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Scapula position in volleyball players with and without infraspinatus atrophy in different arm positions: a cross-sectional study

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Resumo

Introdução: A atrofia do infraespinhoso (ISA) resulta de uma mononeuropatia do nervo supraescapular, que é bastante comum em atletas de voleibol. O infraespinhoso atua como mobilizador e estabilizador do ombro e a sua atrofia pode levar a alterações posicionais e de movimento do complexo do ombro.

Objetivos: Comparar a posição da escápula em três posições estáticas do braço – repouso, mãos na cabeça (HH) e mãos na lombar (HLB) – em atletas com e sem ISA e relacionar estes achados com a ISA e movimentos *overhead*.

Métodos: Estudo observacional, analítico e transversal com uma amostra de 32 jogadores de voleibol de elite voluntários. Foram recolhidos dados da amplitude de movimento do ombro e ratios de torque a 60°/s avaliado com o Biodex System 4 Pro, bem como distâncias e ângulos escapulares avaliado através do sistema de captura de movimento Qualysis, na posição de repouso, HH e HLB. O teste t para duas amostras independentes e o teste Mann-Whitney U foram usados para comparar os grupos, com um nível de significância de 0.05.

Resultados: 32 jogadores de voleibol divididos no grupo com ISA (DIA, n=14) e sem ISA (NDIA, n=18). Não foram encontradas diferenças significativas no ROM nem nos ratios de torque a 60 °/s. Os jogadores com ISA apresentaram maior distância horizontal inferior no lado não dominante (NDOM) em repouso (p=0.032) e no lado dominante (DOM) na posição HH (p=0.029), assim como maior distância entre os ângulos inferiores das escápulas em repouso (p=0.029) e na posição HH (p=0.032). Foi encontrada uma diferença maior entre os lados DOM e NDOM da distância horizontal superior (p=0.044) e da rotação superior (p=0.040).

Conclusão: Os atletas com ISA, apesar de não apresentarem alterações de ROM ou de ratios de torque a 60 °/s, apresentam alterações da posição escapular, especialmente em repouso e em HH. É necessário distinguir estas alterações biomecânicas associadas à ISA de adaptações específicas do desporto, de forma a individualizar e direcionar a reabilitação para as alterações identificadas.

Palavras-chave: atrofia do infraespinhoso, biomecânica do ombro, cinemática escapular

Abstract

Introduction: Infraspinatus atrophy (ISA) results from a mononeuropathy of the suprascapular nerve, that is common in volleyball players. The infraspinatus acts as a mobilizer and stabilizer of the shoulder and its atrophy can lead to positional and motion alterations of the shoulder complex.

Aims: To compare scapular positioning in three static arm positions – rest, Hands in Head (HH) and Hands in Low Back (HLB) – between players with and without ISA and to relate these findings with ISA and overhead movements.

Methods: An observational, analytical and cross-sectional study with a sample of 32 volunteer elite volleyball players. Data on shoulder range of motion (ROM) and torque ratios at 60 °/s were assessed with Biodex System 4 Pro, as well as scapular distances and angles were assessed with Qualysis Motion Capture System. The two independent samples t-test and Mann-Whitney U tests were used to compare groups, with a significance level of 0.05.

Results: 32 volleyball players divided into ISA (DIA, n= 14) and non-ISA (NDIA, n=18) groups. No significant differences were found in ROM and torque ratios at 60 °/s. ISA players had a higher lower horizontal distance in the non-dominant (NDOM) side at rest ($p=0.032$) and in the dominant (DOM) side in HH ($p=0.029$) and scapular lower angles distance at rest ($p=0.029$) and HH ($p=0.032$). A higher difference between DOM and NDOM sides of the upper horizontal distance ($p=0.044$) and upward rotation ($p=0.040$) was found.

Conclusion: Players with ISA did not present alterations of ROM or torque ratios at 60 °/s, but demonstrated altered scapular positioning, specifically in the rest and HH position. It is necessary to differentiate these biomechanical adaptations associated with ISA from sport-specific adaptations, to specify and target the rehabilitation to the identified alterations.

Keywords: infraspinatus atrophy, shoulder biomechanics, scapular kinematics

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1. Introduction

Overhead athletes, due to the repetitive stresses in their dominant shoulder, are prone to develop neuropathy on the suprascapular nerve (Contemori & Biscarini, 2018). The suprascapular nerve is a mixed peripheral nerve that arises from the upper trunk of the brachial plexus, that conveys motor innervation to the supraspinatus and infraspinatus muscles, as well as proprioceptive information to the posterior aspect of the glenohumeral joint. (Contemori & Biscarini, 2018; Reeser et al., 2013). A proximal lesion at the suprascapular notch results in atrophy of the supraspinatus and infraspinatus muscles, while a more distal injury at the spinoglenoid notch results in the atrophy of the infraspinatus (Reeser et al., 2013).

Infraspinatus atrophy (ISA) is thought to be the result of a peripheral mononeuropathy of the suprascapular nerve (Young et al., 2015), but the aetiology of ISA remains controversial, with several theories proposing the compression or traction of the suprascapular nerve at two anatomic locations where the nerve is more vulnerable, the suprascapular notch and the spinoglenoid notch (Challoumas & Dimitrakakis, 2017). According to the systematic review from Challoumas & Dimitrakakis (2017), although some authors have reported combined infraspinatus and supraspinatus atrophy, the majority of literature describes isolated infraspinatus atrophy (ISA) in volleyball athletes. A reduction of the soft tissue bulk in the infraspinatus fossa of the hitting shoulder can be observed in athletes with this injury (Young et al., 2015). In volleyball players, ISA has an incidence ranging from 12,5-34% (Challoumas & Dimitrakakis, 2017).

