Chapter 5

Shoulder Injuries in Volleyball Players: Injury Mechanisms and Injury Prevention

Nadir Tayfun Ozcan[1]

Caglayan Pinar Ozturk[2]

Abstract

Volleyball, one of the most widely followed and team-oriented sports globally, fosters both team cohesion and strategic thinking. Despite its general safety, the sport poses specific injury risks to athletes, particularly due to the repetitive nature of its overhead movements. Shoulder injuries, prevalent among volleyball players, are often attributed to actions such as repetitive spiking, serving, and blocking. These injuries are a leading cause of missed training sessions and competitive events among athletes. When factoring in the financial impact of treatment, developing effective injury prevention strategies becomes essential. Identifying both extrinsic and intrinsic risk factors associated with shoulder injuries is a primary step in prevention efforts. In addition to assessing individual risk profiles, understanding the mechanisms of shoulder injury can significantly enhance both preventive strategies and the efficacy of post-injury rehabilitation programs. Tailored interventions focusing on strength, stabilization, flexibility, and neuromuscular training are recommended for volleyball players to minimize shoulder injury risk.

Introduction

Volleyball is one of the most popular sports, estimated by the International Volleyball Federation to be played by 500 million people worldwide, and the interest in volleyball is growing day by day. Although volleyball is generally considered a safe sport, players are at risk of some types of injuries due to the basic structure and requirements of volleyball. The ball, which

1 Süleyman Demirel University, Isparta Health Services Vocational School, Department of Therapy and Rehabilitation, nadirozcan@sdu.edu.tr, ORCID:0000-0003-2239-2562

2 Süleyman Demirel University, Isparta Health Services Vocational School, Department of Therapy and Rehabilitation, caglayanozturk@sdu.edu.tr, ORCID:0000-0002-7049-9746

https://doi.org/10.58830/ozgur.pub492.c2096

can travel up to 80 mph during the game, can cause upper extremity injuries during hitting, passing or blocking. In addition, overuse-related injuries can be observed in elite volleyball players because of repetitive overhead movements such as spikes or blocks, which can be performed up to 40,000 repetitions per year (1,2).

It is known that the shoulder region is the most frequently injured region after the ankle and knee among volleyball players. It is estimated that shoulder injuries constitute 8-20% of volleyball-related musculoskeletal injuries (3). In a study in which 16 years of injury data were analyzed in female volleyball players, it was found that shoulder injuries ranked first among the reasons for not participating in training and matches (4). In another similar study, it was reported that shoulder injuries in volleyball players caused the athlete to stay away from sports for an average of 6.2 weeks (5). When the annual financial dimension of these injuries is considered, it is seen that emergency room and hospital costs related to injuries reach 4.6 million Euros and the cost of the days the athlete stays away from sports due to injury reaches approximately 11 million Euros (6).

In this context, strategies for the prevention of injuries gain serious importance considering the reasons such as high treatment costs after injury, time away from sports and negative effects on the athlete's career plan. Therefore, it is important to identify external and internal risk factors that may cause sports injuries and to develop strategies to prevent them (7). In addition to questioning why the athlete is at risk for injury, the mechanism of injury (how the injury occurs) is a critical factor for the prevention of injuries with multifactorial nature and the success of rehabilitation. Apart from these, the use of biomechanical models, which are based on risk homeostasis, considering the properties of tissues and the responses of tissues to exertion, will play a key role in both the prevention of injuries and the planning of a successful rehabilitation program in athletes (8).

Mechanism of shoulder injuries

In volleyball, as in handball, tennis or swimming, overhead activities that require sudden power and rotation cause biomechanical adaptations and loads on the shoulder joint. When compared to other major joints, it is seen that the range of motion and flexibility properties of the shoulder joint are more than its stability. The ball-socket relationship of the shoulder joint and the kinematic variability of repetitive overhead movements can cause injuries by overcoming the intrinsic stabilization of the shoulder joint. Apart from repetitive movements, the use of incorrect technique also increases the

risk of injury in athletes. There is also a relationship between the playing positions of volleyball players and the risk of injury. More injuries occur in spiking, serving and blocking movements compared to other movements (1,9,10).

