

Research on injury site characteristics and preventive measures for elite diving athletes

Watanabe Kenta^{1, a, *}, Arthur Evans^{1, b},

¹Institute of Health and Sport Sciences, University of Tsukuba 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8574, JAPAN
a.watanabe_kenta0549@sina.com, b.arthur_e_2011@icloud.com

*Corresponding Author

Abstract: Diving, as a source of pride and a representative of China's competitive sports, has achieved remarkable results for the country in international arenas, standing as a point of national pride. However, alongside these brilliant accomplishments comes the current reality of athletes being plagued by numerous sports injuries. Therefore, scientifically understanding and preventing injuries in diving, based on the realities of training, will be a crucial guarantee for extending the careers of China's elite athletes. To this end, drawing from years of practical experience in diving, this article reviews and compiles information on the high-risk sites and types of injuries in diving. The aim is to provide a data foundation and valuable experience for prolonging the competitive capabilities of China's top athletes and for promoting standardized, scientific training in competitive diving.

Keywords: Diving, Injury Sites, Sport-Specific Characteristics, Preventive Measures

1. Introduction

Diving is a significant force that has contributed to the glory of China's competitive sports. China's competitive diving has won numerous honors for the country in international competitions at all levels. However, behind these remarkable achievements, it is evident that diving athletes experience frequent turnover, generally start training at a young age with high associated costs, and maintain peak competitive performance for a relatively short period. Diving is a high-risk competitive sport, as athletes execute various complex somersaults and twists from great heights before entering the water, a process fraught with potential injury risks. Additionally, the highly repetitive nature of diving movements is a major contributing factor to the frequent occurrence of various injuries [1]. Based on a scientific summary and categorization of diving-related injuries, and drawing from years of practical experience in diving, this study proposes corresponding injury prevention and treatment measures. The aim is to provide a data foundation and valuable insights for the standardized and scientific training of competitive diving in China.

2. Research subjects and methods

2.1. Research subjects

The subjects of this study were 42 currently active athletes from the national training team, comprising 24 male and 18 female athletes. The average age was 17.6 years, with an average training duration of 8.4 years. Their athletic levels were as follows: 36 were International Masters of Sport, and 6 were Masters of Sport.

2.2. Research methods

2.2.1. Literature review method

By reviewing literature related to diving athletes' injuries and prevention measures, a theoretical foundation for this study was established.

2.2.2. Interview method

Leveraging the opportunity to coach the national diving team, the author conducted in-depth interviews with each athlete to understand their current injury status and past injury history, providing reliable data for this research.

2.2.3. *Mathematical statistics method*

Data obtained from interviews were summarized and organized using data processing tools such as Excel 2010, thereby enhancing the practical and theoretical relevance of the study.

3. Results and analysis

The sites of injuries among diving athletes are widespread, with the key areas being the lower back, knees, wrists, eyes, elbows, and cervical spine. For platform diving, upper limb injuries, particularly wrist injuries, are especially common. In contrast, springboard diving sees a higher frequency of lower back and lower limb injuries. Additionally, lower back, wrist, and eye injuries are common to both springboard and platform diving. Table 1 presents the common types of injuries in diving, and Table 2 outlines the characteristics of injury sites.

As shown in Table 1, diving athletes experience a wide range of injury sites. The most frequently occurring injury types are muscle injuries and joint injuries, accounting for 32.8% and 26.6%, respectively. Ligament injuries also represent a significant proportion at 16.4%. According to Table 2, among diving athletes, lower back muscle strains are the most common, with 31 cases, accounting for 16.68%. Cervical spine injuries occur in 11 cases (5.95%), and rotator cuff injuries in 9 cases (4.78%). Furthermore, the incidence of ocular fundus injuries is also relatively high, with retinal degeneration in 16 cases (8.61%), and retinal tears or detachment in 3 cases (1.59%). The following sections will provide a focused analysis of the injuries that occur more frequently among athletes.

3.1. Lower back muscle injuries

3.1.1. *Injury sites*

Strains occur in the sacrospinalis muscle and the lower part of the erector spinae, accompanied by damage and adhesions of related ligaments, leading to chronic injuries in the deep fascia surrounding the third lumbar vertebra.

3.1.2. *Manifestations*

This condition is relatively common among diving athletes. Clinical manifestations often include soreness and a feeling of heaviness in the muscles of the lower back, particularly in the lumbar muscles on both sides, the lower part of the erector spinae, and above the iliac crest. Symptoms may also include localized numbness, pain, muscle spasms, and a sensation of coldness. Pain tends to worsen after training, and in severe cases, it can even affect training performance.

3.1.3. *Injury mechanism*

This is primarily because diving is a sport in which athletes rely on the abdominal and back muscle groups to generate force in the air, without a fixed point of support, and follows a specific movement trajectory [2]. Throughout the execution of a complete dive, the lower back muscles remain under high tension. Athletes complete multiple rotations and somersaults within an extremely short time (approximately 1.4 seconds), with daily training involving 100 to 200 repetitions. The long-term accumulation of fatigue contributes to the high incidence of this injury.

