CLINICAL ASSESSMENT AND MAGNETIC RESONANCE IMAGING OF THE SHOULDER OF PATIENTS WITH SPINAL CORD INJURY

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ABSTRACT

Objective: To study the shoulder of this group of patients using magnetic resonance imaging to detect clinical and subclinical disorders and establish a rehabilitation program. Methods: Nine patients with spinal cord injury followed in the Laboratory of Biomechanics and Rehabilitation of the Locomotive System at HC/UNICAMP were divided into two groups according to the presence of paraplegia and tetraplegia and were clinically assessed for correlation with the imaging exams. Results: Normal results were found in 41% of the shoulders. Most common injuries were tendinopathy of the supraspinatus and acromioclavicular joint degeneration. Eighty percent of injured shoulders had combined lesions. Conclusion: A great variety of causes of shoulder pain was identified in paraplegic and tetraplegic subjects. Routine clinical assessment and imaging studies of the shoulder may contribute to the evolution of rehabilitation and reduction of pain and musculoskeletal disorders. ***Level of Evidence II, Development of Diagnostic Criteria on Consecutive Patients, With Universally Applied Reference "Gold" Standard.***

Keywords: Spinal cord injuries. Shoulder. Magnetic resonance imaging.

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INTRODUCTION

The increasing number of automobile accidents and the spread of violence in the urban areas of metropolitan areas has brought about a rise in the incidence of trauma in the general population.[1] Spinal injuries are less frequent than appendicular skeleton injuries, occurring in approximately 6% of the patients with multiple trauma, half of whom present spinal cord injury.[2]

The prevalence of traumatic spinal cord injury in the USA is estimated at 525 to 1124 people per million inhabitants.[3,4] In spite of the technological advances in the automotive industry, with growing investments in equipment such as seat belts, speed limiters and airbags, the incidence of spinal cord injury associated with trauma has not dropped in the last three decades, and is estimated at between 29-50 new cases per million people every year, excluding fatal victims in the accident.[2] Today there are 200,000 tetraplegic or paraplegic trauma victims living in the US, a population that is growing due to the increase in life expectancy associated with the improvement in the methods of treatment and rehabilitation of these patients.[4]

The most common cause of spinal cord trauma is the automotive accident, corresponding to more than half of the cases. Other causes include falls from heights (25%), firearm projectile injuries (15%) and the practice of sports (10%).[5,6] The most common spinal cord injury region is cervical, present in 50-64% of the patients; the lumbar region represents 20-24% of cases. After the spinal cord injury, a greater biomechanical load is deposited on the patient's upper limbs, since these follow-ups become indispensable for daily activities such as locomotion with walkers, wheelchairs or crutches.[7,8] This overload can lead to muscle and joint pain, affecting, in increasing order, the shoulders, wrists, hands and elbows.[9]

Although the survival rate of spinal cord injured subjects has increased in recent decades, these individuals still have a shorter life expectancy than the healthy population and a series of comorbidities that jeopardizes the quality of life and the productive activity of these individuals. Previous studies describe pain, whether musculoarticular or neuropathic, as one the most prevalent complaints in spinal cord injured subjects and, separately, this condition shows strong correlation with the limitation of patient productivity and independence.[10]

All the authors declare that there is no potential conflict of interest referring to this article.

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It is estimated that 30 to 70% of paraplegics have shoulder pain, yet the considerable variability of age, sexual gender, duration and level of injury among the study populations hinders the characterization of the possible symptom etiologies.[11]

It is believed that shoulder and joint pain in recently injured individuals is associated with acute hypersolicitation on the upper limbs with unconditioned muscles and with insufficient training to satisfy this demand.[12] On the other hand, late complaints of pain may be more closely related to chronic overload, exposing the osteomuscular structures to the continuous and progressive impact resulting from daily activities such as wheelchair propulsion, body weight transfers and use of the walker.[12,13]

Spinal cord injured individuals use their upper limbs for mobility, yet the higher the level of spinal cord injury, the greater the degree of denervation and loss of power of the abdominal and trunk muscles. Therefore, the higher the injury level, the greater the need to use the upper limbs and the shoulder for body stability, further increasing the stress in this segment.[14]