The suprascapular nerve lesion appears to be related to the specific kinematic patterns of overhead sports (Lajtai et al., 2009; Reeser et al., 2013; Witvrouw, Cools, Lysens, et al., 2000; Young et al., 2015), like the ones that volleyball athletes are required to execute, such as spiking, setting, serving and blocking (Pascoal et al., 2023), and the repetitive and continuous nature of the sport (Murray et al., 2013; Wagner et al., 2012; Wang & Cochrane, 2001; Wilk et al., 2009). When performing a spike, the player aims to produce high velocities and large forces on the upper limb that are transmitted to the ball, while maintaining a maximal level of accuracy, to score a point and making it difficult for the opponent to return the ball (Pascoal et al., 2023; Reeser et al., 2010; Rokito et al., 1998). This is achieved by abducting and externally rotating the dominant shoulder at maximal range of motion and afterwards adducting and internally rotating the arm rapidly (Rokito et al., 1998; Reeser et al., 2010). The scapula plays a critical biomechanical role in these movements. During shoulder abduction, the scapula undergoes a combination of posterior tilt, upward and external rotation, whereas shoulder adduction involves anterior tilt, upward and internal rotation (Reeser et al., 2013).

Injury to the infraspinatus compromises both its functions as a prime or synergistic mobilizer in external rotation and its role as a dynamic stabilizer of the glenohumeral joint and its fundamental role in the functional stability of the shoulder (Lajtai et al., 2009; Myers et al., 2006; Myers & Lephart, 2000; Young et al., 2015).

Due to its function and overhead movements, the infraspinatus atrophy in volleyball players can lead to alterations of the shoulder complex elements position and motions during the overhead motions to make them efficient (Borsa et al., 2008). Alterations of the scapula rest position and/or dynamic motion are referred to as scapular dyskinesis (SD) (Huang et al., 2015; Kibler et al., 2013; Pluim, 2013). SD affects the whole kinematic chain (Chopp-Hurley et al., 2016; Lefèvre-Colau et al., 2018; Maenhout et al., 2015) and can lead to inefficient shoulder movements and function and increase injury risk (Kibler et al., 2013).

Despite the significant incidence of ISA, only few studies attempted to link ISA with shoulder biomechanics, that focused on shoulder range of motion (ROM) and strength, injury and performance (Challoumas, Artemiou, et al., 2016; Lajtai et al., 2009; Lajtai et al., 2012; Witvrouw et al., 2000; Young et al., 2015). The aim of this study is to compare shoulder ROM and torque ratios at 60 °/s among athletes with and without ISA, as well as scapular positioning across three static arm positions – at rest, Hands to Head (HH) and Hands to Low Back (HLB). To accomplish the aim of the study, scapula positioning and scapular angles will be determined and analyzed side to side, between positions and between groups. It is our intention to connect the findings to ISA and any potential findings with overhead movements.

2. Methods

2.1. Research design

The study design was observational, analytical and cross-sectional. The data were collected in 2019 and in 2024. The data regarding each athlete was collected in a single moment.

2.2. Participants

The target population of this study are elite senior volleyball athletes from the north of Portugal.

The sample of the study was obtained through recruitment via mobile phone, directly with the athletes that volunteered to participate.

The individuals were selected based on the following inclusion criteria: senior athletes participating in official FPV events and athletes from teams based in the northern region of the country that agreed to participate. Athletes were excluded if they met any of the following criteria: undergone surgery on the shoulder complex or elbow joint and those experiencing pain at the time of evaluation.

The athletes were allocated to the corresponding group, diagnosed infraspinatus atrophy (DIA) and no presence of infraspinatus atrophy (NDIA), according to the presence or absence of infraspinatus atrophy, respectively.

2.3. Ethical considerations

The study was conducted in accordance with the declaration of Helsinki and approved by the Ethics Committee of the Faculty of Sport of the University of Porto with approval number CEFADE 06.2018.

All participants were informed of the study aims, data collection procedures and processing and signed a written consent form to participate in the study. All individuals were informed that the data would be used for research purposes, with guaranteed confidentiality and anonymity. The participants were free to ask questions, decline participation or withdraw at any moment.

2.4. Procedures

Procedures in this study took place at the Porto Biomechanics Laboratory (LABIOMEP) and were performed in a controlled environment, by a single experienced physiotherapist in the volleyball setting and in musculoskeletal physiotherapy.

2.4.1. Biological, volleyball and injury data

A self-produced questionnaire on paper was given to all athletes to characterize the sample. Data was collected on the athletes' biological characteristics, injury history and volleyball background. The arm that executes the serve was classified as dominant. The athletes provided anthropometric data of their mass and height, that enabled the calculation of Body Mass Index (BMI) through the following formula:

$$BMI = \frac{\text{Mass (kg)}}{\text{Height } (m^2)}$$

2.4.2. Presence of visual infraspinatus atrophy

Volleyball players were identified with infraspinatus atrophy if they displayed recognizable and significant infraspinatus muscle atrophy during posterior shoulder visual assessment, noted by a markable depression present at the infraspinatus fossa with increased prominence of the bony borders of the dorsal scapula with clear asymmetry when compared with the contralateral side (Cummins et al., 2004; Ferretti et al., 1987; Young et al., 2015). The assessment was performed by a single physiotherapist with experience in the volleyball setting and in musculoskeletal physiotherapy.

