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Prevention and Rehabilitation Strategies for Hand and Wrist Injuries of E-Sports Athletes

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Abstract. The global e-sports industry has developed rapidly, but due to long-term training and repeated high-precision movements, the incidence of excessive use injuries in athletes' wrists is very high, while targeted health research and standardized management schemes are very limited. This study systematically analyzes the pathophysiological and biomechanical mechanisms of e-sports-related wrist injuries, evaluates the effectiveness of conventional prevention and modern rehabilitation strategies, and puts forward a targeted comprehensive health management model. Research results show that such injuries are mainly chronic overuse injuries caused by cumulative static load and repetitive exercise stress. Its controllable risk factors include poor operating posture and lack of physical exercise. Although traditional preventive measures have a certain effect, they are limited by poor compliance and a long cycle, while modern rehabilitation interventions can significantly improve the rate of functional recovery and return to the field. The integrated prevention-rehabilitation-return training model proposed in this paper is characterized by multidisciplinary collaboration and phased intervention, which solves the current situation of fragmented health management and balances injury treatment and competition schedule. This paper provides evidence-based guidance for injury prevention and post-injury rehabilitation of e-sports athletes, fills the gap in the professional health management framework of e-sports athletes, and supports athletes' health protection and career sustainable development.

Keywords: E-sports athletes, wrist injury, injury prevention

1. Introduction

In the past ten years, the global e-sports industry has grown exponentially and has developed from a casual game to a highly structured competition, which has been recognized by major international sports organizations. University e-sports is developing rapidly, especially in North America. Many universities have established varsity e-sports teams and scholarship systems, which are comparable in scale to traditional sports, which reflects that e-sports is increasingly institutionalized as a formal sport [1]. Despite rapid development, there is still a serious lack of a standardized health research framework and a comprehensive injury management model specifically for e-sports athletes [2].

Unlike traditional sports, the performance of elite e-sports athletes relies entirely on repeated high-precision wrist movements, including continuous keyboard operations, fast mouse clicks, and

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frequent mobile device screen sliding [3]. Professional and college athletes usually perform 5.5 to 10 hours of structured training per day, which will cause continuous static load and repetitive exercise pressure on opponents, wrists and upper limbs [1,4]. This unique physical need leads to a high incidence of chronic repetitive strain, among which carpal tunnel syndrome, radial stem stenotic tenosynovitis and flexor tendon strain are the most common clinical manifestations [5].

These injuries will directly affect the consistency and competitive performance of training, and often force athletes to reduce training time, adjust their competition skills or temporarily withdraw from the competition [6]. A cross-sectional survey of 65 college e-sports athletes from nine universities in the United States and Canada in 2019 found that 36% of the respondents reported chronic wrist pain, and 32% of the respondents experienced persistent hand discomfort associated with long-term games [1]. Worryingly, only a small number of affected athletes will seek professional medical care in the early stages of symptoms, and most university and professional e-sports events do not have specialized sports medicine personnel to address these musculoskeletal problems [7].

Existing studies have identified some basic epidemiological trends, but few studies have developed targeted prevention or rehabilitation strategies for e-sports athletes' unique training plans and exercise patterns [8]. Domestic research lags behind international research in building a comprehensive multidisciplinary health framework, and most existing interventions focus on a single solution rather than a comprehensive care model [9].

This paper aims to systematically summarize the pathophysiological and biomechanical mechanisms of wrist injuries related to e-sports, evaluate the effectiveness of traditional prevention strategies and modern rehabilitation interventions, and put forward a comprehensive health management model to make up for the shortcomings of current research. The goal is to provide evidence-based practical guidance for e-sports organizations, coaches and athletes to prevent overuse injuries, improve functional recovery after injuries, and extend their competitive careers.

