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ARTIGO DE REVISÃO

Métodos de avaliação dos movimentos escapulares durante a elevação dos membros superiores: uma revisão crítica da literatura

Methods of Assessment of Scapular Movements during Upper Limb Elevations: Literature Review

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RESUMO

Objetivo: Realizar uma revisão crítica da literatura sobre os métodos utilizados para avaliar os movimentos escapulares durante a elevação dos membros superiores (MMSS) e apontar as vantagens, desvantagens e limitações associadas a cada um deles. Método: Foram realizadas buscas nas bases de dados *MEDLINE, SCIELO, LILACS* e *PEDro* com combinação de palavras-chave relacionadas ao assunto. Os critérios de inclusão para os estudos foram: estar publicado nos idiomas português/espanhol/inglês/francês até o último dia do ano de 2005 e realizar a avaliação dos movimentos escapulares durante a elevação dos MMSS. Foi considerado como critério de exclusão a avaliação dos movimentos escapulares na posição de decúbito. Resultados: Foram encontrados 181 estudos diferentes e, após a verificação dos critérios estabelecidos, selecionaram-se 29 para análise, os quais foram agrupados em 4 categorias distintas: medidas bidimensionais estáticas, bidimensionais dinâmicas, tridimensionais estáticas e tridimensionais dinâmicas. Apesar da diversidade de métodos empregados na avaliação dos movimentos escapulares, ainda não existe um que tenha aplicabilidade clínica e seja capaz de fornecer medidas relacionadas à real cinemática escapular. Outro problema encontrado foi a ausência de padronização na nomenclatura utilizada para descrever os movimentos, planos e eixos. Além disso, os métodos tridimensionais dinâmicos com aplicabilidade em estudos científicos ainda apresentam importantes limitações, como elevado custo, treinamento de pessoal e erros de medidas que podem ser significativos na determinação de alterações da cinemática escapular. Conclusão: é essencial a padronização da nomenclatura dos movimentos e dos planos e eixos em que eles ocorrem e o desenvolvimento de métodos de análises funcionais completas com aplicabilidade clínica, confiáveis e válidos.

PALAVRAS-CHAVE

técnicas de diagnóstico e procedimentos, biomecânica, cinemática, membros superiores, ombro, escápula

ABSTRACT

Objective: To carry out a literature review on methods to assess scapular movements during upper limb elevation and point out their advantages, disadvantages, and limitations. Methods: The search was performed assessing *MEDLINE, SCIELO, LILACS* e *PEDro* databases with key words related to the subject. To be included, the studies would have to be published in Portuguese/English/Spanish/French until the last day of 2005 and have assessed scapular movement during upper limb elevation. The exclusion criterion included assessments in the decubitus position. Results: one hundred eighty-one different studies were found and after the verification of the established criteria, 29 were selected for the analysis, which were divided into four groups: bidimensional static, bidimensional dynamic, three-dimensional static and three-dimensional dynamic assessment methods. Despite the variety of assessment techniques, a method that shows clinical applicability and is able to carry out measurements related to the functional movements of the scapula is yet to be developed. Another problem found was the lack of standardization of the terminology regarding movements, planes and axes. Furthermore, the three-dimensional methods applicable to scientific studies showed important limitations, such as high cost, need for specialized human resources, and measurement errors, which could be significant when determining changes in scapular kinematics. Conclusion: It is essential to standardize the terminology used to describe scapular movements, planes and axes and to develop complete functional assessment methods with clinical applicability, reliability and validity.

KEYWORDS

diagnostic techniques and procedures, biomechanics, kinematics, upper limbs, shoulder, scapula

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INTRODUCTION

The kinematic relation between the joints of the shoulder complex is very important for the function of the upper limbs (UULL) and therefore, it has been increasingly investigated and reported, mainly between the glenohumeral and scapulothoracic joints during the elevation of the UULL[1,2,3], a relation that is classically called scapulohumeral rhythm[2,4]. In addition to collaborating with the wide range of motion (ROM) and allowing a minimum of dynamic stability impairment of the UULL[3], the scapulothoracic joint motion is considered the best way to analyze the movements that occur in the sternoclavicular and acromioclavicular joints[3].

