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ORIGINAL RESEARCH



Did the prevalence of suprascapular neuropathy in professional volleyball players decrease with the changes occurred in serving technique?

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ABSTRACT

Objectives: Suprascapular neuropathy is more frequent in volleyball as compared to other overhead sports. This study aims to report the actual prevalence of suprascapular neuropathy among elite volleyball players. The hypothesis is that becoming jump topspin serves the most common serving technique, suprascapular neuropathy reduced its frequency.

Methods: A total of 82 professional players were enrolled in the study. The presence of symptoms and the type of serve preferably performed were investigated. The strength and trophicity of the supraspinatus and infraspinatus muscles were evaluated. Patients with positive clinical findings underwent MRI of the shoulder.

Results: The jump topspin serve was found to be the most popular type of serve both in males and females. At physical examination, 9% of the males and 12% of the females presented with infraspinatus muscle hypotrophy. Each case was accompanied by external rotation weakness. None of them complained of pain or reduced performance when they played. MRI confirmed infraspinatus muscle atrophy in all subjects.

Conclusion: A lower prevalence of suprascapular neuropathy was found as compared with that previously reported in the 1980s and 1990s. A reduction in the popularity of the float serve seems to be a possible explanation. Thus, the jump topspin serve could be safe for suprascapular neuropathy and associated injuries in volleyball. The findings of this study should be considered by athletes and coaches for the prevention of activity-related injuries.

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Introduction

At an agonistic level, volleyball is an explosive activity with a high risk of injury for athletes [1–3]. Recently, several studies examining factors associated with injuries, biomechanical analysis of the movements, and tactical strategies have been reported in the literature [1,4–12]. Results from these studies can be useful for coaches and athletes to better train and prepare for matches.

The shoulder is involved in 8% to 20% of volleyball injuries [2,13]. Suprascapular neuropathy is an uncommon condition in the general population, with an estimated prevalence of 4.3% in patients with shoulder pain [14]. However, it is a common lesion in overhead sports and even more frequent among volleyball players [15], with a prevalence of up to 33% [16]. Isolated painless weakness in external rotation and infraspinatus muscle atrophy are the unique findings on examination of subjects [17]. Patients usually did not experience any impairment or reduction in their physical performance [1,5,18,19].

The suprascapular nerve is a mixed motor and sensory nerve originating from the upper trunk of the brachial plexus

(C5, C6, and occasionally C4 nerve roots) [20]. In its route around the scapula, the nerve is susceptible to compression, especially at two points [21] (Figure 1). The first one is located at the suprascapular notch. At this site, the nerve enters the supraspinous fossa passing through a narrow fibro-osseous tunnel. After providing motor and sensory branches, the suprascapular nerve continues distally and encounters the second critical point, the spinoglenoid notch. The spinoglenoid notch is located at the lateral edge of the scapular spine, in relation to the spinoglenoid ligament.

Although in the general population, the most common site of entrapment is thought to be the suprascapular notch, in volleyball players (as with other overhead sports athletes), compression occurs more frequently at the spinoglenoid notch [12,14,22,23]. Several theories about the movements or the positions of the shoulder responsible for the entrapment at this site have been proposed [8,9,24]. Ferretti et al. [25] found that the eccentric contraction of the external rotators, especially the infraspinatus muscle, determines compression of the suprascapular nerve at the spinoglenoid notch. Maximum eccentric