2. Pathophysiological and biomechanical characteristics of wrist injuries related to e-sports

The wrist injuries of the vast majority of e-sports athletes are classified as chronic overuse injuries, not acute traumatic injuries, which are caused by the accumulation of long-term repeated micro-injuries to the upper limbs' musculoskeletal and peripheral nerve structures [10]. A cross-sectional survey of college e-sports athletes shows that participants spend an average of 5.5 to 10 hours a day sitting in front of electronic devices for structured training and competition. This sedentary lifestyle will aggravate musculoskeletal fatigue [1].

Continuous static posture load and high-frequency repeated fine movement produce continuous tension in the internal muscles, external muscles, tendons and ligaments of the wrist, which leads to local tissue ischemia, inflammation, and exudation, and gradually causes connective tissue degeneration during long-term training [11]. It is worth noting that 40% of college e-sports athletes said they did not do regular physical exercise, which further weakened the resilience of the musculoskeletal muscles and aggravated tissue fatigue during long games [1,12].

Changeable risk factors will aggravate tissue fatigue and accelerate pathological progress, including long-term uninterrupted sitting posture, poor operating posture, lack of regular physical exercise, and irregular rest time during training [13]. Typical clinical injuries include carpal tunnel syndrome (chronic compressive stimulation of the median nerve in the carpal tunnel) and stenosis tenosynovitis (a specific inflammatory disease affecting the first dorsal extensor tendon of the wrist); both diseases are directly related to the repetitive and high-density movement patterns unique

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to competitive e-sports training and games, and all of them are manifested as persistent pain, limited mobility and dysfunction, thus interfering with daily training and competition performance [5,14].

3. Prevention strategies and therapeutic effects of wrist injuries for e-sports athletes

3.1. Physical protection measures

Physical protection measures include ergonomic equipment modification, the use of wrist guards, and the optimization of the training environment, all of which are designed to offset the static and repetitive pressure caused by long-term e-sports training [15]. The ergonomic keyboard with split key layout can reduce the abnormal skew of the wrist during operation, while the vertical mouse can reduce the activation of the extensor muscle compared with traditional peripherals, avoiding the user from maintaining a fixed and stressful wrist posture for a long time [2].

Wrist guards can provide external joint stability, limit the range of excessive movement during high-intensity games, and reduce the cumulative pressure on tendons during long-term training, which is crucial for athletes who have to repeat thousands of mouse clicks and keyboard taps every day [11]. Environmental modification, such as adjusting the height of the desk, using ergonomic seats and placing the monitor correctly, can further reduce the pressure of posture, because improper placement of tables and chairs will bring additional pressure to wrist joints and hand joints when sitting for a long time [14].

The main mechanism of physical protection is to reduce the mechanical load of fragile musculoskeletal structures and minimize the repetitive micro-trauma of tendons, ligaments and nerve tissues. Long-term excessive wearing of orthotics may lead to muscle atrophy and loss of body sensation. Therefore, it is recommended to use such orthotics only during high-intensity training, rather than continuous use every day, to avoid weakening the internal stability of the wrist joint over time.

3.2. Training mode optimization

Training optimization strategies include structured rest intervals, movement-standardized training and progressive load management, all of which are tailored to the unique continuous training arrangements common in competitive e-sports [12]. Compared with uninterrupted training, arranging a short break after active training every 20 to 25 minutes can effectively reduce the accumulation of muscle fatigue, because continuous repeated movements without rest will lead to the accumulation of lactic acid and the aggravation of tissue damage [12].

Standardized keyboard and mouse grip guidance can reduce the compensatory exercise mode, thus reducing the pressure on the wrist structure; many athletes adopt unnatural, self-taught grips to improve their speed, which will unconsciously increase the risk of long-term injury [9]. By gradually increasing the training time and intensity, the periodic training plan makes the musculoskeletal tissue produce an adaptive physiological response and avoids a sudden surge in training load, thus reducing the overall risk of injury and preventing the overload of the wrist structure [10].

These interventions work by regulating the cumulative load of the wrist structure to ensure that the tissue has sufficient recovery time and prevents the occurrence of overuse damage. The compliance of the intervention is a major limiting factor, because athletes usually give priority to pre-match intensive training and ignore preventive rest and posture correction programs. Many

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people believe that a short break will disrupt the consistency of training and preparation for the competition.