In volleyball, players perform a highly technical spiking motion that is repeated at high frequencies during training and competition to attack. For an effective spiking, the athlete is expected to have a wide range of motion. After the shoulder joint starts the movement with elevation above 90° and slight abduction during the spiking, the degree of abduction and external rotation of the shoulder joint reaches a maximum before the ball is hit. During the acceleration phase, when the hand strikes the ball, the shoulder joint goes into internal rotation and adduction very rapidly. Internal rotation and adduction of the shoulder joint are maintained until the end of the acceleration phase (2,11,12). When the force values generated during the spiking hit are examined, it is estimated that the internal rotation torque generated at the end of the acceleration phase is approximately 50 Nm. After the ball hit, an adduction torque of 115 Nm occurs in the joint. Currently, a compression force of 800-1,500 Nm acts on the glenohumeral joint (13). Another overhead movement performed repetitively in volleyball players that causes significant loads on the shoulder joint is the serve. The extreme shoulder movements and large angular velocities that occur especially in the jumping serve create a risk for shoulder pathologies by causing an increase in the forces affecting the shoulder (13-15). These techniques that volleyball players use repetitively during training and competition may cause functional, morphologic and biomechanical changes in range of motion, muscle strength, structures of the shoulder joint and scapula.

The forces generated during both the spiking and serve can cause the humeral head to shift anteriorly over the glenoid cavity, resulting in pain and shoulder instability. This may cause overactivation of the rotator cuff muscles, which contribute significantly to the dynamic stability of the humeral head, leading to overuse injuries in this muscle group. In addition, the forces that occur during hitting volleyball players may cause negative changes in the glenohumeral ligament and labrum. The anterior displacement of the humeral head may cause compression of the rotator cuff and labrum at the posterosuperior aspect of the glenohumeral joint, leading to internal impingement (16,17).

In addition, repetitive shoulder external rotation during ball hitting in volleyball players may cause contracture in the posterior joint capsule on the dominant side. This causes the humeral head to shift posterosuperior,

leading to internal rotation deficits on the dominant side in volleyball players and causing painful conditions such as impingement or labrum tear (18). In addition, scapular depression, lateralization or unstable scapula caused by repetitive overhead activities performed by volleyball players may cause impingement syndrome by decreasing the subacromial space. Asymmetric scapular positions and movements seen in these athletes are associated with shoulder injuries. Weakness or imbalance in the periscapular muscles associated with overhead activities can lead to scapular malposition, resulting in negative effects on shoulder kinematics. Delay in activation of the periscapular muscles, which have important roles in stabilization of the shoulder joint, may result in shoulder pain or injury (19).

Risk factors and prevention approaches in shoulder injuries

Repetitive, rapid and rotational shoulder movements in volleyball, as in handball, tennis and softball, create biomechanical loads on the joint and lead to shoulder injuries. These biomechanical forces acting on the shoulder joint may cause subacromial impingement, rotator cuff muscle tears, glenohumeral joint instability and bursitis in athletes (9).

Nowadays, clinicians are working on injury prevention strategies to prevent injuries and to reduce the loss of sporting time associated with injuries. The first step to be taken in determining strategies for the prevention of injuries in athletes is to determine the risk factors related to the sport. Without taking this step, strategies to be applied for the prevention of sports injuries will have a low chance of success. Risk factors for shoulder injuries in sports branches in which repetitive overhead activities such as volleyball are frequently performed are shown below (Table 1) (20).

Table 1. Risk factors for shoulder injuries in sports where repetitive overhead activities are frequently performed

• History of shoulder pain • Loss of range of motion and flexibility • Muscle weaknesses • Agonist-antagonist muscle imbalance • Scapular dyskinesia	• Increased body mass index • Gender • Age • Position errors of the athlete • Training-competition frequency

Glenohumeral internal rotation and rotator cuff strength deficits, scapular dyskinesia, increased subacromial bursa volume and the presence of shoulder pain are the main risks for shoulder injuries in athletes who perform repetitive overhead movements. Especially pre-season loss of shoulder internal rotation range of motion, decrease in the total range of

motion in the glenohumeral joint, loss of strength in the external rotator and supraspinatus muscles, short anatomical distance between the anterior humeral head and the anterior acromion and deviations in the normal scapular position increase the risk of overuse-related injuries in the shoulder joint (21-25).