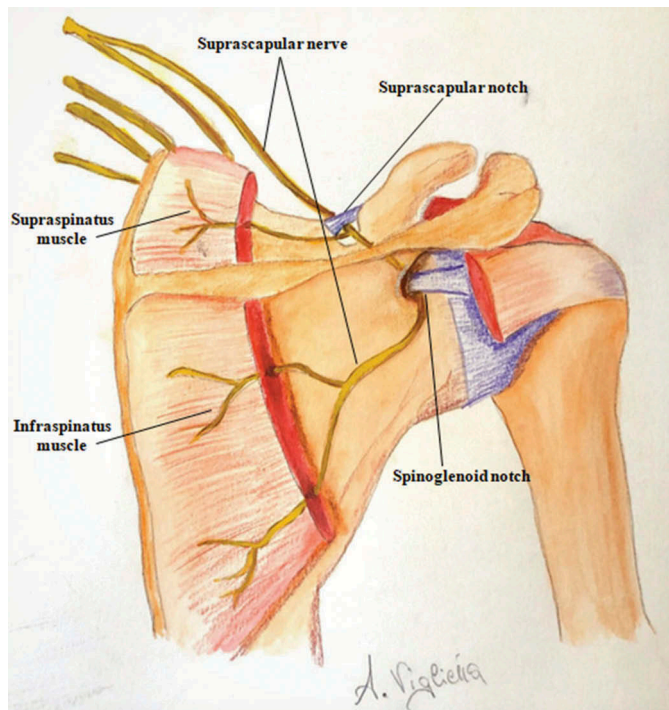


Figure 1. Suprascapular nerve. Route of the nerve and its relation with muscles and entrapment sites are shown.

contraction of the infraspinatus muscle occurs during the serve when a specific skill (i.e. the float serve) is performed.

Three different types of serve could be recognized: the float serve, jump float serve, and jump topspin serve [4]. Historically preferred, the float serve has been reported to be responsible for the highest prevalence of suprascapular neuropathy in volleyball players as compared to other overhead sports. In the last two decades, several changes have occurred in volleyball skills, including the serve technique. While the float serves diminished to 3.3%, the jump topspin serve became the most popular type of serve, increasing from 20.8% in 1992 to 99.2% in 2002 [4,26,27].

The aim of this study is to report the actual prevalence of suprascapular neuropathy among elite volleyball players and correlate it with the type of serve practiced. The hypothesis is that recent changes in serving technique have made suprascapular neuropathy less frequent than previously reported.

Material and methods

Study population

Between March and June 2019, 80 elite volleyball players admitted at our center (Istituto di Medicina e Scienza dello Sport – CONI) for a complete medical check were enrolled in the study.

Inclusion criteria were: 1) all subjects were professional athletes of Italian SuperLega or Serie A1 volleyball teams; 2) all subjects were active at a competitive level at the time of the study; and 3) none of the subjects reported recent discontinuation of activity for trauma or other reasons, training a minimum of 20 hours weekly.

Previous trauma, rotator cuff tears, and surgery or instability of the shoulder were exclusion criteria.

All participants gave informed consent to their inclusion in the study, which was approved by the University's Ethics Committee.

Clinical evaluation

A detailed clinical history was accurately collected by the same orthopedic surgeon. Each patient gave information about the duration of their sport activity, mean weekly hours of their training sessions, the presence of symptoms related to the shoulders, and the percentage of serving performed using the different techniques.

A detailed physical examination was also performed to acquire information about the posture of the shoulder girdle and signs of impingement or instability. The presence of hypotrophy of the supraspinatus and infraspinatus muscles was particularly examined. Infraspinatus hypotrophy was considered for loss of soft tissue bulk in the infraspinatus fossa of the scapula compared to the contralateral side. Strength of the supraspinatus and infraspinatus muscles was assessed with a specific clinical test against resistance. External rotation of the shoulders was assessed both with the arm in a neutral position and the elbow flexed at 90°, both with the arm in 90° of abduction. The external rotation lag sign (ERLS) at 90° in the scapular plane and at almost full external rotation with the elbow flexed at 90° was considered positive if a lag of nearly 5° or 'drop' occurred. Abduction was assessed with the arm abducted at 90° in the scapular plane, shoulder internally rotated and angled forward 30°, elbow extended and forearm pronated. Both shoulders were examined to evaluate differences between the hitting and the contralateral side.

