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REVIEW ARTICLE

Clinical methods of dynamic and quantitative evaluation of the shoulder and scapula complex: a scoping review

Métodos clínicos de avaliação dinâmica e quantitativa do complexo ombro e escápula: uma revisão de escopo

Métodos clínicos de evaluación dinámica y cuantitativa del complejo del hombro y escápula: una revisión de alcance

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ABSTRACT | The shoulder joint has the greatest range of motion and is the most susceptible to dysfunction. Dynamic and quantitative evaluations of this region provide better information for the clinic but the choice of the method depends on its measurement properties. This study aimed to identify the existing methods of quantitative dynamic evaluation of the shoulder and scapula complex, in a clinical context for the general population, identifying the measurement properties and outcomes of each method. The scoping review included *in vivo* studies, with samples without a specific clinical condition and involving applicable methods in a clinical context. We identified evaluated outcome, measurement method, and its measurement properties. We selected 29 studies that investigated 12 measurement methods, and evaluated their validity and reliability for 17 different outcomes. Most studies (n=21) addressed the position of the shoulder and the scapula and the derivative outcomes, using mainly the units of inertial measurement (n=5) and inertial magnetic measurement (n=6) as evaluation methods. The outcomes with valid and reliable methods were: shoulder joint range; scapula and shoulder motion range; muscle activity; shoulder joint center; humerus length; torque-time curve; functional performance; scapular dyskinesia; external shoulder rotators force; shoulder joint functionality and range; initial scapular movement; scapula and shoulder position; and shoulder angular velocity.

Keywords | Reproducibility of Results; Range of Motion, Articular; Evaluation Studies as Topic.

RESUMO | A articulação do ombro possui a maior amplitude de movimento e está mais suscetível a disfunções. Avaliações dinâmicas e quantitativas dessa região fornecem melhores informações para a clínica, mas a escolha do método a ser utilizado depende de suas propriedades de medição. O objetivo deste estudo foi identificar os métodos existentes de avaliação dinâmica quantitativa do complexo ombro e escápula em um contexto clínico para a população em geral, identificando as propriedades de medição e os desfechos avaliados para cada método. A revisão de escopo incluiu estudos *in vivo*, com amostras sem uma condição clínica específica e envolvendo métodos aplicáveis em um contexto clínico. Foram identificados: desfecho avaliado, método de medição e suas propriedades de medição. Foram selecionados 29 estudos que investigaram 12 métodos de medição, sendo avaliadas sua validade e confiabilidade para 17 desfechos diferentes. A posição do ombro e da escápula e os desfechos derivados foram abordados pelo maior número de estudos (n=21), sendo seus principais métodos de avaliação as unidades de medição inercial (n=5) e unidades de medição magnética inercial (n=6). Os desfechos que apresentaram métodos válidos e confiáveis foram: amplitude articular de ombro; amplitude de movimento da escápula e do ombro; atividade muscular; centro articular do ombro; comprimento do úmero; curva torque-tempo;

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desempenho funcional; discinesia escapular; força de rotadores externos do ombro; funcionalidade e amplitude articular; movimento escapular inicial; posição da escápula e do ombro; e velocidade angular do ombro.
Descritores | Reprodutibilidade dos Testes; Amplitude de Movimento Articular; Estudos de Avaliação como Assunto.

