Proceedings of ICBioMed 2025 Symposium: AI for Healthcare: Advanced Medical Data Analytics and Smart Rehabilitation
DOI: 10.54254/2753-8818/2025.AU26696

Mechanisms and Prevention of Upper Limb Injuries in Table Tennis

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Abstract. Arm injuries, particularly affecting the elbow and shoulder joints, represent a significant burden for table tennis players across all skill levels. Driven by the sport's demands for rapid, forceful, and repetitive upper limb movements, injuries such as lateral epicondylitis ("tennis elbow"), medial epicondylitis ("golfer's elbow"), rotator cuff tendinopathy, and labral tears are prevalent. This paper comprehensively analyzes the current evidence on vulnerable anatomical structures, biomechanical mechanisms of injury, major risk factors (including equipment mismatch, technical defects, and training errors), and evidence-based prevention strategies. The analysis of the results showed that the injuries were caused by chronic overload, dynamic instability, and compensatory movements inherent in specific hitting movements (such as forearm pronation during forehand pull and shoulder over position during spike). Effective prevention requires multiple measures, including optimizing hitting movements through biomechanical analysis, implementing structured strength and fitness training programs that focus on centrifugal control and scapular stability, ensuring appropriate equipment adaptation (especially grip size), adopting reasonable load management, and incorporating specialized recovery plans. This evidence-based framework provides a basis for athletes, coaches, and medical professionals to reduce injury risks and promote sustainable participation in table tennis.

Keywords: Elbow joint injury, shoulder joint injury, external epicondylitis, internal epicondylitis, evidence-based sports medicine.

1. Introduction

Table tennis is a globally popular sport whose high-speed rounds and complex hitting techniques place extreme demands on the upper limbs. The arm, as the important link between the player's kinetic chain and the racket, undergoes rapid acceleration, deceleration and powerful rotations with each stroke [1]. Epidemiological studies have consistently shown the predominance of overuse injuries in table tennis, with a large proportion of upper limb injuries. The repetition of hitting motions such as forehand pulls, backhand strokes, and snapping leads to cumulative microinjuries to tendons, ligaments, and joint structures. Internal and external epicondylitis in the elbow, as well as rotator cuff tendinopathy, biceps tendinitis, and glenoid labrum injuries in the shoulder, are commonly diagnosed [2]. These types of injuries not only decrease athletic performance but can also lead to significant loss of training and playing time and, if not managed properly, can lead to chronic

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DOI: 10.54254/2753-8818/2025.AU26696

pain. As a result, the shoulder and elbow joints are high-frequency locations of injury in both amateur players and elite professionals [3]. Epidemiological research consistently identifies the dominance of overuse injury in table tennis, with a large percentage represented by the upper limb, habitually attributed to excessive training volumes, technical deficiencies (action compensation), and intrinsic biomechanical stresses [4].

This paper provides an evidence-based synthesis of arm injuries in table tennis, with a particular focus on elbow and shoulder injuries. The paper explores the joint anatomy relevant to the sport, clarifies the pathomechanical mechanisms of common injuries, determines intrinsic and extrinsic risk factors, and critically assesses prevention strategies based on current scientific evidence. Its purpose is to integrate a detailed understanding to guide best practice injury reduction for players, coaches, and sports medicine clinicians.

2. Common elbow injuries and mechanisms in table tennis

The elbow joint complex is a complex hinge joint between the humerus, radius, and ulna. Stability is largely provided by the medial (ulnar) and lateral (radial) collateral ligament complexes [5]. Epicondylitis (tennis elbow) primarily involves tendinopathy of the radial short wrist extensor tendon at the origin of the epicondyle [6]. The centrifugal loading of the follow-through phase of the swing is particularly stressful when hitting the ball, especially in backhand strokes and plus-rotation curves, with forceful and repetitive extension of the wrist, along with a sharp turn of the wrist after forearm rotation to create rotation [4]. Sudden increases in playing time or intensity are typical predisposing factors [3]. Medial epicondylitis (golfer's elbow) involves tendinopathy at the origin of the flexor-pronator tendon complex at the medial epicondyle, caused primarily by repetitive forceful wrist flexion and forearm rotation. This is common in powerful forehand pulls and snaps, when the athlete rotates the forearm forcefully through the ball [7]. Especially strongly rotated serves can put a lot of stress on the medial elbow [2]. Elbow instability can be caused by chronic overuse or acute trauma can also lead to ulnar collateral ligament (UCL) insufficiency, especially with the valgus stress involved in the late preparation and acceleration phases of the powerful over-the-top maneuver (similar to baseball pitching, but to a lesser extent in table tennis). The main risk factors for elbow injuries include technical deficits (movement compensations), mismatched equipment, overload and muscle weakness and imbalances. Technical deficiencies (movement compensations) are deficiencies in core or lower extremity power transmission, resulting in an over-reliance on the wrist and forearm muscles to generate power. An improperly sized racket grip is a significant external factor. A grip that is too large prevents optimal wrapping of the fingers and forces the grip to increase, transmitting greater vibration and stress to the epicondyle. A grip that is too small can also lead to instability and compensatory gripping [8]. Additionally, a rigid racquet base plate transmits greater vibration. Excessive volume or intensity of training, especially a large number of repetitions emphasizing added rotations with insufficient rest, leads to cumulative microinjuries [3]. Muscle weakness and imbalance involve insufficient centrifugal force in the forearm extensors (to prevent epicondylitis) or flexors (to prevent medial epicondylitis), or a weak kinetic chain (core, hamstrings) so that the elbow has to compensate and generate forces it should not have to [9].