The ample kinematic function of the shoulder is due to a combination of factors: the high mobility of the scapulohumeral joint combined with the acromioclavicular, sternoclavicular anatomical complex and with the functional diversity of the muscles inserted into this topography. When the shoulder becomes a load-bearing joint, situations such as compression and subacromial impingement are more frequent and accentuated, increasing the risk of bursitis, tendinopathy and tears of the rotator cuff structures.[1] It is assumed that chronic overload of the shoulder can cause degenerative osteoarticular alterations in a younger age bracket, with authors having described alterations such as narrowing of the acromiolavicular space with marginal osteophytosis and, in some cases, clavicular osteolysis.[15,16]

In spite of the increasing number of studies geared towards the investigation of shoulder pain and of functional limitation of the upper limbs in spinal cord injured subjects, the causes and the extension of these symptoms have not been fully clarified. The evidence points towards a multifunctional etiology with countless particularities related to the clinical picture and the biomechanical characteristics of the patients' routine.

A shoulder injury, even if minor, can diminish the ability to achieve independence in many everyday activities such as eating, getting dressed, alleviating pressure on the hips, performing personal hygiene tasks, transferring one's own bodyweight to the wheelchair or getting about in this chair.[17] Moreover the intensity of shoulder pain and its relation to the perception of disability potentially act on the reduction of the subjective quality of life of patients.[18,19] Based on the detailed evaluation of degenerative joint lesions in an early phase, it would be possible to propose a specific therapeutic approach for each patient.[20,21]

Magnetic resonance imaging (MRI) can be considered the noninvasive test of choice for patients with suspected rotator cuff injury. Besides its capacity to indirectly reproduce the entire cuff area, the images obtained are very well accepted by clinicians, offering excellent anatomical visualization of the shoulder in multiple cross sections.[22,23]

The aim of this study is to assess complaints of shoulder pain in a group of paraplegics and tetraplegics, correlating the clinical data with MRI exams, for the description of the most prevalent lesions. Through this assessment it is possible to discuss the main clinical presentations and the probable physiological, functional and anatomical etiologies of shoulder pain in spinal cord injured patients.

MATERIAL AND METHOD

The study group consisted of nine patients with post-trauma spinal cord injury, selected from among those who performed follow-up at the Laboratory of Biomechanics and Rehabilitation of the Musculoskeletal System of the Hospital de Clínicas da Universidade Estadual de Campinas (UNICAMP). Complaints of shoulder pain were not an inclusion criterion, since the intention was to identify subclinical lesions. The individuals were divided into two subgroups: Subgroup A - paraplegics (four individuals two men two women, aged between 53 and 23 years, average age 34.25 years and standard deviation of 14.03 years.); Subgroup B - tetraplegics (five individuals, all men, aged between 41 and 22 years, average age 31.8 years standard deviation of 8.87 years). The injury level was established through the systematic classification of the American Spinal Injury Association (ASIA), ranging from A to E, from the most accentuated degree of neurological impairment (complete paraplegia or tetraplegia) to the absence of sensorimotor alterations.

All the selected patients enroll in a rehabilitation program of 3 hours per week split into two periods of 1 hour and 30 minutes on alternate days. The paraplegics execute gait activities with a walker and work the upper limbs according to individual capacity. The tetraplegic patients perform exercises for the lower limbs in suspension but do not perform these exercises for upper limbs.[24,25]

All nine individuals had MRI exams in a 2T apparatus (Elsint/ Prestige - Israel). T2 and proton-density (PD) weighted fast spin echo (FSE) axial, sagittal and coronal images were acquired (TR: 3800 to 4000ms and TE: 80 to 144ms), with 4-mm thickness cuts. Exams were performed on both shoulders in most of the individuals except for one, who was submitted to unilateral analysis (due to their intolerance to spending more time in the apparatus), totaling 17 shoulders. The images were analyzed by a radiologist specialized in MRI, itemizing: the presence of bone trauma or degeneration alterations; the presence of degenerative alterations or osteolysis in the acromioclavicular space (ACS); the characteristics of the acromion and possible compressions or narrowing of the subacromial space (SAS); presence of tendinopathy or tears of the rotator cuff muscles, characterizing the supraspinatus (SST), subscapularis (SSC) and infraspinatus (IST) tendons, besides the evaluation of the tendon of the long head of the biceps brachii (BBT). The presence of fluid and thickening in the subacromial/subdeltoid bursa characterized bursitis. The other synovial spaces were evaluated in search of inflammatory alterations and possible joint effusion or extensive capsular tears.

