Shoulder Internal Rotator Strength as Risk Factor for Shoulder Pain in Volleyball Players

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Bibliography

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ABSTRACT

The aim of this study was to identify the intrinsic factors that could increase risk of shoulder pain in adolescent volleyball players. Twenty-eight young male volleyball players (between 14 and 18 years old) participated in this study. Athletes were submitted to: isokinetic muscle strength assessment of shoulder rotator muscles, ball service speed assessment, anterior and posterior drawer test, apprehension test, groove sign and scapular dyskinesia test. Athletes were followed for 16 weeks to monitor the presence of shoulder pain. All athletes were submitted to the same training protocol. During the 16 weeks, 28.5 % of the athletes (n = 8) experienced shoulder pain in the dominant limb higher than 3 according to Numerical Rating Scale criteria; 71.5 % of the athletes (n = 20) did not experience pain, or pain equal or lower than 3. The main result of our study was that the odds of feeling pain higher than 3 was significantly higher among players who presented higher values for internal rotation peak torque (OR = 1.113, CI 95 % = 1.006 to 1.232 and p = 0.038). The odds of feeling pain increased by 11 % for every N · m of the internal rotator muscles. Pre-season isokinetic rotator strength assessments can help identify adolescent volleyball players at increased risk of a shoulder injury.

Introduction

Volleyball is an overhead sport that has been considered to be one of the most popular sports around the world [1]. The throwing motion performed with plenty of power and high speed has been associated with a high rate of shoulder pain [2], which is one of the most frequently injured joint [2], with approximately 20 % of all volleyball injuries [2].

In young volleyball athletes, the risk factors for developing shoulder pain have not been well defined [1]. It is important to point out that previous studies, which have demonstrated a positive association between strength deficits in the glenohumeral and scapular muscles and shoulder injuries studied adult athletes [3–5], and little is known about young athletes. The importance of the strength balance ratios also has been studied, but the only two prospective studies that aimed to analyze the muscular profile as a risk factors for shoulder injuries in volleyball players were performed with adults [4, 6]. Shoulder and thoracic mobility also has been suggested to be associated with shoulder injury in overhead sports [5]. However, it is unknown if shoulder muscular strength, strength balance ratio, or glenohumeral stability can be considered as risk factors for shoulder injury in young volleyball athletes. This knowledge may help coaches, physicians, and physical therapists create strategies to prevent shoulder pain and injury in young volleyball players.

Therefore, we conducted a prospective study to verify if isokinetic muscle strength of shoulder rotator muscles, strength balance ratios, service ball speed, and morphostatic assessments can be considered as risk factors for shoulder pain in adolescents. We hypothesized that the presence of muscle weakness, muscle imbalance, low ball-throwing speed, or the presence of morphostatic alterations may be associated with a higher incidence of shoulder pain in adolescents during the volleyball season.

Materials and Methods

Ethical approval

All experimental procedures meet ethical standards in Sport and Exercise Science Research [7] and were approved by the Human Research Ethics Committee of the University (approval number 1053/10) and conformed to the principles outlined in the Declaration of Helsinki.).

Participants

Twenty-eight adolescent volleyball players from the Olympic Center of Training and Research (São Paulo, Brazil) participated in the study. After a clear explanation of the procedures, including the risks and benefits of participation, athletes and parents or legal guardians were required to sign a consent form.

The inclusion criteria were: male athletes between 14 to 18 years old, without upper and lower limb injuries in the previous six months, who were not taking medications or using ergogenic aids known to influence neuromuscular function/status, and trained five days weekly for 120 minutes daily for at least one year.

The exclusion criteria were: reported pain, swelling, orthopedic injuries, or participated in another sport. Two athletes were excluded because they stopped training. All athletes continued their regular training programs and were requested, with their coaches' consent, to refrain from strenuous workouts on the day before the research tests.

