N: Mild data counts as a negative response [17].
P: Mild data counts as a positive response [17].
B: Baseline data [14].
F: Follow up data [14].
ACJ: acromioclavicular joint; LR+: positive likelihood ratio; LR−: negative likelihood ratio; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy test; PxS: Paxinos Sign
Likelihood ratio interpretations:
v: very small, usually unimportant.
s: small, sometimes important.
m: moderate, usually important.

PxS and ACJT resulted in the highest specificity and LR+ of all other combinations (Table 5). Using the same data, ACT combined in series with both ACJT and CBA had the second highest specificity and third highest LR+ (Table 5). All but two combinations yielded large, often conclusive shifts in post-test probabilities (Table 5).

Conducting three clinical examination tests in parallel yielded larger shifts in post-test probability than two tests in parallel (Table 6). Utilizing data from the studies with higher methodical quality [1,11–13,15,19], ACT combined in parallel with both PxS and ACJT resulted in a high sensitivity and the lowest LR − of all other composites (Table 6). Using the same data, HKT combined in parallel with both ACJT and PxS had the highest sensitivity, but only moderate shifts in post-test probabilities (Table 6). Three combinations yielded large, often conclusive, shifts in post-test probabilities (Table 6).

Table 4. Sensitivity and negative likelihood ratios of two combined physical ACJ tests in parallel.

Test 1 [data sources]	Test 2 [data sources]	Sensitivity	LR−
CBA [1,11–13,15]	HKT [12,13]	0.814	0.606^{v}
CBA [1,11–13,15]	ACT [11–13,19]	0.762	0.361^{s}
CBA [1,11–13,15]	ACJT [1,12,15,19]	0.798	0.353^{s}
CBA [1,11–13,15]	PxS [11,19]	0.931	0.124^{m}
HKT [12,13]	ACT [11–13,19]	0.790	0.542^{v}
HKT [12,13]	ACJT [1,12,15,19]	0.821	0.529^{v}
HKT [12,13]	PxS [11,19]	0.939	0.186^{m}
ACT [11–13,19]	ACJT [1,12,15,19]	0.772	0.315^{s}
ACT [11–13,19]	PxS [11,19]	0.922	0.111^{m}
ACJT [1,12,15,19]	PxS [11,19]	0.934	0.108^{m}

The Test 1 [data sources] and Test 2 [data sources] columns indicate each test that was used and the referenced sources that contributed to the data. Table 4 describes the mean clinimetric properties of combined physical ACJ tests in parallel.
ACJ: acromioclavicular joint; LR+: positive likelihood ratio; LR−: negative likelihood ratio; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy Test; PxS: Paxinos Sign
Likelihood ratio interpretations:
v: very small, usually unimportant.
s: small, sometimes important.
m: moderate, usually important.
L: large, often conclusive.

Discussion

This systematic review addresses the role of clinical examination tests to identify ACJ related pain. Shoulder pain may stem from multiple sources [4,6,12,21], and differential diagnosis of ACJ related pain presents a clinical challenge. Accurate diagnosis is an essential step in the clinical process [4,12,13,17,19,22]. To provide the most clinically relevant recommendations, data from certain studies [14,16–18,20] were excluded from the conclusion, but the data were included in the appendices. As demonstrated by Table 2, the clinimetric properties in these studies [14,16–18,20] are either markedly higher or lower than the mean clinimetric values in other studies, thus suggesting the methodologies impacted the data.

No single test possessed sufficient clinimetric properties to diagnose pain of ACJ origins [30,34], indicating clinicians should abstain from drawing conclusions from a single test result. Combining multiple tests with high individual clinimetric properties in series and in parallel can produce likely conclusive shifts in post-test probability. To maximize the likelihood of accurate diagnosis while subsequently minimizing patient discomfort, clinicians must exercise clinical reasoning during the examination process. Therefore, a sufficiently conclusive test cluster should be used in conjunction with a thorough history and systems review. Combining three ACJ tests in series and in parallel produces likely conclusive shifts in post-test probability. Without any other component of the clinical examination, three positive results when combining ACT, ACJT, and PxS in series shifts the probability of ACJ related pain by a factor of 53.954 [1,11–13,15,19]. Obtaining three negative results when testing ACT, ACJT, and PxS in parallel results in a large, often conclusive, increase in post-test probability of the absence of ACJ related pain. While conducting four

Table 5. Specificity and positive likelihood ratios of three combined physical ACJ tests in series.