Clinical and demographic information was gathered for subsequent comparison with the physical examination and the image analyses. Participation in the study was voluntary, having been approved by the local committee of ethics.

RESULTS

The injury level ranged between C5 as the highest and T10/T11 as the lowest level. (Table 1) Among the individuals from group A, the injury level is extremely heterogeneous, with each patient having injury at a different point. In group B, the most prevalent level was C5 reported by 60% of the patients. Injury time is also heterogeneous, ranging from 18 months to 21 years, and averaging seven years and seven months with standard deviation of six years and nine months.

Shoulder pain was present in 77.7% of all the patients, appearing in 50% of group A and 100% of group B. (Table 2) Of the paraplegics, 25% presented bilateral pain while 40% of the tetraplegics had the same complaint. Time since onset of the shoulder pain ranged from four months to 12 years.

Upon inspection, 44.44% of all the patients exhibited muscle hypotrophy/atrophy. (Table 3) Group B was the most affected and 100% of the tetraplegics exhibited muscle atrophy in the shoulder girdle and in the arm.

As regards the presence of deformities, one of the four patients from group A presented acromioclavicular dislocation detectable upon physical examination. Among the tetraplegics, two individuals exhibited alterations: one was a case of flying scapula and the other an acromioclavicular dislocation.

Two patients out of the nine examined presented some trophic alteration in the skin of the shoulders, incidence of 24.7%. One patient belonged to the group of the paraplegics and presented a scar in the anterolateral region of the left upper limb relating to an automobile accident, while the other belonged to the tetraplegics group and presented dry, scaly skin in the thoracic region.

During the palpation phase of the physical examination, three of the nine patients presented some alteration (33.3%). Of these, two belonged to group A, and both presented pain upon palpation of soft parts (biceps tendon and trapezium) while one of them presented pain upon palpation of bones and joints (acromioclavicular joint). Among the patients from group B only one presented alteration in the examination, complaining of pain upon palpation of soft parts (biceps tendon and subscapularis tendon).

In the third stage of the physical examination the examiners assessed the range of motion of all the patients included in the project. The results are summarized in Tables 4A and 4B.

According to the assessment of magnetic resonance images of the 17 shoulders of nine patients, it was verified that seven of the 17 shoulders, 41%, presented normal result. Of these, four shoulders belonged to paraplegic patients, one of whom presented with complaints of shoulder pain (bilateral). Of the three shoulders of tetraplegic patients that presented normal resonance results, they all presented with complaints of pain in the shoulder examined. (Figures 1 and 2) Among the altered examination results (10 shoulders), 40% of these presented subacrominal/subdeltoid bursitis, 70% presented supraspinatus tendinopathy, 70% degeneration of the acromioclavicular joint and 50% decreased subacromial space. It was found that 80% of the shoulders had more than one associated lesion. Six of the seven shoulders that presented supraspinatus tendinopathy were tetraplegic, as were four of the five shoulders with decreased subacromial space. Five of the seven shoulders with acromioclavicular degeneration were tetraplegic.

Among the patients with supraspinatus tendinopathy, 57% presented concomitant decreased subacromial space. It was also noted that 85% of the shoulders with degeneration of the acromioclavicular joint developed supraspinatus tendinopathy, affecting both groups.

As isolated additional findings, one paraplegic patient presented unilateral clavicular fracture while two tetraplegic shoulders presented biceps tendinopathy.

Table 1. *Individuals from groups A and B classified in terms of the spinal cord injury level, the type of injury and the time elapsed since the spinal cord injury.*

Patient	Injury level	Type	Time since injury	Asia
A1	T2-T4	Paraplegic	3 years	B
A2	T10/T11	Paraplegic	2 years and 6 months	A
A3	T5	Paraplegic	21 years	C
A4	T3	Paraplegic	3 years and 9 months	A
B1	C5	Tetraplegic – Incomplete	1 year and 6 months	B
B2	C5/C6	Tetraplegic	7 years	A
B3	C5	Tetraplegic	3 years	A
B4	C5	Tetraplegic-Incomplete	13 years	B
B5	C6	Tetraplegic	13 years and 10 months	A

Table 2. *Patients from groups A and B related in terms of presence of pain, time since the onset of the condition and presence or absence of shoulder pain bilaterality.*