Study design

This was a prospective cross-sectional study. Over two consecutive days, athletes performed isokinetic muscle and ball service speed assessment in the pre-season and before the competitive period. During the competitive period (16 weeks), athletes were monitored for pain or injuries to the shoulder joints.

Experimental procedures

Isokinetic muscle assessment

The isokinetic strength test is a valid and reproducible method to evaluate performance of the shoulder rotator muscles in clinical practice [8–10]. Before isokinetic testing, participants were instructed to perform five minutes warm-up with circular movements of the upper limb. After that, participants were placed on the isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) to evaluate the isokinetic concentric and eccentric strength of the dominant upper limb, which was determined by asking the subjects which limb they preferred to use when throwing a ball, and this limb was tested first. The position chosen for shoulder evaluation was the same used in previous studies [8, 10, 11], and it is similar to the throwing position [12]. Participants assumed a seated position on the isokinetic dynamometer with their hips flexed at approximately 85° and their shoulder abducted at 90° in the frontal plane, and the elbows flexed at 90°. Standard stabilization strapping was placed across the trunk and the waist to minimize additional movement and to provide the same conditions for all participants. Strength of internal and external rotators were tested through 110° of range of motion (between 20° of internal rotation and 90° of external rotation) [12]. Correction for gravity was performed with the upper limb relaxed in 90° of shoulder abduction and neutral rotation. The evaluations were conducted in two stages. Firstly, in the concentric action in two angular speeds: 60°/sec and 240°/sec (in this order). Secondly, the eccentric action was evaluated at 240°/sec. Traditionally, shoulder muscle strength is assessed at 60°/sec, however, it is very far from the speed used during volleyball activities. Therefore, a higher angular speed (240°/sec) was also chosen.

Participants performed three submaximal trials at each test angular speed – to familiarize themselves with the range of motion and the accommodating resistance of the dynamometer – and performed five maximal repetitions at each angular speed test. Standard verbal encouragement was provided during all trials. Successive testing angular speeds were separated by one minute of rest. All participants were tested by a single examiner who was trained and experienced in the use of the isokinetic dynamometer. Outcome measures were peak torque in N·m and the average power (AVG power) in watts. The conventional strength ratios were calculated as the concentric peak torque of the external rotator muscles divided by the concentric peak torque of the internal rotator muscles at 60°/sec. The functional isokinetic strength ratios were calculated by dividing the eccentric peak torque of the external rotator muscles by the concentric peak torque of the internal rotator muscles at 240°/sec. To help the analysis, a poor conventional ratio (lower than 50% or higher than 70%) and functional ratio (lower than 1.0) were scored with 1, and a good conventional ratio (between 50 and 70%) and functional ratio (higher or equal than 1.0) scored 0.

Ball speed test assessment

Ball service speed was measured by a radar gun (Stalker Radar; Stalker Sport, Richardson, TX, USA), positioned in front of the athlete on the opposite side of the court. Radar height was visually adjusted individually according to the athlete's service arm height. Athletes were instructed to serve as fast and as accurately as possible, always in a similar location (in the center of the court), with their feet on the ground (without jumps), that is, in the same way that they are accustomed to do. All athletes threw thrice, and the average speed was used to analyze the results. Only valid services were considered for analysis. Ball speed was measured in kilometres·m^{-1}.

Morphostatic assessments

Anterior and posterior drawer test, apprehension test, groove sign and scapular dyskinesia were evaluated by one experienced examiner [13]. In the articular tests, the score zero was given to a negative

▶ **Table 1** Level of the association between pain and shoulder strength values and ball speed (n = 28).