Test 1 [data sources]	Test 2 [data sources]	Test 3 [data sources]	Specificity	LR+
CBA [1,11–13,15]	HKT [12,13]	PxS [11,19]	0.963	7.378^{m}
CBA [1,11–13,15]	ACT [11–13,19]	PxS [11,19]	0.994	38.701^{L}
CBA [1,11–13,15]	ACJT [1,12,15,19]	PxS [11,19]	0.987	19.401^{L}
HKT [12,13]	ACJT [1,12,15,19]	PxS [11,19]	0.973	10.302^{L}
HKT [12,13]	ACT [11–13,19]	CBA [1,11–13,15]	0.986	10.917^{L}
HKT [12,13]	ACJT [1,12,15,19]	CBA [1,11–13,15]	0.967	5.478^{m}
HKT [12,13]	ACJT [1,12,15,19]	ACT [11–13,19]	0.989	15.228^{L}
HKT[12,13]	PxS [11,19]	ACT [11–13,19]	0.988	20.529^{L}
ACT [11–13,19]	ACJT [1,12,15,19]	CBA [1,11–13,15]	0.995	28.702^{L}
ACT [11–13,19]	PxS [11,19]	ACJT [1,12,15,19]	0.996	53.954^{L}

The Test 1 [data sources], Test 2 [data sources], and Test 3 [data sources] columns indicate each test that was used and the referenced sources that contributed to the data. Table 5 describes the mean clinimetric properties of combined physical ACJ tests in series.
ACJ: acromioclavicular joint; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy Test; LR+: positive likelihood ratio; LR−: negative likelihood ratio; PxS: Paxinos Sign
Likelihood ratio interpretations:
v: very small, usually unimportant.
s: small, sometimes important.
m: moderate, usually important.
L: large, often conclusive.

Table 6. Sensitivity and negative likelihood ratios of three combined physical ACJ tests in parallel.

Test 1 [data sources]	Test 2 [data sources]	Test 3 [data sources]	Sensitivity	LR−
CBA [1,11–13,15]	HKT [12,13]	PxS [11,19]	0.972	0.118^{m}
CBA [1,11–13,15]	ACT [11–13,19]	PxS [11,19]	0.964	0.071^{L}
CBA [1,11–13,15]	ACJT [1,12,15,19]	PxS [11,19]	0.970	0.069^{L}
HKT [12,13]	ACJT [1,12,15,19]	PxS [11,19]	0.973	0.103^{m}
HKT [12,13]	ACT [11–13,19]	CBA [1,11–13,15]	0.904	0.345^{s}
HKT [12,13]	ACJT [1,12,15,19]	CBA [1,11–13,15]	0.918	0.337^{s}
HKT [12,13]	ACJT [1,12,15,19]	ACT [11–13,19]	0.907	0.301^{s}
HKT [12,13]	PxS [11,19]	ACT [11–13,19]	0.969	0.106^{m}
ACT [11–13,19]	ACJT [1,12,15,19]	CBA [1,11–13,15]	0.895	0.201^{s}
ACT [11–13,19]	PxS [11,19]	ACJT [1,12,15,19]	0.966	0.062^{L}

The Test 1 [Data sources], Test 2 [Data sources], and Test 3 [Data sources] columns indicate each test that was used and the referenced sources that contributed to the data. Table 6 describes the mean clinimetric properties of combined physical ACJ tests in parallel.
ACJ: acromioclavicular joint; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy test; LR+: positive likelihood ratio; LR−: negative likelihood ratio; PxS: Paxinos Sign
Likelihood ratio interpretations:
v: very small, usually unimportant
s: small, sometimes important
m: moderate, usually important
L: large, often conclusive

ACJ tests in series or in parallel does yield increased clinimetric properties, this process also increases patient discomfort, which may harm the therapeutic alliance. Utilizing clinical reasoning, information obtained from the history, and three tests in series should be sufficient to diagnose an individual with ACJ related pain.

Limitations and strengths

Limitations of this systematic review are the current studies investigating clinical examination tests for ACJ pathology have variable methods, patient chronicities, mechanisms of injury, reference standards, statistical analyses, and interpretations [1,11–20]. Three studies did not specify the chronicity [1,15,19], Bezruchenko et al. specified acute traumatic ACJ sprains [11], Chronopoulos et al. specified chronic [13], and Cadogan et al. specified subacute and chronic [12]. Another potential limitation is PxS [11,18,19] has the smallest population represented in the conclusion ($N = 189$), which should be considered when evaluating its diagnostic utility. A final limitation of this systematic review is most studies included in the analysis were conducted in either orthopedic surgery clinics [6,11,13,15,18] or shoulder clinics [13,14,16,19], which may not accurately reflect the general population.