2.4.3. Disabilities of the Arm, Shoulder and Hand questionnaire

Disabilities of the Arm, Shoulder and Hand questionnaire (DASH) was used and integrated in the questionnaire given to the participants to characterize the sample. The DASH is a self-reported questionnaire that clinically assesses the athletes and identifies symptoms and limitations in daily and sports activities (Santos & Gonçalves, 2006).

The questionnaire consists of 30 questions and 4 additional sports specific questions, expressed on a 5-point Likert scale. The total score is expressed on a scale from 0 to 100, where 0 represents maximum functionality and 100 represents the highest level of disability. DASH is validated to the Portuguese population and is of free use for investigation (Santos & Gonçalves, 2006).

2.4.4. Kinematic data collection and processing

The Biodex System 4 Pro (Biodex Inc., United States of America) and Biodex Medical System software, version 26.2 were used to assess range of motion (ROM) and torque ratios. To collect the data, the participants were positioned according to the manufacturer's instructions in the shoulder external/internal modified neutral position. The glenohumeral joint was positioned in the scapular plane, aligned with the dynamometer's axle, with the elbow at 90° of flexion and neutral forearm. Each individual actively performed the maximum ROM of internal and external rotation and the values were collected. The concentric isokinetic evaluation was performed at the same ROM at a velocity of 60 °/s. The individuals executed 5 repetitions to familiarize themselves with the movement and then 5 maximum repetitions of external and internal rotation were executed. This procedure was performed on the dominant and non-dominant side. The data were exported to Excel.

A 12-camera optoelectronic motion capture system (Qualisys AB, Gothenburg, Sweden), operating at 200 Hz sampling frequency was used to record the scapula position. The wand calibration method was performed for 30 seconds, ensuring that the standard deviation of the wand length remained below 1mm.

The recorded data captured were first processed in Qualisys Track Manager v2023.3 (Qualisys AB, Gothenburg, Sweden), where marker identification was performed. The values of the angles and distances were collected through this software.

Female athletes were asked to wear a crisscross top to reduce the interference with data collection.

Before data collection, all relevant anatomical landmarks were identified through palpation for the placement of 12mm retroreflective markers, that allowed to capture full-body movement. The following anatomical landmarks were marked: sternal notch, xiphoid process, spinous process of 7th cervical vertebra, 3rd and 7th thoracic vertebra; acromioclavicular joint, scapula root spine and scapula lower angle of both upper limbs. A cluster of three markers were placed on the lower lumbar region.

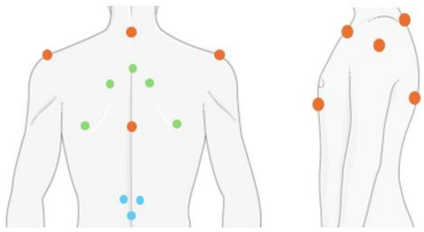
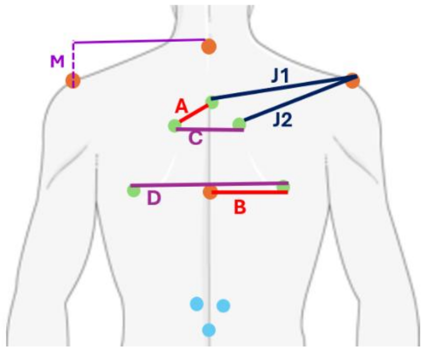
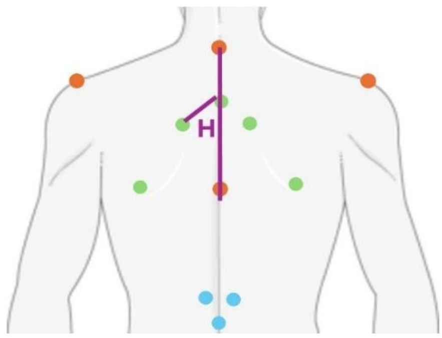


Figure 1 – Anatomic landmarks for skin markers (orange and green): Sternal notch (Bonnefoy-Mazure et al., 2010; Keeley et al., 2012; Mitchinson et al., 2013); Xiphoid process (Bonnefoy-Mazure et al., 2010; Mitchinson et al., 2013; Seminati et al., 2015) ; C7 spinous process (Pecos-Martín et al., 2022; Seminati et al., 2015); D3 spinous process(Gibson et al., 1995; Greenfield et al., 1995); D7 spinous process (Greenfield et al., 1995; Yano et al., 2010); Acromioclavicular joint (Greenfield et al., 1995; Roy & Esculier, 2011; Yano et al., 2010); Scapula root spine (Greenfield et al., 1995; Sobush et al., 1996; Yano et al., 2010); Scapula lower angle (Gibson et al., 1995; Sobush et al., 1996) ; Lumbar region (L3-L5) (cluster) (blue) (Yano et al., 2010).
Note: Figure 1 was generated from adapted figures provided by Servier Medical Art (Servier;https://smart.servier.com/), licensed under a Creative Commons Attribution 4.0 Unported License

A coordination system for the scapula was established using markers, with the X axis denoting flexion (+) and extension (-), the Y axis representing adduction (+) and abduction (-) and the Z axis indicating internal rotation (+) and external rotation (-).