3.3. Basic physical training

The basic physical training program focuses on enhancing wrist muscle strength, joint flexibility and neuromuscular control ability to make up for the widespread lack of physical activity of e-sports athletes. Isometric grip training can improve the load-bearing capacity of the flexor tendon through long-term continuous practice, while wrist joint mobility exercise can reduce the stiffness of connective tissue and improve the range of joint activity, so as to combat wrist stiffness and stiff posture caused by long-term operation of equipment [16].

Neuromuscular training, including ontological sensory training, can improve the efficiency of the exercise mode and reduce the occurrence of unnatural wrist postures during intense games, because athletes tend to ignore the correct movement posture under the pressure of the competition [13]. These physical training interventions can enhance the body's natural protection mechanism, improve tissue resilience, and reduce the risk of injury, especially for 40% of athletes who do not perform any other form of physical activity [1]. A significant limitation of this kind of training program is that it takes 8 to 12 weeks of continuous training to produce measurable physiological adaptive changes, so athletes need to persist for a long time; many e-sports athletes are often reluctant to do additional physical training because of limited time and focus on improving game skills.

4. Modern rehabilitation interventions and clinical results of post-injury recovery

4.1. Core components of the modern rehabilitation system

The comprehensive modern rehabilitation program for e-sports athletes includes three consecutive stages: acute injury management, functional recovery training and return to the field to adapt [10]. Acute phase interventions focus on reducing inflammation and controlling pain, while recovery phase plans focus on tissue repair and strength recovery. The return stage includes special sports training to rebuild the action mode required for high-level games. The structured framework focuses not only on pathological tissue repair, but also on the unique sports function needs of competitive e-sports, ensuring that athletes can restore the sports skills required for specific events while restoring basic hand functions.

4.2. Physical therapy for mild to moderate injuries

Physical therapy, including in vitro shock wave therapy, therapeutic ultrasound and cold therapy, can provide targeted non-invasive treatment for mild to moderate wrist injuries. These injuries are often not treated in the early stage, because only a small number of affected e-sports athletes will seek professional medical care for symptoms [1,11,12]. In vitro shock wave therapy can stimulate tissue repair and collagen synthesis of damaged tendons, thus improving the healing rate of common tenosynovitis. Tenosynovitis is a disease widely reported in athletes with persistent wrist and thumb pain [11]. Therapeutic ultrasound can increase local blood circulation, accelerate the removal of inflammatory mediators, and shorten the recovery time of acute muscle strains caused by repeated high-speed finger and wrist movements [12]. Cold therapy immediately after acute injury can reduce tissue edema and metabolic needs, minimize secondary tissue damage, and relieve dull pain and persistent pain accompanied by overuse injury [12].

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These physical therapies have a therapeutic effect through biophysical stimulation, tissue repair and have little interference with routine training programs, so they are suitable for athletes with limited treatment time. As a single therapy, physical therapy itself cannot fully restore the fine motor control ability required for competitive performance. It must be combined with targeted sports rehabilitation programs to rebuild organizational health and functional skills.

4.3. Personalized exercise rehabilitation for moderate and severe injuries

Personalized sports rehabilitation programs are tailored according to individual injury characteristics, competitive events and training schedules, providing the most effective way to restore the exercise level before injury. For carpal tunnel syndrome, nerve sliding exercises can improve the activity of the central nerve and alleviate sensory symptoms during the structured intervention period [16]. For radial stem stenosis tenosynovitis, centrifugal intensive training can improve the load-bearing capacity of the tendon and reduce the pain of thumb movement [6].

Special sports rehabilitation training, including simulated competition tasks, can ensure the reaction time and action accuracy required for athletes to resume competitive performance. Advanced technologies, such as motion capture systems and wearable sensors, can provide objective feedback on movement patterns, enabling rehabilitation experts to identify and correct compensation mechanisms that increase the risk of re-injury [4].

