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Assessments related to infraspinatus atrophy in volleyball athletes – systematic literature review

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09/2019

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Dissertação apresentada para cumprimento dos requisitos necessários à obtenção do grau de Mestre em **Fisioterapia** – área de especialização em Terapia Manual Ortopédica pela Escola Superior de Saúde do Instituto Politécnico do Porto

Acknowledgement

Acknowledgement to my tutors for their support, help and commitment during the development of the thesis.

Abstract

Infraspinatus atrophy is associated with suprascapular neuropathy and presents as a specific lesion in volleyball athletes and may be related to compression or traction of the suprascapular nerve and excessive use of the shoulder joint complex, especially on the dominant side.

The diagnosis of suprascapular neuropathy is not only based on history and clinical examination. Imaging and electrophysiological examinations are important to identify nerve compression, visualize the degree of atrophy and evaluate muscle function, activity and fatigue, in addition to nerve stimulation velocity.

Aim(s): Systematically review the literature on evaluations related infraspinatus atrophy in volleyball athletes.

Methods: Research carried out in the PubMed and Science Direct database in the period of November 2018 related to infraspinatus atrophy in volleyball athletes.

Results: Of the 3,818 articles identified, 16 articles were selected according to the eligibility criteria. The results consisted of the analysis of the evaluation of muscle strength, joint amplitude, joint kinematics, joint position sense, electrophysiological and imaging exams in volleyball athletes with infraspinatus atrophy.

Conclusion: The best assessment method for volleyball athletes with AI is suggested by the analysis of joint kinematics together with electrophysiological and imaging exams.

Keywords: "infraspinatus atrophy," "assessment", "volleyball" and "suprascapular nerve"

Resumo
A atrofia do infraespinhoso está associada à neuropatia supra- escapular e apresenta-se como lesão específica em atletas de voleibol, podendo estar relacionada à compressão ou tração do nervo supraescapular e ao uso excessivo do complexo articular do ombro, especialmente no lado dominante. O diagnóstico de neuropatia supraescapular não se baseia apenas na históriae no exameclínico. Os examesdeimagemeeletrofisiológicos são importantes para identificar a compressão nervosa, visualizar o grau de atrofia e avaliar a função, atividade e fadiga muscular, além da velocidade de estimulação nervosa.
Objetivo(s): Revisar sistematicamente a literatura sobre as avaliações relacionadas à atrofia do infra-espinhoso em atletas de voleibol.
Métodos: Pesquisa realizada na base de dados PubMed e Science Direct no período de Novembro de 2018 relacionada à atrofia do infraespinhoso em atletas de voleibol.
Resultados: Dos 3.818 artigos identificados, 16 artigos foram selecionados de acordo com os critérios de elegibilidade. Os resultados consistiram na análise da avaliação da força muscular, amplitude articular, cinemática articular, senso de posição articular, exames eletrofisiológicos e de imagem em atletas de voleibol com atrofia do infraespinhoso.
Conclusão: O melhor método de avaliação para atletas de voleibol com AI é sugerido pela análise da cinemática articular juntamente com exames eletrofisiológicos e de imagem.

Palavras-chave: "atrofia do infraespinhoso", "avaliação","voleibol" e "nervo supraescapular"

Summary

List of abbreviations

AI– Infraspinatus atrophy
CoP–L– Displacement the center of pressure
CoP–V– Displacement instantaneous of the velocity
EC– Empty can test
EEG– Electroencephalography
EMG– Electromyography
IST– Infraspinatus strength test
IRST– Scapular retraction test
MRI– Magnetic resonance imaging
NCV– Velocity of nerve conduction
SERPT– Peak external rotation torque of the shoulder
TTDPM– Time to detect passive movement
US– Sonography

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1. Introduction

Volleyball is one of the most popular sports in the world with injuries occurring at both the amateur and elite level. It consists on specific/technical movements such as jumping, landing, block and spike, which are demanding tasks for the musculoskeletal system [1].

The high intensity training and high number of repetitions of movements are aggravating factors that may lead to lesions in several joints and soft tissue [3]. Reeser et al 2006 [2], found that the excessive use of the shoulder joint complex account for 8-20% of the lesions observed in volleyball.

A common pathology in professional volleyball players is the atrophy of the infraspinatus muscle being clinically recognized as corresponding to a suprascapular nerve neuropathy [3]. The suprascapular nerve emerges from the upper trunk of the brachial plexus and is formed by the ventral ramus of the C5 and C6 roots and sporadically C4 root and provides motor innervation to the supraspinatus and infraspinatus muscles, in which it can be compressed or injured in the suprascapular and/or spinoglenoid notch [4]. According to Cummins et al 2004 [6], the location of the muscle atrophy may be useful to identify the location of suprascapular nerve injury. When the lesion occurs at the supraspinatus notch, atrophy occurs in the both supraspinatus and infraspinatus muscles, when the lesion occurs in the spinoglenoid notch an isolated infraspinatus atrophy occurs. Boykin et al 2010 [5] reports that the prevalence of suprascapular neuropathy is between 12.5% and 33% in professional male volleyball athletes and the athletes, normally, do not present pain and functional dysfunction in the shoulder, making the diagnosis difficult.

Some studies observed by Dramis et al 2005[11], this common causes of suprascapular neuropathy are due to fractures of the scapula, proximal humerus and shoulder dislocation accounting for the majority of cases in overhead sports. In addition, other mechanism of nerve lesion is at the suprascapular or spinoglenoid notch due to excessive use of the shoulder joint complex.

In the case of volleyball, some studies [7,8,9,18] reported that there is a hypothesis for this lesion, which is the compression of the suprascapular nerve in the spinoglenoid notch due to the floating service, where the infraspinatus muscle is much more intensely activated than in other throwing actions and the deceleration is much moreprogressive.

The diagnosis making of the suprascapular nerve neuropathy is difficult from the history and clinical examination. There may be a history of trauma, previous shoulder surgery and excessive activity, as well as weakness and loss of function of the rotator cuff muscles [4]. A high rate of this neuropathy occurs in volleyball, basketball and swimmers' athletes, however non athletes with massive lesions in the rotator cuff may also suffer from this condition [10]. As seen in the recent study by Kostretzis et al 2017 [4], a detailed computed tomography may help in cases of fractures and anatomical variations, offering better visualization of nerve compression sites while magnetic resonance imaging serves to visualize the degree of supraspinatus atrophy and infraspinatus atrophy and the electromyography examinations and nerve conduction velocity are used when there is a suspicion of pathology of the suprascapular nerve, being considered a gold standard examination to diagnose it [4].

The present study proposes to approach the process of evaluation used on volleyball athletes to identify infraspinatus atrophy present the best assessment method or methods based on the systematic review.

2. Methods

A systematic review of the scientific literature on assessment methods used in volleyball athletes with infraspinatus muscle atrophy was performed on November 2018, in PubMed and Science Direct databases.

Firstly, we searched with the keywords: "infraspinatus atrophy", "suprascapular nerve," "assessment", "volleyball", evaluation, combining then with the Boolean command "OR" or "AND" for the terms infraspinatus atrophy AND (volleyball OR assessment OR evaluation) and infraspinatus atrophy OR suprascapular neuropathy AND (volleyball OR assessment OR evaluation.

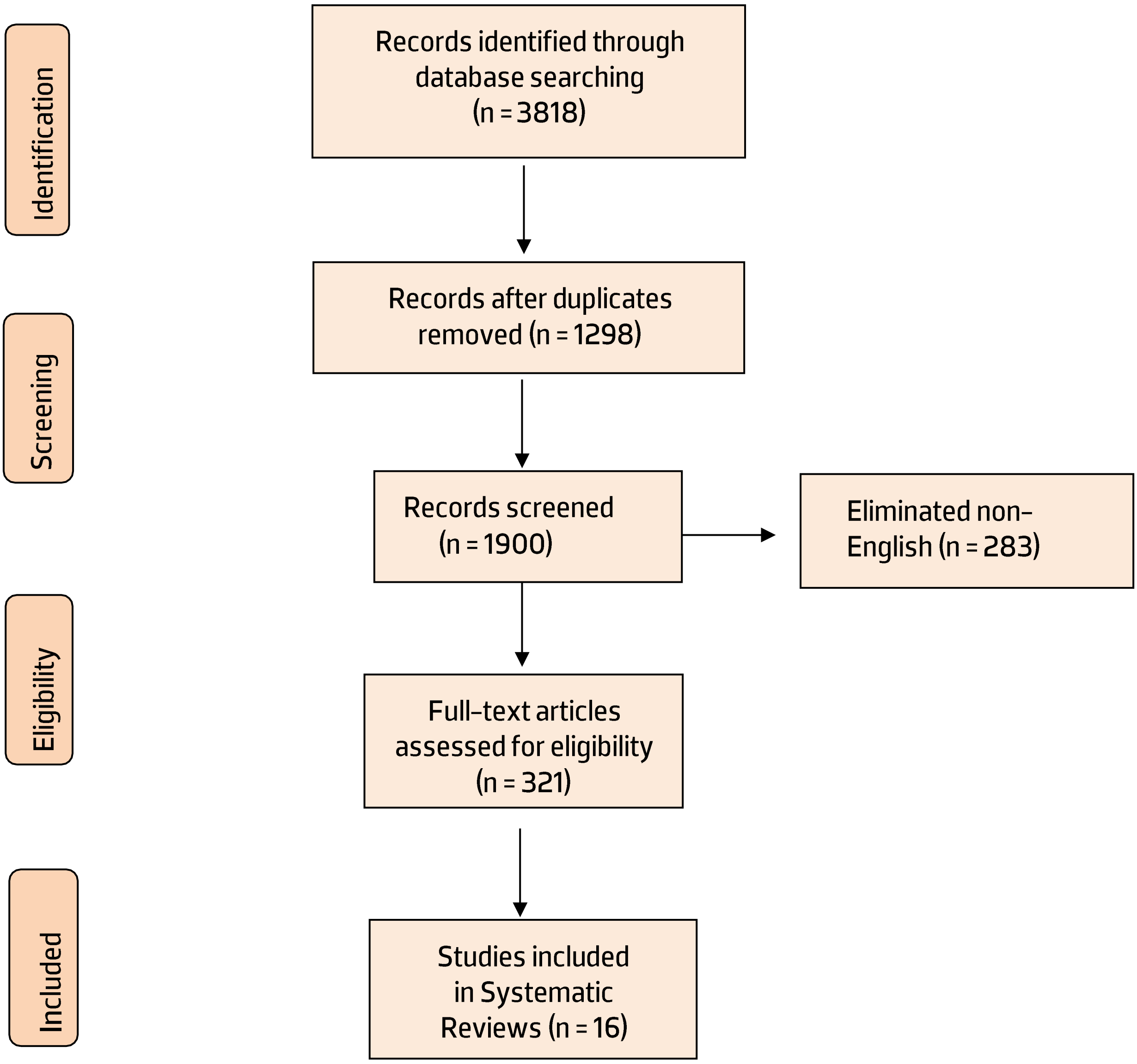
2.1. Eligibility criteria

The articles collected for the systematic review followed inclusion criteria: (1) Population of interest consisted on volleyball athletes; (2) The sample presented athletes with infraspinatus atrophy; (3) Forms of evaluation shoulder joint complex with AI; (4) English language studies.