Although mentioned with the limitations, varying chronicities and mechanisms of injury could also be seen as a strength that increases test generalizability. Other strengths include the agreement on the included articles after independent review, and the inclusion of recent literature. Moreover, by including all available data that met our inclusion criteria, it becomes clear how each study's findings skew the overall diagnostic utility of each test. Similarly, our qualitative analysis limited the risk of low-quality data biasing our results. This analysis maximizes the validity of our findings, and thus the clinical utility.

Conclusion

This systematic review addresses the role of clinical examination tests to identify ACJ related pain. Synthesis of the current data suggests single clinical examination tests are of limited value in identifying the presence or absence of pain of ACJ origin. In the clinical examination process, combining ACT, ACJT, and PxS, in series or in parallel, offer an inexpensive and low risk alternative for ruling in or out pain of ACJ origin.

Disclosure statement

The authors report there are no competing interests to declare.

Disclaimer

None.

Institutional review board

N/A.

Ethical committee approval

N/A.

Appendix I. Search.

Appendix I states the search terms used for PubMed and Scopus databases, respectively. Appendix I also states the number of results obtained from each database.

Results: 31

("diagnostic"[tiab] OR "diagnosis"[tiab] OR "diagnos*"[tiab] OR "diagnose"[tiab] OR "diagnostic Test*" [tiab] OR diagnostic Test[MeSH Terms] OR diagnostic Test[MeSH Major Topic] OR diagnosis[MeSH Major Topic]) AND ("ACJ"[All Fields] OR "AC Joint"[All Fields] OR "acromioclavicular"[All Fields] OR "ACJ pain"[All Fields] OR "acromioclavicular joint pain"[All Fields] OR "AC joint pain"[All Fields] OR "AC joint pathology"[All Fields] OR "acromioclavicular joint pathology"[All Fields] OR "ACJ pathology"[All Fields] OR "AC joint sprain"[All Fields] OR "ACJ sprain"[All Fields] OR "acromioclavicular joint sprain"[All Fields] OR "AC joint dislocation"[All Fields] OR "ACJ dislocation"[All Fields] OR "acromioclavicular joint dislocation"[All Fields] OR "AC joint injury"[All Fields] OR "ACJ injury"[All Fields] OR "acromioclavicular joint injury"[All Fields] OR "ACJ OA"[All Fields] OR "acromioclavicular joint OA"[All Fields] OR "AC joint OA"[All Fields] OR "ACJ osteoarthritis"[All Fields] OR "acromioclavicular joint osteoarthritis"[All Fields] OR "AC joint osteoarthritis"[All Fields]) AND ("active compression"[All Fields] OR "o brien s test"[All Fields] OR "o brien s test"[All Fields] OR "cross body adduction"[All Fields] OR "cross body adduction"[All Fields] OR "ACJ Tenderness"[All Fields] OR "acromioclavicular tenderness"[All Fields] OR "Paxinos test"[All Fields] OR "Paxinos sign"[All Fields] OR "resisted acromioclavicular joint extension"[All Fields] OR "resisted AC joint extension"[All Fields] OR "resisted ACJ extension"[All Fields] OR "resisted acromioclavicular extension"[All Fields] OR "resisted AC extension"[All Fields] OR "resisted AC extension"[All Fields] OR " acromioclavicular joint resisted extension"[All Fields] OR "AC joint resisted extension"[All Fields] OR "ACJ resisted extension"[All Fields] OR "hawkins kennedy"[All Fields] OR "hawkins kennedy"[All Fields] OR "Hawkins impingement"[All Fields] OR "hawkin"[All Fields] OR "kennedy"[All Fields] OR "painful arc II"[All Fields] OR "painful arc sign"[All Fields] OR "painful arc"[All Fields])