	Adjusted Model			
	Pain ≤ 3 (n = 20)	**Pain > 3 (n = 8)**	**OR (CI 95 %)**	**p**
PT IR 240 °/s (N · m)	41.5 (9.6)	52.6 (11.7)	1.113 (1.006; 1.232)	.038
AVG power 240 °/s IR (watts)	65.1 (24.6)	84.3 (25.6)	1.034 (0.995; 1.074)	.090
PT ER 240 °/s (N · m)	29.4 (6.9)	37.2 (12.0)	1.104 (0.996; 1.223)	.060
AVG power 240 °/s ER (watts)	50.4 (18.3)	61.8 (25.5)	1.027 (0.986; 1.70)	.193
Ball speed (km · h^{-1})	63.3 (9.0)	70.2 (5.8)	1.130 (0.988; 1.293)	.075
PT IR Ecc 240 °/s	64.1 (25.1)	72.9 (22.5)	1.016 (0.978; 1.056)	.408
PT ER Ecc 240 °/s	56.1 (16.8)	67.3 (11.9)	1.053 (0.985; 1.125)	.131

Values are presented as mean (standard deviation); PT, peak torque; IR, internal rotation; ER, external rotation; AVG, average; Ecc, eccentric; Con, concentric

test and one to a positive test. In the scapular dyskinesia evaluation, the score zero was given to no dyskinesia, one to moderate, and two to severe [14]. In this analysis, positive scored 1 and negative 0.

Pain score

Pain score was used to monitor for the presence of shoulder pain in the dominant side over a 16-week period. Participants were asked to mark their shoulder pain through a score between 0 and 10 in a Numerical Rating Scales (NRS-10) [13] to describe how much pain they experienced each week. Questionnaires were administered by the researcher every Friday during the study period. If the athlete was not present at the training session, the researcher would contact them by telephone to complete the pain scale questionnaire. Thus, participants were divided into two groups. GROUP 1 included subjects who scored 4 or over on the NRS at least once during the 16 weeks. This level of pain (4) should also have made it difficult for the athlete to train. GROUP 2 included subjects who scored between 0 and 3 during the 16 weeks. This division was proposed taking into account that athletes who presented a lower pain score (< 4) might have less odds to have functional prejudice and need to be removed from volleyball training [9, 14].

Statistical analysis

All variables presented normal distribution in the Kolmogorov–Smirnov normality test, and homogeneous variability tested by Levene's test. Data were presented as mean and standard deviation. The data were analyzed using a generalized estimated equation (GEE) model with an unstructured covariance matrix, a logit link, and a binary outcome distribution. Generalized estimated equation models take into account the non-independence of data collected from the same participants. Results were presented as odds ratio (OR) with a 95 % confidence interval (95 %CI), and were estimated by GEE models for each isokinetic testing variable. The significance level (α) was set at .05 for all statistical procedures. All statistical analyses were performed with STATA/SE 14.1 for Windows (Microsoft, Redmond, WA, USA).

Results

The physical characteristics of athletes were (mean ± standard deviation): age, 15.5 ± 1.1 years; body mass, 73.2 ± 10.9 kg; and height, 1.84 ± 0.08 m.

During the monitoring pain phase (4 months), 28.5 % of the athletes experienced dominant shoulder pain higher than 3 (NRS), and 71.5 % of the athletes experienced no pain, or pain equal to or lower than 3. The odds of feeling pain higher than 3 was significantly higher among athletes who presented higher values for peak torque of internal rotator muscles assessed at 240º/sec (OR = 1.113, CI95 % 1.006 to 1.232, and p = .038). For those who had higher peak torque of the external rotator muscles (240º/sec), the OR for feeling pain, although borderline, did not reach the significant level (OR = 1.104, CI95 % 0.996 to 1.223, and p = .06) (▶ **Table 1)**. Moreover, eccentric peak torque values for internal and external rotator muscles and the ball speed were not associated with the risk of shoulder pain (▶ **Table 1)**.

The OR for feeling pain higher than 3 was eight times greater for those who had a preset strength imbalance in the shoulder conventional ratio. However, the data did not reach the significance level (OR = 8.556, CI95 % 0.881 to 83.057, and p = .06) (▶ **Table 2**). In the same direction, the apprehension test and groin test showed no association with the risk of shoulder pain (▶ **Table 2**).