2.2. Study selection

The studies that corresponded to the used keywords were imported into the EndNote Bibliography manager in order to remove the duplicates. After searching the databases, the articles were selected by titles and abstracts according to the criteria. In the initial obtained from databases 3818 articles. After the elimination of the duplicates and the use of the inclusion criteria, 16 studies were obtained.

Figure 1- PRISMA flow diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med6(7): e1000097. doi:10.1371/journalpmed1000097

2.3. Quality assessment

Except for one study Pierbe et al 2014 [25] and one Merolla et al 2010 [16] that were published in the 3rd quartile and 2nd quartile journals respectively and all there maining were published in 1st quartile journals. The articles with more than 100 citations belonged to the authors Ferreti [8,9], Holzgraefe [23], Witvrouw [18] and Lajtai [13,14].

3. Results

Some authors performed pre-studies assessments in order to group formation. The articles used clinical evaluations, historical and physical exams to identify athletes with AI and submitted them to the athletes to complete the questionnaire. The questionnaire including specific questions duration of high-level volleyball, weekly training activity, problems or pain around the shoulders, hours a week spent playing volleyball and onset of symptoms (years), the amount of weekly training activity, episodes shoulder pain and time of experience [8,13,14,15,16,17,18,22,23].

During the recruitment phase for the group, Contemori et al 2018 [12,20,21] performed an assessment of shoulder strength for abduction, external rotation and internal rotation movements in order to verify the shoulder strength deficit to confirm the group with infraspinatus atrophy because they were diagnosed by evident atrophy and by EMG examination with infraspinatus denervation. The control group was selected by height, weight, age, experience and training time similar to the atrophy group. The sixteen articles selected for the review were identified by the following themes on forms of assessment (table1).

3.1 Clinical assessment in volleyball athletes with infraspinatus atrophy

The clinical assessment used by Lajtai et al 2009 [14] was based on the Constant and Murley score, which is a scale of 100 points: 35 points attributed to subjective variables (pain, activity of daily living and functional use of the arm), 40 points for range of motion and a maximum of 25points for measuring the abduction strength. The clinical evaluation used by Lajtai et al 2009[14] was based on the Constant and Murley score, which is a scale of 100 points: 35 points attributed to subjective variables (pain, activity of daily living and functional use of the arm), 40 points for range of motion and a maximum of 25 points to measure the force of abduction. In addition, they evaluated orthopedic tests for subacromial impact (Neer's signal, modified Hawkins' test), posterosuperior glenoid impact and biceps lesions (velocity test and O'Brien's test). As with Lajtai et al 2009 [14], Witvrouw et al 2000 [18] also evaluated shoulder instability using the seizure test and the sulcus signal and impingement signals.

The 2010 studies by Merolla et al 2010 [15,16,17], the scapular dyskinesis patterns were assessed and classified according to the scale reported by Kibler in 2002 [27]. They also assessed the supraspinatus muscle with the empty can test (EC). In 2012 Lajtai et al [13] also clinically assessed using observation of infraspinatus muscular atrophy was classify as "no atrophy", "slight atrophy" and "severe atrophy" comparing both sides.

3.2. Assessment of joint amplitude in volleyball athletes with infraspinatus atrophy

3.2.1 Range of motion

Witvrouw et al 2000 [18] verified the joint amplitude of the glenohumeral joint with the use of standard goniometry in both shoulders. For the active and passive external rotation movement, the shoulder was 0º, 30º and 90º of abduction in supine position. For the active and passive internal rotation movement, thresholders at 90ºofabductionin supine position. Anterior flexion was performed in supine position, while extension was performed in prone position. For horizontal flexion, the athlete remained in the sitting position allowing the scapula to reproduce the movement freely along the thorax. In the studies by Merolla et al 2010 [15, 16] measurement was made using a standard goniometry in order to observe changes in the angulation of internal rotation with the athlete in the supine position and the examiner manually stabilizes the scapula while performing the movement from external rotation to internalrotation.

3.2.2 Scapular slide measurements

Witvrouw et al 2000 [18] measured the retraction movement of the scapula through the maximum length of the requested shoulder strap and the distance was measured, horizontally, between the spinous process and the lower angle of the medial edge of the scapula using the tape measure. The maximum flexion of the shoulder girdle with the same measure mentioned above was requested for the protational movement. The lateral displacement of the scapula was measured to evaluate the protraction and retraction of the scapular girdle.

3.3. Assessment of muscle strength in volleyball athletes with infraspinatus atrophy

3.3.1 Manual dynamometer isometric contraction

Contemori et al 2018[12] assessed maximum force through isometric contraction for abduction, external rotation and internal rotation using of the manual dynamometer.
Abduction strength was measured in standing position, shoulder abducted at 90° in the scapular plane, elbow extended, and pronated forearm. External and internal rotation strength were measured in standing position, shoulder adducted, elbow flexed at 90° and forearm in a midway position between pronation and supination. There was a 5-minute warm-up and a maximum effort of 2 to 3 seconds with 2minutes of rest per test. Lajtai et al 2012 [13] assessed the strength for the movement of elevation in the scapular plane at 90º of the arm in full pronation and the external rotation strength in the sitting position with adduction and flexion with elbow at 90º of flexion with isometric contraction of the bilateral upper limb was performed with the manual dynamometer.

The measurement was performed three times for each movement. The same author, in 2009 [14], assessed with a manual dynamometer applied to the wrist to abduction force measured at 90º of the shoulder abduction in the scapular plane, extension elbow and pronounced forearm with performing three repetitions of five seconds each. The same procedure was performed for external rotation with the elbows at 90º, bilaterally. The 2010 studies by Merolla et al [15,16,17] the strength of the infraspinatus muscle was assessed with the infraspinatus strength test (IST) with the upper limb adduced and 90º flexion of the elbow. The athletes performed the movement with the maximum force isometric contraction measured by means of the handheld dynamometer recorded in kilograms for both shoulders. In two studies Merolla et al 2010 [15,17] used the scapular retraction test (ISRT), Merolla et al 2010 [15] performed with the scapula retracted by the athlete in voluntary isometric contraction registered. However, the Merolla et al 2010[17] the ISRT test was performed with a small modification, and the examiner manually performed the retraction of the scapula with one hand while the other hand applied a resistance to the external rotation force applied by the athlete in voluntary isometric. In Merolla et al 2010 [16] besides the IST, they applied the empty can test (EC) in the scapular plane to assess the strength of the supraspinatus muscle. The athlete was standing position with the arm in the scapular plane (shoulder at 90º abduction and 30º flexion) and in full internal rotation. The examiner applied a resistance while the athlete exerted the maximum lifting force.

3.3.2 Isokinetic dynamometer concentric

The study of Ferretti et al 1987[8], twelve athletes with infraspinatus atrophy on the dominant side were assessed, using the isokinetic dynamometer Cybex-II for the bilateral external rotation movement with the arm at 0º and 90º abduction with a speed of 90º/s.

Witvrouw et al 2000 [18] assessed the concentric peak of torque of external rotation and internal rotation of the shoulder with the Cybex 350 isokinetic dynamometer, at 60º/s and 180º/s according to the Cybex testing manual. In the most recent study, Salles et al 2018 [19] assessed the concentric peak torque of external rotation of the shoulder. The data was the resulted of the average of five repetitions with an angular velocity of 60º/s of the dominant shoulder. The athlete was positioned in supine decubitus with the shoulder abducted and the elbow flexed at 90º.

3.4. Assessment of static and dynamic stability in volleyball athletes with infraspinatus atrophy

3.4.1 Static stability

Contemori et al 2018 [12] assessed static and dynamic stability. The static stability was assessed using a force platform in closed kinetic chain position with partial weight. The test was performed in a randomly order the six different conditions: 1) Bilateral hand support with open eyes; 2) Bilateral hand with closed eyes; 3) Unilateral hand support on the contralateral shoulder with open eyes; 4) Unilateral hand support on the shoulder with closed eyes contralateral; 5) Unilateral hand support on the hitting shoulder with open eyes; 6) Unilateral hand support on the dominant shoulder with closed eyes. With bilateral hand support two force platforms were used to simultaneously record the signs of static stabilization of the dominant shoulder and the contralateral one. For unilateral support, the position of the support hand was the same as for bilateral support, but the free hand pressed theabdomen.

The recordings of data started five seconds after the correct positioning and the isometric contraction lasted for twenty-five seconds with a rest period of sixty seconds between positions to avoid fatigue. The parameters registered were the total pressure displacement and the instantaneous mean velocity of the center of pressure, in which they are related to the sensory-motor activity necessary to maintain static stability. The index of difference side by side and the index of influence of vision were calculated.

3.4.2 Dynamic stability

Dynamic stability was assessed with the upper quarter balance test (UQYBT), which challenges the balance, proprioception, strength and mobility of the shoulder. During the test, subjects had to keep a plank position with 3-points of support on the ground (one hand and both feet) andperform the maximum effort with the free hand (concentric contraction) in three directions (medial, upper-lateral and lower-lateral) in relation to the support hand (isometric contraction). Three attempts were made for each direction and both hands were positioned in relation to the axis in the transverse plane and to the axis in the sagittal plane[12].

3.5 Assessment of joint position sensation in volleyball athletes with infraspinatus atrophy

In the studies carried out by Salles et al 2013 [22] and 2018 [19], the aim was to assess the time to detect passive movement (TTDPM) through the proprioception test device. The equipment used was the isokinetic dynamometer, at a speed of 0.4/s and following the position described for the peak external rotation torque of the shoulder (SERPT), in which the athlete sits with the earplugs and eyes blindfolded to limit the visual feedback. The athletes were informed to press the hand switch button from the moment they felt the internal rotation movement that was initiated at the maximum externalrotation.