Patient	Shoulder pain		
	Presence of pain	Time since onset	Bilateral
A1	Yes	1 year and 6 months	Yes
A2	No	NA*	NA*
A3	Yes	3 years	No
A4	No	NA*	NA*
B1	Yes	1 year	Yes
B2	Yes	1 year and 6 months	No
B3	Yes	1 year	Yes
B4	Yes	4 months	No
B5	Yes	12 years	No

Table 3. *Stages of inspection and palpation of the physical examination of the study patients.*

Patient	Inspection			Palpation
	Trophism	Deformity	Skin	
a1	Normal	Absent	Without Trophic Alterations	Pain on palpation of the L biceps and R scapularis tendons
A2	Normal	Sign of R acromioclavicular dislocation	Scar in L upper limb anterolateral region	Painless
A3	Normal	Absent	Without Trophic Alterations	Pain on palpation of the L acromioclavicular joint and of the L trapezium
A4	Normal	Absent	Without Trophic Alterations	Painless
B1	Important bilateral muscular atrophy	Flying scapulas	Without Trophic Alterations	Painless
B2	Important bilateral muscular atrophy	Absent	Without Trophic Alterations	Painless
B3	Moderate bilateral muscular atrophy	L ACL signal (Shoulder strap)	Without Trophic Alterations	Painless
B4	Important bilateral atrophy	Absent	Dry, scaly	Painless
B5	Normal	Absent	Without Trophic Alterations	Pain bilateral biceps tendon. Pain R subscapularis tendon

Tables 4A and 4B. *Relation of the ranges of motion described passively (5A) and actively (5B) in all the patients studied. Values in degrees for abduction, adduction, flexion, extension, external rotation and elevation and according to hand reach for internal rotation.*

4A	Range of motion - Passive						
	ABD	AD	Flexion	Ext	ER	IR	Elev
Patient	R/L	R/L	R/L	R/L	R/L	R/L	R/L
A1	180/180	30/45	180/180	NA/NA	40/50	T8/T8	180/180
A2	90/90	60/60	180/180	70/70	70/70	T8/T8	180/180
A3	90/90	45/45	180/180	30/30	80/80	NA/NA	180/180
A4	180/180	60/60	180/180	45/45	75/75	T11/T11	180/180
B1	90/70	0/0	180/100	45/30	75/60	NA/NA	180/130
B2	150/130	60/60	150/120	80/60	90/80	T8/T11	NA/NA
B3	180/180	60/60	180/180	60/60	70/70	T8/T8	180/180
B4	150/110	20/5	180/90	40/40	45/30	NA*	130/100
B5	180/180	60/60	180/180	60/60	70/70	T8/T8	180/180
4B	**Range of motion – Active**						
	ABD	AD	Flexion	Ext	ER	IR	Elev
Patient	R/L	R/L	R/L	R/L	R/L	R/L	R/L
A1	180/180	30/45	180/180	NA/NA	40/50	T8/T8	180/180
A2	90/90	60/60	180/180	60/60	60/60	T8/T8	180/180
A3	90/90	30/30	180/180	30/30	75/75	NA/NA	180/180
A4	180/180	60/60	180/180	40/40	75/75	T11/T11	160/160
B1	0/0	0/0	0/0	0/0	0/0	0/0	0/0
B2	0/0	0/0	0/0	0/0	0/0	0/0	0/0
B3	90/90	45/45	100/100	40/40	60/60	T8/T8	105/105
B4	90/70	20/0	90/60	30/30	40/20	NA*	100/80
B5	180/180	50/50	180/180	45/45	60/60	Gluteus	180/180

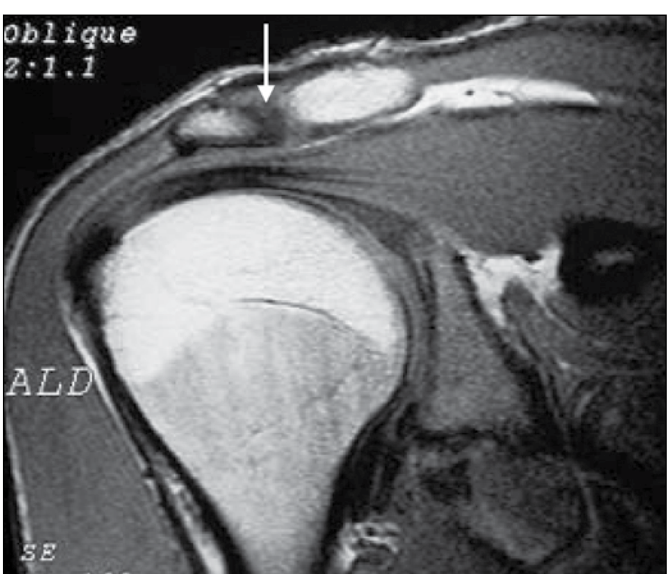

Figure 1. *Patient B1. Coronal section T1. In this sequence it is possible to analyze the preservation of the bone texture and of the spinal cord signal. It is also easier to assess the regular contour and preservation of the acromioclavicular space (arrow).*