RESUMEN | La articulación del hombro tiene la mayor amplitud de movimiento y es más susceptible a disfunciones. Las evaluaciones dinámicas y cuantitativas de esta región proporcionan mejores informaciones para la clínica, pero la elección del método a utilizar depende de sus propiedades de medición. El objetivo de este estudio fue identificar los métodos existentes de evaluación dinámica cuantitativa del complejo del hombro y escápula en un contexto clínico para la población general, identificando las propiedades de medición y los resultados evaluados para cada método. La revisión de alcance incluyó estudios *in vivo*, con muestras sin una condición clínica específica y con métodos aplicables en un contexto clínico. Se identificaron el resultado evaluado, el método de medición y sus propiedades de medición. Se seleccionaron 29 estudios que investigaron 12 métodos de medición, y se evaluó su validez y confiabilidad para 17 resultados diferentes. La posición del hombro y de la escápula, y los resultados derivados fueron abordados por el mayor número de estudios (n=21), y sus principales métodos de evaluación fueron las unidades de medición inercial (n=5) y las unidades de medición magnética inercial (n=6). Los resultados que presentaron métodos válidos y confiables fueron: amplitud articular del hombro; amplitud de movimiento de la escápula y del hombro; actividad muscular; centro articular del hombro; longitud del húmero; curva torque-tiempo; desempeño funcional; discinesia escapular; fuerza de los rotadores externos del hombro; funcionalidad y amplitud articular; movimiento escapular inicial; posición de la escápula y del hombro; y velocidad angular del hombro.
Palabras clave | Reproductibilidad de los Resultados; Rango del Movimiento Articular; Estudios de Evaluación como Asunto.

INTRODUCTION

The scapulothoracic and sternoclavicular synovial, acromioclavicular and glenohumeral physiological joints form the shoulder and scapula complex[1]. This complex has the greatest range of motion in the body, in which kinematics changes are related to musculoskeletal dysfunctions[2-4].

Static evaluations are limited regarding the evaluation of complex movements such as sports and labor gestures as well as daily living activities[2]. Dynamic quantitative evaluation allows for the characterization of 3D kinematics and the measurement of outcomes regarding movement[3,5,6]. This evaluation overcomes the subjectivity of qualitative evaluations such as clinical tests or evaluation scales. However, a clinical evaluation is only adequate if its measurement properties indicate valid and reliable results for the context[7].

This scoping review aimed to identify the methods of quantitative dynamic evaluation of the shoulder and scapula complex in a clinical and generalizable context for the population. Therefore, we established the following study questions: (1) What are the existing clinical methods to perform the dynamic evaluation of shoulder and scapula complex quantitatively? (2) What measurement properties are evaluated in these methods? (3) What outcomes do these methods evaluate?

METHODOLOGY

This is a scoping review, following the guidelines of the evidence synthesis manual of the Joanna Briggs Institute (JBI)[8] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR)[9], without public protocol. Regarding population, were established: *in vivo* studies of populations without a specific clinical condition. For concept: quantitative dynamic evaluation of shoulder and scapula complex. For context: clinical evaluations. As eligibility criteria: publications in peer-reviewed journals of studies that evaluated measurement properties of existing methods. No date or language restrictions have been established. Studies involving laboratory methods and dedicated to unrestricted outcomes to the shoulder and scapula complex were excluded.

The studies were conducted at PubMed, Embase, and Scopus databases in January 2022. Figure 1 shows the descriptors used in PubMed. The search in the other databases used the same descriptors with some adaptations.

