Contemporary Pediatric and Adolescent Sports Medicine
Series Editor: Lyle J. Micheli

Michael O'Brien
William P. Meehan III *Editors*

Head and Neck Injuries in Young Athletes

Springer

Contemporary Pediatric and Adolescent Sports Medicine

Series Editor
Lyle J. Micheli

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Head and Neck Injuries in Young Athletes

Springer

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The Micheli Center for Sports Injury Prevention

The mission of the Micheli Center for Sports Injury Prevention is at the heart of the *Contemporary Pediatric and Adolescent Sports Medicine* series.

The Micheli Center uses the most up-to-date medical and scientific information to develop practical strategies that help young athletes reduce their risk of injury as they prepare for a healthier future. The clinicians, scientists, activists, and technologists at the Micheli Center advance the field of sports medicine by revealing current injury patterns and risk factors while developing new methods, techniques, and technologies for preventing injuries.

The Micheli Center had its official opening in April 2013 and is named after Lyle J. Micheli, one of the world's pioneers in pediatric and adolescent sports medicine. Dr. Micheli is the series editor of *Contemporary Pediatric and Adolescent Sports Medicine*.

Consistent with Dr. Micheli's professional focus over the past 40 years, The Micheli Center conducts world-class medical and scientific research focused on the prevention of sports injuries and the effects of exercise on health and wellness. In addition, the Micheli Center develops innovative methods of promoting exercise in children.

The Micheli Center opens its doors to anyone seeking a healthier lifestyle, including those with medical conditions or illnesses that may have previously limited their abilities. Fellow clinicians, researchers, and educators are invited to collaborate and discover new ways to prevent, assess, and treat sports injuries.

Series Editor Biography

Dr. Lyle J. Micheli is the series editor of *Contemporary Pediatric and Adolescent Sports Medicine*. Dr. Micheli is regarded as one of the pioneers of pediatric and adolescent sports medicine, a field he has been working in since the early 1970s when he co-founded the USA's first sports medicine clinic for young athletes at Boston Children's Hospital.

Dr. Micheli is now director of the Division of Sports Medicine at Boston Children's Hospital, and Clinical Professor of Orthopaedic Surgery at Harvard Medical School. He is a past president of the American College of Sports Medicine and is currently the Secretary General for the International Federation of Sports Medicine. Dr. Micheli co-chaired the International Olympic Committee consensus on the health and fitness of young people through physical activity and sport.

In addition to many other honors, Dr. Micheli has served as Chairperson of the Massachusetts Governor's Committee on Physical Fitness and Sports, on the Board of Directors of the United States Rugby Football Foundation, as Chairman of the USA Rugby Medical and Risk Management Committee, and on the advisory board of the Bay State Games. He has been the Attending Physician for the Boston Ballet since 1977 and is Medical Consultant to the Boston Ballet School.

Dr. Micheli received his undergraduate degree from Harvard College in 1962 and his medical degree from Harvard Medical School in 1966. As an undergraduate student, Dr. Micheli was an avid athlete, competing in rugby, gridiron football, and boxing. Since graduating, Dr. Micheli has played prop for various Rugby clubs including, the Boston Rugby Football Club, the Cleveland Blues Rugby Football Club, Washington Rugby Club, and Mystic Valley Rugby Club where he also served as team coach.

Dr. Micheli has authored over 300 scientific articles and reviews related to sports injuries, particularly in children. His present research activities focus on the prevention of sports injuries in children. Dr. Micheli has edited and authored several major books and textbooks.

Foreword

It gives me great pleasure to be writing the foreword for this excellent book on head and neck injuries in young athletes.

The problem of head and neck injuries has been cast into sharp relief the last few years. The focus has shifted from professional adult athletes to young athletes. Fortunately, our profession has responded with research into not just the most effective diagnosis and treatment but also into identifying the most common risk factors for these injuries. Identifying and addressing these risk factors is the most successful way to prevent them.

