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Diagnosis, Treatment, and Prevention of Sport-related Concussion

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Abstract. Concussion is a serious injury with potential long-term cognitive complications. Due to the prevalence of undiagnosed concussions and their detriments to health, concussion treatment and prevention are important topics of exploration. By investigating concussion diagnosis and management, the types of treatment, and preventive methods, this study demonstrates the positive role of active rehabilitation in concussion management. It presents opportunities for future studies to focus on more specific types of exercise and possible rule regulations. Results show that concussion symptoms may vary according to severity, from minor headaches and loss of concentration to depression, dementia, and impaired cognitive function. Clinical or syndromic concussion diagnosis is the most used and reliable subjective assessment method in the contemporary health and scientific field. Immediate removal from sport and vigorous exercise is crucial after athletes experience a concussion to avoid exacerbating the symptoms or causing an additional concussion. Contrary to the belief of complete rest after a concussion, early sub-symptom aerobic exercise and a gradual return to sports participation are important and effective measures for concussion treatment. Patients experiencing prolonged symptoms may also benefit from aerobic exercises. Additionally, there is no effective equipment for preventing concussions in the current sports world. Sports rule changes and education could be efficacious in preventing concussions.

Keywords: concussion, traumatic brain injury, treatment, active rehabilitation

1. Introduction

In exercise and performance, injuries are almost inevitable for the participating populations. Despite so, many athletes still risk their physical and psychological health to train and compete. Perhaps the area that is most important and most vulnerable to an injury would be the brain. A sport-related concussion is a serious injury that haunts many athletes yearly and it is receiving considerable attention.

Concussions are historically underdiagnosed and under-reported in sports. The culture of risk in sports likely contributes to such a phenomenon, as athletes expose themselves to great danger by returning to sport without proper treatment due to various reasons. In addition, the ambiguous concussion signs also tend to confuse people in its diagnosis. Thus, the management of concussions has been extensively studied and modified to present an evolving protocol for improving athletes' well-being. This paper gathered and evaluated evidence of the historical management and current

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trends of concussion treatment and the preventative methods for athletes to avoid a sport-related concussion.

2. Epidemiology

While there have been ongoing debates on concussion's definition, the Concussion in Sport Group published a consensus statement defining concussion. The group provided a comprehensive definition of concussion as a mild traumatic brain injury resulting from a direct or indirect force transferred to the head [1].

The symptoms of concussion may vary across people according to severity, from minor headaches and loss of concentration to depression, dementia, and impaired cognitive function [2]. Previously injured people also have a higher chance of getting persistent symptoms produced by post-concussion syndrome, including headache and mood disorders [3]. McKee et al. stated that people with multiple unrecovered concussions could experience chronic traumatic encephalopathy with dysfunction of higher executive functions such as memory loss, impaired cognition, and decision-making. Typically, the symptoms of concussion resolve spontaneously. However, signs and symptoms could appear hours after a concussion, which makes it crucial for game supervisors to identify possible causes [2].

Players bumping into each other and collisions are the most prevailing injury mechanism for contact sports [4]. Contact that decelerates (accelerates) the body and causes brain tissue deformation is the primary mechanism of concussion. Predictably, concussions are high in rugby, ice hockey, football, and other sports, with routine contact and collisions as the game's features [4]. Notably, combative sports, including boxing and MMA, have the most frequent concussion occurrence due to the nature of the sport, but relatively few studies recognize their presence.

3. Diagnosis and assessment

A concussion is a killer in sports and should be taken seriously due to its severity and dangerousness if left undiagnosed. That being the case, athlete should be removed from sports participation immediately when a concussion is suspected. Coaches and relevant personnel should be aware of athletes' concussion symptoms and any action that could have caused a concussion. Other than an educated suspicion, the diagnosis and assessment of concussion are also crucial to determine the subsequent actions of the affected athlete.

The pathoanatomic diagnosis of concussion is often tricky and sometimes impossible since structural injury is at the cellular level. Therefore, conventional structural abnormalities in concussions are absent for the most part under neuroimaging such as CT and MRI [5]. With technological advancements, imaging agents are steadily developing in hopes of diagnosing concussions. Functional MRI, 1H MR spectroscopy, perfusion imaging, and positron emission tomography are all imaging techniques under clinical trial probing the molecular level of the brain [5]. Nevertheless, pathoanatomic concussion diagnosis is still not yet possible with the current technology.