The data regarding distances, angles and scapular positioning, for both upper limbs, were gathered in three static positions: neutral (REST), Hands in Head (HH) and Hands in Low Back (HLB). Values were obtained for all the positions mentioned above.

Table 1 – Variables of collected distance and angles and respective description

▪ **A Upper horizontal distance** – from D3 to scapula root spine (bilateral) – measure of lateral displacement : the higher the distance, the farthest the root spine is from the midline (da Costa et al., 2010; Juul-Kristensen et al., 2011; Sobush et al., 1996; Sousa et al., 2019) ▪ **B Lower horizontal distance** – D7 to scapula lower angle (bilateral) – measure of lateral displacement: the higher the distance, the farthest the scapula lower angle is from the midline (da Costa et al., 2010; Juul-Kristensen et al., 2011; Sobush et al., 1996; Sousa et al., 2019) ▪ **C Scapula root spine distance** – right to left scapula root spine: the higher the distance, the more the scapula right and left root spine are apart. ▪ **D scapula lower angle distance** – right to left scapula lower angle: the higher the distance, the more the scapula right and left lower angle are apart. ▪ **J Scapular protraction at rest** – (distance D3 - acromion) **J1**/distance root – acromion **J2** –(Greenfield et al., 1995) ▪ **M Acromial depression at rest** – vertical distance between acromion and C7 – indicator of depression of the scapula, downward rotation or both (da Costa et al., 2010; Roy & Esculier, 2011)	 **Figure 2** – Distance variables
▪ **H Upward rotation** – Scapular root and line D3-D7 (Yano et al., 2010)	 **Figure 3** – Angle variable

Note: Figure 2 and Figure 3 were generated from adapted figures provided by Servier Medical Art (Servier;https://smart.servier.com/), licensed under a Creative Commons Attribution 4.0 Unported License

The participants were positioned in a relaxed bipedal stance with the arms alongside the body (REST). To maintain consistent scapular movement conditions without the interference of glenohumeral range of motion due to trunk placement, two compound movements were used: the Hands to Head (HH) and Hand to Low Back (HLB) movements. To execute the HH movement, that combines shoulder external rotation and abduction, the participants were instructed to place both hands behind the neck, at the same time. To perform the HLB movement, that associated shoulder internal rotation and adduction (that occurs in the acceleration, deceleration and follow-through phases of the spike), the players were told to place both hands on the lumbar region. It was not asked to reach as far up as possible on the HLB as it typically is (Beshara et al., 2022; Ogawa et al., 2025; Satpute et al., 2016), so that the range of motion was equal for all. In both movements, the hands were overlapping each other. When the participants reached the intended position, each skin marker was individually and manually positioned at the new skin locations of the scapular anatomic landmarks (Yano et al., 2010).

The data file was trimmed at REST and seconds after the end of the HH and HLB.

2.4.5. Calculations

To obtain the values of difference between the dominant and non-dominant side for each variable, the value of the non-dominant side was subtracted from the dominant side.

The total ROM was obtained through the sum of internal plus external rotation ROM.

2.5. Statistical analysis

Descriptive and inferential statistics analysis were performed by IBM SPSS Statistics® version 29.0.2.0 (IBM Corp.®, New York, United States), for Windows, with a significance threshold of $p<0.05$.

The Shapiro-Wilk test was applied to assess the normality of each variable. For normally distributed data, comparisons between groups were performed using the independent samples t-test, for non-normally distributed data, the Mann-Whitney U test was applied.

A descriptive statistical analysis was conducted to characterize the sample, including calculation of means, standard deviations (SD), medians 25th-75th percentiles for continuous variables and absolute and relative frequencies for categorical variables. The Pearson Chi-Square test with continuity correction was applied to assess the gender variable. The Fisher's Exact test was applied to the players' position variable.

All variables were analyzed separately for the dominant and non-dominant side, across the three static positions (Rest, HH and HLB), Intergroup comparisons were made for each position and side independently, as well as for side-to-side differences and total ROM.

3. Results

3.1. Sample

Figure 4 represents the sample flow diagram. In total, 59 individuals were contacted to participate in the study. Of these individuals, 24 did not have the availability to participate and 35 agreed to participate in the study. 3 individuals were excluded due to history of shoulder or elbow joint surgery, resulting in a sample of 32 individuals, that were allocated to the corresponding group according to the presence or absence of infraspinatus atrophy. 14 athletes were assessed in 2019 and 18 athletes were assessed in 2024.