MRI evaluation

Patients with a positive clinical test for muscle strength or clinical evidence of atrophy underwent a MRI to assess the trophicity of the supraspinatus and infraspinatus muscles. MRI scans were performed on a 1.5-T device (Siemens Maestro Sonata, gradient 40 mT, software Syngo A35). The size of both muscles was evaluated according to the grading system proposed by Ludig et al. [28], on a sagittal oblique cut with spin-echo T1-weighted and T2-weighted images 2 cm from the inward edge of the scapular spine. Convex muscle profile represented normality and was considered a grade 0. If a straight or a concave profile was found, a grade 1 or a grade 2 was respectively assigned.

Results

Eighty-two patients (49 females and 33 males) underwent a complete medical evaluation. The mean age was 25.8 (range 18–29) years for female players and 27.4 (range 19–30) years for male players. Seventy-two patients were right hand dominant, while 10 patients were left hand dominant (7 females and 3 males). None of the patients complained of pain in the affected shoulder. None of the patients reported previous injuries or fractures of the shoulder girdle. None of the patients were using medication at the time of the physical evaluation.

The jump topspin serve was reported as the most commonly performed type of serve. The main percentages of serving technique performed were 4% for float serve, 47% for jump float serve, and 49% for jump topspin serve among female players, and 1% for float serve, 22% for jump float serve and 77% for jump topspin serve among male players. At physical examination, hypotrophy of the infraspinatus muscle was found in 6 of the 49 (12%) female subjects and in 3 of the 33 (9%) male subjects (Figure 2). At clinical tests, each case of hypotrophy was accompanied by external rotation weakness as compared to the contralateral side. None of the patients reported any impairment or loss of function playing volleyball. None of the patients had impingement or instability of the shoulder. Overall results are shown in Table 1.

In all cases, hypotrophy of the infraspinatus muscle was confirmed with MRI (Figure 3). According to the Ludig classification, a grade 1 lesion was found in one female athlete, and grade 2 lesions were reported in the other eight subjects. In one case, teres minor hypertrophy was detected.

No patient presented with ganglia, rotator cuff tears or any other specific pathology at MRI. No other abnormalities were found. All patients were encouraged to perform shoulder rehabilitation, with particular attention to stretching and strengthening external rotation.

Discussion

The main finding of this study is that the actual prevalence of suprascapular neuropathy among elite volleyball players is less frequent than previously reported (Table 2). Our hypothesis that changes in the serving technique reduced suprascapular neuropathy has been reliably confirmed.

The risk of generic or specific injuries is elevated among volleyball athletes. Similarly, to other overhead sports, overuse injuries of the hitting shoulder (including subacromial impingement, glenohumeral instability, scapular dyskinesis, and muscle imbalance) occur more frequently than acute ones [5]. Suprascapular neuropathy, although unusual, seems to be more frequent among volleyball players as compared to players of other overhead sports, such as baseball or tennis [29–31].

Table 1. Overview of the results in the study population. A slightly higher prevalence of IS was found in female athletes. Male players reported to serve with jump topspin slightly more often than females. n: frequency; %: percentage; μ : mean.

	Male	Female
Gender, n	33	49
Age, μ	25.8	27.4
Right dominant, n (%)	30 (91%)	42 (86%)
IS prevalence, n (%)	3 (9%)	6 (12%)
Most performed serving type, %		
Float serve	1%	4%
Jump Float Serve	22%	47%
Jump Topspin Serve	77%	49%

If the suprascapular nerve is compressed proximally at the suprascapular notch, atrophy of both the supraspinatus and infraspinatus muscles will be found. Furthermore, proximal entrapment is usually accompanied by pain in the posterior region of the shoulder. Differently, distal entrapment at the spinoglenoid notch will result in selective atrophy of the infraspinatus muscle known as infraspinatus syndrome (IS) [9]. In IS, no further symptoms other than isolated muscle atrophy were reported. Indeed, at the spinoglenoid notch, the sensory branches have yet to leave the nerve [32]. In our study, none of the volleyball players complained of shoulder pain; in recent literature, IS has been considered a totally asymptomatic condition [16,18,19,23,29,32]. External rotation weakness assessed with specific text or dynamometric exams may be the only suspicion finding. Each case of hypotrophy in our study was accompanied by external rotation weakness as compared to the contralateral side. This is in line with the study of Witvrouw et al. [19] who found a significant reduction in external rotation strength of the affected side.