Clinical observations suggest that most syndromes involving the shoulder complex originate from alterations in the coordination of the scapular motion[5]. These disorders are associated with several disabling situations, which can lead to individuals' physical inactivity[6] and quality of life impairment[7].

Due to the aforementioned reasons, several studies on the scapular positioning and motion during the elevation of the UULL in different clinical conditions have been carried out[1, 8-12]. These studies have used diversified methods of evaluation of scapular positioning and displacement during the elevation of the UULL. However, due to the complexity related to such evaluation, such as the shape of the scapula and the difficulty in palpating its bone structures[13], its wide rotation and translation amplitude[14] (different movement directions, plans and axes)[13] and its movement under the skin, the described results are conflicting. For some, many of these studies are compromised due to the limitations of the instruments and methods regarding the analysis-related complexity. All of these facts generate a great discussion in literature about the subject and consequently result in a lack of consensus[2], which compromises clinical decision-making and scientific progress in the area.

OBJECTIVE

Considering: a) the relevance of the full understanding of the human functional movement associated to the shoulder complex to achieve a correct diagnosis and clinical decision-making[5], mainly during the process of rehabilitation of the UULL; b) the importance of scapular movements for the maintenance of this complex integrality and functional performance of the UULL; and c) the diversity and particularities of the methods used for the evaluation of these movements, the aims of the present study were: to perform a critical review of the literature on the methods used to evaluate the scapular movements during the elevation of the UULL and point out advantages, disadvantages and limitations associated to each one of the described methods.

METHOD

Searches were carried out in the MEDLINE, SCIELO, LILACS and PEDro databases, aiming at identifying studies that used methods of evaluation of scapular movement during the elevation of the UULL. A search strategy was established for each one of the databases, using the following combined keywords: escápula (scapula) or ritmo escapuloumeral (scapulohumeral rhythm) or movimento escapuloumeral (scapulohumeral motion) or movimento escapulotorácico (scapulothoracic motion) and cinemática (kinematics) or biomecânica (biomechanics) or movimento (movement, motion), or análise (analysis) or avaliação (assessment or evaluation) or instrumentação (instrumentation).

The inclusion criteria were: study found by the established search strategy, published in the Portuguese, Spanish or English languages until the last day of the year 2005 and having performed the evaluation of scapular movements during the elevation of the UULL. The exclusion criterion was the evaluation of scapular movements in the dorsal decubitus position.

Five phases were used to select the studies according to the established criteria. The first phase consisted of searching the selected databases, followed by the second phase, which consisted of the selection of all studies published in the Portuguese, Spanish or English languages. The third phase consisted of reading the titles of all the studies selected in the first phase by two independent examiners, who were chosen according to the following two criteria: to be a physical therapist and to be involved in research related to scapular movement during the elevation of the UULL. The examiners were selected by convenience and advised to select all studies related to scapular movement evaluation. All of the studies selected by each of the examiners were included in the fourth-phase analysis, which consisted of the reading of all the study abstracts by the same examiners.

The fifth and last phase consisted of the full-text reading of the studies selected in the previous phase by the same examiners, who were instructed to disregard those studies that evaluated scapular movements in the decubitus position.

RESULTS

The search resulted in 181 different studies. Thirty-four studies were excluded in the second phase and 106 in the third phase, and the remaining 41 study abstracts were read by the two examiners. After this phase, 3 studies were excluded, and thus, 38 studies remained for full-text reading and analysis. Of these, six were excluded as they did not evaluate scapular movements during the elevation of the UULL, two for carrying out the evaluation of the individual in the dorsal decubitus position, and one for not being available through any access method up to the development of this study. Thus, this review was carried out with a total of 29 studies, which were grouped in four different categories: static two-dimensional measurements (6 studies), dynamic two-dimensional measurements (2 studies), static three-dimensional measurements (13) and dynamic three-dimensional measurements (10). As two studies used two different evaluation methods, the total number of studies in the categories was 31 (Chart 1).