In addition to the risks mentioned above, factors such as increased body mass index, older age and years of experience may also increase the risk of injury in athletes (20). Another risk factor for shoulder injuries is the position of the volleyball player. In attacking positions, volleyball players experience shoulder injuries more frequently compared to players in blocking, setter, and libero positions (25). In addition, the structural and muscular differences of the female gender put female athletes at a higher risk for shoulder injuries. Differences in glenoid height and width, and changes in the location and depth of the glenoid notch compared to the male gender increase the risk of shoulder injury. In addition, loss of shoulder stability associated with muscular factors also increases the risk of injury in female athletes (24,26). To prevent shoulder joint injuries in volleyball players, it is important to perform the following evaluations to determine the risk factors (Table 1) (14).x

Table 2. Risk factors that should be evaluated in volleyball players for injury prevention

• Inspection and palpation (to define the number and width of problematic areas) • Evaluation of scapulohumeral rhythm. • Evaluation of scapular winging. • Evaluation of infra-lateral scapular displacement/scapular abduction. • Evaluation of impingement. • Evaluation of shoulder flexion in the sagittal plane.	• Assessment of coracoid tightness/ pectoral shortening. • Assessment of glenohumeral joint range of motion. • Assessment of anterior capsular laxity. • Assessment of strength imbalances. • Internal and external isometric muscle strength assessment. • Assessment of core stability

The first step in injury prevention in volleyball players is the use of warm-up programs consisting of both conventional and volleyball-specific exercises that focus on neuromuscular control, concentric and eccentric rotator muscle strength, scapular stabilization, and trunk stability.

Cardiorespiratory exercises with gradually increasing intensity such as running, sprinting, agility and directional running, jumping or shoulder joint circulation can be used as conventional warm-up exercises in volleyball players. After the conventional exercises, the main body of the warm-up program should consist of volleyball-specific anti-injury exercises. At

this point, shoulder external rotation strengthening, core stabilization, proprioception, plyometric and push-up exercises and passing exercises can be performed in different positions (27).

Rotator cuff muscle strengthening should be a key factor in preventing shoulder injuries in volleyball players. In recent years, the importance of eccentric strength values rather than isometric and concentric strength values of this muscle group has been emphasized. Especially eccentric strengthening exercises applied to the external rotator muscles of the shoulder make a very important contribution to the deseralization of the upper extremity during serving or hitting (28). Adaptive strength losses observed in shoulder external rotator muscle strength in volleyball players may also cause strength imbalance in the rotator cuff muscles. In one study, it was emphasized that the shoulder external rotation/internal rotation isokinetic muscle strength ratio should be 66% to prevent shoulder injuries (29). In another similar study, it was emphasized that a shoulder external rotation/internal rotation isometric muscle strength ratio of 75% may reduce the risk of shoulder injury (30).

To strengthen the rotator cuff muscles in volleyball players, exercise programs that reduce subacromial contact and do not create stress on the static stabilizers of the glenohumeral joint should be applied. Exercises performed in 90° shoulder abduction and scapular plane provide biomechanical advantages in volleyball players. In addition, oscillation, rhythmic stabilization or perturbation training added to the exercises will increase the effectiveness of the strength exercises (31)

Scapular stabilization is another important point to be considered in improving the function of the shoulder joint and protecting it against injuries in volleyball players. Since abnormal scapular positions and movements are associated with shoulder joint pathologies, scapular kinematics should be optimized in volleyball players. In this context, a slight increase in favor of scapular retractor muscles is accepted, but in general, a scapular retraction/protraction isokinetic muscle ratio of "1" is required (32). A strength increases of 10% in the dominant extremity scapular muscle strength compared to the non-dominant scapular muscle strength is also suggested (33). Increasing activity in the serratus anterior and lower-middle trapezius muscles and decreasing the increased activity in the upper trapezius muscle fibers will also contribute positively to scapular kinematics. In addition, since loss of flexibility in the pectoralis minor, levator scapula, latissimus dorsi and rhomboid muscles and the posterior glenohumeral capsule may

negatively affect scapular kinematics, methods to increase the flexibility of these tissues should be applied (31).