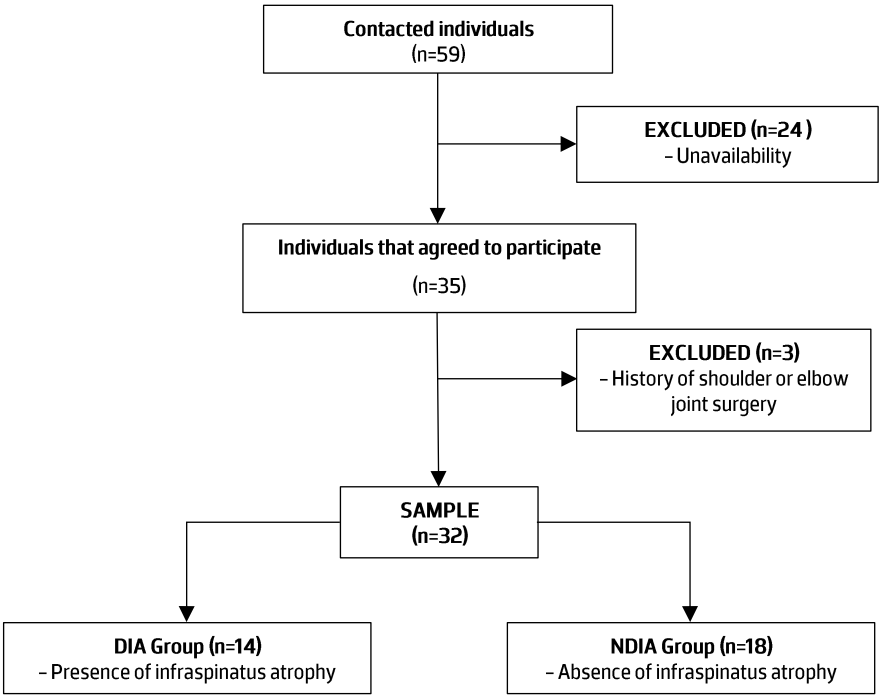


Figure 4 – Sample flow diagram. DIA – Diagnosed Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy

The sample consisted of 32 volleyball players (16 males and 16 females), all actively engaged in regular training and competition. The NDIA group was composed of 6 males and 12 females and the DIA group was composed of 10 males and 4 females. A group of athletes (n=14) was identified with visual infraspinatus atrophy (DIA) in the dominant upper limb, although none reported limitations in activity or sports performance. The remaining 18 athletes did not present visual infraspinatus atrophy and were classified as NDIA. All participants were right arm dominant, apart from 3 athletes that were left arm dominant, 2 belonged to the healthy group and the remaining in the DIA group.

Most participants were spikers (n=18), but liberos and setters were also assessed. In the NDIA group, players positions were distributed as follows: 5 libero players, 5 Z4 players, 3 middle players, 3 setters and 2 opposites. In the DIA group, 5 were middle players, 4 were libero players, 3 were Z4 players and 2 were setters.

The age of the sample varied between 17 and 40 years old. The minimum and maximum age in the NDIA group were 18 and 40 years old, respectively. The minimum and maximum age in the DIA group were 17 and 37 years old, respectively.

The mass and BMI variables were significantly higher in the DIA group when compared to the healthy group. The remaining variables showed no significant differences, as shown in Table 2.

Table 2 – Descriptive statistics on biologic characteristics, years playing volleyball and DASH scores

	Group		**Inter-group comparison**
	NDIA	**DIA**	**p value**
Gender	M:6 / F: 12	M:10 / F: 4	0,075
Age *(years)*	24,67 ± 5,74	25,57 ± 5,03	0,398
Mass (kg)	69,25 ± 10,36	79,75 ± 12,65	0,015*
Height (m)	1,77 ± 0,07	1,83 ± 0,11	0,126
BMI (kg/m2)	22,40 [20,49 : 23,24]	23,76 [22,51 : 24,75]	0,037†
Years of Practice	15,22 ± 6,88	16,36 ± 5,50	0,464
Player's position	Libero: 5 Z4: 5 Middle: 3 Setter: 3 Opposite: 2	Libero: 4 Z4: 3 Middle: 5 Setter: 2 Opposite: 0	0,717
DASH total (%)	7,31 ± 8,88	6,07 ± 6,62	0,955
DASH Sport total (%)	10,07 ± 15,18	14,73 ± 25,43	0,925

Note: DIA – Diagnosed Visual Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy; M – male; F – female; BMI – Body Mass Index; * p≤ 0.05 parametric test; † p ≤0, 05 non-parametric test between Healthy and DIA groups

3.2. Range of motion and rotation torque ratios at 60º/s

Table 3 show the descriptive statistics of dominant and non-dominant shoulder range of motion, as well as shoulder torque ratios at 60º/s.

No statistically significant differences were found between groups across all ROM variables and torque ratio at 60º/s.

Table 3 – Descriptive statistics of ROM, Mean ± Standard Deviation (SD)

ROM (°)	**Side**	**NDIA**	**DIA**	**p value**
Lateral rotation	Dominant	88,83 ± 13,29	91,07 ± 16,19	0,667
	Non-dominant	86,33 ± 8,51	82,29 ± 20,23	0,493
Medial rotation	Dominant	28,50 ± 12,12	25,50 ± 10,04	0,461
	Non-dominant	24,33 ± 9,15	23,86 ± 7,80	0,877
Total ROM	Dominant	115,57 ± 14,21	116,04 ± 17,74	0,935
	Non-dominant	110,51 ± 10,25	106,34 ± 19,19	0,471
Torque Ratio				
Ratio agonist/antagonist at 60 °/s	Dominant	79,71 ± 13,15	74,24 ± 14,79	0,278
	Non-dominant	84,73 ± 13,63	76,57 ± 16,98	0,142

Note: DIA – Diagnosed Visual Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy; ROM – Range of Motion

3.3. Scapula rest position

In the resting position, athletes with DIA showed significantly higher non-dominant lower horizontal distance (p=0.032) and scapula lower angle distance (p=0.029) than their NDIA counterparts, as shown on Table 4. No significant differences were found between the two groups in the remaining variables.