It is notable that the editors of this latest volume in the series Contemporary Pediatric Sports Medicine chose to include a chapter on injury prevention and make it the very first chapter in the book. This is in keeping with philosophy of the sponsoring institution for the book series, The Micheli Center for Sports Injury Prevention.

The Micheli Center hosts one of the first Concussion Clinics for young athletes in the country, and the co-editors of this book have been instrumental in making it one of the best possible resources for athletes who sustain these kinds of head injuries.

As an examination of the Table of Contents reveals, this is a comprehensive volume with authors drawn from the top ranks of their respective fields. The information you will find in these pages is first-rate. As such, it deserves a place on the bookshelf of anyone with an interest in sports medicine in young athletes.

Congratulations to the editors for their efforts at creating a very important new contribution to the literature.

Lyle J. Micheli, MD
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Preface

Head and neck injuries are among the most serious injuries in sports. They are responsible for greater incidences of disability and fatality in athletes than sports injuries of any other body parts. Increasingly, these injuries are a source of concern among parents who see the media scrutiny over head and neck injuries and ask the question, "Is my child at risk?" and "Should I let me child play sports?"

In particular, there is a lot of attention focused on the long-term implications of concussions sustained by athletes engaged in collision sports such as football, ice hockey, and rugby.

The good news is that serious head and neck injuries are rare in all sports, youth sports included, even in those sports with the potential for falls and collision. When a serious head or neck injury occurs, however, the consequences are profound and far-reaching. The implications may extend beyond the health of the child to the well-being of the child's family, school, fellow athletes, and the community at large.

With all this in mind, we set about to create a book that contained the most up-to-date information about the head and neck injuries sustained by young athletes. We are fortunate to have attracted some of the preeminent names in the field.

Our authors were able to provide a thorough review of several complex and emerging issues for adolescent athletes. Some chapters expand on previous treatment guidelines, like encouraging some early cognitive activity in concussion management, while others attempt to summarize the current evidence of topics that are still incompletely understood, like chronic traumatic encephalopathy. We have striven to make this book complete with practical information that ranges from the sideline assessment of injuries, to the safe transport of athletes, to the theory of a stepwise approach to rehab and return to sports.

In addition to addressing the kinds of head and neck injuries one might ordinarily expect to see in a sports medicine book with an orthopedic orientation, we were also able to enlist the expertise of authors to write about important related issues such as visual dysfunction and protective equipment. We felt it was important to include practical information for the sports medicine physician on topics that are often treated by specialists in other fields such as dental and ear injuries. The inclusion of these chapters makes this book all the more comprehensive and useful.

It goes without saying that our stellar authors are busy people, and we thank them for taking time out of their busy schedules to share their expertise in the chapters they contributed.

With head and neck injuries increasingly in the spotlight, the time is right for a new book that covers the important subject matter. We are pleased to share with you this new addition to the literature. We are proud of the amount of time and effort that went into this book by so many people and trust that you will find such effort reflected in the finished product.

Boston, MA — Michael O'Brien, MD
Waltham, MA — William P. Meehan III, MD

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Head and Neck Injury Prevention

1

David Howell and William P. Meehan III

Introduction

In high school athletics, concussion comprises more than 10 % of sport-related injuries [1]. Approximately 7 % of paraplegia or quadriplegia cases occur during sport participation [2]. More than a third of life-threatening injuries to the head and neck sustained by children are sport-related, and 12 % of those sustained by adults are sport-related [3]. This includes nearly a quarter of cervical spine fractures sustained by children [3]. Therefore, seeking out proactive methods for preventing head and neck injuries sustained during sports is crucial to preserving the safety of young athletes. Although the prevention of head and neck injuries has proven a difficult task, substantial gains have been made over the last 50 years. Although there are no empirically proven methods to eliminate head and neck injury risk, researchers have employed various intervention programs and treatment protocols in order to investigate the best ways to keep athletes safe. Thus, the purpose of this chapter is to briefly review the mechanism and epidemiology of common head and neck injuries sustained during sports participation and discuss various proposed methods for preventing those injuries.