SCOPUS

Results: 767

('diagnostic' OR 'diagnosis' OR 'diagnos*' OR "diagnose"OR "diagnostic Test*" OR diagnostic Test OR diagnostic Test OR diagnosis) AND ("ACJ" OR "AC Joint" OR "acromioclavicular" OR "ACJ pain" OR "acromioclavicular joint pain" OR "AC joint pain" OR "AC joint pathology" OR "acromioclavicular joint pathology" OR "ACJ pathology" OR "AC joint sprain" OR "ACJ sprain" OR "acromioclavicular joint sprain" OR "AC joint dislocation" OR "ACJ dislocation" OR "acromioclavicular joint dislocation" OR "AC joint injury" OR "ACJ injury" OR "acromioclavicular joint injury" OR "ACJ OA" OR "acromioclavicular joint OA" OR "AC joint OA" OR "ACJ osteoarthritis" OR "acromioclavicular joint osteoarthritis" OR "AC joint osteoarthritis") AND ("active compression" OR "o brien s test" OR "o brien s test" OR "cross body adduction" OR "cross body adduction" OR "ACJ Tenderness"OR "acromioclavicular tenderness" OR "Paxinos test" OR "Paxinos sign" OR "resisted acromioclavicular joint extension" OR "resisted AC joint extension" OR "resisted ACJ extension" OR "resisted acromioclavicular extension" OR "resisted AC extension" OR "resisted AC extension" OR "acromioclavicular joint resisted extension"OR "AC joint resisted extension" OR "ACJ resisted extension"OR "hawkins kennedy" OR "hawkins kennedy" OR "Hawkins impingement"OR "hawkin" OR "kennedy" OR "painful arc II" OR "painful arc sign" OR "painful arc")

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Appendix II. The formulae for calculating clinimetric properties in series and in parallel as described by Krill et al. [4], modified for additional tests.

In Series Testing (2 tests)	Sensitivity = Sensitivity Test A × Sensitivity Test B	Specificity = (Specificity Test A + Specificity Test B) − (Specificity Test A × Specificity Test B)
In Parallel Testing (2 tests)	Sensitivity = (Sensitivity Test A + Sensitivity Test B) − (Sensitivity Test A × Sensitivity Test B)	Specificity = Specificity Test A × Specificity Test B
[redacted]	[redacted]	[redacted]
In Series Testing (3 tests)	Sensitivity = (Sensitivity Test A × Sensitivity Test B) × Sensitivity Test C	Specificity = (Specificity Test AB + Specificity Test C) − (Specificity Test AB × Specificity Test C)
In Parallel Testing (3 tests)	Sensitivity = (Sensitivity Test AB + Sensitivity Test C) − (Sensitivity Test AB × Sensitivity Test C)	Specificity = (Specificity Test A × Specificity Test B) x Specificity Test C

Appendix II details the calculations for composite sensitivity and specificity through series and parallel analysis.

Appendix III. Stratification of LRs based on shifts in probability that a condition is present [34].

Shift in probability	LR+	LR−
Very small, usually unimportant shifts in probability a condition is present.	≤ 2	≥ 0.5
Small, sometimes important shifts in probability a condition is present	$2 < x \leq 5$	$0.2 \leq x < 0.5$
Moderate, but usually important shifts in probability a condition is present	$5 \leq x \leq 10$	$0.1 \leq x < 0.2$
Large, often conclusive shift in probability a condition is present	>10	<0.1

Appendix III details the stratification system developed by Jaeschke et al. [34] detailing the importance of the LRs impact on post-test probability based on the numerical values.

Appendix IV. Studies, total participants, clinical examination tests, and reference standards.

Title	Author	Year	N	Physical ACJ diagnostic test(s) performed	Reference standard
Diagnostic values of tests for acromioclavicular joint pain	Walton et al.	2004	38	-ACT -ACJT -PxS	Infiltration test radiograph
Shoulder pain in primary care: diagnostic accuracy of clinical examination tests for non-traumatic acromioclavicular joint pain	Cadogan et al.	2013	153	-CBA test -ACT -ACJT -HKT	Fluoroscopically guided intra-articular ACJ diagnostic injection
Diagnostic value of physical tests for isolated chronic acromioclavicular lesions	Chronopoulos et al.	2004	880	-CBA test -ACT -HKT	Diagnostic arthroscopy
The active compression test: a new and effective test for diagnosing labral tears and acromioclavicular joint abnormality	O'Brien et al.	1998	318	-ACT	Various combinations of radiographs, MRIs, and surgical data
Seven-year course of asymptomatic acromioclavicular osteoarthritis diagnosed by mri	Frigg et al.	2019	114	-CBA test -ACJT	MRI
The effect of acromioclavicular joint degeneration on orthopedic shoulder tests	Ulaşlı et al.	2013	62	-CBA test -HKT	US or MRI
Bony edema and clinical examination findings predict the need for distal clavicle excision at the time of shoulder arthroscopy	Garry et al.	2022	400	-ACJT -CBA	MRI
Correlation of findings in clinical and high resolution ultrasonography examinations of the painful shoulder	Micheroli et al.	2015	100	-ACJT -CBA test	High resolution US
Clinical evaluation of acj pathology-sensitivity of a new test	van Riet and Bell	2011	58	-CBA test -ACT -PxS	Radiograph, US, or MRI
Role of ac arthritis in impingement syndromes	Gürbüz et al.	1998	27	-Horizontal adduction test	Radiograph and lidocaine injection test
Critical evaluation and instrumental diagnostics in acute ACJ dislocation	Bezruchenko et al.	2022	151	-PxS -CBA -ACT	Surgical