#1	Scapula [Mesh] OS Scapula OR Scapulae OR "Shoulder Blade" OR "Shoulder Blades" Shoulder [Mesh] OR Shoulder OR Shoulders
#2	Movement [Mesh] OR Movement OR Movements OR Dynamic OR kinematic [Mesh] OR Kinematic OR "Phenomena, Biomechanical" OR Biomechanics; Biomechanic OR "Biomechanic Phenomena" OR "Biomechanic Phenomenas" OR "Phenomena, Biomechanic"; Phenomenas, Biomechanic" OR Kinematics OR "Functional Test" OR "Funcional Performance"
#3	Quantitative OR Scale OR "Measure; Measurement" OR "Measurements; Evaluation" OR Evaluations OR Rating OR Test OR Tests OR Assessment OR Assessments OR Evaluation OR "Diagnosis, Computer-Assisted/instrumentation" OR "Diagnosis, Computer-Assisted/methods"
#4	"Reproducibility of Results" [Mesh] OR "Reproducibility of Results" OR "Reproducibility of Findings" OR "Reproducibility Of Result" OR "Of Result, Reproducibility" OR "Of Results, Reproducibility" OR "Result, Reproducibility Of" OR "Results, Of" OR "Reproducibility of Finding" OR "Finding Reproducibilities" OR "Finding Reproducibility" OR Reproducibility OR "Reliabilitity of Results" OR "Reliability of Result" OR "Result Realiabilities OR "result Reliability" OR "Reliability" OR "Vality" OR "Validity of Results" OR "Validity of Result" OR "Result Validities" OR "Result Validity" OR "Face Validity" OR "Validity, Face" OR "Reliability and Validity", "Validation Study" [Mesh] OR "Validation Study" OR "Validation Studies"
#5	"Physical Examination" [Mesh] OR Physical Examination OR "Examinations, Physical" OR "Physical Examinations" OR "Physical Exam" OR "Exam, Physical" OR "Exams, Physical" OR "Physical Exams" OR "Examination, Physical" OR "Physical Examinations and Diagnoses" OR Measure OR Measurement OR "Clinical Outcome" OR "Exercise Test"

#1 AND #2 AND #3 AND #4 AND #5

Figure 1. Keywords used in PubMed database

The studies were imported into the Rayyan platform, excluding duplicates. Two evaluators blindly selected the studies, initially considering titles and abstracts and then the full articles. Discordant evaluations were resolved in a meeting, seeking a consensus.

Data were extracted via a form prepared by the research team. Information was extracted regarding: authorship, year of publication, method, measured outcome, and the measurement properties evaluated. The measurement properties were analyzed according to the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN)[10,11]. We did not establish *a priori* criteria to determine the contemplation of each measurement property, accepting what each study indicated.

RESULTS

We identified 373 studies in PubMed, 149 in Embase and 130 in Scopus. After removing duplicates and selecting studies, we included 29 in this scoping review (Figure 2). We identified 12 different evaluation methods for 17 outcomes related to shoulder and scapula complex.