3.1.4. *Preventive measures*

Alleviate fatigue. Emphasize regular massage, relaxation, and recovery for this area, including methods like DMS (Deep Muscle Stimulator) relaxation. For mild injuries, approaches such as acupuncture can be employed to prevent the condition from worsening.

Table 1: Types and Percentages of Common Injuries Among Diving Athletes

Injury Type	Muscle Injuries	Joint Injuries	Ligament Injuries	Cartilage Wear	Enthesopathy	Stress Fracture	Others	Total

Number of Cases	42	34	21	9	7	6	9	128
Percentage (%)	32.8	26.6	16.4	7.0	5.5	4.7	7.0	100

Table 2: Statistical Table of Injury-Prone Sites and Types Among Diving Athletes

Site of Injury	Injury Diagnosis	Number of Cases	Percentage (%)
Lower Back	Lower back muscle strain	31	16.68
	Lower back myofascitis	28	14.97
	Lumbar spondylolysis	6	3.19
	Lumbar disc herniation	6	3.19
Knee joint	Patellar injury	15	8.08
	Medial collateral ligament injury	12	6.48
	Meniscus injury	8	4.25
	Knee joint bursitis	4	2.13
Eyes	Retinal degeneration	16	8.61
	Retinal tear/detachment	3	1.59
Shoulder joint	Rotator cuff injury	9	4.78
	Subacromial bursitis	5	2.66
	Glenoid labrum injury	3	1.59
	Shoulder dislocation	1	0.53
Cervical spine	Cervical injury	11	5.95
Elbow joint	Medial collateral ligament injury of the elbow joint	6	3.19
	Elbow joint osteochondritis	3	1.59
	Elbow joint dislocation	1	0.53
Wrist joint	Wrist joint osteochondritis	4	2.13
	Wrist joint synovitis	3	1.59
	Scaphoid fracture	2	1.06
Lower leg	Tibial stress fracture	6	3.19
	Tibial stress periostitis	1	0.53
Other	Finger contusion	2	1.06
	Achilles peritendinitis	1	0.53

Enhance Strength.

Four-Directional Static Support (Increasing Instability and Reducing Contact Area):

Action Points – Includes four exercises: Plank, Supine Static V-Up, Prone Static V-Up, and Side Plank.

Prone Opposite Side Lift: Action Points – The athlete lies prone on a mat with one hand behind their head. During the movement, the athlete is required to rotate the torso of the same side as the arm behind the head while simultaneously lifting the opposite leg upward. The leg should remain straight. After completing one side, switch to the other.

Four-Directional Log Push Exercise: Action Points – The athlete lies supine on a mat with legs together and hands crossed over the chest. The athlete keeps the whole body rigid. The coach lifts the athlete's legs upward with both hands. The athlete uses core strength to maintain the "rigid" body position. Repeat multiple times.

3.2. Cervical spine injury

3.2.1. Injury site

The injury primarily occurs at the axis (C2) and atlas (C1). Specific manifestations include possible transient subluxation of the axis and atlas, accompanied by injuries to the upper trapezius, levator scapulae, and sternocleidomastoid muscles.

3.2.2. Injury manifestations

Pricking pain at the axis and atlas locations in the neck, reduced neck mobility, and difficulty performing rotational movements smoothly.

3.2.3. Injury mechanism

Diving athletes face a higher risk of cervical spine injury compared to other sports, primarily due to the characteristics of the sport. Athletes enter the water in an "inverted streamlined" body posture. At this moment, the impact force between the water and the head/neck is immense. If the water entry angle is too large or too small, the probability of injury increases by 4 to 6 times. Secondly, the occurrence of injury is also related to athletes' young age and relatively weak neck muscle strength. Furthermore, young athletes' bones and muscles are still developing, with ligaments and joint capsules being relatively lax. Improper behaviors in daily life and training can also lead to cervical spine injuries. Therefore, special attention should be paid.

3.2.4. Preventive measures

The primary preventive measure is neck strength training, as detailed below.

Neck Resistance Retraction/Protraction Exercise: Action Points – Use a mini resistance band to secure the athlete's head. The athlete performs protraction (forward) and retraction (backward) movements. The coach holds the other end of the band and performs the opposite motion, creating resistance.

Neck Resistance Left Rotation and Depression Exercise: Action Points – Use a mini resistance band to secure the athlete's head. The athlete first rotates the head to the left, then depresses it (moves it downward). The coach holds the other end of the band and performs the opposite motion, creating resistance. Neck Resistance Right Rotation and Depression Exercise: Action Points – Similar to the left rotation exercise, but performed to the right.

3.3. Shoulder joint injury

3.3.1. Injury site

Shoulder injuries in diving athletes are often complex, but the most common include:

Rotator cuff injuries due to long-term accumulated fatigue.