Appendix IV displays the articles that this article utilized in the data analysis. Appendix IV also depicts the first author, the year of publication, and the total number of participants within each study. Lastly, Appendix IV denotes the physical ACJ diagnostic tests performed within and the reference standard for each study that contributed to the data analysis.
AC: acromioclavicular; ACJ: acromioclavicular joint; *N*: number of participants; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins – Kennedy test; PxS: Paxinos Sign

Appendix V. Specificity and positive likelihood ratios of two combined physical ACJ tests in series (all data).

Test 1 [Data sources]	Test 2 [Data sources]	Specificity	LR+
CBA [1,12–13,15]	HKT [12,13]	0.840195	2.013806
CBA [1,12–13,15]	HKT^{P} [12,13,17]	0.840195	2.736853
CBA [1,12–13,15]	HKT^{N} [12,13,17]	0.840195	0.889477
CBA [1,12–13,15]	ACT [11–13,19]	0.975296	10.56313
CBA [1,12–13,15]	ACT [11–13,16,18,19]	0.981301	18.95287
CBA [1,12–13,15]	ACJT [1,12,15,19]	0.942857	5.295331
CBA [1,12–13,15]	ACJT^{B} [1,12,14,15,18,19]	0.942857	4.882445
CBA [1,12–13,15]	ACJT^{F} [1,12,14,15,18,19]	0.942857	4.970417
CBA [1,12–13,15]	PxS [11,19]	0.935554	7.138592
CBA [1,12–13,15]	PxS [11,18,19]	0.935554	5.142806
CBA^{PF} [1,11–15,17,18,20]	HKT [12,13]	0.840195	2.013737
CBA^{PF} [1,11–15,17,18,20]	HKT^{P}[12,13,17]	0.840195	2.73676
CBA^{PF} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.840195	0.889447
CBA^{PF} [1,11–15,17,18,20]	ACT [11–13,19]	0.975296	10.56277
CBA^{PF} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.981301	18.95223
CBA^{PF} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.942857	5.295151
CBA^{PF} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.942857	4.882278
CBA^{PF} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.942857	4.970247
CBA^{PF} [1,11–15,17,18,20]	PxS [11,19]	0.935554	7.138348
CBA^{PF} [1,11–15,17,18,20]	PxS [11,18,19]	0.935554	5.14263
CBA^{NF} [1,11–15,17,18,20]	HKT [12,13]	0.840195	1.800361
CBA^{NF} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.840195	2.446772
CBA^{NF} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.840195	0.795201
CBA^{NF} [1,11–15,17,18,20]	ACT [11–13,19]	0.975296	9.443539
CBA^{NF} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.981301	16.94404
CBA^{NF} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.942857	4.734075
CBA^{NF} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.942857	4.364951
CBA^{NF} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.942857	4.443598
CBA^{NF} [1,11–15,17,18,20]	PxS [11,19]	0.935554	6.381967
CBA^{NF} [1,11–15,17,18,20]	PxS [11,18,19]	0.935554	4.597716
CBA^{PB} [1,11–15,17,18,20]	HKT [12,13]	0.840195	1.942612
CBA^{PB} [1,11–15,17,18,20]	HKT^{P}[12,13,17]	0.840195	2.640097
CBA^{PB} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.840195	0.858032
CBA^{PB} [1,11–15,17,18,20]	ACT [11–13,19]	0.975296	10.1897
CBA^{PB} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.981301	18.28283
CBA^{PB} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.942857	5.108126
CBA^{PB} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.942857	4.709836
CBA^{PB} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.942857	4.794697