In the present study, considering the functional ratio, only 4 athletes presented lower values than 1.0, and not one of them presented a pain level higher than 3. For the anterior drawer test, only one athlete presented a positive result and for the posterior drawer test and none presented positive results. In the same manner, only one athlete presented severe scapular dyskinesia.

Discussion

The main result of our study was that the odds of feeling pain higher than 3 was greater among adolescent volleyball players who presented higher values for internal rotator muscle peak torque. This finding indicates that the odds of feeling pain increased by 11 % for each N · m the internal rotator muscles got stronger. Moreover, the present results also showed no association between ball speed, strength balance ratio and joint stability tests and risk of feeling pain higher than 3. Therefore, these data contradict our initial hypothesis that muscular weakness would be a risk factor for shoulder pain in adolescent volleyball players.

One possible reason for stronger athletes presenting more risk of shoulder joint pain may be related to the greater forces acting on an immature joint (neuromuscular and bone development during growth continues until approximately 18 years of age) [15–17].

▶ **Table 2** Level of the association between shoulder pain and shoulder strength balance ratios and stability joint tests (n = 28).

	Adjusted Model			
	Pain ≤ 3 (n = 20)	Pain > 3 (n = 8)	OR (CI 95 %)	p
Conventional ratio (ERcon/IRcon)				
0	11 (91.7 %)	1 (8.3 %)	1.000	
1	9 (56.3 %)	7 (43.8 %)	8.556 (0.881; 83.057)	.064
Functional ratio (ERecc/IRcon)				
0	15 (68.2 %)	7 (31.8 %)	–	
1	4 (100.0 %)	0 (0.0 %)	–	–
Anterior drawer test				
0	19 (73.1 %)	7 (26.9 %)	–	
1	1 (100.0 %)	0 (0.0 %)	–	–
Posterior drawer test				
0	20 (74.1 %)	7 (25.9 %)	–	–
Apprehension test				
0	17 (77.3 %)	5 (22.7 %)	1.000	
1	3 (60.0 %)	2 (40.0 %)	2.267 (0.292; 17.577)	.434
Groove sign				
0	18 (75.0 %)	6 (25.0 %)	1.000	
1	2 (66.7 %)	1 (33.3 %)	1.500 (0.115; 19.640)	.757
Scapular dyskinesia				
0	12 (80.0 %)	3 (20.0 %)	–	
1	7 (63.6 %)	4 (36.4 %)	–	–
2	1 (100.0 %)	0 (0.0 %)	–	–
Values presented are number of occurrences (percentage values)				

As muscle strength is an essential physiological capacity for the volleyball game, individuals presenting greater strength levels would probably be required more in the games and training sessions and that this frequent requirement could lead to shoulder pain. Differently from our study, Forthomme et al. [4] found that the eccentric maximal strength developed by the internal and external rotators represents a protective factor for shoulder pain in volleyball players; however, the author evaluated adult volleyball players (age = 24 ± 5 yrs.), who probably present a mature musculoskeletal system that may be more able to support greater muscle torque acting on the shoulder joint than the adolescent ones.

The conventional ratio was calculated, considering its importance as a variable reflecting joint static stability [18]. The odds ratio for feeling pain when the conventional ratio is far from the literature recommendation was eight times higher than when the rotator muscles were balanced, however the p-value for this association was borderline (p = 0.06). Therefore, these results do not allow the affirmation of an association between muscle imbalance and shoulder pain. On the other hand, it is possible that the sample size was not large enough to identify in a significant manner the association between these variables.