Due to the lack of pathoanatomic diagnosis that objectively tests the presence of concussions, clinical or syndromic concussion diagnosis is still the most used and reliable subjective assessment method. When there is a suspected concussion, the Sports Concussion Assessment Tool (SCAT) can mark the affected athlete's experienced symptoms. As an immediate assessment for concussion, SCAT is administered on-field for possible red flags, signs, and self-reported symptoms [6]. Figure 1 illustrates the content of SCAT 5th edition [7]. Athletes' orientation, concentration, and memory are also examined for cognition assessment within SCAT 5. Notably, the etiology of concussion during sports practice and its consequences lead to concussion diagnosis by health care professionals in elite sports and community members at the recreational level. The hospital serves to identify mainly more severe brain injury complications such as hemorrhage and amnesia. However, the lack of professional care could contribute to an immediate return to play and other improper management of concussions [8].

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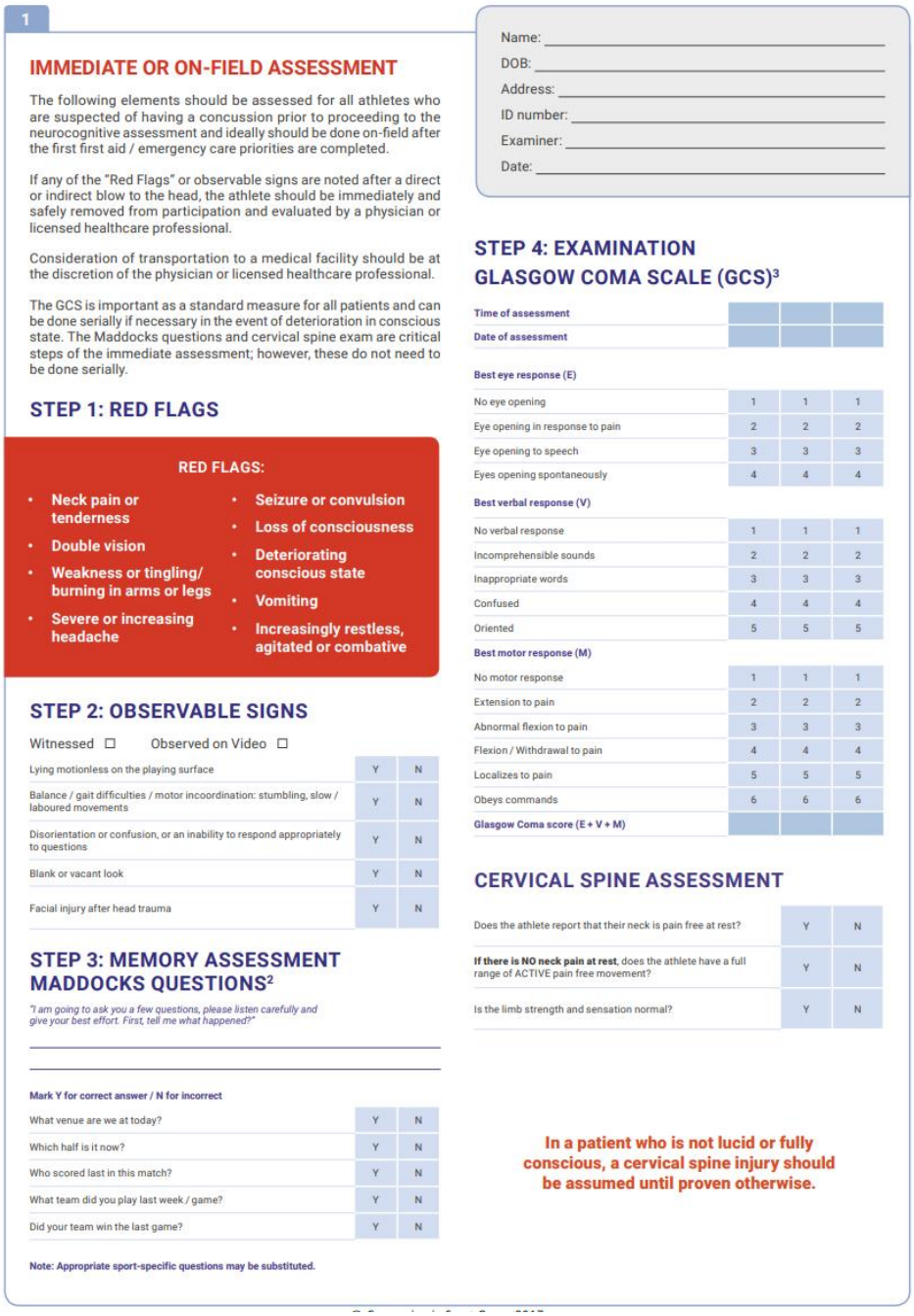

1

IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The Maddocks questions and cervical spine exam are critical steps of the immediate assessment; however, these do not need to be done serially.