Static two-dimensional measurements

The present review showed six studies[1,14-17] that used two-dimensional measurement methods of the scapular position in a certain

Chart 1
Studies that were selected for the analysis.

Study – Evaluation method
Static two-dimensional measurements (6 studies)
T'Jonck and Lysens (1996)[18] – Linear measurements – measuring tape
Doody, Freedman, Waterland (1970)[17] – Goniometry
Endo et al (2001)[14] – Digitized radiography
Johnson et al, McClure, Karduna (2001)[15] – Modified digital inclinometer
Mandalidis et al (1999)[16] – Digital fluoroscopy
Bagg and Forrest (1988)[1] – Recording of bone marks in video
Dynamic two-dimensional measurements (2 studies)
Talkhani & Cormac (2001)[13] – Fluoroscopy in video images
Michiels & Grevenstein (1995)[19] – Dynamic radiographies
Static three-dimensional measurements (13 studies)
Warner et al (1992)[20] – Moiré technique
Ludewig et al (1996)[21] – Electromechanical system
Barnett et al (1999)[22] – Electromagnetic system (IsotrakII®)
Kebaetse et al (1999)[23] – Electromechanical system (Metrecom®)
Lukasiewicz et al (1999)[11] – Electromechanical system (Metrecom®)
Meskers et al (1999)[24] – Electromagnetic system (Flock of Birds®)
Wang et al (1999)[25] – Electromechanical system (Metrecom®)
Price et al (2000)[26] – Electromagnetic system (Polhemus®)
Hébert et al (2000)[27] – Infrared markers (Optotrak®)
de Groot & Brand (2001)[28] – Digitized image (system not mentioned)
Price et al (2001)[29] – Electromagnetic system (IsotrakII®)
Hébert et al (2002)[30] – Infrared markers (Optotrak®)
Vermeulen et al (2002)[31] – Electromagnetic system (Flock of Birds®)
Dynamic three-dimensional measurements (10 studies)
Warner et al (1992)[20] – Moiré technique
Johnson et al (2001)[15] – Electromagnetic system (Polhemus FasTrak®)
McQuade et al (1998)[4] – Electromagnetic system (Polhemus FasTrak®)
McQuade & Smidt (1998)[2] – Electromagnetic system (Polhemus FasTrak®)
Karduna et al (2000)[32] – Electromagnetic system (Polhemus FasTrak®)
Ludewig et al (2000)[10] – Electromagnetic system (Polhemus FasTrak®)
Borstad & Ludewig (2002)[8] – Electromagnetic system (Polhemus FasTrak®)
McClure et al (2004)[33] – Electromagnetic system (Polhemus FasTrak®)
Borstad et al Ludewig (2005)[34] – Electromagnetic system (Flock of Birds®)
Ebaugh et al (2005)[9] – Electromagnetic system (Polhemus FasTrak®)

ROM when the UULL are elevated. A very simple evaluation method of scapular abduction was applied in the study by T'Jonck and Lysens[18]. Using a measuring tape, the scapular abduction was determined by the ratio between the linear distance of the lower acromion process to the third thoracic vertebra and the linear distance of the lower acromion process to the medial border of the scapula. All measurements were carried out with the individual sitting down and the upper limb was maintained at 0º, 45º and 90º. The intra-examiner method reliability was higher for the 0 to 45º positions (ICC between 0.78 and 0.90) and lower for the 90º position (ICC between 0.3 and 0.55). The inter-examiner reliability was mostly low, with moderate values for the 45º position (ICC between 0.53 and 0.65)[18].

The goniometer was used in one study and allowed the simultaneous determination of scapular and glenohumeral angles[17]. The scapular movement assessed was not reported, but it could be inferred that the upward scapular rotation angle was measured.

Endo et al[14] evaluated the upward rotation and axial rotation of the scapula through x-rays of the anteroposterior (AP) plane followed by the digitization of the images obtained from the x-rays in a computer, using a scanner.