Figure 2. *Patient B1. Coronal section T2. Observe the acromioclavicular joint with smooth articular surfaces and without capsular bulging (black arrowhead). The signal of the rotator cuff tendons is preserved. Observe focus of fluid in the interval of the anterosuperior rotators (white arrow), compatible with fluid in the articular recess, without signs of tears in this topography.*

DISCUSSION

In the tetraplegic patient the muscular physiology of the shoulder is generally altered as a result of alterations of the nerve conduction in the cervical intumescence. This condition depends on the injury level and on the degree of denervation. It is known that after an axonal injury at a particular spinal level, there is a variable chance of Wallerian degeneration compromising the adjacent levels. Therefore, most spinal cord injuries are of a potentially heterogeneous neural behavior nature.

The injury of a neural level compromises the innervation of the muscle structures in a different way. The established injury level determines a picture of denervation only in the musculature in which the nerve nuclei are originated at that precise spinal level. The other levels continue innervated, yet with functional deficit or with a condition of loss of the upper neuron. At these levels, the spasticity may be increased, which may theoretically maintain intermediate muscle trophism. Hypothetically, depending on the severity of the injury and on the level of Wallerian degeneration, the denervation of the structures would be variable.

Traumatic cervical spine injuries can be divided into injuries above C5, below C5 and at C5, when we evaluate the biomechanical function of the shoulder girdle. Due to the considerable frequency of cervical flexion trauma, there is a high incidence of injuries at the level of C5[1], as evidenced in the patients involved in the study. Thus there is the likelihood of functional impairment of the rotator cuff. The rotator cuff muscles, besides assisting in the execution of complex movements, also contribute to the stabilization of the humerus in relation to the glenoid.[26] The denervation of these structures can lead to chronic muscle atrophy. (Figure 3) Besides the rotator cuff muscles, shoulder kinematics depends on the performance of the trapezius and deltoid muscles. In most spinal cord injuries that have preserved some autonomy of the upper limbs, there is maintenance of function of the trapezius, the

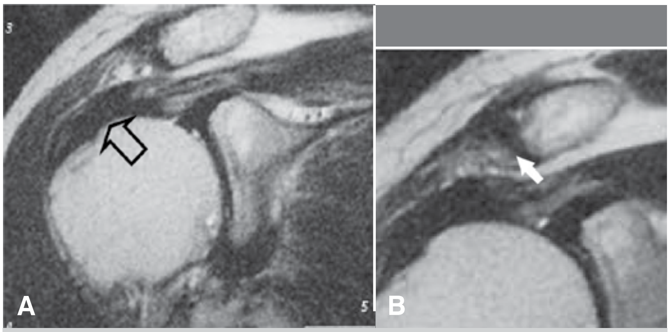

Figure 3. *Patient B4. Coronal section weighted in density of protons (SD) of the right shoulder. (A) Note peri-insertional supraspinatus thickening (open arrow). The myotendinous junction is thin and with hypersignal, compatible with fatty replacement due to atrophy or following injury. (B) Observe reduction of the acromioclavicular space with irregularity of the articular surfaces in the detail (arrowhead).*

innervation of which originates from higher cervical levels (C2), maintaining the elevation and superior rotation of the scapula. The predominance of the trapezoidal action to the detriment of the deltoid and rotator cuff forces can overburden the osteoarticular system of the shoulder, exacerbating the impact between the bone, ligament, and especially synovial (bursae) structures, producing chronic micro-traumatic effects and inducing slight and recurrent inflammatory alterations.[27]

As described for other neuromuscular pathologies, the neuropathy determined by spinal cord injury can compromise the arthromuscular physiology. Caused by an etiological mechanism not yet fully understood, the vascularization and the supply of blood to these structures are altered, with early degenerative effects, leading to structural alterations with thickening and variable degrees of muscle, tendon and ligament fibrosis, besides articular degeneration. These alterations justify the findings of tendinopathy and arthropathy in the shoulders of the tetraplegic patients, who presented 86% of the total supraspinatus tendinopathies, whereas 57% of these shoulders presented decreased subacromial space. (Figure 4)

A similar effect was found in relation to the degeneration of the acromioclavicular joint, where the tetraplegic patients presented 71% of the total degeneration found even in the absence of mechanical overload resulting from wheelchair propulsion and from transfers of the body.