Name: _____
DOB: _____
Address: _____
ID number: _____
Examiner: _____
Date: _____

STEP 1: RED FLAGS

RED FLAGS:

- Neck pain or tenderness
- Double vision
- Weakness or tingling/ burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"

Mark Y for correct answer / N for incorrect

What venue are we at today?	Y	N
Which half is it now?	Y	N
Who scored last in this match?	Y	N
What team did you play last week / game?	Y	N
Did your team win the last game?	Y	N

Note: Appropriate sport-specific questions may be substituted.

STEP 4: EXAMINATION GLASGOW COMA SCALE (GCS)[3]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

Figure 1. The content of scat 5th edition [15].

4. Treatment

After a concussion, the most imperative action would be treatment. For athletes, optimal concussion management could maximize their recovery and performance by helping them return to play at the appropriate time.

In the history of concussion research, Martland discovered the interesting phenomenon of boxers who get considerable head blows have flopping legs, unsteady gait, and mental confusion. Boxers that exhibit these symptoms were described to be "punch drunk". At the time of Martland's research in the 1920s, the suggestion for athletes who were experiencing "punch drunk" was to rest until the symptoms were no longer present. According to Martland, it takes a few hours for a fighter to heal

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from a severe head blow [9]. Decades have elapsed, and the advancements in research and the cumulation of knowledge transformed concussion management in sports.

It has been well-established that the most crucial step of concussion management is to remove the affected athlete from play immediately after suspicion of concussion. As previously explored, there is a significant risk for athletes with a neglected concussion in sports play [3]. There are many instances where the affected athlete would hide their injury and react to questioning and suspicions with a denial of their symptoms. In this case, coaches should evaluate the situation and incident and provide an ethical response to the athlete's fate. Current research indicated that rest during the acute onset of concussion is critical to early concussion management when athletes are symptomatic. Instead of allowing athletes with concussive signs to keep playing, they are examined for concussion and asked to take a break from the sport. Aside from current sport removal, it is also crucial for recently concussed athletes to stay away from high-intensity exercises as they could possibly worsen post-concussion symptoms [10].

In addition to physical rest, cognitive rest is equally important and should be of prominent concern in concussion management, as many consensus statements suggest [11]. However, the universal belief that cognitive rest immediately after a concussion is beneficial lacks research support. A current study suggests that cognitive rest is useful in concussion treatment regardless of the prescribed time. This study removed participants from school and restricted any cognitive activity, which begs the question of the influence of different cognitive stimulations on concussion recovery [12]. However, the definition of cognitive stimulation remains ambiguous. The degree of a mental challenge and whether it is harmful to a concussed brain do not appear to be available in current research. Therefore, the efficacy of cognitive rest after a concussion needs further investigation.

Although removing athletes from laboring exercise aims to diminish the concussive symptoms and eliminate their vulnerability, gradual exposure to physical activity may benefit baseline recovery. Restricting exercise and removing athletes from their athletic environments for an extended period of time deteriorates their physical abilities as well as sport-specific skills. In addition, high-performance athletes could suffer mental struggles for missed training, competition, and potential achievement. While the other athletes are improving, the affected athlete is regressing away from their best athletic selves, being stuck to blindly resting. Thus, the practicality and functionality of exercise in the post-concussion stage should be explored.

Lawrence et al. conducted a retrospective study on the impact of exercise on return to sport in acutely concussed mid-adolescents. Researchers collected data on participants' time to a full return to sport or study and the time of their exercise initiation. Physicians prescribed standardized stationary bike sessions for all subjects with increasing workloads each successive day for better study control. After analysis, the results showed that participants who started aerobic exercise earlier post-concussion had a quicker complete return to play and work. This study provided a novel outlook on active rehabilitation for concussion management and opposed the use of complete and prolonged rest. A limitation of this study is that the effect of other exercise choices was unexplored, and the differences in rest across participants were unknown [13].

Similarly, another cohort study supports Lawrence et al. study on early exercise exposure. Howell et al. looked at concussed collegiate athletes longitudinally and grouped them according to whether they exercised or only rested between concussion and intervention. Following data collection and analysis, researchers found that light aerobic exercise after concussion may have lowered symptom severities compared to the resting group. In addition, the symptom resolution time was similar in both groups, which implies that exercise after concussion does not cause delayed concussive symptoms [14]. Looking at all the evidence from current research, acutely concussed populations could exercise as long as they are asymptomatic with the activity. Hence, blindly following the complete rest and no exercise protocol is not an effective response and treatment to acute concussions.