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Concussion

Biomechanics and Pathophysiology

Concussion is defined as a traumatically induced alteration of mental status that may or may not involve loss of consciousness [4]. When an external force is applied to the head, neck, or elsewhere on the body, it may result in an impulsive force which acts on the head [5]. This force creates a sudden acceleration or deceleration of the brain within the cranium causing a temporary disruption of the axons [6]. Correcting axonal function requires adenosine triphosphate. There is, however, a simultaneous alteration of blood flow to the brain after concussion that leads to a mismatch of energy supply and demand. This mismatch is thought to underlie the common signs and symptoms associated with a concussion [6, 7].

Recovery times after concussion vary widely, and the duration of time that is needed for the brain to fully heal after injury is unknown. Oftentimes parents, coaches, athletic trainers, or other clinicians rely on symptom reporting when determining when to return an athlete to play. But this can be problematic because objective impairments resulting from a concussion have been reported to require a longer duration of recovery than self-reporting symptoms in some athletes [8–12], and returning to play too early may put an athlete at an increased risk for a subsequent injury [13, 14].

Epidemiology

Over the past decade, an increased rate of diagnosed concussions [15] and concussion-related emergency room visits [16] indicate that either more individuals are sustaining concussions or that the awareness of concussions has recently increased. The diagnosis and management of the injury still remains controversial and variable among healthcare professionals [17]. Although several prevention strategies have been theorized, no overwhelming evidence has demonstrated clear efficacy for a specific type of intervention to reduce the risk of concussions.

In addition to high incidence rates, anatomical, physiological, and biomechanical factors may put younger athletes at an increased risk of sustaining a concussion. Factors such as the relative size of the head and neck compared with the body, the degree of myelination of nerves, and the shape of the skull have all been identified as reasons which may contribute to worse outcomes following head injuries for children [18]. As a vulnerability to concussive injuries may exist for youth athletes [18, 19], there is a need to identify and test potential strategies which help to reduce the risk of suffering a concussion.

Proposed Methods of Concussion Prevention

Previously, epidemiological studies have identified a higher concussion injury risk for those who previously suffered a concussion compared with those who did not [13, 20]. The factors which contribute to this risk, however, are not fully understood.

Due to the metabolic vulnerability in brain tissue following a concussion, a second insult of modest intensity before full recovery may cause further neuronal impairment, delay recovery [6, 21, 22], or result in cerebral edema and permanent neurological injury, a rare but devastating entity known as second impact syndrome [23]. Thus, proper management of a concussion and appropriate timing of returning to sports may be the primary key to reducing the risk of a secondary injury. Currently, many athletes fail to report concussion symptoms to medical personnel or other responsible adults, leaving many concussions unreported [24, 25]. Educating athletes about the signs and symptoms of concussion as well as the risk of returning to play prior to full recovery may decrease the incidence of recurrent injuries and second impact syndrome [26].

Motor deficits have been reported to persist in some adolescent athletes beyond symptom resolution [12]. If these motor abilities are compromised, the athlete may possess a decreased ability to properly orient their body in space in response to an oncoming impact, thus increasing the likelihood of sustaining a concussion [27]. In a study conducted by Mihalik and colleagues, youth hockey players who anticipated an oncoming collision were able to adequately position their body and brace for the impact [27], thereby decreasing their risk of sustaining a concussion, while unanticipated collisions were more likely to result in a concussion. Such abilities require proper motor function and awareness, both of which may provide a crucial role in preventing a concussion. Thus, identification of complete motor and cognitive recovery following concussion or training interventions aimed to increase awareness and improve technique may be beneficial in reducing the risk of recurrent and secondary concussion injuries. Similarly, the adequate tracking of neurocognitive function may decrease the risk of early return to play and associated secondary injuries, as some studies have shown incomplete cognitive recovery in some athletes, even when they report being symptom-free [9, 28]. Thus, the assessment of cognitive function as one of several determinants of recovery may also decrease the risk of additional, secondary injuries, prior to full recovery.