Thus, the clinical history and examination alone could miss the diagnosis of suprascapular neuropathy. Historically, the gold standard exams have been electromyography (EMG) and nerve conduction velocity (NCV) studies [22]. The diagnostic accuracy of these exams is estimated at being more than 90% in patients with muscle weakness [33].

Recently, Ahlawat et al. [33] reported that MRI is not inferior to electrodiagnostic tests when used to diagnose suprascapular neuropathy. Unlike ultrasound examination which could miss the diagnosis of suprascapular neuropathy [34], MRI



Figure 2. Isolated hypotrophy of infraspinatus muscle of 2 right dominant professional volleyball players. Note how evident is the loss of soft tissue bulk in the infraspinatus scapular fossa.

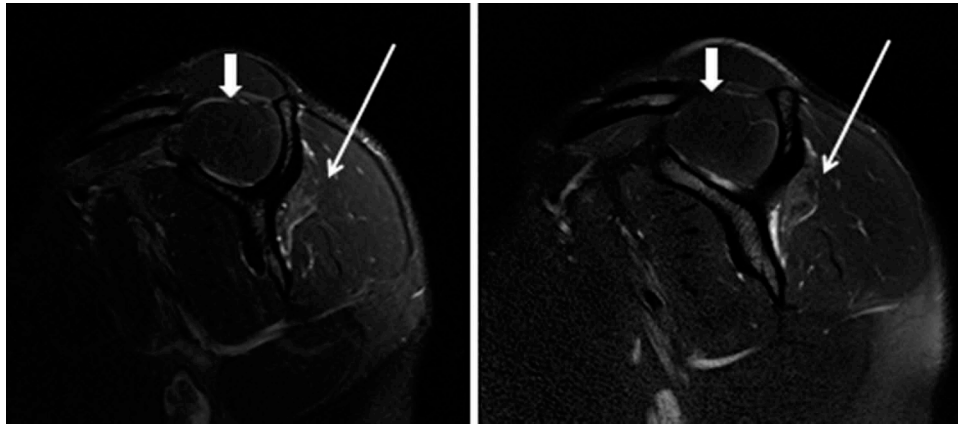


Figure 3. MRI evaluation of muscles trophicity. A 21 years old female player and a 25 years old male player with a grade 2 fatty atrophic infraspinatus muscle (concave profile: long white arrows) are shown on the left and right side, respectively. In both the athletes no hypotrophy of the supraspinatus muscle (convex profile: short white arrows) is present, indicating a nerve entrapment at the spinoglenoid notch.

Table 2. Prevalence of infraspinatus syndrome reported in previous study present in the literature examining professional volleyball and beach volleyball players. Note the absence of mean age in the most of the studies. † nf: not found.

	Nationality	Subjects, n	Male, %	Age, yy	Prevalence, %
Ferretti (1987) ²⁵	Italy	96	98	nff	13
Holzgraefe (1994) ¹⁶	Germany	66	100	nff	33
Witvrouw (2000) ²⁰	Belgium	16	100	26	25
Lajtai (2009) ¹⁸	Austria	84	64	nff	30
Lajtai (2012) ⁴⁷	Austria	35	100	28	34

allows us to observe not only the indirect findings of nerve entrapment (i.e. hypotrophy, muscle edema, or fatty infiltration) [12,33] but also the exact site at which the injury has occurred. MRI can provide a simultaneous evaluation of the cervical spine, brachial plexus, and rotator cuff, which are characterized by similar clinical findings. Furthermore, MRI is a noninvasive and widespread exam.