Johnson, McClure and Karduna[15] modified a digital inclinometer to obtain the two-dimensional measurements of the upward scapular rotation movement. Mandalidis et al[16] used digital fluoroscopy, connected to a microprocessor and a scanner, being the angles of elevation of interest determined by the use of a universal goniometer. No specifically assessed scapular movement was reported, but the interpretation of the reported measurements allowed us to infer that the upward rotation angle was determined.

Finally, Bagg and Forrest[1] used a method of filming bone marks. At each position, anatomical marks were carefully located, identified and filmed. The analysis of the film was carried out by digitizing the images in a movement analyzer followed by processing of the data in a computer software[1].

Dynamic two-dimensional measurements

The two-dimensional measurements of the scapular movements were also carried out dynamically by methods that used radiation emission[13,19]. Talkhani & Cormac[13] applied fluoroscopy, exhibited and recorded in real-time video, during the movement of full elevation. The video images were captured and edited with the help of a computer program, which allowed the use of sequences of static images to calculate the movements of interest. The authors did not specify the scapular movement assessed and determined the movement angulation from the difference between the scapular angle in the beginning and the end of the elevation phase[13], which led us to infer the measurement of the upward scapular rotation. Michiels & Grevenstein[19] used a sequence of x-rays of the shoulder complex obtained during the elevation movement, associated to a real-time image processing and digitizing system. The study did not specify the specific scapular movement that was assessed; however, we could infer that the upward scapular rotation movement was measured, considering how the analysis of the angles was described.

Static three-dimensional measurements

Thirteen studies[11,20-31] applied methods of three-dimensional measurements of the scapular position, in certain elevation ROM of the UULL. All of them used digitized images of the anatomical references.

Of these studies, four used a three-dimensional computerized electromechanical digitizing system. Basically, the phases followed for the data collection were: establishing the global reference system, palpation and digitization of the anatomical marks in moments of interest. The data were recorded in a computer for future three-dimensional angle determination. The Metrecom® system was used in three studies[11,23,25] and consists in articulated arms with potentiometers connected to a computer with a program capable of converting the measurements obtained in X, Y and Z coordinates, thus defining the position of the digitized points. To carry out the study by Ludewig et al[21], an instrument was manufactured, which worked based on three-dimensional electromechanical digitization from information supplied by a pendulum potentiometer. The conversion of data was also carried out by a computer program, especially developed for the study[21].

Systems with electromagnetic technology to capture the scapular movements in three dimensions during maintained positions were used in 7 studies. These systems consisted, basically, of sensors of which positions were taken in at the electromagnetic field emitted by a transmitter. Subsequently, the three-dimensional coordinates of these sensors were calculated by a computer program. The data collection comprehended the definition of the bone marks used, the positioning of the sensors on the anatomical points for calibration of the local coordinate system and for the data collection in the desired positions. One of the systems used was the Flock of Birds®, of which sensors were coupled to a triangular equipment to facilitate the identification of the previously established scapular bone references[24,31]. Another system used was the IsotrakII®, of which sensors were positioned on the Scapular Locator System, a triangular instrument supplied by the manufacturer specifically to allow the palpation and fixed identification of the scapular bone strucutures[22,29]. In addition, a third electromagnetic system was used by one of the studies, called Polhemus®, which also presents a Locator[26].

De Groot & Brand[28] used a digitizing image system related to bone marks. However, the authors did not specify the characteristics of this system.

Two studies were carried out by Hébert et al[27,30] in which they used digitized images of anatomical points obtained with the Optotrak® system. Infrared markers were positioned in specific anatomical points and the images captured at the moments of interest were digitized and processed in a computer. To guide the identification of the scapular points, a triangular apparatus with fixed arms, especially developed for the study, was used.

The other methodology used for the static three-dimensional analysis of scapular movements was based on biostereometry: Moiré's topography technique. It consisted in an optical effect produced when the individual was positioned behind a grid with horizontal lines and illuminated by a source of light. The shaded line was projected by the grid, according to the individual's topography, forming fringed patterns that appear as contour lines, which reflected the asymmetry of the scapulothoracic area. The asymmetrical areas were identified by visual inspection and the differences between the opposite fringe points, equidistant from the median line, were determined by comparison[20].