Specific strengthening protocols may be also beneficial. Different research groups have investigated interventions which may strengthen neck muscles in order to better stabilize the head and neck together during an impact. No reports up to this point, however, have identified an effective, easily implementable, and cost-effective prevention protocol [29]. Two studies employed an 8-week resistance training program targeted at increasing neck strength and reported modest improvements in the overall strength of neck muscles, but no muscle activation or movement pattern changes [30, 31]. Neck strength may be a key factor in the odds of sustaining a concussion, as recent epidemiological evidence suggests that greater neck strength may be associated with reduced odds of sustaining a concussion in contact sport athletes [29]. This indicates that targeted neck strengthening protocols may provide a feasible mechanism to reduce the risk of concussion for adolescent athletes and warrants further exploration. Neuromuscular training regimens may also help to enhance the dynamic response of the head during an impact, as this type of training has been reported to reduce odds of sustaining a high magnitude impact to the head [32]. Thus, a combination of strength and proper neuromuscular response training may reduce the risk of sport-related concussion.

Researchers have investigated new and innovative head and neck protective equipment hoping to reduce concussion risk [33–35]. Within the context of sport-related concussion, however, little reliable evidence exists to support the idea that a helmet can effectively decrease injury risk. Instead, helmets have been designed to prevent serious head trauma such as skull fractures, rather than concussion, and they have been highly successful in reducing injuries such as fractures and severe traumatic brain injury [36]. However, for most sports, there is sparse evidence reporting any changes in the incidence of concussion due to different helmet types. Mouth guards have also been proposed as a type of equipment to prevent head injuries, but little reliable evidence exists to support their efficacy for any protection against concussion [35].

Rule changes, however, have been documented to positively influence behavior and may reduce concussion rates [37]. In ice hockey, rule changes encouraging "fair play" have been observed to reduce aggressive, dangerous behavior [38] as well as the number of face lacerations and time-loss injuries [39]. Therefore, although hope remains for development of protective equipment that will effectively reduce the risk of concussion, protective equipment may not provide the best way to prevent a concussion. Instead, focusing efforts on proper conditioning and training along with appropriate rule changes and enforcement may best prepare athletes to safely compete in sports.

Catastrophic Head Injury

Biomechanics and Pathophysiology

Catastrophic head injury is a serious and potentially life-threatening form of brain injury which may occur during athletic participation. By definition, a catastrophic injury results in death or permanent neurologic sequelae. Although catastrophic injuries occur much less frequently than concussion, the consequences are devastating [1, 40].

Intracranial hemorrhages result from a high velocity impact which damages arteries (epidural) or veins (subdural) causing an accumulation of blood within the cranial vault. Although initial symptoms may be subtle, intracranial hemorrhages can result in rapid deterioration and eventual coma or death [23]. To rule out this type of injury, removal from the field of play and evaluation by medical personnel are recommended for all athletes that sustain a head injury during sports, especially when symptoms persist and worsen over time or neurological findings are detected [23].

As noted above, "second impact syndrome" [41] has been documented throughout a series of case studies since the 1980s. Second impact syndrome occurs when an athlete sustains a head injury, followed by a second head injury prior to symptom resolution, and results in rapid deterioration and eventually permanent disability or death [23]. The majority of cases of second impact syndrome involve athletes who are adolescents [42]. Although the mechanism underlying this

pathological condition remains unknown, it is hypothesized that the loss of cerebral blood flow autoregulation leads to unrestricted swelling of the brain within the cranium [23]. This condition has been reported to result in a mortality rate of 50 % and a morbidity rate of 100 % [2]. Thus, while it may occur rarely, due to its catastrophic nature, prevention is of utmost importance.