One of the most important ways to reduce the stress on the shoulder joint caused by repetitive overhead activities requiring high performance in volleyball players is to provide coordination of the muscles around the shoulder. The harmonious functioning of these muscles is provided by proprioception. In volleyball players, proprioception contributes to muscle coordination and has a positive effect on the dynamic stabilization of the shoulder joint (34). A significant increase in proprioception sensation can be achieved by increasing muscle spindle sensitivity and joint position sensation with exercise programs applied in volleyball players. Resistance exercises for the shoulder girdle increase the functional capacity of the dynamic stabilizers of the shoulder joint and lead to improvement in proprioception (35). Closed kinetic chain exercises may also be preferred in maintaining and restoring the dynamic stability of the joint by causing co-activation in the muscles around the shoulder with aproximations in the shoulder joint (36). In addition, open kinetic chain exercises, which provide an increase in joint position sensation, may also be preferred in the development of shoulder proprioception (37).

Conclusion

In this study, the risk factors, injury mechanisms and prevention strategies associated with shoulder injuries in volleyball players were examined. Weakness or imbalances in the rotator cuff muscles, changes in scapula kinematics, and stresses on the shoulder joint during ball contact may cause shoulder injuries. In this context, individualized strengthening, stabilization, flexibility and neuromuscular training programs minimize the risk of shoulder injury. Approaches to be applied for the prevention of shoulder injuries will reduce losses related to sports participation and health expenses. It will also contribute to minimizing the physical and psychological deterioration that can be seen in athletes after injury.

References

1. Eerkes K. Volleyball injuries. Curr Sports Med Rep. 2012;11(5):251–6.
2. Challoumas D, Stavrou A, Dimitrakakis G. The volleyball athlete's shoulder: biomechanical adaptations and injury associations. Sport Biomech [Internet]. 2017;16(2):220–37. Available from: http://dx.doi.org/10.1080/14763141.2016.1222629
3. Skazalski C, Whiteley R, Sattler T, Kozamernik T, Bahr R. Knee, Low Back, and Shoulder Problems Among University and Professional Volleyball Players: Playing With Pain. J Athl Train. 2024;59(1):81–9.
4. Agel J, Palmieri-Smith RM, Dick R, Wojtys EM, Marshall SW. Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association injury surveillance system, 1988-1989 through 2003-2004. J Athl Train. 2007;42(2):295–302.
5. Wang, H. K., & Cochrane T. A Descriptive Epidemiological Study of Shoulder Injury in Top Level English Male Volleyball Players. Int J Sports Med. 2001;22(2):159–63.
6. Kilic O, Maas M, Verhagen E, Zwerver J, Gouttebarge V. Incidence, aetiology and prevention of musculoskeletal injuries in volleyball: A systematic review of the literature. 2017;17(6):765–93.
7. James LP, Kelly VG, Beckman EM. Injury risk management plan for volleyball athletes. Sports Med. 2014;44(9):1185–95.
8. Bahr R, Krosshaug T. Understanding injury mechanisms: A key component of preventing injuries in sport. Br J Sports Med. 2005;39(6):324–9.
9. Kibler W Ben, Wilkes T, Sciascia A. Mechanics and Pathomechanics in the O verhead Athlete. Clin Sport Med. 2019;32(2013):637–51.
10. Lin DJ, Wong TT, Kazam JK. Shoulder Injuries in the Overhead-Throwing Athlete: Epidemiology, Mechanisms of Injury, and Imaging Findings 1. Radiology. 2018;286(2):370–87.
11. RF E, JR A. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. Sport Med [Internet]. 2009;39(7):569–90. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=105395182&site=ehost-live
12. Liu, L. F., Liu, G. C., Sue, C. W., Huang CF. The application of range of motion (rom) and coordination on volleyball spike. In: ISBS-Conference Proceedings Archive. 2008. p. 690–3.
13. Reeser JC, Fleisig GS, Bolt B, Ruan M. Upper Limb Biomechanics During the Volleyball Serve and Spike. Sports Health. 2010;2(5):368–74.
14. Reeser JC, Joy EA, Porucznik CA, Berg RL, Colliver EB, Willick SE. Risk Factors for Volleyball-Related Shoulder Pain and Dysfunction. PM R. 2010;2(1):27–36.