The evaluation performed by Salles et al 2013 [22] involved the internal rotation of the shoulder in the longitudinal axis, from the 80º position of external rotation established for three repetitions. Each test started with 15 seconds of EGG and EMG recording, without any motor movement, to program the basic measurements. The TTPM was calculated by the time of detecting the passive movement and the time of pressing the switch button. However, in the assessment by Salles et al 2018 [19], the internal rotation angle was chosen similarly to the direction of movement of the athlete's arm during the phase of spiking, at 45º. The calculation was made by the 3 repetitions and the proprioception acuity measured as absolute error. Both studies by Contemori et al 2018 [20,21], used kinematics to evaluate the sensation of the joint position of the dominant and non-dominant shoulder using a six-cameras Smart-DX 6000" optoelectronic system that collected information from 16 markers in the study by Contemori et al 2018 [20] and 17 markers by Contemori et al 2018 [21] positioned at the anatomical points (on the seventh cervical vertebra, eighth thoracic vertebra, xiphoid process, acromion, medial and lateral epicondyles of the elbows, styloid process of the radius and ulna and metacarpophalangeal joint of the bilateral hand) for 3 functional movements of the glenohumeral joint: 1) abduction in the scapular plane; 2) flexion; 3) and a combined movement of abduction with external rotation with the elbow in 90º flexion; in the sitting position and with the eyes blindfolded. Each of these movements was demonstrated and explained verbally to each athlete before the test session. Before starting the test, the reference position was kept arm within the movement path for 2 to 3 seconds to define the "target position". The athletes were then instructed to reposition the hand at the target point most accurately possible, starting from the reference position, with the movement speed that allowed the greatest accuracy. They were instructed to finish the movement at the exact moment they thought they had reached the target position, through six consecutive repetitions movements described above in random order. The same standardized protocol was followed for each movement in the opposite arm.

3.6 Changes in imaging exams in volleyball athletes with infraspinatus atrophy

3.6.1 Magnetic resonance imaging

Lajtai et al 2009 [14] assessed the dominant shoulder with MRI according to the protocol for overhead-throwing athletes performed in the oblique coronal plane and in the transverse plane of the dominant shoulder. Merolla et al 2010 [15,16,17] assessed the ligamentous structure, the rotator cuff tendons and the glenoid labrum by means of shoulder MRI performed oblique coronal and oblique sagittal.

Although Salles et al 2018 [19] used MRI to allocate the athletes ingroup. The MRI enable the identification of AI in the athletes and observed diffuse fat infiltration or more than two points on the Goutallier five points grading scale.

3.6.2 Sonography

Lajtai et al 2009 [14] also used sonography (US) to assess the musculotendinous structures like capsular thickening, long biceps tendon, subscapular, infraspinatus and supraspinatus abnormalities (tendinosis, pulley injury, partial or total laceration); abnormal postero-superior glenoid impact (tendinosis, partial laceration) and ganglion cyst of both shoulders with sonography in beach volleyball athletes.

3.7 Changes in electrophysiological examines in volleyball athletes with infraspinatus atrophy

3.7.1 Electromyography

The electromyography exam enables the investigation of the muscles in relation to the level of muscle activation during the requested movement, its intensity and duration and also to evaluate muscle fatigue. The EMG test can be performed in two ways: a surface that contains information on the recruitment of the motor unit; and a needle, which provides complementary information on nerve conduction [39]. It is utilized by many authors to identify the presence of AI in athletes [8,9,12,21,22].

3.7.2 Surface electromyography

Lajtai et al 2012 [13] assessed the deltoid, pectoralis major, upper and middle trapezoid, supraspinatus and infraspinatus muscles with surface EMG. A total of 33 electrodes for each athlete were divided into 2 electrodes per muscle, 1 reference electrode and 1 electrode in the acromioclavicular joint of both shoulders. The athletes were requested to perform 3 repetitions for both the right and left sides for the movements of flexion, abduction, internal rotation and external rotation of the shoulders. The results were recorded by video adjusted with the measurements of the EMG of 16 channels.

Pieber et al 2014 [25] also performed the surface EMG exam in the infraspinatus muscle of the dominant side in order to identify the signs of denervation at rest, action potential of the motor unit and modified patterns along the maximum voluntary contraction.

In the most recent study, Contemori et al 2018 [21] used wireless EMG was used to record EMGs signals of the activity level of several muscles (anterior deltoid, middle deltoid, posterior deltoid, upper trapezius, lower t trapezius, middle trapezius and anterior serratus) during the abduction of the glenohumeral joint in the scapular plane. The EMGs electrodes were placed on the center of the muscle belly in the direction of the muscle fibers, according to the "European recommendations for surface electromyography. The measurement was performed by the mean of 6 repetitions of the 8 intermediate repetitions.

3.7.3 Needle electromyography

Montagna et al 1993 [24] performed a case report study, in which two cases of six cases were described in their study. Only one case identified the use of needle EMG and it was not clear whether the others used it. All cases measured the action potential of the infraspinatus muscle motor unit, the distal latency and motor response amplitude after stimulation in the suprascapular nerve to both sides. However, one case approached the use of the needle electrode to record the Erb point. In the study Holzgraefe et al. 1994 [23], the records also were with electromyography (EMG) and measured the supraspinatus and infraspinatus muscles at five different points on both shoulders.

3.7.4 Nerve conduction velocity

Witvrouw et al 2000 [18] measured the nerve conduction velocity (NCV) through EMG surface electrodes, assessing the conduction time. Lajtai et al 2012 [13] assessed the NCV in conjunction with surface EMG in beach volleyball athletes. The positioning of the electrode for the nerve conduction velocity was positioned in the supraclavicular region. Latency and signal amplitude were measured in the supraspinatus and infraspinatus muscles of both shoulders. Another article that evaluated the values of NCV with EMG was Pieber et al 2014 [25] who applied surface EMG in the infraspinatus muscle in the dominant arm to identify possible neurogenic changes. The NCV in the suprascapular nerve was recorded bilaterally, using surface electrodes in the motor point of the supraspinatus and infraspinatus muscles and the other electrode in the acromioclavicular joint

Table 1- Assessment methods and parameters of the selected article

Article and year	Type of study	Population	Assessment method	Instruments and assessed parameter	Protocol	Positioning
Sensorimotor Control of the Shoulder in Professional Volleyball Players with Isolated Infraspinatus Muscle Atrophy Contemori, S., et al, 2018	Cross-sectional design	Volleyball players n= 24 (12 AI and 12 GC) mean ages 23 (+-4,2) with AI 24 (+3,1) with CG	(AI were identified prior fine wire EMG) Strength Measurements Manual Testing (SM-MT) (pre study for group formation) Upper Limb Static Stability (ULSS) Upper Limb Dynamic Stability (ULDS) Strength Assessment - Isometric force (SA-ISOM)	SM-MT: Manual muscle testing: Abduction, External rotation, Internal rotation ULSS: Force platform the BTS P-6000 and analyzes with the "Smart Analyzer®" software (BTS Engineering, Milano, Italy): Isometric contraction Assessing stabilometric: Displacement the centre of pressure (CoP-L, in mm) Mean instantaneous CoP-velocity (CoP-V, in mms-1) 1.the "side to side difference index" defined as 100 (HS-value- CS-value)/ CS- value was calculated to quantify the percentage difference between the hitting and the contralateral shoulder 2. The "Influence of vision index" defined as 100 (CE-value OE- value)/ OE-value was calculated to quantify the effect of eye closure. ULDS: The upper quarter Y balance test kittest Contraction concentric -Isometric concentric (support hand) SA-ISOM Manual Dynamometer Kern	SM-MT: Classifying presence or not of strength loss in AI athletes in abduction, lateral rotation and internal rotation (helping on AI allocation - confirmation) ULSS: 6 different conditions/ trials: uni and bilateral hand support, closed and open eyes bilaterally Familiarization period: 30 seconds Test time: 25 seconds of recording after taking the correct test position Rest period: 60 seconds ULDS: Upper Quarter Y Balance Test protocol bilaterally (UQYBT) Repeats: 3 tests for each direction SA-ISOM: Maximum effort time: reached in 2 to 3 seconds and maintained for 3 Heating: 5 minutes Resting time: 2 minutes 5 minutes of warmup Rest between trials of 2 minutes.	SM-MT: NA ULSS: Pronation; hands on the force platforms glued to the transverse and sagittal planes with 4 cm between each wrist Member States greater than 90° ground extension with 90° shoulder flexion; 90º extension cuffs for the upper limbs to be 90º in relation to the platform and elbows in full extension ULDS: Position: board with 3 ground support points: one hand and both feet and 3 directions: medial, upper-lateral and lower-latera l AS-ISOM: Abduction force: standing, shoulder abducted at 90º in the scapular plane, elbow extended, and forearm pronounced; external and internal rotation forces: standing, shoulder abducted, and elbow flexed in neutral position (90º) and

				HCB 200K10 Shoulder maximum force: Abduction, external and internal rotation bilaterally. Contraction isometric		forearm between pronation and supination.
Isolated Infraspinatus Atrophy Secondary to Suprascapular Nerve Neuropathy Results in Altered Shoulder Muscles Activity Contemori, S. and A. 2018	Cross-sectional design	Professional volleyball players n=24 (12 AI and12 CG) Mean age: 25 (21-30) with AI; 26 (21-32) with CG	AI were identified prior fine wire EMG) Strength Measurements Manual Testing (SM-MT) was used for the normalization the EMG Surface electromyography (EMGs) Upper limb 3D kinematics (K)	SM-MT: Using- Manual muscle testing: abduction, Flexion, Horizontal extension, Horizontal abduction, Horizontal flexion, Elevation and Internal rotation Maximal voluntary isometric contraction The EMGs of the muscles were recorded at every 10º of amplitude of abduction movement of the glenohumeral joint in the scapular plane. Motion cadence: concentric phase: 1 second eccentric phase: 1 second Frequency: 0,5Hz EMGs FREEEMG 1000 (BTS engineering, Milano, Italy) Software (BTS Engineering, Milano, Italy) EMG signals: Filters: band-pass 10 to 500 Hz Frequency: 1 kHz Amplitude: filter involves through a movable point-to-point root filter square mean filter Interval: 500 milliseconds Muscle response latency:	SM-MT: The isometric force was 5 seconds for each muscle The resting time of 2 minutes between tests Familiarization phase: 3 tests for each shoulder Repeats: 8 Resting time: 2 minutes EMGs: Localization of the electrodes: centre of the muscle belly, there is a distance of 1.5cm in the direction of the muscle fibres according to the "European recommendations for Surface electromyography" Activity level: Repetitions: 6 intermediates of the 8 complete repetitions every 10º of the range of motion of the shoulder abduction for each muscle. Muscle response latency: Repetitions: 6 intermediates out of 8 complete repetitions for each muscle K: 17 reflective markers were placed on the skin following the instructions of the "shoulder sub-committee" of the "International Society of Biomechanics committee for standardization and terminology" Anatomical landmarks: the spinous processes of the seventh cervical vertebra and the eighth thoracic vertebra, the sternal notch, the xiphoid process, the lateral aspect of the acromion of both	SM-MT: N.A EMGs: N.A K: N. A