Epidemiology

Due to their rarity [23], it is difficult to properly study and reliably estimate the incidence of catastrophic head injuries. The available evidence suggests the incidence is low, even in high risk sports such as American football, where the incidence may be higher in the adolescent population than in the young adult population [40]. Although the exact mechanism for this increased incidence is not clear, multiple possibilities have been identified. The brain is not fully developed during adolescence, and due to ongoing development, the threshold for injury may be decreased [40]. The ongoing development of the brain may also affect brain blood vessels, which may be more likely to tear during adolescence than during adulthood [40]. Further, high school events often have less medical coverage than professional or collegiate sporting events. Therefore, there may be limited recognition and immediate treatment of neurological injuries resulting in worse outcomes, including an increased risk of second impact syndrome [42], as athletes with unrecognized concussions return to play.

A study conducted by Boden and colleagues reported that among those who sustained a catastrophic head injury, 71 % reported that they suffered a concussion earlier in the season, indicating a potential risk factor [40], a finding that has been reported subsequently as well [43]. Thus, due to this increased risk of reinjury, all states in the USA have enacted legislation to reduce the likelihood of an adolescent athlete continuing to play while still experiencing head injury symptoms [44, 45]. However, this type of legislation still relies on accurate recognition and reporting. As such, proper education and medical personnel presence remain critical components in reducing the risk of subsequent injury.

Proposed Methods of Injury Prevention

Since the addition of helmets with a hard plastic shell to American football in the 1950s, severe head injuries and associated fatalities have decreased, due, in part, to the regulatory body which oversees equipment regulation and inspection: the National Operating Committee on Standards for Athletic Equipment (NOCSAE), as well as improved medical care [46]. Initially, the implementation of helmets was associated with a dramatic increase in catastrophic spinal cord injuries, outlined in the next section of the chapter. Consequently, helmets may be effective at reducing the risk of a catastrophic head injury but may also lead to a more aggressive, dangerous playing style, potentially predisposing athletes to vulnerable postures leading to neck injuries.

Other than equipment, measures exist which may assist to prevent serious head injuries. The pre-participation examination allows a physician to understand the athlete's injury history, including instances where the athlete may still be suffering from any previous head-related trauma, and may help to identify if an athlete is not ready to begin participation in a sport [2, 47]. Once competition begins, proper on-site medical personnel, ideally including a certified athletic trainer and a physician, may improve outcomes by identifying those who should be removed from play, initiating early medical care, and referring players with potentially severe injuries promptly to a hospital [2, 47]. Proper coach training and the hiring of coaches who can teach proper fundamental skill acquisition are another imperative aspect to the safety of the adolescent athlete, as improper teaching may increase risk for a direct catastrophic injury [47, 48].

Cervical Spine Fracture and Quadriplegia

Biomechanics and Pathophysiology

The cervical spine is an area of the body that performs a variety of complex movements while protecting the fragile spinal cord. As a result, trauma to the spinal cord at the neck may result in devastating and irreversible consequences [49]. Although advances in rules, training, and equipment may have helped to reduce the overall incidence rates of cervical spine fractures and quadriplegia, it is still a complex condition that must be recognized properly and managed appropriately to avoid further damage [49].

Cervical spine injuries most often occur when a compressive force is applied to the top of the head in a downward direction [50]. Events such as being driven into the mat in wrestling, tackling headfirst in American football, or getting knocked into the boards headfirst during ice hockey place the cervical spine in a vulnerable position [47, 50]: directly between the rapidly decelerating mass of the body and a fixed mass such as the dasher boards or wrestling mat or an oncoming mass such as an opposing player [51, 52]. The type and severity of the injury that results depends on the position of the individual's neck at the time of impact. In its usual resting position, the cervical spine of most athletes has a lordotic curve. This positioning allows the cervical spine to extend slightly as a force is applied to the top of the head and allows force to be absorbed, in part, by the cervical musculature. The most vulnerable position when an impact occurs to the top of the head is when the neck is flexed forward and aligns the spinal column into a straight line. When this happens, the force from the impact is directed straight down the spinal column, which is poorly equipped to withstand these forces [50]. Further, this position decreases the efficacy of the neck musculature, which typically serves to dissipate forces imparted to the head–neck segment [52].