3. Shoulder injuries and mechanisms in table tennis

The glenohumeral (shoulder) joint is the most mobile but least stable major joint in the human body and relies heavily on dynamic stabilizers. Some of the important structures include the rotator cuff (RTC), the glenoid labrum, the long head of biceps tendon (LHBT), the subacromial space and the

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scapulothoracic wall joint. Power snapping (“killing the high ball”) and high-throwing serves result in mechanical compression of the supraspinatus tendon below the acromion (external impingement) or at the rostro-shoulder ligament, especially during the preparation and acceleration phases [2]. Extreme external rotation during the preparation phase may lead to internal impingement (rotator cuff contact with the posterior superior glenoid). Fatigue can lead to altered scapular kinematics (dyskinesia), decreasing the subacromial space and further exacerbating the impingement stimulus [10]. Biceps long head tendinopathy is due to repetitive over-the-top movements (snaps, serves) and sudden deceleration forces during follow-through swings, which place excessive tensile and shear stresses on the tendon within the biceps groove and its glenoid labral attachment [7]. While Bancart injuries (anterior inferior glenoid labral tears) are typically traumatic instability injuries, repetitive over-the-top stresses in table tennis can lead to glenoid labral abrasion or separation, particularly in the posterior-superior (internal impingement) or superior (SLAP) [11]. Scapular dyskinesia is due to fatigue or weakness of the scapular stabilizing muscles (anterior serratus, middle and lower trapezius) altering the normal scapulohumeral rhythm, which can alter glenohumeral joint position, narrow the subacromial space, decrease rotator cuff efficiency, and place abnormal stresses on all structures of the shoulder joint during the high speed, multiplanar motion of table tennis [10]. There are five main risk factors for shoulder joint injury. The first issue is technical defects and instability. Inefficient hitting movements lead to a "shoulder-dominated" playing style, with insufficient core/leg drive and excessive reliance on shoulder internal rotation and adduction, especially during smashes. The ineffective transmission of the power chain ("disconnection") forces the shoulders to generate excessive force [12]. The second is fatigue or weakness of the core muscles, as insufficient strength or endurance of the core muscle groups (abdominal muscles, oblique muscles, lumbar extensor muscles) can affect trunk stability. This can lead to more compensation of shoulder muscles to control racket position and generate strength, increasing fatigue and susceptibility to overload and movement disorders [10]. The third factor is weakness or imbalance of the scapular muscles, inhibition or weakness of the serratus anterior and inferior trapezius muscles, and tension or dominance of the pectoralis minor and superior trapezius muscles, which are the main causes of scapular movement disorders and resulting rotator cuff dysfunction/impingement [13]. The fourth is the dominance and load of the top movements. Players who are good at offensive play need to pay more attention, as they have a large number of dunks and additional topspin. Excessive serving practice, especially jumping or spinning serves, can cause significant strain on the shoulders and result in a sudden increase in training intensity/volume [3]. The fifth is glenohumeral internal rotation defect (GIRD), which significantly reduces the range of internal rotation relative to the contralateral shoulder joint and is often accompanied by posterior capsule tension. This may alter the kinematics of the glenohumeral joint by pushing the humeral head forward during the preparation phase, increasing impact and labrum tension [11].