Dynamic three-dimensional measurements

Ten studies[2,4,8-10,15,20,32-34] used methods capable of supplying information on the scapular movements in three dimensions during the dynamic elevation of the UULL. Of these, 9 used systems with electromagnetic technology.

The most often used system was the Polhemus FasTrak®[2,4,8-10,15,32,33], a three-dimension movement digitizer and receptor, with six degrees of freedom, capable of computing, in real-time, the positions and directions of the small receptors located in space, which took in electromagnetic signals emitted by a transmitter, usually placed on a stationary base[2,4,8-10,15,32,33].

The other system with electromagnetic technology used by one of the studies was the previously described Flock of Birds®, with the addition of miniBird®[34] sensors, with six degrees of freedom capable of instantaneous capture of position and direction of movement in three dimensions, from electromagnetic signals emitted by a transmitter.

The other technology used for the dynamic three-dimensional analysis of scapular movements was based on the topography technique of Moiré, described in the previous item, with the obtainment of a picture of the fringes formed at the moment of interest for later description[20].

DISCUSSION

Different methods have been demonstrated in literature to evaluate scapular movements during the elevation of the UULL. The first significant difference among these methods is related to the amount of information provided: the two-dimensional methods do not describe all of the movements that occur in the scapula during the elevation of the UULL. If, on the one hand, it has been established that these movements are three-dimensional and, therefore, its complete analysis must be carried out when the objective is the functional assessment of UULL during elevation, on the other hand, many previously discussed difficulties are faced during this evaluation. Thus, some studies still present the results of two-dimensional evaluations, with efforts being made towards attaining the validation and reliability of these methods.

The second large difference among these methods is related to their descriptions: static positioning or dynamic displacement data. Conditions that are maintained statically, which can occur during functional activities performed with the shoulder in static positions[25] do not represent a pattern of continuous functional movement[11] and, therefore, the results of static assessments cannot be generalized for dynamic activities[30], although some authors affirm that, in certain situations, such as the elevation of the UULL without load[17], inferences can be made on the dynamic patterns based on the static evaluations, without major problems[11,17].

One of the simplest instruments that had high clinical applicability for the evaluation of the joint movements is the goniometer. Although the validity and reliability of the goniometric technique have been described in the literature[35], the only study found that used this instrument[17] did not mention these properties for the scapular measurements, which generated another limitation for the method, in addition to the fact that it was a static two-dimensional measurement. On the other hand, a similarly simple and clinically applicable instrument, the measuring tape, was used in a study and presented satisfactory intra-examiner reliability for most measurements[18]. However, the validity of the method was not investigated. Additionally, the measurements are static and provide information solely on the scapular abduction[18].

The inclinometer, a hand instrument used to measure the inclination of segments in relation to the horizontal plane[15], also used in clinical practice[36,37], was used by one of the studies to evaluate scapular movements[15].

With the objective of validating a method of a clinically applicable two-dimensional measurement of scapular movements, Johnson et al adapted a digital inclinometer designed to present an accuracy of 0.1º, and compared their static measurements with both, dynamic and static measurements supplied by a electromagnetic equipment of movement capture with validity described in literature. The intra-examiner reliability (3.1) of the measurements supplied by the inclinometer varied from 0.89 to 0.96, increasing with higher humeral elevation, with good criterion validity, showing that this is better for the static measurements of the electromagnetic equipment (r=0.59-0.92) than for the dynamic measurements (r=0.59-0.73), with the standard error for the measurement < 3º15. Although it was the first study to compare a clinically applicable two-dimensional method with a three-dimensional method[15] the results were restricted to the scapular upward rotation movement.

Techniques with radiation emission were applied for both static[14,16] and dynamic[13,19] two-dimensional analysis. Endo et al[14] stated that they developed a simple and accurate method to evaluate two-dimensional scapular movements based on x-rays digitized into a computer. The intra-examiner reliability analysis showed good method reproducibility and the measurements obtained were comparable[14] to those obtained at another study[11], which used static three-dimensional analysis with an electromechanical equipment.