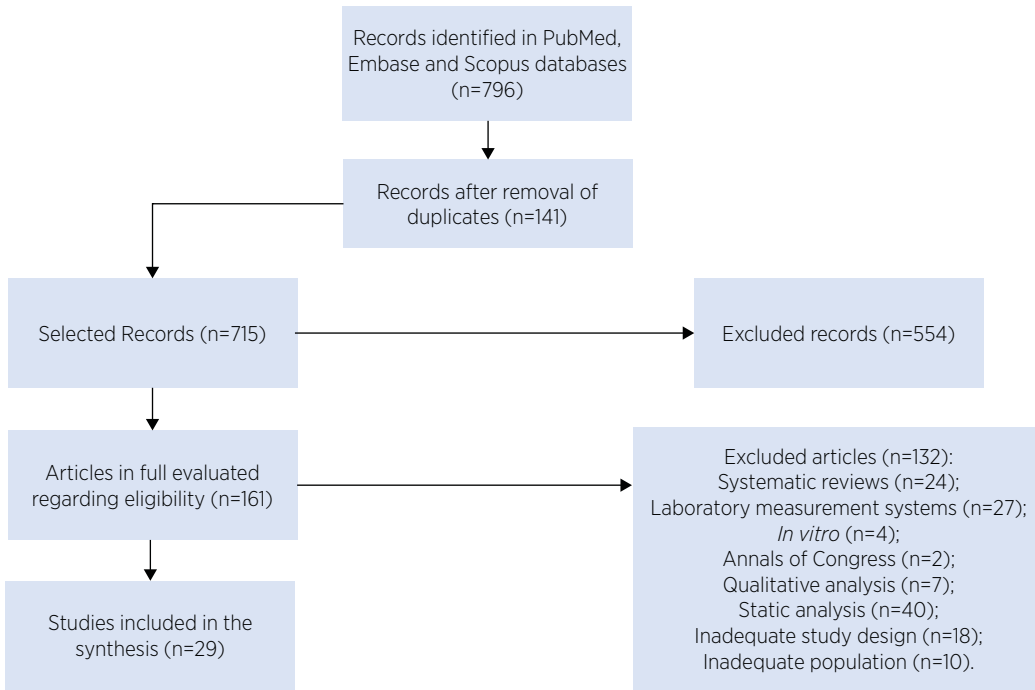

Figure 2. Flowchart of the selection process of this scoping review studies, following the PRISMA-ScR recommendations

Table 1 shows the extracted data. The most common outcomes were those assessing the position of the scapula[4,12,13] or shoulder[12,14-19], as well as derivative measures from the scapula and shoulder: motion range[20-25] resulting from the difference of two positions; joint amplitude[26,27] regarding extreme positions of a movement; and angular velocity measures[15,19,28]. Among the 29 included studies, 18 (62%) evaluated these outcomes. Accelerometers and gyroscopes were the most commonly used devices (56%, n=10), both by inertial measurement units (IMU)[14,15,17,28] and inertial and magnetic measurement units (IMMU)[12,13,18,21,22,25], when combined with magnetometers. These measurement units were also used to evaluate shoulder joint center[29], humerus length[30], torque-time curve[15], and functional performance[31].

Table 1. Data extracted from the studies included in the review

Outcome	Method	Author	Year	Reliability				Validity	
				Repeatability	Intra-rater reproducibility	Inter-rater reproducibility	Other	Concurrent	Hypotheses-testing
Shoulder joint range	Kinect	Lee et al.[27]	2015					O	
		Kuster et al.[26]	2016		O			O	
Scapula range of motion	Electromagnetic sensors	Thigpen et al.[20]	2005	O	O				
	IMMU	Parel et al.[21]	2012		O	O			
		Parel et al.[22]	2014	O				O	
Shoulder range of motion	Kinect	Xu et al.[23]	2017					O	
	Electromagnetic sensors	Jordan et al.[24]	2000		O	O			
	IMMU	Picerno et al.[25]	2019					O	
Muscle activity	Surface electromyography	Seitz and Uhl[32]	2012	O	O				
		Hackett et al.[33]	2014					X	
Shoulder joint center	IMMU	Crabolu et al.[29]	2017	O				O	
Humerus length	IMMU	Crabolu et al.[30]	2018					O	
Torque-time curve	IMU	Picerno et al.[15]	2015	O					
Functional performance	FIT-HaNSA	MacDermid et al.[34]	2007				O	O	O
	IMU	Jolles et al.[31]	2011		O			O	O
Scapular dyskinesis	Video analysis	Totlis et al.[35]	2021	O					O
External shoulder rotators force	Repetition until failure	Popchak et al.[36]	2021		O			X	
	Manual dynamometer	Johansson et al.[37]	2015			O		O	
Shoulder joint functionality and range	ABC loops	Pearl et al.[38]	2014		O	O			
	Mallet Scale				O	O			
Initial scapular movement	Inclinometer	Larsen et al.[39]	2020			X			
Scapula position	Electromagnetic sensors	Haik, Alburquerque-Sendín and Camargo[4]	2014	O	O				
	IMMU	van den Noort et al.[13]	2014		O	O			
		Höglund, Grip and Öhberg[12]	2021				X		
Shoulder position	Video analysis	Melton et al.[19]	2011						O
		Oyama et al.[16]	2017		O	X		X	
	IMU	Picerno et al.[15]	2015	O				O	
		Ertzgaard et al.[17]	2016	O				O	
		Morrow et al.[14]	2017					O	
	IMMU	Zhou et al.[18]	2008					O	
		Höglund, Grip and Öhberg[12]	2021				X		

(continues)