Additional studies explored the influence of exercise on prolonged concussion symptoms. Researchers randomly assigned adolescent participants who were experiencing persistent concussion symptoms to two groups. One group received the usual treatment, and the other received

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physiotherapy with aerobic training and exercises. After analysis, research showed that sub-symptom threshold aerobic exercise was helpful for symptom lessening and recovery towards baseline in cases of persistent symptoms [15]. Therefore, active rehabilitation with an appropriate workload is an efficacious method for post-concussion treatment in both the instance of acute concussions and concussions with stubborn symptoms. Contrary to what many believe, aerobic exercise within a reasonable intensity and volume could benefit concussion recovery. Nevertheless, a temporary break from previous sports and vigorous exercise is still necessary as a gradual return to baseline is essential.

For concussion management, many sports organizations and experts support the return to play model. The protocol follows the principle of a gradual, stepwise progression from resting to a complete return to sport as symptoms reduce. According to consensus, athletes follow the functional exercises in each rehabilitation stage to fulfill their recovery objective. Athletes who are symptom-free after completing a rehabilitation stage are permitted to advance to the next stage for active progression towards full recovery. On the contrary, athletes who experience concussion symptoms at a given stage should rest for an entire day and regress to the last stage. Each rehabilitation stage also presents the priority objective in the progression of the recovery. Athletes, especially those of a high calibre, should pay careful attention to rehabilitation for important reasons. As athletes recover from an injury, they are removed from their usual competition, training, and potential eating environment. As they recover towards the baseline, they are only back to their healthy selves rather than their competitive selves. Athletes removed from a sport require an incremental progression of physical abilities and skills, which can be achieved by following the graduated return to play protocol. Figure 2 presents the original graduated return to play model, including the five rehabilitation stages, objectives of each stage, example exercises, and progression instructions [11].

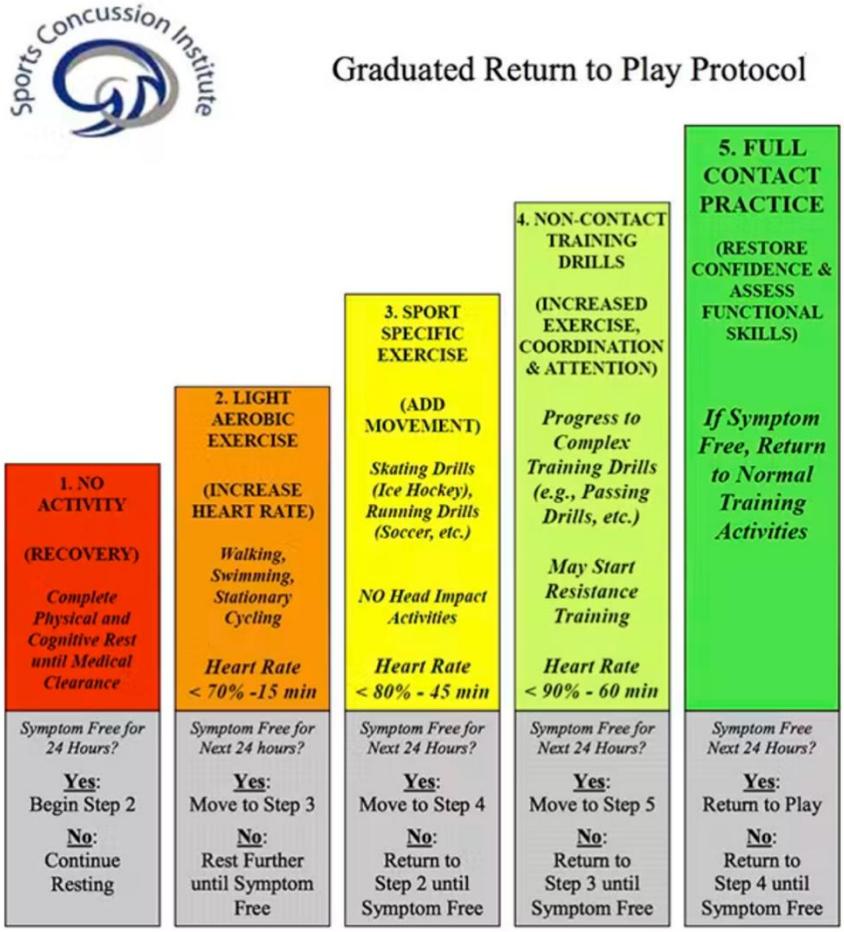

Figure 2. Graduated return to play protocol.