In our study, we performed an MRI of the shoulder in patients with clinical evidence of IS, and we did not consider the necessity of additional exams (e.g. EMG) to confirm the diagnosis. We used the scoring system proposed by Ludig et al. [28], which allows for an easy assessment of the trophicity of the supraspinatus and infraspinatus muscles. At the clinical evaluation, infraspinatus muscle hypotrophy was found in all the subjects. A grade 1 lesion was found in one female athlete, and grade 2 lesions were reported in the other eight subjects. Together with infraspinatus muscle hypotrophy, one male athlete presented with teres minor hypertrophy. Teres minor hypertrophy could be secondary to the infraspinatus muscle weakness. Indeed, both of these muscles work as agonists in the external rotation of the shoulder. If one reduces its effectiveness, the other has to increase its size as a compensative mechanism. In all cases, a normal convex profile of the supraspinatus muscle was found, indicating distal compression of the suprascapular nerve.

None of our patients complained of reduced performance or any problem playing volleyball. These data are supported

by most of the studies in the present literature, which consider IS a totally asymptomatic condition [18,19,23]. In their study, Ferretti et al. [25] found that none of the IS cases was associated with reduced efficiency in the volleyball performance of subjects. In a successive study [35], the same authors confirmed this data. After a mean follow up of 5.5 years, hypotrophy of the infraspinatus muscle remained unchanged in all patients with IS, and its effect on volleyball performance was still insignificant. A suitable explanation may be the compensatory mechanism adopted by the other shoulder girdle muscles.

Many mechanisms have been proposed to explain the origin of suprascapular neuropathy [9,19,22,24,29,36–40]. In the general population, suprascapular neuropathy is thought to occur most commonly at the suprascapular notch. Indeed, fractures of the scapula, shoulder dislocation, or other trauma and anatomical variations involving this proximal region are responsible for the majority of cases of suprascapular neuropathy [36,41–43]. In volleyball players, entrapment occurs more frequently at the spinoglenoid notch [19,21,37,38,44]. Several studies reported a much higher prevalence among professional volleyball players [7,18] as compared to players of other overhead sports [29,30,45]. Holzgraefe et al. [16] found a prevalence of up to 33% in German professional volleyball players. The actual prevalence among professional volleyball players found in our study was lower than previously reported. We believed that this could depend on the reduction in the float serve rate that has occurred in the last decades.

The float serves represents a specific skill in which the players, with both feet on the ground, hit the ball very sharply trying to give a floating trajectory and as little spin as possible. Thus, during the float serve, the arm must be stopped immediately after contact with the ball. This quick deceleration is obtained by a very intense eccentric contraction of the infraspinatus muscle. As reported by dynamic EMG analysis, the activation of the infraspinatus muscle is much stronger during the float serves as compared to other throwing movements or overhead sports [31]. The same floating trajectory was obtained in jump float serve with the same movement of

the shoulder and the only difference consisting in the vertical jump performed just before hitting the ball. To the best of our knowledge there are no studies in literature discussing a correlation between IS and jump float serve.

Nowadays, while the float serve has reduced its frequency, the jump topspin serve has become the most popular type of serve [4,26]. In the jump topspin serve, the ball is hit with maximum strength and topspin high in the air through a great vertical jump. It has gone from being an uncommon type of serve (20.8% of the total in 1992) to the preferred one (99.2% in 2002) in the last decades [27].

In order to understand the higher rate of IS in volleyball, the functional anatomy of the shoulder needs to be mentioned [6,8,9,11,27]. During maximum abduction and external rotation, it has been proved that the terminal trunk of the suprascapular nerve is pulled against the lateral margin of the spine, causing tension and possible compression of the nerve [10]. Other authors [36] have reported that adduction and internal rotation of the shoulder are the responsible movements. Ferretti et al. [35] suggested that maximum eccentric contraction of the infraspinatus muscle, the main external rotator of the shoulder, causes stretching of the suprascapular nerve, determining entrapment at the spinoglenoid notch. According to their hypothesis, which is the most accepted one in the literature [42], this mechanism occurs during the float serve.