				difference in time betweenthe beginning of the movement and the onset of muscle activity K: Six-camera "Smart-DX 6000" optoelectronic motion capture system Software (BTS Engineering, Milano, Italy) Upper limb	scapula, the medial and lateral epicondyle of both elbows, the radial and ulnar styloid of both wrists, and the middle metacarpophalangeal joint of bothhands	
Effect of specific exercise strategy on strength and proprioception in volleyball players with infraspinatus muscle atrophy Salles, J.I 2018	Cross-sectional design	Professional Volleyball players and non-athletes n= 54 (18 with AI; 18 without AI (CG) and 18 -not Athletes Mean age:26 ± 4.6 with AI; 28 ± 6.3 with CG; 27 ± 4.9 with not athletes	Magnetic resonance imaging (MRI) Joint position sense (JPS) Detection of passive movement Strength Assessment - concentric isokinetic (SA-CONC)	MRI: Goutallier five-point grading scale for athletes with AI JPS: Isokinetic dynamometer HUMAC NORM, CSMI, USA for all strength tests on the dominant upper limb The proprioception was calculated through the absolute error, through the mean value of the individual differences in the module. Maximum external rotation Detection of passive movement: Motor-driven proprioception testing (TTDPM) To assed internal rotation time to detect passive movement (TTDPM) The TTDPM was measured by the time lapse between motor movement start and button press Dominant shoulder	MRI: N.A JPS: Concentric shoulder external rotation peak torque (SERPT) The maximum external rotation angle was measured individually and established as the initial position (0°). The 45° position was maintained for 5 seconds to enable athletes to experience their target joint position and with 3 attempts Voluntary internal rotation movements in the 0° to 45°position Velocity: 60º/s Detection of passive movement: The athletes were instructed to press the hand switch immediately when they detected shouldermovement Velocity:0,4º/s Repetitions:3 attempts The mean of three trials was calculated and proprioception acuity measured as the absoluteerror SA-CONC: Concentric shoulder external rotation peak torque (SERPT)	MRI: N.A JPS:Athletes sitting; shoulders and elbows at 90º flexion and eyes blindfolded Detection of passive movement:Athletes sitting; shoulders and elbowsat 90º flexion SA-CONC: The positioning wasin ventral decubitus position with the shoulder abducted and flexion of the elbow, both at 90º and at the neutralforearm.

				SA-CONC: Isokinetic dynamometer HUMAC NORM, CSMI, USA. The highest instantaneous value found was identified as peak torque external rotation. Concentric and dominant shoulder	Repeats: 5 maximums Velocity: 60º/s	
Shoulder position sense in volleyball players with infraspinatus atrophy secondary to suprascapular nerve neuropathy Contemori, S. and A., 2018	Cross-sectional design	Professional Volleyball players n= 24 (12 with AI and 12 GC) Mean age: 26 with AI; 25 CG	(AI were identified prior fine wire EMG) Joint position sense (JPS) Upper limb 3D kinematics (K)	JPS: N.A K: Six-camera "Smart-DX 6000" optoelectronic motion capture system Software (BTS Engineering, Milano, Italy) for the selected shoulder movements Concentric contraction To analyze in detail the kinematics of the upper limb and the position of the hand in space during the test Both shoulders	JPS: Standardized protocol 3 functional movements of the glenohumeral joint: abduction in the scapular plane, flexion and combined movement of abduction and external rotation with the elbow at 90º of flexion 3 practice trials until they felt comfortable with the movements The blindfolded athletes held the position for 2-3 seconds before returning to the starting position to define the point of the movement trajectory for 6 repetitions Resting time: 2 minutes K: 16 reflective markers were placed on the skin following the instructions of the "shoulder sub-committee" of the "International Society of Biomechanics committee for standardization and terminology" Anatomical landmarks: the spinous processes of the seventh cervical vertebra and the eight thoracic vertebras, the sternal notch, the xiphoid process, the lateral aspect of the acromion of both scapula, the medial and lateral epicondyle of both elbows, the radial and ulnar styloid of both wrists, and the middle metacarpophalangeal joint of both hands.	JPS Sitting posture K: N. A.

Is suprascapular neuropathy common in high performance beach volleyball players? A retrospective analysis Pieber, K., et al2014	Cross-sectional design	Professional Volleyball players n= 18 (5 with AI 13 without AI) Mean age: 8.7 years' old	Needle electromyography (EMGn) Nerve conduction velocity (NCV)	EMGn: Alteration of interference patterns at the time of maximum voluntary contraction Signs of denervation at rest Characterization of the action potentials of the motor unit Fibrillation Amplitude Positive sharp waves Dominant shoulder NCV: Latency; amplitude; dominant and non-dominant shoulder	EMGn: Location of the needle: infraspinatus muscle on the dominant side NCV: Surface electrodes, above the motor point of the supraspinatus and infraspinatus muscles. The reference electrode was placed on the acromioclavicular joint Stimulation was applied at Erb's point.	EMGn: Applied to the infraspinatus muscle dominant NCV: Applied to the infraspinatus and supraspinatus muscles both shoulders
Electrophysiological Correlates of the Threshold to Detection of Passive Motion: An Investigation in Professional Volleyball Athletes with and without Atrophy of the Infraspinatus Muscle Salles, J.I., et al., 2013.	Cross-sectional design	Professional Volleyball players n= 38 (18 with AI 20 without AI and 20 GC (not athletes) Mean age: 29.4 (4.7) with AI; 32.5 (4.1) without AI; 30.3 (4.3) CG	Detection of passive movement Electroencephalogram (EEG) Surface electromyography (EMGs) Clinical assessment (CA)	Detection of passive movement: A motor-driven, proprioception testing device, which was developed at the Neuromuscular Research Laboratory of the National Institute of Traumatology and Orthopedics (INTO) to assess the TTDPM. TTDPM was measured by time recording to detect passive motion by pressing the initial stimulation switch button Dominant shoulder EEG: 20-channel Braintech-3000 (EMSA Medical Instruments, Rio de Janeiro, Brazil) to capture the activity during the movement Software Data Acquisition developed at Neuromuscular Research Laboratory (INTO, Rio	Detection of passive movement: Threshold to detection of passive motion (TTDPM) The equipment is designed to passively move the arm for internal rotation Start position: 80º external rotation Internal rotation: all along the longitudinal axis 4 attempts Velocity: 0.4/s EEG + EMG: Recorded after 15 seconds, without motor movement Activity of the deltoids and pectoralis Electrodes EGG: Two bipolar electrodes of 9mm diameter fixed above and in the external canal of the right eyes CA: Orthopaedic doctor assessed the athletes visually to detect the presence or not of infraspinatus atrophy.	Detection of passive movement: Positioned at 90º abduction and 90º flexion of the elbow in the scapular plane EMGs: Deltoids and pectoralis major muscles

				de Janeiro, Brazil) used to acquire the EEG Data collected during the experiment were processed with Matlab 5.3 (MathWorks, M, USA) High-pass: 0.1Hz and Low-pass: 50Hz; Sampling rate of 200Hz Alpha frequency Beta frequency EMGs: The activity of the deltoid and pectoralis major muscles was recorded at EGG using the EMG 1000 device (Lince, São Paulo, Brazil) Data collected during the experiment were processed with Matlab 5.3 (MathWorks, M, USA) -Sampled at 1,000 Hz. EEG + EMG: Repetitions of passive movements in internal rotation with latency of the response in milliseconds, being established by the passive movement and pressing the button The acquired data had a total amplitude of less than 100$\mu\mu$V		
Electromyography and Nerve Conduction Velocity for the Evaluation of the Infraspinatus Muscle and the Suprascapular Nerve in Professional Beach	Cross-sectional design	Professional Beach volleyball players n= 35 (12 with AI, 08 AI severe and 04 AI light; 23 without AI (GC))	Surface electromyography (EMGs) Nerve conduction velocity (NCV): Strength assessed:	EMGs: Muscles assessed: Deltoid (clavicular, acromial, and scapular part); pectoralis major (sternal and clavicular part); trapezius (upper and middle part); supraspinatus and Infraspinatus muscles bilaterally.	EMGs: Reference electrode: acromioclavicular joint; In each muscle, 2 electrodes were placed on both shoulders. -The total of 33 electrodes on the skin of each athlete Individual movements: maximum flexion, maximum abduction, maximum external	EMGs: N.A NCV: The electrode was positioned in the supraclavicular region to stimulate the suprascapular nerve.

Volleyball Players Lajtai, G., et al., 2012.		Mean age: 28 years (range, 20-37 years)	Concentric force (SA-CON) Clinical assessment (CA)	The measurements were recorded by video synchronously to the 16-channel EMG measurements for both shoulders The hardware was used with a Noraxon TeleMyo 2400 G2 16-channel EMG device (Scottsdale, Arizona) For the data recordings used software MyoResearch XP Master Edition version 1.07.41 (Noraxon) The muscles assessed were: Deltoid (clavicular, acromial, and scapular part); Pectoralis major (sternal and clavicular part); Trapezius (upper and middle part); Supraspinatus and Infraspinatus muscles Bilaterally The assessed movements were for flexion and abduction from the neutral position, external rotation with the lateral arms and elbow flexed at 90° and internal rotation The impedance of the system was measured for the results. NCV: The measurements were made with the device Neurowerk EMG4 NCV device (SIGMA Medizin-Technik GmbH, Gelenau, Germany) The measurements were performed bilaterally with	rotation and maximum internal rotation. Movements of external rotation and internal rotation against resistance Performed 3 hits on both sides to replicate the overhead smashes on court. The assessed movements were for flexion and abduction from the neutral position, external rotation with the lateral arms and elbow flexed at 90° and internal rotation NCV: N.A SA-CONC: The measurements were made for shoulder elevation and external rotation forces for three repetitions and the measurement was calculated	SA-CONC: Force of elevation: in the standing position with the arm in the scapular plane at 90º elevation and pronation of the forearm. For the external rotation: in the sitting position with the arm in adduction with the elbow at 90º flexion CA: N. A