Michiels e Grevenstein[19] used an x-ray equipment coupled to a real-time processing and digitizing system, which allowed the dynamic two-dimensional analysis of the movement, but they did not mention the psychometric properties of the method[19]. Digital fluoroscopy, another type of radiation, was used for the static[16] as well as for the dynamic two-dimensional analysis[13]. One of the advantages, when compared to x-rays, is the low radiation level[13]. The technique, when employed statically, showed to be accurate and reliable[16], but the psychometric properties were not reported for its dynamic use; the authors only stated that the method is safe and clinically applicable[13]. Considering the radiation, it is necessary to mention two of its large disadvantages: the exposure to which the individual is submitted and the need for equipment acquisition and training, in addition to being restricted to two-dimensional analysis.

With the objective of fully describing the scapular movements during the elevation of the UULL, three-dimensional analysis methods, static as well as dynamic ones, have been proposed. Electromechanical equipment has been employed for the static analysis[11,21,23,25], presenting adequate reliability for all scapular movements (0.72 to 0.99)[11,21], measurement standard error varying from 2º to 3º[11,21], with the worst values of the resulting linearity, hysteresis, reproducibility and accuracy being 1mm, 2mm, 2mm and 4mm, respectively[21]. The electromagnetic technology was employed for the static as well as for the dynamic analysis. At the static analyses, the method presented good inter- and intra-examiner reliability[29], with variance peak values between the examiners < 0.5% for most part of the scapular movements[22], systematic error of measurement at acceptable ranges[29], being necessary to provide adequate training for this level of accuracy to be reached[29]. It is important to mention that distortions in the electromagnetic field can alter the measurements, the signal amplification can be modified according to the digitizing equipment used and its accuracy depends on the calibration performed initially, with the systematic errors being associated to this process[24].

Digitized infrared markers and matrix-based rotation calculation were another proposal presented for static three-dimensional evaluation[27,30]. The accuracy of this method was demonstrated and the values were higher when only one direction of scapular movement was imposed; it was valid and reliable[27], with standard errors of measurement <2º[30].

The dynamic three-dimensional analysis of the scapula is commonly performed with electromagnetic equipments[2,4,8-10,15,32-34]. The method has been adapted and used in biomedical research9, as well as for the analysis of three-dimensional kinematics of the scapula[2,4,8-10,15,32-34]. It presented validity when its results were compared to measurements made by pins inserted directly into the scapula, with a mean error of 5º[12,38]. Additionally, the positioning of superficial marks, when compared to x-ray images, showed excellent results, with a general accuracy of 1.3 mm, of 1.3º for the angular orientation, and errors related to sensor displacement on the skin of the scapular region were 4.2mm. A good association was observed between the angular measurements obtained by x-ray and the angles calculated by the system (r2=0.94) as well as adequate reproducibility, with these values being different when comparing the studies by McQuade & Smidt[2], who found intraclass correlation coefficients for the intra-examiner measurements varying from 0.94 and 0.982 and that by McClure et al[33], between 0.69 and 0.95, depending on the scapular movement analyzed[33]. The possible errors that can take place when the system is used are related to the process of manual fixation of the receptors, the quantity of receptors used and the digitization of bone marks[32]. Furthermore, the system is validated for measurements of up to 120º of humeral elevation, the point from where the major errors occur[9], which limits the analyses to that ROM[34].

Although the method allows dynamic three-dimensional measurements, some disadvantages can be associated with it. The first is the need for the system acquisition and training. The second is the absence of standardization in the description of scapular movements among the different manufacturers of this system, which makes it difficult to compare the results among the studies and to establish a scientific consensus.

Of all the presented methods, the Moiré technique is worth mentioning due to the distinctive information provided. The descriptions are three-dimensional and can be interpreted statically as well as dynamically. Although it is a simple and easy to apply method in clinical practice[20], the method allows only the comparison of asymmetry between the scapulae, being, therefore, restricted to this type of information. Additionally, data on its psychometric properties were not presented and there were no other studies reporting its use.