CBA^{PB} [1,11–15,17,18,20]	PxS [11,19]	0.935554	6.886221
CBA^{PB} [1,11–15,17,18,20]	PxS [11,18,19]	0.935554	4.960992
CBA^{NB} [1,11–15,17,18,20]	HKT[12,13]	0.840195	1.729236
CBA^{NB} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.840195	2.350109
CBA^{NB} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.840195	0.763785
CBA^{NB} [1,11–15,17,18,20]	ACT [11–13,19]	0.975296	9.070461
CBA^{NB} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.981301	16.27465
CBA^{NB} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.942857	4.54705
CBA^{NBn}[1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.942857	4.192508
CBA^{NBn}[1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.942857	4.268049
CBA^{NBn}[1,11–15,17,18,20]	PxS [11,19]	0.935554	6.12984
CBA^{NBn}[1,11–15,17,18,20]	PxS [11,18,19]	0.935554	4.416078
HKT [12,13]	ACT [11–13,19]	0.948889	5.608947
HKT [12,13]	ACT [11–13,16,18,19]	0.961313	10.06384
HKT [12,13]	ACJT [1,12,15,19]	0.881776	2.811783
HKT [12,13]	ACJT^{B} [1,12,14,15,18,19]	0.881776	2.592543
HKT [12,13]	ACJT^{F} [1,12,14,15,18,19]	0.881776	2.639255
HKT [12,13]	PxS [11,19]	0.866667	3.790541
HKT [12,13]	PxS [11,18,19]	0.866667	2.730793
HKT^{P} [12,13,17]	ACT [11–13,19]	0.948889	7.622812
HKT^{P} [12,13,17]	ACT [11–13,16,18,19]	0.961313	13.67721
HKT^{P} [12,13,17]	ACJT [1,12,15,19]	0.881776	3.821339
HKT^{P} [12,13,17]	ACJT^{B} [1,12,14,15,18,19]	0.881776	3.523382
HKT^{P} [12,13,17]	ACJT^{F} [1,12,14,15,18,19]	0.881776	3.586867
HKT^{P} [12,13,17]	PxS [11,19]	0.866667	5.151515
HKT^{P} [12,13,17]	PxS [11,18,19]	0.866667	3.71127
HKT^{N} [12,13,17]	ACT [11–13,19]	0.948889	2.477414
HKT^{N} [12,13,17]	ACT [11–13,16,18,19]	0.961313	4.445093
HKT^{N} [12,13,17]	ACJT [1,12,15,19]	0.881776	1.241935
HKT^{N} [12,13,17]	ACJT^{B} [1,12,14,15,18,19]	0.881776	1.145099
HKT^{N} [12,13,17]	ACJT^{F} [1,12,14,15,18,19]	0.881776	1.165732
HKT^{N} [12,13,17]	PxS [11,19]	0.866667	1.674242
HKT^{N} [12,13,17]	PxS [11,18,19]	0.866667	1.206163
ACT [11–13,19]	ACJT [1,12,15,19]	0.981724	14.74881
ACT [11–13,19]	ACJT^{B} [1,12,14,15,18,19]	0.981724	13.59882
ACT [11–13,19]	ACJT^{F} [1,12,14,15,18,19]	0.981724	13.84384
ACT [11–13,19]	PxS [11,19]	0.979388	19.88274
ACT [11–13,19]	PxS [11,18,19]	0.979388	14.32399
ACT [11–13,16,18,19]	ACJT [1,12,15,19]	0.986166	26.46301
ACT [11–13,16,18,19]	ACJT^{B} [1,12,14,15,18,19]	0.986166	24.39964
ACT [11–13,16,18,19]	ACJT^{F} [1,12,14,15,18,19]	0.986166	24.83927
ACT [11–13,16,18,19]	PxS [11,19]	0.984398	35.67456
ACT [11–13,16,18,19]	PxS [11,18,19]	0.984398	25.70077
ACJT [1,12,15,19]	PxS [11,19]	0.952323	9.96728
ACJT [1,12,15,19]	PxS [11,18,19]	0.952323	7.180658
ACJT^{B} [1,12,14,15,18,19]	PxS [11,19]	0.952323	9.190113
ACJT^{B} [1,12,14,15,18,19]	PxS [11,18,19]	0.952323	6.620769
ACJT^{F} [1,12,14,15,18,19]	PxS [11,19]	0.952323	9.355701
ACJT^{F} [1,12,14,15,18,19]	PxS [11,18,19]	0.952323	6.740062

The Test 1 [data sources] and Test 2 [data sources] columns indicate each test that was used and the referenced sources that contributed to the data. The superscript letters within that column denote how the data for a test were stratified. Appendix V describes the mean clinimetric properties of all amalgamations used when combining physical ACJ tests in series.