				latency and signal amplitude in the supraspinatus and infraspinatus muscles SA-CONC : Isobex dynamometer (Cursor SA, Bern, Switzerland) – Concentric contraction CA: Questionnaire: Specific questions about duration of high-level volleyball and beach volleyball activity, weekly training activity and problems or pain around the shoulders		
Infraspinatus strength assessment before and after scapular muscles rehabilitation in professional volleyball players with scapular dyskinesia Merolla, G., et al., 2010	Cohort study	Professional volleyball players (n=31 with scapular dyskinesia) Mean age: 22 ± 2.5 years	The patterns of scapular dyskinesia were assessed and classified based on the scale by Kibler before the beginning of the tests Magnetic resonance imaging (MRI)- using pré-groups Strength assessment: -Isometric force (SA-ISOM) Clinical Assessent (CA)	MRI: The glenoid labrum, ligaments and rotator cuff tendons SA-ISOM: Handheld dynamometer (Lafayette Instruments, Lafayette, IN) Isometric contraction CA: Questionnaire: Training program, hours a week spent playing volleyball and onset of symptoms (years)	Scale by Kibler: Type I scapular dyskinesia; Type II scapular dyskinesia; Type III and IV scapular dyskinesia. MRI : N.A SA-ISOM: Infraspinatus strength test (IST); Infraspinatus scapula retraction test (IRST) and alternative ISRT	Scala by Kibler: A standing position with shoulder in neutral rotation and elbow flexed to 90º and arm in adduction. MRI : Oblique coronal and oblique sagittal SA-ISOM: The IST test was performed with the upper limb adducted and 90° bending of the elbow with manual resistance of the examiner. The IRST test evaluated with one hand of the examiner manually retracting the scapula and with the other hand of the examiner resisting the applied force of the athlete in the external rotation The alternative ISRT test is the same position as the IRST test,

						but performed with two examiners
Supraspinatus and infraspinatus weakness in overhead athletes with scapular dyskinesis: strength assessment before and after restoration of scapular musculature balance Merolla, G., et al., 2010	Cohort study	Overhead athletes (n=29 with 21 volleyball players and with 08 tennis players) Mean age: 23 ± 4.2 years	The patterns of scapular dyskinesia were assessed and classified based on the scale by Kibler before the beginning of the tests. Magnetic resonance imaging (MRI) using pré-groups Strength assessment: Isometric force (SA-ISOM) Range of motion (ROM) Clinical Assessent (CA)	MRI: The glenoid labrum, ligaments and rotator cuff tendons SA-ISOM: Lafayette handheld dynamometer (Lafayette Instruments, Lafayette, Ind, USA) to quantify the strength of the infraspinatus and supraspinatus muscles Data were recorded and analysed by use of SPSS v.10 software (SPSS Inc, Chicago, IL, USA) voluntary isometric contraction force of the infraspinatus muscle. ROM: Standard goniometry Passive shoulder internal rotation CA: Questionnaire: Training program, hours a week spent playing volleyball and onset of symptoms (years) .	Scale by Kibler: Type I scapular dyskinesia; Type II scapular dyskinesia; Type III and IV scapular dyskinesia. MRI: N.A SA-ISOM: The strength tests were used: Infraspinatus strength test (IST); empty can test (EC) and strength supraspinatus muscle ROM: Maximum passive shoulder internal rotation	Scala by Kibler: A standing position with shoulder in neutral rotation and elbow flexed to 90º and arm in adduction MRI: N.A SA-ISOM: Standing the IST test was performed with the upper limb adducted and 90° bending of the elbow with manual resistance of the examiner The EC was evaluated with the athlete standing with the arm in the scapular plane and complete internal rotation by examining the athlete making resistance while the athlete was performing maximum elevation force ROM: Goniometer positioned on the humeral head of the glenohumeral joint of the shoulder Supine position with the arm abducted, 90º flexion of the elbow and stabilization of the scapula performed manually by the examiner .
Infraspinatus scapular retraction test: a reliable	Cohort study	Overheads athletes (n=29,	The patterns of scapular dyskinesia were assessed and classified based on the	MRI: The glenoid labrum and rotator cuff tendons	Scale by Kibler: Type I scapular dyskinesia; and Type II scapular dyskinesia.	Scala by Kibler: A standing position with shoulder in neutral rotation and elbow flexed to 90º

and practical method to assess infraspinatus strength in overhead athletes with scapular dyskinesis Merolla, G., et al., 2010		with 21 volleyball players and with 08 tennis players) Mean age: 23 ± 4.5 years	scale by Kibler before the beginning of the tests. Magnetic resonance imaging (MRI) using pré-groups Strength assessment: Isometric force (SA-ISOM) Range of motion (ROM)i	SA-ISOM: Handheld dynamometer (Lafayette Instruments, Lafayette, IN) Maximum voluntary isometric contraction force of the infraspinatus muscle. ROM: Standard goniometry -Passive shoulder internal rotation	MRI : N.A SA-ISOM: The strength tests were used: Infraspinatus strength test (IST) and Infraspinatus scapula retraction test (IRST) ROM: Maximum passive shoulder internal rotation	and arm in adduction MRI: N.A SA-ISOM: The IST test was performed with the upper limb adducted and 90° bending of the elbow with manual resistance of the examiner The IRST test evaluated with one hand of the examiner manually retracting the scapula and with the other hand of the examiner resisting the applied force of the athlete in the external rotation ROM: Supine position with the arm abducted, 90º flexion of the elbow and stabilization of the scapula performed manually by the examiner.
The Shoulders of Professional Beach Volleyball Players Lajtai, G., et al., 2009	Cross-sectional design	Professionals beach Volleyball players (n= 84 with 22 with AI and 58 without AI) Mean age: 28	Magnetic resonance imaging (MRI) Sonography (US) Strength assessment: isometric isokinetic (SA-ISOM) Clinical assessment (CA): Questionnaire i	MRI: Soft tissue US: N.A SA-ISOM: Isobex dynamometer (Cursor SA, Bern, Switzerland) To measure abduction force and external rotation of the shoulder on both sides CA: Questionnaire: Duration of high-level indoor and beach	MRI: Protocol overhead throwing athletes US: Standardized examination of both shoulders in the regions of acromioclavicular joint, capsular thickening; acromioclavicular joint, osteophytes; long biceps tendon, tendinosis;-subscapularis, abnormal (tendinosis, pulley lesion, partial tear) Supraspinatus, abnormal (tendinosis, partial or full thickness tear); supraspinatus, tears (partial or full thickness); infraspinatus, abnormal	MRI: Parasagittal and axial US: N.A SA-ISOM: Abduction: in the standing position, abduction at 90º in the scapular plane, extension of the elbow and pronation of the forearm External rotation: in the standing

				volleyball activity; The amount of weekly training activity (including games); Possible episodes of shoulder pain, and prior shoulder surgeries. Clinical tests: Constant and Murley score; Shoulder instability (anterior and posterior apprehension tests); Laxity (sulcus sign); Rotator cuff lesions (Jobe test, external rotation strength, lift-off test); Subacromial impingement (Neer sign, modified Hawkins test); Posterosuperior glenoid impingement; Biceps injuries (Speed test and O'Brien test).	(tendinosis, partial tear); postero-superior glenoid impingement; greater tuberosity, cortical irregularities; lesser tuberosity, cortical irregularities; ganglion cyst; labrum, fraying or tear SA-ISOM: The force of abduction and of external rotation: the calculation to measure the force was 3 successive measurements of 5 seconds duration Applied to the wrist	position, abduction 0º and 90º in the scapular plane, elbow at the side and pronation of the forearm CA: N. A
Suprascapular neuropathy in volleyball players Witvrouw, E., et al, 2000	Cross-sectional design	Professional volleyball players (n=16, 4 with AI 12 without AI) Age: 20-35 years old	Needle electromyography (EMGn) Range of motion (ROM) Strength assessment: concentric isokinetic (SA-CON) Clinical assessment (CA) Lateral displacement scapula (LDS)	EMGn: Characterization of the action potentials of the motor unit CA: Clinical tests; Impingement tests: Hawkins and -Kennedy and Neer;-sulcus sign; scapulothoracic rhythm; Physical examination Posture of the shoulder girdle; signs of impingement or instability; ROM: Standard goniometry to measure the mobility of the shoulder girdle and the range of motion passive and active bilaterally Measured the retraction	EMGn: Four different regions of the supraspinatus and infraspinatus muscles on both sides Standard procedures consisting of standardized placement of surface electrodes to monitor the responses on Erb's point stimulation ROM: AAOS protocol SA-CONC: Cybex testing manual protocol; velocities: 60º/s and 180º/s SA-CONC: Cybex 350 isokinetic dynamometer to measure bilateral isokinetic concentric peak torque strength Lateral displacement of the scapula	EMGn: N.A ROM: Supine active and passive external rotation 0 º, 30 º and 90 ° abduction; Active and passive internal rotation 90º adduction; Horizontal flexion: patient sitting on a stool to allow the scapula to move freely along the thorax; Extension: prone position on the examiner's table SA-CONC: Supine position with the shoulder at 90º abduction; sitting with the shoulder at 90º flexion; standing with the shoulder at 90º flexion and then

				movement of the scapular through the maximum length of the requested shoulder strap and the distance was measured, horizontally, between the spinous process and the lower angle of the medial edge the scapula using the tape measure The maximum flexion of the shoulder girdle with the same measurement of the retraction movement of the scapula but requested for the protational movement .		with the shoulder in neutral position. Lateral displacement of the scapula: flexion and extension of the shoulder girdle (protraction and retraction)
Injury of the Suprascapular Nerve at the Spinoglenoid Notch Ferretti, A, et al 1998	Observational study	Volleyball players (n=38 with AI) Mean age: 26 (range, 15 to 27)	Magnetic resonance imaging (MRI) Electromyography (EMG) Clinical examination (CE)	MRI: Supraspinatus tendon and Infraspinatus tendon EMG: N.A.	EMG:Denervation infraspinatus muscle CE: Athletes evaluated by the responsible doctor for the selection of groups	MRI:N.A. EMG:N.A.
Suprascapular neuropathy in volleyball players Ferretti, A, et al 1987	Cross-sectional design	Volleyball players (n=96, with 20 AI) Mean age: 22 to 26 years' old	Electromyography (EMG) Strength assessment: concentric isokinetic (SA-CONC) Clinical assessment (CA)	EMG: N.A SA-CONC: Cybex II dynamometer (Cybex, Division of Lumex; Ronkonkoma, New York) The peak torque and work dominant and non-dominant shoulders were measured abduction and external rotation CA: History and clinical examination	EMG: N.A SA-CONC: Velocity: 90º/s Averages were recorded with the arm in zero and 90º of abduction concentric maximum peak torque 6 repetitions CA: N. A	EMG: N.A SA-CONC: Shoulder in external rotation bilateral the arm in 90º abduction CA: N. A

Prevalence of latent and manifest suprascapular neuropathy in high-performance volleyball players Holzgraefe, M, et al 1994	Cross-sectional design	Volleyball players (n=66 with AI) Mean age: N. A	Needle electromyography (EMGn) Clinical assessment (CA)	EMGn: Potentials of the motor unit of the infraspinatus muscle Fibrillation CA: History and clinical examination	EMGn: Assessed the infraspinatus and the supraspinatus muscles on both sides Five different regions of the infraspinatus and the supraspinatus muscles on both sides	EMGn: N.A.
Suprascapular neuropathy restricted to the infraspinatus muscle in volleyball players Montagna, P, et al 1993	Case reports	Volleyball players (n=6 with AI) Mean age: 16 to 32 years old	Needle electromyography (EMGn)	EMGn: Potential of the motor unit of the infraspinatus and supraspinatus muscles Denervation Amplitude Evoked response	EMGn: Stimulus local: suprascapular nerve Stimulus point: Erb´s point	EMGn: N. A.