For the spinal cord injured subjects, the upper limb plays an important role in mobility and in the recovery of activities and of daily autonomy. The shoulder girdle with the constituent joints of the shoulder and the associated muscle groups are fundamental in the positioning and in the transfer of forces to the upper limb.

The paraplegic patient uses the upper limb as a loadbearing joint, using it in transfers of the body and to handle the wheelchair, among other activities. Kinematic and biomechanical studies demonstrated that the load applied on the shoulder during chair transfers becomes very high, and can overburden the musculo-articular system[1].

Accordingly, the shoulder, its osteoarticular framework and muscle mechanism are critically solicited in two everyday activities that are essential for paraplegics. Not only is acromioclavicular stabilization solicited by the mechanical overload during transfer, but this action can also intermittently reduce the subacromial space, determining compression of the rotator cuff structures, especially of the suprascapularis muscle[28]. The recurrent compression can lead to hypovascularization besides mechanical stress on the muscle fiber due to micro strains. These situations are associated with inflammatory tendinopathies and can determine consequent fragilization and intrasubstance degeneration of fibers, initially leading to thickening, edema and inflammation, predisposing these segments to tears. (Figure 5)

Figure 4. *Patient B3. Sagittal section T2 of left shoulder. Observe acromion type II (star) with slight angulation of its periarticular edge. The acromioclavicular joint also presents another variation that may compromise the subacromial space: superior displacement or subluxation of the clavicle, with inferior superposition of the acromion. Slight hypersignal adjacent to the supraspinatus (arrow) and in the anterosuperior rotator interval and small quantity of fluid in the subacromial/subdeltoid bursa.*

Figure 5. *Patient A2. Sagittal section T2 of left shoulder. Note peritendinous hypersignal in the supraspinatus (1) besides fluid in the subacromial/subdeltoid bursa. Note hypersignal of the rotator interval, between the insertion of the supraspinatus (1) and of the subscapular (3), which may be related to reactional inflammatory alteration or to capsular tear in the rotator interval. The infraspinatus does not demonstrate significant abnormalities (2).*

Moreover, the chronic stress on the acromioclavicular joint can lead to degeneration, found in 28.5% of the shoulders of paraplegic patients, reducing the articular space and its mobility, with consequent capsular and osteophyte bulging. A variable alteration will be produced in the subacromial space as a result, with chronic compression of the cuff and of the underlying synovial structures (bursae). A series of inflammatory and degenerative events may be associated at this point.[27]

Although the paraplegics presented functional overload on the shoulders in habitual activities, only 42% of the shoulders assessed presented alterations in the MRI, against 70% among the tetraplegics. This scenario favors the hypothesis of multivariate etiology for shoulder pain in spinal cord injured subjects.

CONCLUSION

Shoulder pain is a frequent complaint in patients with spinal cord injury and may impair the quality of life of the individual and limit their potential in functional rehabilitation. Based on the study sample it is possible to identify a multivariate etiology of this symptom, with particularities for paraplegic and tetraplegic individuals. As observed in the paraplegic individuals, pain is not always related to acute anatomical injury, but may be related to functional overload. Consequently, there is an even greater need to establish strategies to prevent injuries, valuing the effect of specific rehabilitation techniques for this population.

The muscle physiology is affected in tetraplegic individuals. Although the functional recovery of the upper limb in these individuals represents a threshold as yet only partially achieved, the development and greater use of electrical stimulation techniques for the upper limb could contribute positively to the improvement of muscle trophism in these individuals and, theoretically, enable physiologic improvement.

Therefore, this study draws our attention to the recognition of complaints of shoulder pain and demonstrates the importance of more detailed studies about this subject, aiming to improve the quality of life of these individuals. The routine inclusion of the clinical and radiological assessment of the shoulder in individuals with spinal cord injury can contribute towards the evolution of rehabilitation techniques and towards the reduction both of musculoarticular injuries and of pain symptoms.

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