According to the functional balance ratio, our results showed that the functional ratio was not associated with shoulder pain. On the other hand, Edouard et al. (2013) demonstrated that the shoulder functional balance ratio represented a risk factor for injury in adult female handball players and not in adolescents. Wang and Cochrane (2001) found a statistically significant association between shoulder functional ratio and shoulder injuries, but these authors also studied adult athletes. Stickley et al. (2008) conducted a study with younger volleyball players, and they found a significant difference in functional ratio between athletes with and without shoulder injuries, however the authors developed a transversal study, and with this study design, it is not possible to conclude whether muscle imbalance is associated with the cause or whether it is a consequence of shoulder pain. Therefore, this issue continues to be controversial in the literature, which may be affected by the different ages of the volunteers, sex, different levels of trainability, and different sports modalities.

Data from the present study demonstrated that eccentric internal rotator and external rotator muscle strength were not associated with shoulder pain. However, previous studies developed with adult athletes [11, 21–23] showed an important role of this muscle strength in injury prevention. Forthomme et al. (2013) reported that the eccentric maximal strength developed by the internal and external rotators represents a protective factor in volleyball players. One more time, the ages of the sample could explain this difference among the studies.

Despite internal rotator strength being associated with shoulder pain, the throwing ball velocity was not associated with shoulder pain, which suggests that the risk of presenting pain in adolescent volleyball players is the strength of the shoulder rotators but not the sporting gesture of the throw made at great speed. Anterior and posterior drawer tests were chosen in order to evaluate the displacement level of the humerus to the glenoid. However, just one of 28 athletes presented a positive result for the anterior drawer test, and none of the volunteers presented positive results for the posterior drawer test. Therefore, these tests suggest no association with the presence of pain during the four month period considered in the present study. The apprehension test was chosen because it represents anterior shoulder instability when the glenohumeral capsule is injured. Although the study sample was relatively young, 18 % of them scored one in this test. However, both groove and apprehension tests presented no association with shoulder pain in young athletes. Scapular dyskinesia can be defined as a collective term that refers to the movement of the scapula that is dysfunctional and may create a possible impairment of overall shoulder function [24–28]. In this study, 12 athletes presented scapular dyskinesia. Despite the relatively high incidence of scapular dyskinesia, this condition was not associated with an increased risk factor for shoulder pain in adolescents. This is in accordance with Wang and Cochrane's results, who found no association between injury and scapular dyskinesia in adult volleyball players [6].

One limitation of the present study was the relatively small sample size. In those who had higher peak torque of the external rotator muscles (240º/sec) or strength imbalance, the OR for feeling pain, although borderline, did not reach the significant level. Therefore, the authors recommend future studies with a larger sample size. On the other hand, an important strength of the study was the fact that it was a prospective study. Therefore this study more clearly indicates the temporal sequence between exposure and outcome than the retrospective studies.

In conclusion, higher levels of internal rotator peak torque may impact negatively on shoulder pain of male adolescent volleyball players. Therefore, specific strengthening exercises for shoulder internal rotator muscles should be avoided among adolescent volleyball athletes. Future studies might investigate a larger sample size to verify the role of the external rotator and conventional ratio as potential risk factors for shoulder injuries among young athletes.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Reeser JC, Verhagen E, Briner WW et al. Strategies for the prevention of volleyball related injuries. Br J Sports Med 2006; 40: 594–600

[2] Seminati E, Minetti AE. Overuse in volleyball training/practice: a review on shoulder and spine – related injuries. Eur J Sport Sci 2013; 13: 732–743

[3] Tyler TF, Nahow RC, Nicholas SJ et al. Quantifying shoulder rotation weakness in patients with shoulder impingement. J Shoulder Elbow Surg 2005; 14: 570–574

[4] Forthomme B, Wieczorek V, Frisch A et al. Shoulder pain among high-level volleyball players and preseason features. Med Sci Sports Exerc 2013; 45: 1852–1860

[5] Cools AM, Johansson FR, Borms D et al. Prevention of shoulder injuries in overhead athletes: a science-based approach. Braz J Phys Ther 2015; 19: 331–339

[6] Wang HK, Cochrane T. Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. J Sports Med Phys Fitness 2001; 41: 403–410