N.A.: not available

4. Discussion

This study aims to present, through the systematic review, the evaluations that can be used and have been proved effective in assessing AI on volleyball athletes.

The literature addresses different reasons for infraspinatus atrophy, which can be by overhead shoulder activity, overuse, or trauma leading to a neuropathy of the suprascapular nerve. Such neuropathy can be caused respectively by direct compression of the suprascapular nerve at the level of the scapular or at the spinoglenoid notch [13]. The atrophy of the infraspinatus is not easily diagnosed, since most athletes do not complain of pain or do not show decrease in performance during sports. However, the reduction of the external rotation movement of the dominant side of the shoulder is detected frequently, which may be related to the excessive use of the shoulder joint complex [27].

4.1 Clinical assessment in volleyball athletes with infraspinatus atrophy

The clinical examination is performed to obtain detailed information about shoulder pain and injury, hile the physical examination should have information about the shoulder girdle, signs of impingement or instability and also to determine a possible association of the atrophy of the infraspinatus muscle with the parameters described above.

The Empty Can test (EC) is sensitive for a rotator cuff tear when the definition of a positive test is broad and specific as the definition of a positive test narrows. This test was originally described by Jobe and Moynes in 1982 as a supraspinatus strength test only. According Park et al 2005, Michener et al 2009 and Kelly et al 2010, which are related to impingement test, present the test as high quality, from 10 to 11 points, in the QUADAS score. These studies have classified the test for high specificity and only one study added moderate reliability, Itoi et al 1999 with a score of 9 on the QUADAS score (Chad Cook, Eric Hegedus, 2012) [36].

Regarding the external rotation forcetest, Ostoret al 2004 only applied the reliability of the test, represented as moderate. Micheneret al 2009 qualified reliability 0.67; sensitivity 56; specificity 87; while Itoi et al 1999 didn't test reliability having sensitivity and specificity 54; Kelly et al 2010 didn't test reliability but having sensitivity 55 and specificity 25. Only one study, Ostoret al 2004, didn't apply the QUADAS score and the other studies presented scores between 8-11, which means it's a high-quality test [36].

The Neer test, evaluated in the studies by Bak and Fauno et al 1997 and Jia et al 2009, has a score of 6 points, considered the low-quality test. Unlike studies by Michener et al 2009, Kelly et al 2010 and Silva et al 2008, which presented 11 points, corresponding to a high-quality test. Most studies have not evaluated its reliability, except for Michener et al 2009 who consider it moderate. Only Bak and Fauno et al 1997 with high specificity in the 100 test and 0 sensitivity. The other studies obtained high sensitivity for the Neer test. This test is of little or no use in impact diagnosis [36].

The apprehension test was originally described by Rowe and Zais et al 1981 to detect anterior instability. The studies Guanche and Jones et al 2003, Lo et al 2004, Farber et al 2006 and Oh et al 2008 presented high quality QUADAS score, with 7, 11 and 12 points, respectively. Only Jia et al 2009 scored 6, considering low quality. No study tested the reliability however this test has high specificity [36].

The Speed's test was not tested for reliability and the studies of Calis et al 2000 and Park et al 2005 classified with 8 and 10 points the score of QUADAS, being a test of high quality. The study by Calis et al 2000 considers a high sensitivity test, 69, while Park et al 2005, considers high specificity, 83 [36].

Sulcus sign is often used clinically has been researched in only one study the use of this sign to detect inferior instability is not supported but the sulcus sign may be a specific test that rules in a superior labral tear when positive. Seen in the study by Nakagawa et al 2005 with 93 specificity and high quality, QUADAS score of 10 points [36].

The O'Brien test for SLAP lacerations and specific for an acromioclavicular joint problem presents two studies with a low-quality QUADAS score classification of 3 and 6 points for the AC joint (O'Brien et al 1998 and Jia et al 2009) and two studies for the SLAP, with 5 and

6 points (Parentis et al 2002 and Jia et al 2009). Another four studies scored with high quality with scores above 8 (Guanche et al 2003; Morgan et al 1998; McFarland et al 2002 and Myers et al 2005). In this case, it is a test that may have little clinical utility, but a well-designed study can define this [36].

On physical examination, each athlete presented normal results for the scapulothoracic rhythm, Kennedy test and groove sign [14] and in the studies of Contemori [12,20,21] presented force deficit for external rotation and shoulder abduction on the atrophy side. Lajtai et al 2009 [14] used a Constant score in the average of 11 of the 15 possible points, however it is not a result that impairs the high performance of beach volleyball athletes, because it does not have a significant clinical result. Most players with infraspinatus atrophy did not report any subjective restriction, only relevant for shoulder strength for abduction. Witvrouw et al 2000 [18] had four athletes who presented severe hypotrophy of the infraspinatus muscle of the dominant side and presented grade II instability in the Neer test in the anterior direction of the shoulder and positive apprehension of the dominant side. The three articles [15,16,17] evaluated scapular dyskinesia in volleyball and tennis athletes used for the first time the Kibler scale that represents the patterns of scapular dyskinesia classified into three categories that correspond to the three planes of scapular movements in relation to the chest. In fact, it is considered as a reference for the evaluation of scapular movements. Type I and II classifications are commonly associated with labrum lesions and type III with coping lesions and impingement syndrome. In the studies, type I and type II dyskinesia were found in volleyball and tennis athletes [16,17]. Although this evaluation method is considered clinically simple and easy to perform, it has limitations due to the difficulty of visually classifying the scapula in the three planes of movement [27].

4.2 Assessment of joint amplitude in volleyball athletes with infraspinatus atrophy

The use of standard goniometry has advantages once it is an inexpensive, easily used instrument and the measurements can be taken quickly. The precision of the measurement is influenced by the joints, the procedure used, the different pathologies and the use of passive or active movement during the measurement [31].

The study by Witvrouw et al 2000 [18] performed the measurement, with active and passive movements, to observe the mobility of the shoulder girdle and the presence of neuropathy of the infraspinatus muscle with standard goniometry. The athletes with AI presented greater mobility in the shoulder in relation to the athletes without AI, and the greater the mobility of the shoulder can lead to greater the probability of the suprascapular nerve being injured by traction. Although it is effective, he comments that in his study the number of athletes was small, limiting the interpretation of the result due to standard errors, which suggests a cautious interpretation of accuracy. Merolla et al [15,16,17] used standard goniometry to examine the internal rotation of the shoulder before and after an established rehabilitation program. They found an increase in the internal rotation angle of the glenohumeral joint.

4.3 Assessment of muscle strength in volleyball athletes with infraspinatus atrophy

Muscular strength can be measured by various equipment's, the most common being the manual and isokinetic dynamometers that quantify and define the deficits of the musculoskeletal system [26].

The infraspinatus muscle plays an important role in the dynamic stability of the humerus head during functional movements. It is important to determine its dynamic strength and muscle activity in different exercises [34]. In the studies of Merolla et al 2010 [15] and Salles et al 2018 [19] both highlight the muscle imbalance in the scapula-thoracic dysfunction, which increases the demand for the rotator cuff of muscles that do not have the capacity to generate the necessary strength. In the case of the study by Merolla et al 2010 [16] detected increased strength of the infraspinatus muscle in athletes due to synchronization of the muscles of the shoulder girdle for a good scapular humeral rhythm. In fact, during the study, they observed that the imbalance of the scapular muscles increases the risk of shoulder injury, such as, for example, the excessive use of the same. However, Contemori et al 2018, also add that when there is alteration of the shoulder girdle muscles, which impairs its coordination, and there may be a greater risk of acute injury or excessive use in the shoulder joint complex, making it important to synchronize the humeral scapular rhythm.

4.3.1 Manual dynamometer isometric contraction

In the studies that used the manual dynamometer, four articles instructed [12,15,16,17] the maximum force to accurately evaluate the athletes' ability to actively generate the force at a specific angle, but one article [12] reported to have cautious interpretation of the results, because it did not verify the reliability of measurement for abduction force, external rotation and internal rotation of the shoulder.

The clinical tests of empty can (EC), scapular retraction (IRST) and infraspinatus strength (IST) were used to measure the strength of the infraspinatus and supraspinatus muscles. The authors report the easy reproducibility of IRST, which makes it an excellent exam to evaluate infraspinatus weakness, while EC and IST tests are practical and reliable to treat athletes with supraspinatus and infraspinatus muscle weakness associated with scapular dyskinesia for a specific protocol of functional reeducation [15,16,17]. In this study, Merolla et al [16] with EC and IST obtained a significant elevation in the strength of the infraspinatus and supraspinatus muscles. However, the studies of Merolla et al [15, 17] found a significant increase in strength with the IST, but when compared to the value found in the IRST, both found no difference in it. In the study Donatteli et al 2000 [28] found high reliability when performing the strength test of the rotator muscles of the glenohumeral joint in the scapular plane for internal rotation, external rotation and abduction, as in the studies above.

4.3.2 Isokinetic dynamometer concentric

The isokinetic dynamometer measures force from a given movement that usually has constant activity and comes from a combination of the defined mechanical speed and the movement of the individual [26]. Is a reliable instrument to evaluate muscle functions, such as rotation and elevation of the shoulder. The velocities can be considered slow (< 180°/s) or fast (> 180°/s) and the 180°/s velocity intermediate of execution. For power assessment, it is used 180°/s at 300°/s velocities, mainly for high level athletes. For the best study of peak torque and work, it is used angular velocity of the slow type, because the lower the angular velocity, the higher the torque or the work. In this case, the most commonly used 60°/s velocity [35]. In relation to reliability, Kuhlmann et al 1992 [29] demonstrated high reliability of concentric peak torque measurements for glenohumeral joint external rotation at 90º/s and 210º/s velocity in healthy individuals and Greenfiedl et al 1990 [30] found the same result, for internal rotation and external rotation at 60º/s velocity in healthy individuals.

The articles that used the equipment Cybex 350 [18] and Cybex-II [8], being an article used Cybex protocol and the Humac Norm test manual. In these cases, the athletes went through the process of familiarization with the equipment to present less error in the results. In the study by Ferreti et al 1987 [8], they used a velocity of 90º/s for abduction and external rotation of the shoulder, while Witvrouw et al 2000 [18] measured with a velocity of 60º/s and 180º/s for external rotation and internal rotation of the shoulder and Salles et al 2018 [19] measured with a velocity of 60º/s for external rotation of the shoulder. The three studies found a reduction in the movement of external rotation of the dominant side when compared to the contralateral side and Witvrouw et al 2000 [18] didn't obtain significant results for internal rotation of the shoulder.