N: Mild data counts as a negative response [17].

P: Mild data counts as a positive response [17].

B: Baseline data [14].

F: Follow up data [14].

ACJ: acromioclavicular joint; LR+: positive likelihood ratio; LR–: negative likelihood ratio; ACJT: acromioclavicular joint tenderness; ACT: active compression test; CBA: cross body adduction; HKT: Hawkins–Kennedy test; LR+: positive likelihood ratio; LR–: negative likelihood ratio; PxS: Paxinos Sign

Likelihood ratio interpretations:

v: very small, usually unimportant.

s: small, sometimes important.

m: moderate, usually important.

L: Large, often conclusive.

Appendix VI. Sensitivity and negative likelihood ratios of two combined physical ACJ tests in parallel.

Test 1 [data sources]	Test 2 [data sources]	Sensitivity	LR–
CBA [1,11–13,15]	HKT [12,13]	0.814015	0.606045
CBA [1,11–13,15]	HKT^{P} [12,13,17]	0.911955	0.286902
CBA [1,11–13,15]	HKT^{N} [12,13,17]	0.66172	1.102308
CBA [1,11–13,15]	ACT [11–13,19]	0.762426	0.361113
CBA [1,11–13,15]	ACT [11–13,16,18,19]	0.841637	0.235136
CBA [1,11–13,15]	ACJT [1,12,15,19]	0.797718	0.352644
CBA [1,11–13,15]	ACJT^{B} [1,12,14,15,18,19]	0.77772	0.387508
CBA [1,11–13,15]	ACJT^{F} [1,12,14,15,18,19]	0.781981	0.38008
CBA [1,11–13,15]	PxS [11,19]	0.931186	0.124071
CBA [1,11–13,15]	PxS [11,18,19]	0.822165	0.320632
CBA^{PF} [1,11–15,17,18,20]	HKT [12,13]	0.814008	0.606069
CBA^{PF} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.911951	0.286914
CBA^{PF} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.661707	1.102352
CBA^{PF} [1,11–15,17,18,20]	ACT [11–13,19]	0.762417	0.361127
CBA^{PF} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.841631	0.235146
CBA^{PF} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.79771	0.352659
CBA^{PF} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.777711	0.387524
CBA^{PF} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.781972	0.380095
CBA^{PF} [1,11–15,17,18,20]	PxS [11,19]	0.931183	0.124076
CBA^{PF} [1,11–15,17,18,20]	PxS [11,18,19]	0.822158	0.320645
CBA^{NF} [1,11–15,17,18,20]	HKT [12,13]	0.790759	0.681828
CBA^{NF} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.900945	0.322778
CBA^{NF} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.61942	1.240146
CBA^{NF} [1,11–15,17,18,20]	ACT [11–13,19]	0.732719	0.406268
CBA^{NF} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.821834	0.264539
CBA^{NF} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.772424	0.396741
CBA^{NF} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.749925	0.435964
CBA^{NF} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.754719	0.427607
CBA^{NF} [1,11–15,17,18,20]	PxS [11,19]	0.922581	0.139585
CBA^{NF} [1,11–15,17,18,20]	PxS [11,18,19]	0.799928	0.360725
CBA^{PB} [1,11–15,17,18,20]	HKT [12,13]	0.806258	0.631322
CBA^{PB} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.908282	0.298868
CBA^{PB} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.647611	1.148284
CBA^{PB} [1,11–15,17,18,20]	ACT [11–13,19]	0.752517	0.376174
CBA^{PB} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.835032	0.244943