CONCLUSIONS

The methods used to evaluate scapular movements during the elevation of the UULL in the scapular plane were considerably diversified, using equipment that varied from the simplest ones such as the goniometer and the measuring tape, to sophisticated ones, such as the electromagnetic systems.

These methods were, basically, classified as two- or three-dimensional, according to the number of planes analyzed and as static or dynamic, according to the form of data collection. Among all the methods analyzed, the electromagnetic systems (dynamic three-dimensional methods) are noteworthy due to the amount of information they can provide, the fact that they can perform dynamic measurements and also due to their proven validity. However, they also presented limitations such as measurement errors, which can be significant in the determination of important alterations of scapular kinematics, and the limitation of accurate analyses up to the amplitude of 120º of elevation. In addition, they are high-cost methods and need trained professionals to obtain and process the supplied data.

The lack of standardization of the movement nomenclature, of the planes and axes where they occur and of the full functional analysis methods that are reliable and valid and can be easily applied to clinical use are still important limitations related to the assessment of scapular movements during the elevation of the UULL. It is likely that a study developed with the objective of revising the nomenclature used to describe the scapular movements during the elevation of the UULL, as well as the planes and axes where they occur, will allow a more detailed discussion of this subject, and consequently, the establishment of a consensus about the more adequate nomenclature. However, the limitations that are intrinsically associated to the methods of evaluation will require a large technical-scientific investment to be solved.