A biomechanical study conducted by Reeser et al. [9] in 2013 criticized the float serve theory as the prevalence of IS did not decrease together with the decreasing popularity of the float serve itself. Indeed, according to the studies of Lajtai et al. infraspinatus muscle atrophy was still present in 30% and 34%, respectively, in 2009 [18] and 2010 [46]. In their kinematic analysis, Reeser et al. [9] noted greater shoulder abduction and horizontal adduction during the serve and spike in volleyball as compared to a baseball pitch and tennis serve. Thus, they proposed that these extreme shoulder positions, typical of volleyball players, represent the main risk for nerve traction and development of IS. However, some limitations in their study need to be mentioned. Firstly, they did not provide any explanation for the exact site of compression. Furthermore, the study population was very small. Only 14 subjects were examined, and all of them were healthy subjects. Thus, as the same authors conclude, the absence of any clinical correlation makes their theory just speculative. Also, the studies by Lajtai et al. [18,46] is limited by the small sample and by the absence of any correlation between clinical findings and the type of serve performed. Furthermore, no study investigating the age at which IS arise are present in literature. At their career' beginning, athletes could perform serving types with different frequencies. IS onset may happen early in athletes' career and asymptotically go undetected for so long. The prevalence of suprascapular neuropathy found by Lajtai et al. [18] may be the expression of such a damage previously occurred in their career. Thus, a perspective study investigating when the syndrome's onset happens may be useful to fully understand findings reported in the literature and also in our study.

To the best of our knowledge, no other studies aiming to correlate IS prevalence and the type of serve preferably

performed are presently in the literature. In our study, the jump topspin serve was the most commonly used serving technique, both in female and male players (with a frequency of 49% and 77%, respectively). This data confirms the changes in the technique of serving reported in the literature. Even though we did not investigate if the athletes with IS are those with the highest rate of jump topspin serve, a compensatory finding could be deduce by the slightly lower IS prevalence found in male athletes who reported an overall corresponding higher rate of jump topspin serve rather than females. Furthermore, because of the young mean age of our study population (25.8 years for females and 27.4 years for males), there was not a previous period during their professional career in which the float serve was the most commonly performed serve. For these reasons, we can assert that the reduced prevalence of IS found in our study population is likely due to the changes that have recently occurred in the technique of serving. Of course, other predisposing and anatomical factors and anatomical variants may also be implied [42,47].

There were limitations to this study. Firstly, there were no electrodiagnostic exams performed to confirm the diagnosis and site of suprascapular neuropathy; however, as discussed above, recent literature has reported that MRI provides excellent results in detecting and grading IS. MRI also represents a noninvasive and more available exam. Secondly, we have no information about the evolution and clinical consequences of IS after it is diagnosed. However, this is a cohort study with the aim to investigate changes in the prevalence of IS among elite volleyball athletes. The following evolution or possible treatments were not investigated here. Thirdly, MRI of only the affected side was executed. Bilateral MRI could provide interesting information about the presence of teres minor hypertrophy, which is not so evident (although present) if compared to the contralateral side. Fourthly, the sample size was small, but it was similar to other studies presently in the literature.

There were strengths to this study. Firstly, at the time of the study, all players were involved at an active elite level, with a minimum of 20 hours of weekly games. Secondly, females and males were about equally represented in the study population, and both reported a preference for the jump topspin to serve. Thirdly, to the best of our knowledge, this is the first study that correlated the prevalence of IS with the skills preference (i.e. type of serve) of the players.

Conclusion

The greatest prevalence of suprascapular neuropathy has been reported among volleyball players. Because none of the affected players complained of pain, loss of function, or reduced performance when they played volleyball, the syndrome went undetected for a long period of time, resulting in complete irreversible denervation of the infraspinatus muscle. However, in recent years, changes in the technique of serving have occurred. The jump topspin serve is the most commonly performed type of serve worldwide. On the basis of these results, the prevalence of suprascapular neuropathy is much lower than that previously reported in the 1980s and 1990s, and our hypothesis is confirmed. The jump topspin serve

could be beneficial in reducing the prevalence of suprascapular neuropathy. The findings from this study should be considered by professional athletes and coaches for the prevention of activity-related injuries. Of course, further perspective studies investigating at which age players develop the syndrome are necessary to completely understand suprascapular neuropathy.

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