Table 4 – Descriptive statistics of the distance and angle variables in rest position, Mean ± SD

Distance (mm)	**Side**	**NDIA**	**DIA**	**p value**
Upper horizontal distance	Dominant	87,08 ± 12,22	93,81 ± 15,97	0,186
	Non-dominant	88,12 ± 14,06	87,37 ± 12,55	0,878
Lower horizontal distance	Dominant	99,68 ± 15,34	111,34 ± 19,40	0,067
	Non-dominant	94,83 ± 13,60	105,45 ± 12,80	0,032 *
Scapula root spine distance	N/A	168,06 ± 20,95	174,50 ± 26,01	0,444
Scapula lower angle distance	N/A	175,57 ± 50,46	210,10 ± 28,27	0,029 *
Scapular protraction at rest	Dominant	1,78 ± 0,52	1,86 ± 0,20	0,562
	Non-dominant	1,93 ± 0,30	1,64 ± 0,69	0,119
Acromial depression at rest	Dominant	40,36 ± 16,53	44,34 ± 14,86	0,487
	Non-dominant	34,57 ± 17,73	37,40 ± 16,53	0,648
Angle (°)				
Upward rotation	Dominant	89,04 ± 14,24	81,25 ± 11,82	0,109
	Non-dominant	86,45 ± 12,88	84,90 ± 11,10	0,722

Note: DIA – Diagnosed Visual Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy; N/A – Not Applicable; * p≤ 0.05 parametric test between NDIA and DIA groups.

3.4. Hands in Head position

In the hands in head position, those with DIA showed significantly higher dominant lower horizontal distance(p=0.029) and scapula lower angle distance (p=0.025), when compared to the NDIA athletes, as shown on Table 5. No other significant differences were observed.

Table 5 – Descriptive statistics of the distance angle variables in Hands in Head position, Mean ± SD

Distance (mm)	**Side**	**NDIA**	**DIA**	**p value**
Upper horizontal distance	Dominant	73,09 ± 13,96	85,28 ± 21,26	0,06
	Non-dominant	73,58 ± 17,82	81,92 ± 15,24	0,173
Lower horizontal distance	Dominant	160,08 ± 20,77	177,82 ± 22,98	0,029 *
	Non-dominant	154,42 ± 27,87	167,78 ± 21,64	0,145
Scapula root spine distance	N/A	128,87 ± 20,49	143,65 ± 32,38	0,220
Scapula lower angle distance	N/A	299,33 ± 44,49	332,50 ± 36,59	0,032 *
Angle (°)				
Upward rotation	Dominant	75,61 ± 18,69	68,43 ± 15,73	0,258
	Non-dominant	74,14 ± 17,27	70,66 ± 15,37	0,750

Note: DIA – Diagnosed Visual Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy; N/A – Not Applicable; * p≤ 0.05 parametric test between NDIA and DIA groups.

3.5. Hands in Low Back position

No statistically significant differences were observed between groups, in the HLB position, as shown in Table 6.

Table 6 – Descriptive statistics of the distance and angle variables in Hands in Low Back position, Mean ± SD

Distance (mm)	**Side**	**NDIA**	**DIA**	**p value**
Upper horizontal distance	Dominant	86,42 ± 15,81	94,91 ± 15,43	0,138
	Non-dominant	88,14 ± 12,19	88,34 ± 14,01	0,965
Lower horizontal distance	Dominant	97,64 ± 20,54	99,30 ± 15,52	0,803
	Non-dominant	92,70 ± 17,56	99,85 ± 17,66	0,263
Scapula root spine distance	N/A	167,91 ± 26,76	165,01 ± 47,70	0,829
Scapula lower angle distance	N/A	174,02 ± 33,17	190,70 ± 31,67	0,160
Angle (°)				
Upward rotation	Dominant	98,31 ± 14,71	94,28 ± 10,41	0,392
	Non-dominant	99,98 ± 9,53	95,16 ± 11,90	0,213

Note: DIA – Diagnosed Visual Infraspinatus Atrophy; NDIA – Absence of infraspinatus atrophy; N/A – Not Applicable.

3.6. Differences between dominant and non-dominant side

Figure 5 depicts the differences between the dominant and non-dominant in the rest position, with the respective mean and standard deviation represented.

The analysis of the difference between the dominant and non-dominant side revealed a significant higher difference in the upper horizontal distance between sides (p=0.044), with the dominant side being superior to the non-dominant, in the DIA group when compared to the NDIA group. It was also found a higher difference in the upward rotation between sides (p=0.040), with the non-dominant side being superior to the dominant, as shown in Figure 5.