REFERENCES

1. Bagg SD, Forrest WJ. A biomechanical analysis of scapular rotation during arm abduction in the scapular plan. Am J Phy Med Rehab 1988;67(6):238-45.
2. McQuade KJ, Smidt GL. Dynamic scapulohumeral rhythm: The effects of external resistance during elevation of the arm in the scapular plane. J Orth Sports Phys Ther 1998;27(2):125-133.
3. Hamill J, Knutzen KM. Membros superiores. In: Hamill J, Knutzen KM, editor. Bases Biomecânicas do Movimento Humano. São Paulo: Manole; 1999.
4. McQuade KJ, Dawson J, Smidt GL. Scapulothoracic muscle fatigue associated with alterations in scapulohumeral rhythm kinematics during maximum resistive shoulder elevation. J Orth Sports Phys Ther 1998;28(2):74-80.
5. Sahrmann SA. Movement impairment syndromes of the hip. In: Sahrmann SA, editor. Diagnosis and treatment impariment syndromes.St. Louis Missouri: MOSBY; 2002.
6. Doukas WC, Speer KP. Anatomy, pathophysiology, and biomechanics of shoulder instability. Orthop Clin of North Am 2001;32:381-91.
7. MacDermid JC, Ramos J, Drosdowech D, Faber K, Patterson S. The impact of rotator cuff pathology on isometric and isokinetic strength, function, and quality of life. Journal of Shoulder and Elbow Surgery 2004;13(6):593-8.
8. Borstad JD, Ludewig PM. Comparison of scapular kinematics between elevation and lowering of the arm in the scapular plane. Clin Biomech 2002;17:650-9.
9. Ebaugh DD, McClure P, Karduna AR. Three-dimensional scapulothoracic motion during active and passive arm elevation. Clin Biomech 2005;20(7):700-9.
10. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther 2000;80(3):276-91.
11. Lukasiewicz AC, McCLure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. J Orth Sports Phys Ther 1999;29(10):574-83.
12. McClure P, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. J Shoulder Elbow Surg 2001;10(3):269-77.
13. Talkhani IS, Kelly CP. Movement analysis of asymptomatic normal shoulders: A preliminary study. J Shoulder Elbow Surg 2001;10(6):580-4.
14. Endo K, Ikata T, Katoh S, Takeda Y. Radiographic assessment of scapular rotational tilt in chronic shoulder impingement syndrome. J Orthop Sci 2001;6(1):3-10.
15. Johnson MP, McClure PW, Karduna AR. New method to assess scapular upward rotation in subjects with shoulder pathology. J Orthop Sports Phys Ther 2001;31(2):81-9.
16. Mandalidis DG, McGlone BS, Quigley RF, McInerney D, O'Brien M. Digital fluoroscopic assessment of the scapulohumeral rhythm. Surg Radiol Anat 1992;21(4):241-6.
17. Doody SG, Freedman L, Waterland JC. Shoulder movements during abduction in the scapular plane. Arch Phys Med Rehabil 1970;51(10):595-604.
18. T'Jonck L, .Lysens R, Grasse G. Measurements of scapular position and rotation: a reliability study. Physiother Res Inter 1996;1(3):148-158.
19. Michiels I, Grevenstein J. Kinematics of shoulder abduction in the scapular plane. On the influence of abduction velocity and external load. Clin Biomech 1995;10(3):137-43.
20. Warner JJP, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome: A study using Moiré topographic analysis. Clin Orthop 1992;(285):191-9.
21. Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected position of humeral elevation. Phys Ther 1996;27(2):125-33.
22. Barnett ND, Duncan RD, Johnson GR. The measurement of three dimensional scapulohumeral kinematics: A study of reliability. Clin Biomech 1999;14(4):287-90.
23. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. Arch Phys Med Rehab 1999;80(8):945-50.
24. Meskers CG, Fraterman H, van der Helm FC, Vermeulen HM, Rozing PM. Calibration of the "Flock of Birds" electromagnetic tracking device and its application in shoulder motion studies. J Biomech 1999;32(6):629-33.
25. Wang C, McClure P, Pratt NE, Nobilini R. Stretching and strengthening exercise: their effect on three-dimensional scapular kinematics. Arch Phys Med Rehab 1999; 80:923-9.
26. Price CIM, Franklin P, Rodgers H, Curless RH, Johnson GR. Active and passive scapulohumeral movement in healthy persons: a comparison. Arch Phys Med Rehab 2000;81:28-31.
27. Hébert LJ, Moffet H, McFadyen BJ, St-Vincent G. A method of measuring three-dimensional scapular attitudes using the Optotrak probing system. Clin Biomech 2000;15(1):1-8.
28. De Groot JH, Brand R. A three-dimensional regression model of the shoulder rhythm. Clin Biomech 2001;16(9):735-43.
29. Price CI, Rodgers H, Franklin P, Curless RH, Johnson GR. Glenohumeral subluxation, scapula resting position, and scapula rotation after stroke: a noninvasive evaluation. Arch Phys Med Rehab 2001;82(7):955-60.
30. Hébert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. Arch Phys Med Rehab 2002;83:60-9.
31. Vermeulen HM, Stokdijk M, Eilers PH, Meskers CG, Rozing PMVVTP. Measurement of three dimnensional shoulder movement patterns with an electromagnetic tracking device in patients with a frozen shoulder. Ann Rheum Dis 2002;61(2):115-20.
32. Karduna AR, McClure PW, Michener LA. Scapular kinematics: effects of altering the Euler angle sequence of rotations. J Biomech 2000;33(9):1063-8.

33. McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. Phys Ther 2004;84(9):832-48.
34. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther 2005;35(4):227-38.
35. Balmer S, Brosseau L. Intratester and intertester reliability of the parallelogram goniometer in the measurement of hip abduction among patients: a pilot study. Spine 1998;123-6.
36. Faria CDCM, Lima FFP, Teixeira-Salmela LF. Testes de Ober e Ober Modificado: um estudo comparativo e de confiabilidade. Fisiot Mov 2005; 18(3);31-38.
37. Melchione WE, Sullivan MS. Reliability of measurements obtained by use of an instrument designed do indirectly measure iliotibial band length. J Orthop Sports Phys Ther 1993;18(3):511-515.
38. Karduna AR, McClure PW, Michener LA, Sennett B. Dynamic measurements of three-dimensional scapular kinematics: A validation study. J Biomech Eng 2001;123:184-90.