[7] Harriss DJ, Macsween A, Atkinson G. Ethical standards in sport and exercise science research: 2020 update. Int J Sports Med 2019; 40: 813–817

[8] Andrade MDS, Fleury AM, de Lira CAB et al. Profile of isokinetic eccentric-to-concentric strength ratios of shoulder rotator muscles in elite female team handball players. J Sports Sci 2010; 28: 743–749

[9] Dvir Z. Isokinetics: Muscle Testing, Interpretation and Clinical Applications. 2nd ed. Philadelphia: Churchill Livingstone; 2003

[10] Andrade MS, Vancini RL, De Lira CAB et al. Shoulder isokinetic profile of male handball players of the Brazilian National Team. Braz J Phys Ther 2013; 17: 572–578

[11] Andrade MS, De Carvalho Koffes F, Benedito-Silva AA et al. Effect of fatigue caused by a simulated handball game on ball throwing velocity, shoulder muscle strength and balance ratio: a prospective study. BMC Sports Sci Med Rehabil 2016; 8: 13

[12] Scoville CR, Arciero RA, Taylor DC et al. End range eccentric antagonist/concentric agonist strength ratios: a new perspective in shoulder strength assessment. J Orthop Sports Phys Ther 1997; 25: 203–207

[13] Magee D. Orthopedic Physical Assessment. 6th ed. Philadelphia: Saunders; 2014

[14] Huang TS, Huang HY, Wang TG et al. Comprehensive classification test of scapular dyskinesis: A reliability study. Man Ther 2015; 20: 427–432

[15] Olds M, Donaldson K, Ellis R et al. In children 18 years and under, what promotes recurrent shoulder instability after traumatic anterior shoulder dislocation? a systematic review and meta-analysis of risk factors. Br J Sports Med 2016; 50: 1135–1141

[16] Hogan KA, Gross RH. Overuse injuries in pediatric athletes. Orthop Clin North Am 2003; 34: 405–415

[17] Malina R. Growth, Maturation and Physical Activity. 2nd ed. Champaign (IL): Human Kinetics; 2004

[18] Ellenbecker TS, Mattalino AJ. Concentric isokinetic shoulder internal and external rotation strength in professional baseball pitchers. J Orthop Sports Phys Ther 1997; 25: 323–328

[19] Edouard P, Degache F, Oullion R et al. Shoulder strength imbalances as injury risk in handball. Int J Sports Med 2013; 34: 654–660

[20] Stickley CD, Hetzler RK, Freemyer BG et al. Isokinetic peak torque ratios and shoulder injury history in adolescent female volleyball athletes. J Athl Train 2008; 43: 571–577

[21] Gozlan G, Bensoussan L, Coudreuse J-M et al. Mesure de la force des muscles rotateurs de l'épaule chez des sportifs sains de haut niveau (natation, volley-ball, tennis) par dynamomètre isocinétique: comparaison entre épaule dominante et non dominante. Ann Readapt Med Phys 2006; 49: 8–15

[22] Hadzic V, Sattler T, Veselko M et al. Strength asymmetry of the shoulders in elite volleyball players. J Athl Train 2014; 49: 338–344

[23] Noffal GJ. Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. Am J Sports Med 2003; 31: 537–541

[24] Benjamin Kibler W, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg 2012; 20: 364–372

[25] Kibler W Ben, McMullen J. Scapular dyskinesis and its relation to shoulder pain. J Am Acad Orthop Surg 2003; 11: 142–151

[26] Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther 2000; 80: 276–291

[27] Schmitt L, Snyder-Mackler L. Role of scapular stabilizers in etiology and treatment of impingement syndrome. J Orthop Sports Phys Ther 1999; 29: 31–38

[28] Hickey D, Solvig V, Cavalheri V et al. Scapular dyskinesis increases the risk of future shoulder pain by 43 % in asymptomatic athletes: a systematic review and meta-analysis. Br J Sports Med 2018; 52: 102–110