4.4 Assessment of static and dynamic stability in volleyball athletes with infraspinatus atrophy

The proprioceptive system is important for the correct positioning of the hand during serving and spiking in volleyball and also for the preservation of functional stability, since it regulates the muscular responses that protect the joint from rapid loads that occur during spike, serve and blocking opponent's attack. When there is a reduction in proprioceptive information, neuromuscular function may be compromised, hindering the functional stability of the shoulder [33].

The authors comment that the static and dynamic patterns of movements performed in their studies aren't reproduced according to the specific gestures of volleyball. The high incidence of shoulder injury results from repetitive movements of elevation of the upper limb's and high degree of external rotation reached in the phases of serve and spike, making important the proprioceptive information for the perception of exact movement and efficient sports gesture, with high level of accuracy [12,19,20,21].

4.4.1 Static stability

Previous studies reported by Contemori et al 2018 suggest that the positioning of the closed kinetic chain in the weight bearing position of the upper limb's challenges proprioception, joint stability and muscle coactivation. It is also seen that balance and posture are controlled by the glenohumeral joint and scapulothoracic joint when there is stabilization of the lower limbs [12]. The force platforms used have the position of support of the upper limb in closed kinetic chain. The use of force platforms with different vision (open eyes and closed eyes) and upper limb support conditions (bilateral support and unilateral support) suggests that the deficit in sensory motor control results from a compromise of the proprioceptive component and the postural control system, hindering a certain level of muscle strength to maintain the specific body posture.

In fact, the largest stabilometric parameters displacement of the center of pressure (CoP-L) and instantaneous velocity (CoP-V) register for the side of the group with infraspinatus muscle atrophy, in comparison to the control group, that there is a reduction in static stability in the shoulders, which may be due to a deficit in the shoulder sensorimotor system [12]. However, Contemori [12] considers that the closed kinetic chain of the upper limb is less functional in high level athletes, since they move more frequently in open kinetic chain.

4.4.2 Dynamic stability

Goman et al 2012 [37] report that UQYBT testing is a tool that allows quantitative assessment of the athlete's ability to achieve with the free hand while maintaining weight on the contralateral side of the upper limb. Borms et al 2016 [38] adds that the test is reliable for measuring the unilateral function of the extremity of the upper limb in the closed kinetic chain position. Both agree that the test challenges both mobility and stability, allowing to demonstrate good reliability and a good way to determine the deficits and asymmetries of each athlete. Contemori et al 2018 [12], in his study, describes that the Upper Quarter Y Balance test (UQYBT) challenges proprioception, joint stability and muscle co-activation around the shoulder. However, they observed that, to achieve the lower-lateral and upper-lateral movements, athletes must actively control the flexion movement in the transverse plane. In volleyball players with AI, changes in the lower-lateral an dupper-lateral ranges cannot be clearly obtained due to the functional impairment of the infraspinatus muscle, which presents little flexibility and is also not fully balanced by the synergic muscles, consequently there is no control to support the weight and perform the movements correctly.

4.5 Assessment of joint position sensation in volleyball athletes with infraspinatus atrophy

The proper motor sensory control is important to keep the upper limb in the position that allows proper movement of the arm and hand during reach. The proprioception can be divided into joint position sense, perception of passive movement and sense of strength. These three are essential for neuromuscular control during dynamic activity. However, the sense of joint position is important to understand the upper limb in space and determine the range of motion required to complete the activity [33].

In the study by Salles et al 2013 [22], the assessment is determined by the ability to detect joint movement and it has been suggested to perform it by measuring the TTDPM in conjunction with the electroencephalogram (EEG) examination as an element of choice to certify passive movement. In his most recent study, Salles et al 2018 [19] reported that the evaluation of these parameters SERPT, TTDPM and joint position sense (JPS) shows good reliability. Salles et al 2013 [22] observed that the group with AI presented proprioceptive deficits as seen by TTDPM, in addition to a delay in the detection of passive movement when compared with the group without AI and the control group (non-athletes). In turn, the group without AI was detected the passive stimulus faster than the group with AI. The study by Salles et al 2018 [19] did not identify significant differences for the SERPT when comparing the AI group with the control group, but both groups showed reduced strength for external rotation in relation to the group without AI, but no significant differences were detected for TTDPM and JPS. However, the group without AI, achieved higher performance in both proprioceptive measures, TTDPM and JPS, than the group with AI and control group. In addition, a program of eccentric exercises and, subsequently, concentric exercises have been shown to directly improve functional capacity in the dynamic stabilizers of the glenohumeral joint and a change in proprioceptive tests, increasing the performance of passive motion detection. The athletes with infraspinatus atrophy who participated in the study reported an improvement in the sensation of position and also in the stabilization of the shoulder joint [19].

4.6 Changes in imaging exams in volleyball athletes with infraspinatus atrophy

4.6.1 Magnetic resonance imaging

Some articles report on imaging exams in athletes with AI. Those who report, refer to magnetic resonance imaging (MRI) as a preferential exam to evaluate the atrophy of the rotator cuff and the causes of compression of the suprascapular nerve.

Ferretti et al 1998 [9] verified that athletes with suprascapular nerve entrapment present normal radiography and reported that MRI is the best means to locate soft tissue masses and provide evidence of secondary denervation, concluding that it is the only examination that finds abnormality in athletes with AI. However, the athletes presented severe degeneration of the supraspinatus tendon, supporting the diagnosis of impingement syndrome II. Lajtai et al 2009 [14] used MRI to observe the changes found in the rotator cuff as in the studies of Merolla et al 2010 [15,16,17], especially the infraspinatus and supraspinatus muscles. In turn, Lajtai et al 2009 [14] found 3 ganglion cysts in the SLAP and anterosuperior regions, not related to the suprascapular nerve and also found significant differences in the labrum, such as fraying or tear. While Merolla et al 2010 [15,16,17] observed labral lesions, partial lesions of the supraspinatus and rotator cuff ruptures in athletes with scapular dyskinesia.

4.6.2 Sonography

The sonography (US) is amply used because it is an economic instrument, easy to evaluate with non-invasive measurement, but safe and efficient, providing dynamic imaging studies. The US is considered accurate with a sensitivity range of 92.4% to 96% and a specificity range of 93% to 94.4% for the diagnosis of total thickness rupture and partial thickness rupture, a sensitivity range of 66.7% to 84% and specificity of 89% to 93.5% [41]. In the study by Lajtai et al 2009 [14], they identified in the US examination that the group with AI had irregularity in the rotator cuff tendons, especially the supraspinatus, infraspinatus and subscapular. Other findings regularly seen in the dominant shoulder were the posterosuperior impact of the glenoid, greater tuberosity (cortical irregularities) and osteophytes in the acromioclavicular joint. Although Ferretti et al 1998 [9] did not use US to evaluate athletes with AI, they added that US is reliable to detect lesions in the infraspinatus fossa space.

4.7 Changes electrophysiological exams in volleyball athletes with infraspinatus atrophy

4.7.1 Electromyography

According to Reaz et al 2006 [40], needle electromyography is a method of needle electrodes that are placed directly in the muscle in order to acquire the individual potential of the action of muscle fiber. The surface electromyography records the information present in the potentials of muscle action. The EMG signal reaches noises when walking through different tissues. When identifying and recording the EMG signal, there are two main issues to influence the signal fidelity, the signal-to-noise ratio issue and the noise that means that they are electrical signals that are not part of the desired EMG signal. Another point to pay attention to is the distortion of the signal which is the relative contribution of any frequency component in the EMG signal that should not be altered. There is yet another limitation related to the detection and characterization of existing nonlinearities in the surface EMG signal. However, the validity and precision of any EMG measurement is derived from the signal detection process that includes the distance between the electrodes, their sizes and locations, and skin preparation for minimizing impedance[40].

4.7.2 Surface electromyography

In the most recent study, Lajtai et al 2012[13], add that the tension and traction that occur in the suprascapular nerve result in the neuropathy of the suprascapular, which can occur in the change in the velocity of nerve conduction and in the activation pattern of the infraspinatus muscle when it is atrophied, which confirms the injury in the infraspinatus muscle. Thus, the result found in relation to the activation pattern of the infraspinatus muscle during external rotation of the shoulder showed a significant difference between the side of the group and the AI compared to the contralateral side. However, this difference occurred in the group with slight atrophy, because in the group with severe atrophy it was reduced. Contemori et al 2018 [20] performed surface EMG in the scapulothoracic muscles. Although the infraspinatus muscle does not act directly on the scapulothoracic joint, there is also a change in the muscles of this joint, and it is important to monitor it. The changes found were, specifically, increased activity of the upper trapezius muscle and reduced activity of the anterior serrated muscle, which consider imbalance in pairs of force for scapular rotation during the movement of elevation of the humerus, compromising, consequently, the scapulohumeral rhythm. Although they did not use the EMG for evaluation of athletes with AI, Lajtai et al 2009 [14] suggest more studies based on surface EMG to confirm the cause of AI in volleyball players is due to nervous elongation neuropathy caused by repetitive activity.

4.7.3 Needle electromyography

In the study by Montagna et al 1993 [24], presented in two cases described six cases of loss of the motor unit to the infraspinatus muscle and to the supraspinatus muscle, their denervation and reinnervation signs restricted to the infraspinatus on the dominant side. The study by Holzgraefe et al 1994 [23], the athletes with severe atrophy of the infraspinatus muscle presented more than three fibrillations and loss of action potential of the motor unit, indicating complete denervation. The supraspinatus muscles showed polyphasic and prolonged potentials, assuming chronic nerve damage. Although the athletes with AI did not present any functional disability during the game, those who had severe atrophy reported shoulder pain and mild impairment of the daily routine but presented partial denervation of the supraspinatus and infraspinatus muscles detected in the examination. For this reason, it suggests that electrophysiological studies with needle should be more used to monitor the state of the suprascapular nerve and prevent the appearance of injury. The same happened in the study of Witvrouw et al 2000[18], the athletes with denervation of the infraspinatus muscle of the dominant side presented complete motor reduction of the same muscle, both at effort and at rest. Unlike the study by Pieber et al 2014[25], which verified whether there was acute or chronic neurogenic alteration in the infraspinatus muscle, in which there was no alteration. Only in the study of Salles et al. 2013[22] the electroencephalogram (EGG) was used in conjunction with needle EMG in order to ensure that the motion detection was totally passive. The AI group demonstrated a reduction in power when compared to the control group and the group without AI in relation to planning and motion control. There was no difference between the control group and the IA group in terms of part of planning, motion control and integration of sensory information from different parts of the body. Finally, when comparing the three groups, they found differences in the representation of sensoryareas.