5. Integration and optimization of prevention and rehabilitation modes

5.1. Integrate the precise prevention system

Traditional prevention strategies are low-cost and easy to implement, which can effectively reduce the risk of injury to a wide range, but their degree of individualization and adaptability to specific sports is limited [9]. Physical protection measures can provide instant mechanical relief, but cannot solve the potential problem of insufficient strength, while training optimization requires the high cooperation of athletes [12]. Basic physical training can improve long-term recovery ability, but it takes a long time to implement [13]. The optimized integrated framework combines general ergonomic adjustment for all athletes, personalized training load monitoring through wearable devices, and targeted physical training for identified musculoskeletal defects, which has a better preventive effect than the single-mode method [3].

5.2. Graded rehabilitation plan for the competition

Compared with traditional conservative treatment, modern rehabilitation interventions can provide better functional recovery and faster rehabilitation speed. However, in the schedule of e-sports, the competition schedule often conflicts with the recommended rehabilitation schedule, so it faces great implementation challenges [10]. Physical therapy can quickly relieve symptoms, but functional recovery is not enough to meet the requirements of the competition; although personalized exercise rehabilitation can provide better long-term results, it requires long-term persistence [11].

This program stratifies the intervention measures according to the severity of the injury and the requirements of the competition: mild injury allows partial training; moderate injury is combined with structured rehabilitation and training load reduction; severe injury gives priority to full functional recovery before the gradual resumption of competition training, to improve the needs of organizational healing and Achieve a balance between the competition schedule restrictions [8].

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5.3. Comprehensive prevention-rehabilitation-return to training management model

One of the main limitations of the current system is the isolated provision of preventive and rehabilitation services, limited coordination between coaching staff, trainers and medical personnel, and the lack of full-time sports medical personnel in most e-sports projects highlights this gap [7]. Most teams put competitive performance above the health of athletes and regard injury prevention and treatment as a secondary link rather than the core part of training management.

The proposed comprehensive model establishes a continuous nursing path with three core elements: active prevention, early intervention and structured rehabilitation [9]. This model requires close multidisciplinary cooperation between sports medicine doctors, rehabilitation experts, fitness coaches and e-sports coaches, and the adoption of standardized interdisciplinary communication protocols to keep health goals consistent with training goals. Studies show that the implementation of such a model can reduce the overall injury rate and shorten the average recovery time [1]. By integrating prevention, acute treatment and rehabilitation, the model aims to meet the unique needs of e-sports athletes. They face the same risk of overuse injury as traditional athletes, but lack the same medical support system.

6. Conclusion

This study systematically evaluates the protective effect of traditional prevention strategies on wrist injuries of e-sports athletes and the repair effect of modern rehabilitation interventions, and puts forward a comprehensive management framework for the unique needs of professional e-sports competitions. Traditional prevention methods, including physical protection, training optimization and basic physical training, provide complementary methods to reduce the risk of injury, and joint implementation is more effective than single-based intervention measures. Modern rehabilitation interventions, including targeted physical therapy and personalized sports rehabilitation, have significantly improved the rehabilitation effect and return rate. The comprehensive prevention-rehabilitation-return training framework makes up for the shortcomings of the current distributed health management system and provides a practical and clinically applicable model for professional e-sports organizations.

By clarifying the advantages and limitations of existing interventions, this study puts forward discipline-specific strategies for different e-sports categories and establishes a comprehensive health management model that fits the e-sports training and competition schedule, contributing to this field. The research results provide evidence-based guidance for organizations, medical institutions and athletes to reduce the risk of injury and improve the effect of post-injury rehabilitation. There are some limitations in this review. The analysis mainly relies on existing epidemiology and clinical research, and the raw data from the group of professional e-sports athletes is limited. Future research should carry out forward-looking long-term cohort studies, expand the sample size, cover more e-sports projects, and explore the application of emerging technologies such as virtual reality rehabilitation and artificial intelligence predictive risk assessment. With the continuous development of the e-sports industry, it is crucial to continue to carry out research on the health protection of athletes to ensure the long-term health of professional e-sports players and prolong their careers.

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