If forces imparted to the spine are high enough, a fracture or dislocation may occur, leading to a risk of bony impingement into the cervical canal. When the cervical spine is fractured, bone fragments may intrude into the spinal canal, injuring the cord and may lead to permanent disability (quadriplegia) or death [49].

Epidemiology

In the context of American football, technology and equipment regulations have appeared to dramatically influence the rate of catastrophic cervical spine injuries. In the 1950s, when face masks were not a part of the standard equipment in football, athletes primarily initiated contact with the shoulder during a tackle [53]. But the introduction of the face mask resulted in athletes more readily initiating contact with their heads first, leading to a high rate of death or disability [53]. Following this rise, helmets were regulated, beginning in 1978 at the collegiate level and in 1980 at the high school level [53]. While these changes led to a dramatic decrease in fatalities caused by catastrophic head injury, they may have led to an increase in neck injuries. In addition, the scalp, which typically is highly sensitive to trauma, is protected by the hard plastic shell of the helmet. Thus, techniques such as butt blocking and spear tackling, in which the athlete initiates contact with the top of the head as opposed to the shoulder, became more common after the introduction of the hard plastic shell helmets with face masks. This led to an increase in cervical spine injuries and quadriplegia.

In the early 1970s, there were 259 documented cases of cervical fractures or dislocations in the National Football League, which primarily occurred due to an axial loading of the neck [50]. In response to such a high incidence rate, headfirst contact was banned from American football in January 1976 [49]. Following this rule change, a substantial decrease in the number of cases of cervical fractures, dislocations, and subluxations occurring in American football was observed (see Fig. 1.1). Although improvements in conditioning, education, equipment, and technique may have also contributed to this decrease, the rule change to disallow headfirst tackling appears to have had the biggest impact on the reduction of catastrophic cervical spine injuries [50]. Proper coaching of tackling technique may continue to keep the rate of this type of injury low in the high school athlete population.

Proposed Methods of Injury Prevention

Anatomical factors may play a role in the risk of cervical spine fracture or quadriplegia. Individuals with cervical spine stenosis, narrowing of the cervical spinal canal, have an increased risk for suffering permanent neurological injury [50, 54]. Further, the combination of anatomy and playing style may increase the risk for cervical spine fracture or dislocation. The combination of spinal stenosis, persistent straightening of the typically curved cervical spine, radiographic abnormalities, and a history of headfirst tackling has been termed “spear tackler’s spine,” and, in the athletic setting, may present for an increased risk for cervical spine fracture [52].

Once headfirst tackling was banned from American football in 1976, the rate of catastrophic cervical spine injuries steadily decreased (see Fig. 1.1) [55]. Further, the removal of the word “intentional” in 2005 made any type of headfirst tackling illegal and allowed referees to call a penalty without having to interpret intention of the player, creating a safer playing environment [56]. While these rule changes have