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5. Prevention

The complex pathology and management of sport-related concussions make injury prevention valuable and a critical and multifaceted field of study. Some widespread protective equipment includes helmets and mouthguards. However, protective headwear does not prevent or reduce concussion incidence but potentially reduces the risk of skull fracture [11, 16]. The reason why helmets are ineffective in preventing or reducing the risk of concussion is that they do not decrease force and acceleration from collisions. Although mouthguards have protective effects on dental and oro-facial injuries, no clinical evidence supports their use in concussion prevention [11]. When a head motion in sports satisfies the injury mechanism of concussion, no equipment is useful in preventing its occurrence. Therefore, protective gear for concussions is an aera of research and innovation in dealing with sports with a high risk of concussion.

Aside from equipment, rules and policies in sports could be examined and revised to prevent concussions. For example, an elbow to the head is not uncommon in soccer, and the rapid acceleration of the head is the typical injury mechanism for a concussion [17]. Therefore, organizations could ban soccer athletes from elbowing another player's head in heading duels to control the trigger for concussion [11, 17]. More research should be done to investigate the movements that have concussion mechanisms and those that could be protective of athletes and enforce new rules. In addition, players should distinguish between aggression and violence in competitions. Although players should be competitive to increase the fun and entertainment aspect of the game, deliberate violence should not be used. For example, many concussion cases could be prevented if violent bodychecking and fighting did not happen [11]. Fighting in hockey is a prime instance of a sport that legalizes violence and exposes athletes to an increased risk of concussion. However, spectators enjoy these adrenaline-boosting moments hence why this type of deliberate aggression is still allowed. On the other hand, there are sports that praise and glorify one athlete concussing another athlete, such as boxing and mixed martial arts. Namely, a knockout in boxing almost aligns with the injury mechanism of a traumatic brain injury. Fighters would also try to get back up after being knocked down to keep fighting and possibly experience multiple concussions in a single event. Moreover, the accumulated head hits a fighter gets in their career could result in substantial conditions in later stages, as Muhammad Ali was a victim of this issue. Sadly, the complete banning of these striking martial arts does not seem practical in the contemporary world, and the risk of concussion in certain sports would not drop.

Other considerations include education for athletes and other athletic personnel on the fair play principle and the pathology, diagnosis, assessment, treatment, and prevention of concussion [11]. Educating players on concussions could decrease their feeling of invulnerability. Moreover, players with more knowledge of the detriments of concussions would be more mindful of brain protection in-game and more likely to report a potential concussion. In addition, the coaches could be informed of the ethical considerations when a concussion occurs and make the most appropriate actions. Revenue safety is another consideration to reduce the risk of concussion as best as possible. The surfaces should be clean and free of obstacles to prevent the occurrence of tripping. The sharp edges and dangerous locations should also be addressed. For instance, foam pads on the sides of a basketball court could dissipate the energy of collisions and reduce the risk of concussions.

6. Conclusion

Sport-related concussion is a complicated injury and a prevalent issue for athletes at all levels and ages. This study reviewed concussion's injury mechanism and symptoms and its pathoanatomic and clinical diagnosis. In addition, concussion treatment was extensively investigated, and prevention methods were explored.

Concussions are caused by force transmitted to the head that rapidly accelerates or decelerates the brain. People with multiple concussions in a short interval are at risk of prolonged cognitive impairments. Contact sports and combative sports have the highest concussion occurrence.

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Pathoanatomic diagnosis is not yet possible due to its structural injury at the cellular level, and SCAT is typically used to assess the symptoms of a concussion after a dangerous exposure in sport.

After athletes experience a concussion, removing them from sport and any high-intensity exercises that may exacerbate the symptoms or cause an additional concussion is critical. Complete and prolonged rest was not shown to have beneficial effects on concussion management, whereas starting light aerobic exercise early after a concussion assists injury recovery.

Moreover, sub-symptom exercise could also aid persistent concussion symptoms. However, there is a lack of evidence of the effect of cognitive rest as it remains ambiguous in its definition. The graduated return to play protocol could be efficacious in concussion rehabilitation for athletes to follow a stepwise progression of stressors towards full sports participation. In terms of prevention, no evidence supports the efficacy of protective equipment in concussion prevention. Rule changes could control concussion-triggering actions and decrease the risk of concussion. Proper education could inform athletes to be more aware of concussions and reduce violent acts. This study combined the role of rest and exercise in concussion treatment and gathered comprehensive evidence to indicate the effectiveness of active rehabilitation and gradual progression. For future directions, studies could explore cognitive rest's effect with a standardized stimuli inventory. The impact of different aerobic and anaerobic-aerobic exercises could be examined. In addition, mental well-being during a concussion could be a fruitful area of research.

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