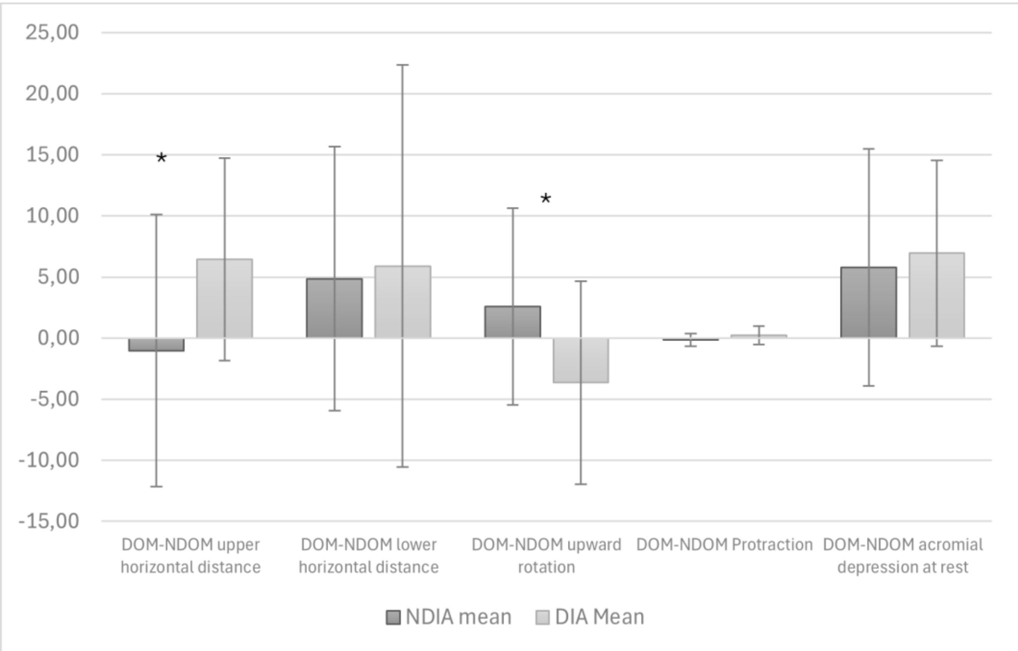


Figure 5 – Differences between dominant and non-dominant side in rest position, Mean ± SD
Note: * p≤ 0.05 parametric test

The differences between dominant and non-dominant sides in the HH and in HLB position are represented in Figure 6 and Figure 7, respectively, but none reached a statistically significant difference.

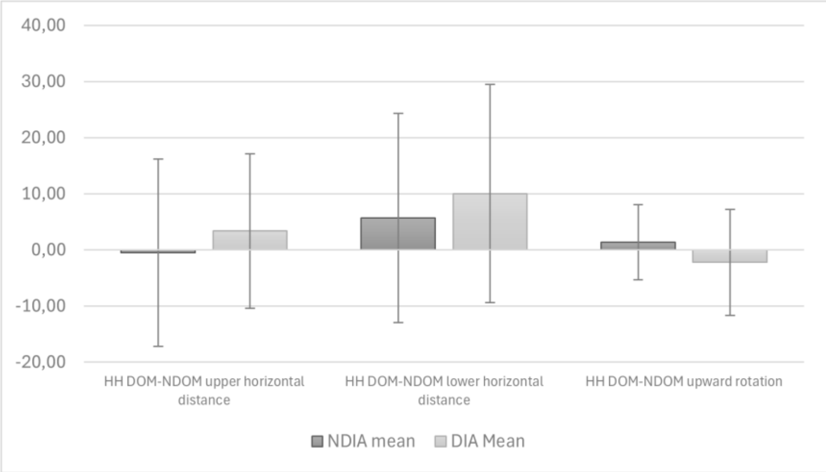


Figure 6 – Differences between dominant and non-dominant side in Hands in Head position, Mean ± SD

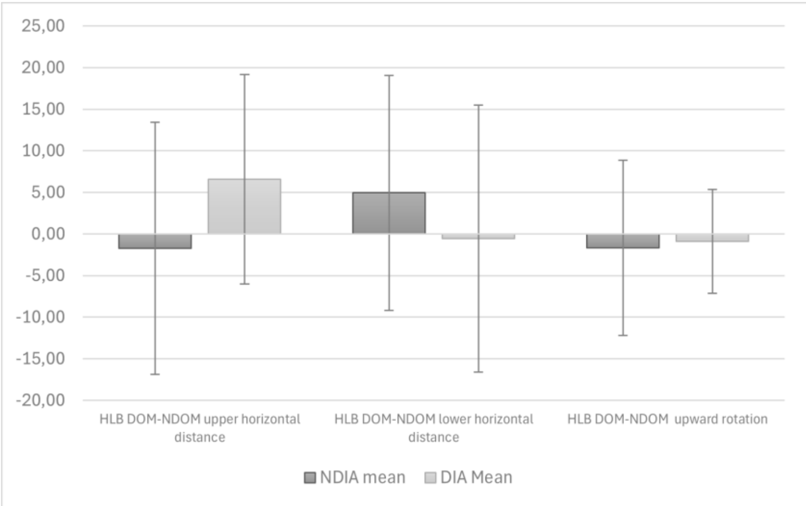


Figure 7 – Differences between dominant and non-dominant side in Hands in Low Back position, Mean ± SD

4. Discussion

In this study, no significant differences were found in ROM or torque ratios between groups. However, significant differences emerged in scapular positioning, particularly in the rest and in the HH positions. In the rest position, the DIA group showed a higher distance between the NDOM lower horizontal distance, as well as a higher distance between DOM and NDOM scapula lower angles. In the HH position, had a higher distance in the DOM lower horizontal distance and between scapula lower angles. The difference between sides in respect to the upper horizontal distance and upward rotation was higher in the DIA group.