4. Prevention strategies

Evidence-based prevention of arm injuries in table tennis requires proactive and multi-faceted strategies, comprehensively addressing known risk factors from training, equipment, to recovery. In terms of technical and biomechanical optimization, with the help of 3D motion capture or high-speed video analysis technology, professional coaches or sports scientists can detect technical issues that may increase joint stress during hitting movements, such as excessive wrist deviation, disordered power chain sequence, etc., which can provide an objective basis for technical correction. On this basis, it is necessary to prioritize the construction of an efficient hitting mechanism, emphasizing the orderly power chain from the legs to the wrists, grasping the best hitting timing to

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avoid "stretching enough ball" or "lagging", maintaining the wrist neutral position and controlling the acceleration and deceleration stages of the movement, while paying attention to the stability of the shoulder blades during over the top movements. Regular guidance from professional coaches can help athletes strengthen their correct movement patterns and avoid injuries caused by accumulated technical deficiencies. The core of this process lies in reducing unnecessary loads on the elbows and shoulders from the source of movement through scientific analysis and targeted adjustments, which is the foundation for preventing injuries.

Structured strength and physical training are key supports for preventing injuries. Centrifugal training has a significant effect on the prevention and rehabilitation of tendinopathy. For the elbow, eccentric wrist extension and flexion/pronation exercises can be used to prevent external epicondylitis and internal epicondylitis, respectively. For the shoulders, it is necessary to strengthen the eccentric training of the rotator cuff and scapular stabilizing muscles. In rotator cuff and scapular stability training, first perform isometric exercises and then transition to isometric exercises, focusing on external rotation, scapular plane elevation movements, and related muscle groups. At the same time, incorporate exercises that simulate the deceleration stage of hitting the ball, which can effectively improve shoulder dynamic stability [14]. Core reinforcement can improve the efficiency of the power chain, reduce arm compensation, and balance centripetal and centrifugal components in forearm strength and endurance training. Neuromuscular control and reinforcement training can further enhance the adaptability of joints in rapid hitting. These trainings enhance upper limb tolerance from multiple dimensions, such as muscle strength, stability, and coordination, and reduce the risk of injury. Equipment optimization, although often overlooked, has a direct impact on damage prevention. The grip size should ensure comfortable finger wrapping, which can be selected with simple testing assistance. Professional adaptation combined with anti-vibration tape can reduce the stress caused by vibration. The weight and balance of the racket need to be adjusted according to individual circumstances. Overloading can easily cause fatigue, while being too light may lead to improper force application. Although the selection of rubber is weakly associated with injury, a hard rubber will increase muscle load, and it needs to be selected reasonably based on the sports style. Appropriate equipment can reduce compensatory actions caused by instrument discomfort and lower the likelihood of injury from an external environmental perspective [15]. In summary, prevention of table tennis arm injuries requires an organic combination of technical optimization, strength training, equipment adaptation, load management, recovery and regeneration, and auxiliary methods to form a comprehensive protection system, in order to effectively reduce the risk of injury and ensure the sustainable participation of athletes.

5. Conclusion

Due to its unique biomechanical characteristics, table tennis has made arm injuries (especially elbow and shoulder injuries) a prominent problem that troubles athletes at all levels. The occurrence of these injuries is closely related to the complex anatomical structures of the elbow and shoulder joints, and their pathological mechanisms involve various types, such as internal and external epicondylitis, rotator cuff/labrum lesions, etc. Multi-dimensional risk factors such as technical movement defects, improper equipment adaptation, excessive training load, and muscle strength imbalance further exacerbate the risk of injuries. Therefore, a deep understanding of the anatomical basis, pathological mechanisms, and risk factors mentioned above is a prerequisite for developing effective prevention strategies. The prevention of arm injuries in table tennis is not achievable by a single measure, but requires the construction of multidimensional and evidence-based comprehensive strategies, which should be integrated into athletes' daily training and life. The core

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measures include: optimizing hitting movements through biomechanical analysis and professional coach guidance to reduce joint abnormal loads; Implement structured strength and physical training, with a focus on strengthening centrifugal control ability, rotator cuff and scapular stability, and core strength; Ensure equipment adaptability (especially precise selection of grip size); Realize scientific load management through periodic training programs; Assisted by standardized stretching, reasonable nutritional supplementation, sufficient water intake, and high-quality sleep as recovery methods. As for auxiliary tools such as compression sleeves, they can only serve as supplementary means and cannot replace the role of core preventive measures. This comprehensive prevention model provides a practical framework for athletes, coaches, and medical personnel to actively reduce the risk of injury. It not only helps to improve the stability of sports performance and prolong sports careers, but also protects the health and well-being of table tennis players at all levels, promoting their sustainable participation in the sport. Future research should further explore personalized intervention plans, verify the application value of innovative technologies such as 3D motion capture in daily prevention, and establish a personalized injury risk assessment system for table tennis players, providing a more accurate scientific basis for injury prevention.

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