CBA^{PB} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.789282	0.367353
CBA^{PB} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.768449	0.403671
CBA^{PB} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.772888	0.395933
CBA^{PB} [1,11–15,17,18,20]	PxS [11,19]	0.928315	0.129245
CBA^{PB} [1,11–15,17,18,20]	PxS [11,18,19]	0.814748	0.334005
CBA^{NB} [1,11–15,17,18,20]	HKT [12,13]	0.783009	0.707081
CBA^{NB} [1,11–15,17,18,20]	HKT^{P} [12,13,17]	0.897276	0.334733
CBA^{NB} [1,11–15,17,18,20]	HKT^{N} [12,13,17]	0.605324	1.286078
CBA^{NB} [1,11–15,17,18,20]	ACT [11–13,19]	0.72282	0.421315
CBA^{NB} [1,11–15,17,18,20]	ACT [11–13,16,18,19]	0.815236	0.274337
CBA^{NB} [1,11–15,17,18,20]	ACJT [1,12,15,19]	0.763995	0.411435
CBA^{NB} [1,11–15,17,18,20]	ACJT^{B} [1,12,14,15,18,19]	0.740663	0.452111
CBA^{NB} [1,11–15,17,18,20]	ACJT^{F} [1,12,14,15,18,19]	0.745634	0.443444
CBA^{NB} [1,11–15,17,18,20]	PxS [11,19]	0.919713	0.144755
CBA^{NB} [1,11–15,17,18,20]	PxS [11,18,19]	0.792517	0.374085
HKT [12,13]	ACT [11–13,19]	0.790058	0.542175
HKT [12,13]	ACT [11–13,16,18,19]	0.860056	0.353033
HKT [12,13]	ACJT [1,12,15,19]	0.821245	0.52946
HKT [12,13]	ACJT^{B} [1,12,14,15,18,19]	0.803573	0.581805
HKT [12,13]	ACJT^{F} [1,12,14,15,18,19]	0.807338	0.570652
HKT [12,13]	PxS [11,19]	0.939189	0.18628
HKT [12,13]	PxS [11,18,19]	0.842848	0.481396
HKT^{P} [12,13,17]	ACT [11–13,19]	0.900613	0.256666
HKT^{P} [12,13,17]	ACT [11–13,16,18,19]	0.93375	0.167126
HKT^{P} [12,13,17]	ACJT [1,12,15,19]	0.915377	0.250647
HKT^{P} [12,13,17]	ACJT^{B} [1,12,14,15,18,19]	0.907011	0.275427
HKT^{P} [12,13,17]	ACJT^{F} [1,12,14,15,18,19]	0.908794	0.270147
HKT^{P} [12,13,17]	PxS [11,19]	0.971212	0.088185
HKT^{P} [12,13,17]	PxS [11,18,19]	0.925604	0.227893
HKT^{N} [12,13,17]	ACT [11–13,19]	0.618146	0.986137
HKT^{N} [12,13,17]	ACT [11–13,16,18,19]	0.745462	0.642117
HKT^{N} [12,13,17]	ACJT [1,12,15,19]	0.674871	0.963012
HKT^{N} [12,13,17]	ACJT^{B} [1,12,14,15,18,19]	0.642728	1.058219
HKT^{N} [12,13,17]	ACJT^{F} [1,12,14,15,18,19]	0.649576	1.037933
HKT^{N} [12,13,17]	PxS [11,19]	0.889394	0.338815
HKT^{N} [12,13,17]	PxS [11,18,19]	0.714164	0.875591
ACT [11–13,19]	ACJT [1,12,15,19]	0.771662	0.31548
ACT [11–13,19]	ACJT^{B} [1,12,14,15,18,19]	0.749088	0.346669
ACT [11–13,19]	ACJT^{F} [1,12,14,15,18,19]	0.753898	0.340024
ACT [11–13,19]	PxS [11,19]	0.922321	0.110995
ACT [11–13,19]	PxS [11,18,19]	0.799258	0.286841
ACT [11–13,16,18,19]	ACJT [1,12,15,19]	0.847793	0.205422
ACT [11–13,16,18,19]	ACJT^{B} [1,12,14,15,18,19]	0.832746	0.225731
ACT [11–13,16,18,19]	ACJT^{F} [1,12,14,15,18,19]	0.835952	0.221404
ACT [11–13,16,18,19]	PxS [11,19]	0.948221	0.072274
ACT [11–13,16,18,19]	PxS [11,18,19]	0.866188	0.186774
ACJT [1,12,15,19]	PxS [11,19]	0.933861	0.108392
ACJT [1,12,15,19]	PxS [11,18,19]	0.829078	0.280114
ACJT^{B} [1,12,14,15,18,19]	PxS [11,19]	0.927322	0.119108
ACJT^{B} [1,12,14,15,18,19]	PxS [11,18,19]	0.81218	0.307807
ACJT^{F} [1,12,14,15,18,19]	PxS [11,19]	0.928715	0.116825
ACJT^{F} [1,12,14,15,18,19]	PxS [11,18,19]	0.815781	0.301907

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