The dominant shoulder of volleyball players displays several biomechanical and structural adaptations in response to the extreme physiological demands and repetitive movements of overhead activity (Pascoal et al., 2023). The dominant shoulder presents an external rotation gain (ERG) and a glenohumeral internal rotation deficit (GIRD) that are well documented in overhead sports (Borsa et al., 2008; Alqarni et al., 2024). According to Young et al., (2015), players with ISA have less internal rotation and Witvrouw, Cools, Cambier, et al., (2000) reported that athletes with ISA have greater range of motion in external rotation when compared to non-affected players. Conversely, our results found no significant differences in the range of motion of internal and external rotation in athletes with and without ISA. According to Lajtai et al., (2012), the more visible the ISA, the more the middle trapezius activates, acting as possible compensatory mechanism for the lack of shoulder external rotation, by rotating the scapula outwards.

The dominant shoulder of overhead athletes typically appears to have a muscular imbalance, with lower external rotation strength than internal rotation strength (Challoumas, Stavrou, et al., 2016). This is thought to be due to the demands of the sport gestures, that increase internal rotation strength with an unchanged external rotation strength (Challoumas, Stavrou, et al., 2016). Several authors (Challoumas, Artemiou, et al., 2016; Lajtai et al., 2012; Witvrouw, Cools, Cambier, et al., 2000; Young et al., 2015) agree that IA causes a deficit in external rotation strength, which may even occur before clinical signs. Contrary to expected, our results showed no significant differences in torque ratios between groups. It is hypothesized that the teres minor and posterior deltoid muscles compensate for the loss of the infraspinatus function and strength (Young et al., 2015).

Young et al., (2015) reported no effect of IA in sports performance. Similarly, we found no effect on sports performance and function when comparing athletes with and without DIA, evaluated through DASH Sport total (%) (p=0,925).

The knowledge of the scapular resting posture and scapulohumeral rhythm adaptations that volleyball players suffer as a consequence of the specific demands of the sport is crucial during clinical assessment, to be able to differentiate them from pathological changes that are related to complaints/shoulder injuries and negatively impact function and sports performance (Pascoal et al., 2023). In this sense, Downar & Sauers, (2005) and Myers et al., (2005) reported that during arm elevation tasks the dominant scapula of overhead athletes shows greater upward rotation, internal rotation and retraction . Also, Pascoal et al., (2023) reported that the adaptations of scapula resting position and scapulohumeral rythm were as follows - greater internal rotation, agreeing with the findings from Downar & Sauers, (2005) and Myers et al., (2005), greater scapula anterior tilt, but found no differences in scapular upward rotation during upper limb elevation.

Our study found that in the rest position and in the HH position, the dominant and non-dominant scapulas were more laterally displaced in the DIA players, that aligns with the results from Witvrouw, Cools, Cambier, et al., (2000). In the HH position, the dominant scapula showed the same behavior with greater lateral displacement, that can be due to lengthening of the trapezius and rhomboids muscle (Challoumas, Artemiou, et al., 2016). When comparing side to side in the rest position, the athletes with DIA showed a bigger difference, with the dominant scapula more lateralized than the non-dominant. Interestingly, at rest, the non-dominant scapula displayed greater upward rotation in players with DIA. The infraspinatus also acts on the scapula allowing the abduction of the inferior angle of the scapula (Williams, Sinkler, & Obremskey, 2023). With an injury on the infraspinatus, such as the atrophy, this function can be compromised, resulting in a decrease of abduction on the scapula lower angle, but also of upward rotation.

No alterations in ROM or torque ratios were found in this study, but it revealed scapular dyskinesis, is present in athletes with ISA. Although ISA does not appear to have an impact on sports performance, scapular dyskinesis is strongly associated shoulder pathologies in overhead athlete's (Kibler et al., 2021). As so, it should be treated as a part of a comprehensive rehabilitation program that should be tailored to the specific individual, to optimize the identified alterations (Kibler et al., 2021).

This study has a few limitations, firstly, the small sample size and hence a limited power to generalization. The sample was recruited through athletes that volunteered to participate in the study, which may present as a selection bias and not be an accurate representation of the population. The elite nature of the players included in this study means that the results cannot be generalized to volleyball players at a lower level of competition. A clinical definition of ISA was used, which is a subjective measure, that lacks objective quantification such as magnetic resonance imaging (MRI) or ultrasound confirmation, but this is common in other studies of ISA, which is, by its nature, a clinical finding. The postural assessments were also limited to static positions that combine movements that occur during sport specific actions but may not fully represent dynamic movement patterns.

Future research should consider the incorporation of dynamic scapular kinematic during volleyball specific tasks to better understand possible adaptations.

5. Conclusion

Players with infraspinatus atrophy (ISA) exhibit altered scapular positioning, despite reporting no functional limitations or deficits in sports performance. They displayed bilaterally a more lateralized scapula in the rest and HH position and the scapula resting position of the affected side is less upwardly rotated compared to the non-affected side.

This research provides valuable insights into the biomechanical implications of ISA and enables clinicians to differentiate between typical biomechanical adaptations to overhead sports and alterations specifically associated with ISA.

Understanding the impact of ISA on scapular biomechanics enhances clinical reasoning and supports the decision-making process, that allow the development of targeted interventions to optimize shoulder function and sports performance in volleyball athletes.

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P.PORTO

ESCOLA
SUPERIOR
DE SAÚDE

M

MESTRADO

Fisioterapia Neuro-Músculo-Esquelética