15. Seminati E, Minetti AE. Overuse in volleyball training/practice: A review on shoulder and spine-related injuries. Eur J Sport Sci. 2013;13(6):732–43.
16. Drakos MC, Rudzki JR, Allen AA, Potter HG, Altchek DW. Internal impingement of the shoulder in the overhead athlete. J Bone Jt Surg. 2009;91(11):2719–28.
17. Heyworth BE, Williams RJ. Internal impingement of the shoulder. Am J Sports Med. 2009;37(5):1024–37.
18. Lintner D, Mayol M, Uzodinma O, Jones R, Labossiere D. Glenohumeral internal rotation deficits in professional pitchers enrolled in an internal rotation stretching program. Am J Sports Med. 2007;35(4):617–21.
19. 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(3):403–10.
20. Tooth C, Gofflot A, Croisier J, Beaudart C. Risk Factors of Overuse Shoulder Injuries in Overhead Athletes: Sports Health. 2020;12(5):478–87.
21. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: A prospective cohort study. Br J Sports Med. 2014;48(17):1327–33.
22. Shanley E, Rauh MJ, Michener LA, Ellenbecker TS, Garrison JC, Thigpen CA. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. Am J Sports Med. 2011;39(9):1997–2006.
23. Wilk KE, MacRina LC, Fleisig GS, Porterfield R, Simpson CD, Harker P, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. Am J Sports Med. 2011;39(2):329–35.
24. Steele MC, Lavorgna TR, Ierulli VK, Mulcahey MK. Risk Factors for Shoulder Injuries in Female Athletes Playing Overhead Sports: A Systematic Review. Sports Health. 2024 Jun 20:19417381241259987. doi: 10.1177/19417381241259987.
25. Skazalski C, Bahr R, Whiteley R. Shoulder complaints more likely in volleyball players with a thickened bursa or supraspinatus tendon neovessels. Scand J Med Sci Sport. 2021;31(2):480–8.
26. Merrill A, Guzman K, Miller SL. Gender differences in glenoid anatomy: an anatomic study. Surg Radiol anatomy. 2009; 31:183–9.
27. Tooth C, Schwartz C, Croisier JL, Gofflot A, Bornheim S, Forthomme B. Prevention of shoulder injuries in volleyball players: The usefulness and efficiency of a warm-up routine. Phys Ther Sport. 2023;64(September):97–103.

28. Engineer K, Cools AM. Measuring Eccentric Strength of the Shoulder External Rotators Using a Handheld Dynamometer: Reliability and Validity. J Athl Train. 2015;50(7):719–25.
29. Byram IR, Bushnell BD, Dugger K, Charron K, Harrell FE, Noonan TJ. Preseason shoulder strength measurements in professional baseball pitchers: Identifying players at risk for injury. Am J Sports Med. 2010;38(7):1375–82.
30. Cools AM, Palmans T, Johansson FR. Age-related, sport-specific adaptations of the shoulder girdle in elite adolescent tennis players. J Athl Train. 2014;49(5):647–53.
31. Ellenbecker T, Plus R, Therapy S, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. Br J Sports Med. 2016;44(5):319–27.
32. Cools AM, Geerooms E, Berghe DFM Van Den, Cambier DC, Witvrouw EE. Isokinetic Scapular Muscle Performance in Young Elite Gymnasts. J Athl Train. 2007;42(4):458–63.
33. Cools AM, Johansson FR, Borms D. Prevention of shoulder injuries in overhead athletes: a science-based approach. Brazilian J Phys Ther. 2015;19(5):331–9.
34. Zarei M, Eshghi S, Hosseinzadeh M. The effect of a shoulder injury prevention programme on proprioception and dynamic stability of young volleyball players; a randomized controlled trial. BMC Sports Sci Med Rehabil. 2021;13(1):1–9.
35. Velasques B, Cossich V. Strength Training and Shoulder Proprioception ´. J Athl Train. 2015;50(3):277–80.
36. KE Wilk CA. Current Concepts in Rehabilitation. J Orthop Sport Phys Ther. 1993;18(1):365-378.
37. Myers JB, Lephart SM. The Role of the Sensorimotor System in the Athletic Shoulder. J Athl Train. 2000;35(3):351–63.