Table 1. Continuation

Outcome	Method	Author	Year	Reliability				Validity	
				Repeatability	Intra-rater reproducibility	Inter-rater reproducibility	Other	Concurrent	Hypotheses-testing
Shoulder angular velocity	Video analysis	Melton et al.[19]	2011	O					O
	IMU	Roldán-Jiménez, Martin-Martin and Cuesta-Vargas[28]	2019					O	
Shoulder mean angular velocity	IMU	Picerno et al.[15]	2015	O					

Validity and reliability: evaluated and acceptable (O); evaluated and not acceptable (X); empty spaces indicate that the property was not evaluated. IMU: inertial measurement units; IMMU: inertial and magnetic measurement units; FIT-HaNSA: Functional Impairment Test-Hand and Neck/Shoulder/Arm.

Among the measurement properties, 21 studies addressed reliability and 20 validity. Also, 12 (41%) studies conducted a associated analysis of validity and reliability. Concurrent validity was verified in 18 studies[14-18,22,23,25-31,33,34,36], the hypotheses-testing in four[19,31,34,35] and two[31,34] studies verified both. Reliability had a more heterogeneous analysis profile. Intra-rater reproducibility was investigated by 10 studies[4,13,16,20,21,24,31,32,36,38], repeatability by 10[4,15,17,19,20,22,26,29,32,35] and inter-rater reproducibility by seven[13,16,21,24,37-39]. No study verified the three reliability properties simultaneously and one[34] evaluated reliability by an unidentified property. Furthermore, a study[12] evaluated another reliability property: reproducibility for different sensor positioning.

DISCUSSION

Concurrent validity requires the agreement of the tested method with a valid reference. Some studies used static[29] or semi-dynamic[27] evaluation methods, which is contradictory when evaluating dynamic methods. The results of dynamic and static evaluations[40] are different, indicating a limitation of studies that use this procedure. Similar limitation occurs among studies dedicated to functional performance that established as reference subjective and/or nonspecific evaluations for the shoulder such as Disabilities of the Arm, Shoulder and Hand (DASH)[31,34]. Since the evaluated methods propose an advance compared with the references[3,5,6], agreement may indicate that this did not occur.

We believe that exploring new validation methods can overcome such limitations. Metrology and psychometrics advanced in their processes based on the incorporation of concepts of the philosophy of measurement—such as the model-based approach and the epistemology of measurement[41]. The dialogue between philosophy and health sciences may offer new possibilities of validation, or even assist in the adaptation of procedures used in other areas, such as convergent and discriminant validity, commonly used in psychometrics[42] and present in some studies included in this review[31,34,35].

Each study had a difficulty in identifying the property of the analyzed measurement. Some studies used different methods to analyze a property under the same term. Others applied similar methodologies, however with different terminologies. Among 29 studies, only four[15,21,22,25] indicated objective criteria for the acceptance of a measurement property. The need for definitions of terms, methodologies, and criteria is a challenge among health measurement and generates methodological guides for researchers[10,11,42]. However, the studies in this scoping review did not use these guides. Therefore, a gap may exist regarding the terms, methodologies, and criteria that should evaluate the methods of measuring clinical phenomena based on physical phenomena, such as the methods present in this study.

CONCLUSION

We identified 12 methods that assess shoulder and scapula outcomes: ABC loops; video analysis; kinect; manual dynamometer; surface electromyography; Mallet scale; FIT-HaNSA; inclinometer; repetition until failure; electromagnetic sensors; IMU; and IMMU. In these methods, the measurement properties evaluated varied in: concurrent validity, hypotheses-testing, repeatability, inter-rater reproducibility, intra-rater reproducibility, and reproducibility for different sensor positions. This study presented a compilation of all existing methods to date and their measurement properties. Based on these data, the health professional can be aware of the adequacy of each method to promote a quantitative dynamic evaluation of the shoulder and scapula complex in a clinical context supporting their choice.

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