The authors also hypotize that the different frequencies (alpha and beta) are able to discriminate the imbalance caused by the infraspinatus atrophy, being important to consider them in the evaluation of athletes with AI because the beta frequency is more sensitive to sequential and repetitive movement and is associated with movement preparation and contralateral movement than the alpha frequency that can be correlated to cortical areas activities during sensorimotor processing[22].

4.7.4 Nerve conduction velocity

According to Boykin et al 2010[5], electromyography (EMG) is commonly used to assess muscle activity, function, and fatigue, while nerve conduction velocity (NCV) assesses to the speed of nerve stimulation[5]. The study Witvrouw et al 2000[18] showed complete denervation of the infraspinatus muscle of the dominant side, while Lajtai et al 2012[13] found significant findings in the measurement of latency on the dominant side in relation to the contralateral side but found no difference in the measurement of amplitude. According to the authors, this would be compatible with a repetitive strain injury or trauma[18,13]. Pieber et al 2014[25] found only two athletes with suprascapular nerve denervation for the group with AI. They comment that EMG and NCV are the standard diagnosis for suprascapular nerve injury.

5. Conclusion

As seen in the literature review, infraspinatus atrophy is associated with suprascapular neuropathy and presents increased joint movement of the shoulder joint complex and decreased muscle strength, especially for lateral rotation. External rotation strength measurements and NCV measurements can detect a side-to-side difference early on, while EMG may only show compensation mechanisms and progressive damaging of the suprascapular nerve compression and, as a result, of infraspinatus muscle strength loss.

Professional volleyball athletes use their upper limbs often and with repetitive gestures. Once the imbalance of the scapular muscles appears, the joint of the shoulder joint complex becomes unstable, compromising its stabilization. The clinical tests are practical and valid in the assessment of the shoulder joint, although the impact tests are not reliable because they are a manual measurement, and persistent errors occur.

Kinematics 3D has been suggested to obtain a more detailed assessment of both kinematics and shoulder joint amplitude, proprioceptive tests that determine the ability to perceive movement, since athletes with IA have a delay in the detection of passive movement and joint position sensation, which may be indicative of impairment in the proprioceptive component that is essential for shoulder functionality and for correct sports gesture. Although some articles have used imaging examinations, they found that MRI is the best exam to identify changes in the infraspinatus muscle, while US is good way to detect lesions in the infraspinatus fossa space and recommend ruling out the use of radiography, as it does not any change in the shoulder of athletes with AI.

Therefore, it is concluded that the best evaluation method for volleyball athletes with AI is suggested by the analysis of joint kinematics together with electrophysiological and imaging exams.

References

1. Uluoz, E., An analysis of the sports injuries occurred in competitions in Men's VolleyballLeagueduring fiveyearperiod(2011-2016)1.JHumanSciences,2016.13(3):p.5786-5795.

2. Reeser, J.C., et al., Strategies for the prevention of volleyball related injuries. Br J Sports Med, 2006. 40(7): p.594-600;discussion599-600.

3. Schafle, M.D., Common injuries in volleyball. Treatment, prevention and rehabilitation. Sports Med, 1993. 16(2):p.126-9

4. Kostretzis, L., et al., Suprascapular Nerve Pathology: A Review of the Literature.OpenOrthopJ,2017. 11:p. 140-153.

5. Boykin,R.E.,et al.,Suprascapularneuropathy.J BoneJointSurgAm,2010. 92(13):p.2348-64.

6. Cummins, C.A., T.M. Messer, and M.F. Schafer, Infraspinatus muscle atrophy in professional baseball players.Am J SportsMed,2004.32(1):p.116-20.

7. Briner, W. W., Jr. and L. Kacmar (1997). "Common injuries in volleyball. Mechanisms of injury, prevention andrehabilitation." Sports Med 24(1): 65- 71.7.

8. Ferretti,A.,G.Cerullo,andG.Russo,Suprascapularneuropathyin volleyball players. J Bone Joint Surg Am, 1987.69(2):p.260-3.

9. Ferretti, A., A. De Carli, and M. Fontana, Injury of the suprascapularnerve at the spinoglenoid notch. The naturalhistoryofinfraspinatusatrophyinvolleyballplayers.AmJ SportsMed,1998.26(6):p.759-63.

10. Yao,L.andU.Mehta,Infraspinatusmuscleatrophy:implications?Radiology, 2003. 226(1): p.161-4.

11. Dramis,A.andA.Pimpalnerkar(2005)."Suprascapularneuropathyinvolleyballplayers." ActaOrthop Belg 71(3):269-272.

12. Contemori, S., et al., Sensorimotor Control of the Shoulder inProfessional Volleyball Players With IsolatedInfraspinatusMuscleAtrophy.J SportRehabil,2018. 27(4):p.371-379.

13. Lajtai, G., et al., Electromyography and nerve conduction velocity for the evaluation of the infraspinatus muscle and the suprascapular nerve in professional beach volleyball players. Am J Sports Med, 2012. 40(10): p. 2303-8.

14. Lajtai, G., et al., The shoulders of professional beach volleyball players: high prevalence of infraspinatus muscleatrophy.Am J Sports Med,2009.37(7):p.1375-83.

15. Merolla, G., et al., Infraspinatus scapular retraction test: a reliableand practical method to assess infraspinatus strength in overhead athletes with scapular dyskinesis. JOrthop Traumatol, 2010. 11(2): p. 105-10.

16. Merolla, G., et al., Supraspinatus and infraspinatus weakness in overhead athletes with scapular dyskinesis: strength assessment before and after restoration of scapular musculature balance.

MusculoskeletSurg,2010.94(3):p.119-25.

17. Merolla, G., et al., Infraspinatus strength assessment before and after scapularmusclesrehabilitation inprofessionalvolleyballplayerswithscapulardyskinesis.JShoulderElbowSurg,2010.19(8):p.1256-64.

18. Witvrouw,E.,et al.,Suprascapularneuropathyin volleyball players.Br J Sports Med,2000.34(3):p.174-80.

19. Salles,J.I.,et al.,Effect of a specific exercise strategy on strength and proprioception in volleyball players with infraspinatus muscle atrophy.Scand JMed Sci Sports,2018.28(9):p.2093-2099.

20. Contemori, S. and A. Biscarini, Shoulder position sense in volleyball playerswithinfraspinatusatrophy secondarytosuprascapularnerveneuropathy.ScandJMedSciSports,2018.28(1):p.267-275.

21. Contemori, S. and A. Biscarini, Isolated Infraspinatus Atrophy Secondary to Suprascapular Nerve NeuropathyResultsin AlteredShoulderMusclesActivity.J SportRehabil,2018:p.1-29.

22. Salles JI, Cossich VR, Amaral MV, Monteiro MT, Cagy M, Motta G, et al. Electrophysiologicalcorrelates ofthethresholdtodetectionof passivemotion: an investigation in professional volleyball athletes with and withoutatrophyof the infraspinatusmuscle.BiomedRes Int.2013;2013:634891.

23. Holzgraefe,M.,B.Kukowski,andS.Eggert,Prevalenceoflatentandmanifest suprascapular neuropathy in high-performancevolleyballplayers.Br J SportsMed,1994.28(3):p.177-9.

24. Montagna, P. and S. Colonna, Suprascapular neuropathy restricted to the infraspinatus muscle in volleyballplayers.ActaNeurolScand,1993.87(3):p.248-50.

25. Pieber, K., et al., Is suprascapular neuropathy common in high-performance beachvolleyballplayers? Aretrospectiveanalysis.WienKlinWochenschr,2014.126(19-20):p.655-8.

26. Duzgun,I.,et al.,Theeffectsofjump-ropetrainingonshoulderisokineticstrengthin adolescentvolleyball players.J SportRehabil,2010.19(2):p.184-99.

27. KIBLER, W. Ben, et al; Scapular Summit 2009, Lexington, Kentucky." journal of orthopaedic &sports physicaltherapy39.11(2009):A1-A13.

28. Donatelli, R., Ellenbecker, T. S., Ekedahl, S. R., Wilkes, J. S., Kocher, K.,& Adam,J.(2000).Assessment of ShoulderStrengthinProfessionalBaseball Pitchers.Journal of Orthopaedic & SportsPhysicalTherapy,30(9), 544–551.doi:10.2519/jospt.2000.30.9.544

29. Kuhlmann JR, Ianotti JP, Kelly MJ, et al. Isokinetic and isometric measurement of strength of external rotationandabductionof the shoulder.J BoneJointSurg[Am]1992;74:1320–33.

30. Greenfield BH, Donatelli R, Wooden MJ, et al. Isokinetic evaluation of shoulderrotationalstrength betweentheplaneofscapulaandthefrontalplane.AmJ SportsMed1990;18:124–8.

31. Riddle DL, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting: shoulder measurements. Phys Ther1987;67:668–73.

32. LaudnerKG,SipesRC,WilsonJT.Theacuteeffectsofsleeperstrengthonshoulderrangeofmotion.J Athl

Train2008;43:35963.

33. Myers JB, Wassinger CA, Lephart SM. Sensorimotor contribution to shoulder stability: effect of injury and rehabilitation. Man Ther. 2006;11:197–201.

34. Yu, I. Y., et al. (2018). "Effects of 3 Infraspinatus Muscle Strengthening Exercises on Isokinetic Peak Torque and Muscle Activity." J Sport Rehabil: 1- 7.

35. FronteraWR,HughesVA,DallalGE,EvansWJ.Reliabilityofisokineticmuscle strengthtestingin45to78-year-oldmenandwomen.ArchPhysMedRehabil1993;74:1181-5.

36. Chad Cook, Eric Hegedus. Orthopedic Physical Examination Tests: An Evidence- Based Approach, Second Edition. 2012 byPearson Education, Inc.

37. Gorman PP, Butler RJ, Plisky PJ, Kiesel KB. Upper Quarter Y Balance Test: reliability and performance comparison between genders in active adults. J Strength Cond Res. 2012;26(11):3043–3048.

38. Borms, D., et al. (2016). "Upper Quadrant Field Tests and Isokinetic Upper Limb Strength in Overhead Athletes." J Athl Train 51(10): 789-796.

39. Kuniszyk-Jozkowiak, W., et al. (2018). "Changes in electromyographic signals and skin temperature during standardised effort in volleyball players." Acta Bioeng Biomech 20(4):115-122

40. Raez, M. B., et al. (2006). "Techniques of EMG signal analysis: detection, processing, classification and applications." Biol Proced Online 8:11-35.

41. Kim, K., et al. (2016). "Ultrasound Dimensions of the Rotator Cuff and Other Associated Structures in Korean Healthy Adults." J Korean Med Sci 31(9): 1472-1478.