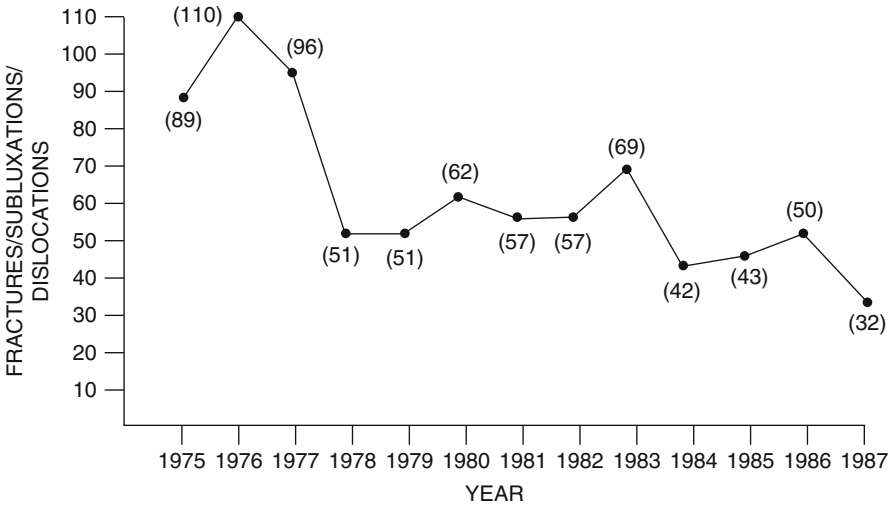

Fig. 1.1 Cervical spine fractures, dislocations, and subluxations for high school, collegiate, and professional football players decreased substantially beginning in 1977 as a result of rule changes implemented in 1976, which banned head-first blocking, tackling, and spearing. From Torg et al. [51] © 1990, reprinted by Permission of SAGE publications

been effective in reducing the incidence of cervical spine fractures and quadriplegia, proper instruction remains a key component in preventing catastrophic injuries. A poorly executed block or tackle may be one cause of cervical spine fractures [47], so coaches play a pivotal role in athlete protection. Avoidance of any repeated posture which creates a vulnerable position for an athlete, including leading with the top of the head or an impact that combines a headfirst and slightly flexed neck posture, should be stressed by all coaches in all sports.

Burners and Stingers

Biomechanics and Pathophysiology

Burners and stingers are typically transient events involving sensory and/or motor function loss in the arms resulting from a rapid stretch of the brachial plexus or compression of the exiting nerves to the upper extremity [54]. During a collision, particularly those involving younger athletes, the shoulder nerves may stretch when the head is abruptly flexed laterally while simultaneously the shoulder is displaced in a downward direction, stressing the nerves that travel from the cervical spine into the upper extremity, resulting in a burning sensation down the arm [50]. This injury is always unilateral and rarely persists beyond 30 min but has been documented to go on for days to months in rare circumstances [50]. For a further discussion of burners and stingers, please see the chapter by Kerr et al.

Epidemiology

Various risk factors have been explored related to the occurrence of a burner or stinger. It appears that they take place most often during participation in American football or wrestling [50]. As with cervical spine injuries, burners or stingers have been implicated to occur more frequently in athletes with a spinal stenosis [50]. Continued presence of this injury may be indicative of a lesion in the brachial plexus or underlying dislocation of the shoulder joint [57], and a physician referral should be made if stingers or burners are experienced frequently.

Proposed Methods of Injury Prevention

Of particular importance following a burner or stinger is proper management, including ruling out any cervical spine or spinal cord injury, which may be the cause of the reported pain [54]. But as no randomized control trials exist examining this type of injury, strong evidence to support prevention measures is sparse [54]. Expert opinion has identified risk factors following the first burner or stinger, which may help to prevent further burners or stingers. Following any type of cervical spine injury, an athlete should not return to play until they have demonstrated full strength and full range of motion in the injured areas [54]. By identifying residual symptoms, neck pain, or incomplete strength or range of motion, the healthcare provider may help to allow time for proper recovery and reduce the risk of sustaining a future burner or stinger.

The use of proper fitting protective equipment such as shoulder pads, cowboy collars, and neck rolls may reduce the risk of these injuries [58], but there is little currently available evidence supporting their use [57, 59, 60]. However, adherence to proper equipment regulations, instruction of proper tackling technique, and appropriate conditioning are all currently employed in order to reduce the likelihood of sustaining a burner or stinger.

Conclusion

While it may be impossible to completely eliminate the risk of injury, reducing risks of all types of injury, from severe to mild, may be achievable with proper education, training, equipment, and medical management to reduce the likelihood of a repeat injury. Future research should prospectively examine each of these components individually and when performed in conjunction with each other in order to identify how well these strategies help reduce head or neck injury rates. In addition, research will help advance the development of innovative and clinically implementable ways to proactively help athletes compete in sport activities in a safer manner.