Glenoid impingement injuries caused by improper water entry angles during the "hands-together" entry.

Long head of biceps tendon injuries resulting from the knee-hugging position during multiple somersault rotations.

3.3.2. Injury manifestations

Restricted range of motion in the shoulder joint, preventing full arm elevation and hindering the completion of the "hands-together" entry. Pain is typically localized deep to the anterior deltoid, in the soft tissues surrounding the glenoid, and deep to the middle deltoid.

3.3.3. Injury mechanism

In diving, the platform competition height is 10 meters. Athletes jump from the platform, and the velocity at water entry is typically around 14 m/s. According to the law of conservation of momentum, this means the impact force the athlete's body must withstand exceeds 400 kg. When technical errors occur, leading to significant changes in the water entry angle, the forces on the upper limbs also change accordingly. Particularly during entry, the angle between the athlete's torso and upper limbs, under the dual forces of water surface impact and the athlete's own muscular contraction, subjects the shoulder joint to intense impingement. This impingement typically occurs beneath the acromioclavicular joint, at the anterior

third of the acromion, or below the coracoacromial arch. Over time, this can lead to glenohumeral joint instability, resulting in impingement injuries to the surrounding shoulder muscles and ligaments.

3.3.4. Preventive measures

Prone Fly: Action Points – The athlete lies prone on a high bench, feet naturally placed on the ground for support, holding dumbbells of appropriate weight in both hands. The athlete repeatedly performs arm abduction and adduction with straight arms.

Bent-Over Reverse Fly: Action Points – The opposite of the prone fly. **Shoulder "Y" Exercise: Action Points** – Start in a half-squat position with a straight back, hands at the sides. Then, retract and depress both shoulder blades downward and inward. Next, lift both arms overhead, forming a "Y" shape with the torso. Repeat.

3.4. Tibial stress fracture

Injury Site: Mid-shaft of the tibia. **Manifestations:** Fracture at the mid-shaft of the tibia may present in a "bird's beak" shape.

Injury Mechanism: This injury typically occurs when platform divers execute high-difficulty dives like 109C or 5156B. For example, during the hurdle step for a 109C, a very powerful push-off force is required to generate reaction force from the platform. At this moment, the tibia bears longitudinal compressive force. Due to the action of the tibialis anterior muscle, tensile stress is generated anteriorly in the tibia, while compressive force occurs posteriorly. Simultaneously, the constant traction from muscle pull during plantarflexion on the tibial periosteum gradually causes it to detach. This leads to subperiosteal inflammation, obstructing local blood circulation and causing ischemia, which contributes to the occurrence of a stress fracture.

Preventive Measures: Currently, aside from surgical intervention, rehabilitation for this condition can involve walking and leg-strength push-off exercises in shallow water to reduce gravitational load on the limb. Additionally, regular training should appropriately reduce the volume of specific optional dives in Groups 1 and 4, and minimize unnecessary acute running, jumping, and forceful push-off movements.

3.5. Ocular fundus injury

Injury Site: The primary ocular fundus injury is retinal degeneration. **Manifestations:** In the early stage of the injury, the athlete's vision gradually declines, accompanied by a certain degree of eye soreness. In the later stages, retinal detachment may occur, potentially leading to blindness.

Injury Mechanism: This injury is a common and highly detrimental condition among diving athletes. Particularly when platform divers jump headfirst from the 10-meter platform, the immense impact force upon water entry causes the eye to undergo shock deformation. The vitreous base tissue, compressed by the impact force, fails to extend synchronously with the eyeball wall. Over time, this can lead to retinal tears or detachment. More severely, if the athlete opens up too late during entry or the body's angle of entry is too large, the water surface may directly strike the eyes, causing acute retinal detachment. Most fundus lesions are chronic injuries resulting from the gradual accumulation of microtrauma over long-term training and competition. The longer the training duration, the higher the likelihood of fundus injuries [3].

Preventive and Treatment Measures: There are limited preventive and treatment measures for this injury. Currently, protection relies on enhancing athletes' awareness of prevention and correcting faulty techniques.

4. Conclusions and recommendations

4.1. Conclusions

The sites of injuries among diving athletes are widespread, with key areas being the lower back, knees, wrists, eyes, elbows, and cervical spine. For platform diving, upper limb injuries, particularly wrist injuries, are especially common, while springboard diving sees a higher frequency of lower back and lower limb injuries. Based on the investigation and analysis of this study, it is concluded that five types of sports injuries are most prevalent among diving athletes: lower back muscle injuries, cervical spine injuries, shoulder joint

injuries, tibial stress fractures, and ocular fundus injuries. These account for 39.21% of the total injuries surveyed, representing a significant proportion.

4.2. Recommendations

Enhance athletes' awareness of self-protection and strengthen targeted training for vulnerable areas. Improve medical supervision and functional assessments of body parts prone to injury in athletes. Emphasize psychological support for diving athletes to alleviate the psychological pressure associated with competition and training.

5. References

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