

Epidemiology of Sports Injury in Pediatric Athletes

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Abstract: In the United States, youth interest in sports participation has increased steadily over the past 2 decades. Although such trends are encouraging to the medical community, especially given the concurrent obesity epidemic among American youth, this increase in sports participation is accompanied by an increase in rates of sports injury in the pediatric population. Appropriate diagnosis and treatment of these injuries by primary care and orthopedic providers rests heavily on a fundamental understanding of the epidemiology of such pathologies.

Key Words: epidemiology sports injury, pediatric sports injury, pediatric sports pathology, pediatric injury rates, youth sports injury epidemiology, adolescent sports injury epidemiology

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The number of adolescents participating in sports in the United States has been steadily increasing over the past 20 years.¹ By the 2009 to 2010 academic year, more than 7,600,000 adolescents were participating annually in high school sports.² Although initially that figure seems impressive, it is almost diminutive when compared with the approximately 30,000,000 to 44,000,000 youth who participate in nonscholastic sports annually.^{3,4} When one considers the unrelenting pediatric obesity epidemic in the United States,^{5,6} these numbers are welcome news. Inevitably although with increasing numbers of sports participants comes increasing numbers of sports injuries. Collectively United States' high school athletes sustain an estimated 2,000,000 injuries per year.⁷

Attempts to study the epidemiology of sports injuries are not new. In 1962 Dr William Haddon of the New York State Department of Health, published an elegant report on the rates of skiing accidents in male and female skiers⁸; and the medical community's interest in sports injury epidemiology began.⁹

Owing both to the wealth of well-performed studies and data collection on high school athletes, and to the dearth of similar studies on elementary and middle school athletes, this study focuses heavily on adolescent (age 13 to 18 y) athletes. We the authors suspect there are fewer elementary and middle school studies because (1) there are fewer organized elementary and middle school sports teams and (2) there are fewer regional and national organizations collecting and following data on athletes of these age, whereas there are several organizations that formally (and meticulously) collect data on high school sports participants and teams (eg, National Federation of State High

School Associations, National Alliance for Youth Sports, and National Council of Youth Sports to name but a few).

In addition, European studies are mentioned throughout this study not infrequently. Although the authors concede that there are variations in population interest in different sports—and therefore differences in participation rates—on either side of the Atlantic, particularly well-designed and/or pertinent studies are included when appropriate throughout this text. On a final note, the term “football” in this text refers to American football, and the term “soccer” will refer to the sport commonly called football by just about everyone living outside of the United States.

BODY PARTS MOST COMMONLY INJURED

An in-depth meta-analysis compiled epidemiologic sports injury studies from 1966 to 2006.⁹ The authors found that most injuries are to the lower extremity, and of those, knee and ankle injury predominate.⁹ Taekwondo is a notable exception to this rule in which the foot and toes are the most commonly injured.^{9,10} In certain sports, the upper extremity is more commonly injured. These tend to be throwing sports or sports in which the upper extremity is recruited to catch oneself during a fall and include baseball, gymnastics, judo, and snowboarding.⁹ The rank order of shoulder, elbow, and wrist injury depends on the sport.⁹ The highest frequencies of head and facial injury were seen in ice hockey,¹¹ and the martial arts karate and taekwondo.^{9,10} A study of multiple high school sports over the 1995 to 1997 seasons noted head/neck/spine injury rates to be highest in male football and wrestling athletes.⁷

SPORTS INJURY IN THE EMERGENCY DEPARTMENT (ED) AND PRIMARY CARE CLINICS

The Centers for Disease Control and Prevention (CDC) reviewed data from the National Electronic Injury Surveillance System All Injury Program to evaluate nonfatal sports-related and recreation-related injuries treated in United States' EDs. In the 12 months from July, 2000 to June, 2001, an estimated 4,300,000 nonfatal sports-related and recreation-related injuries (of all age groups) presented to EDs.¹² The highest rates of injury for both male and female participants occurred in the 10 to 14-year-old category (male: 75 per 1000 and female: 36 per 1000 persons).¹² An earlier study of data extracted from the National Center for Health Statistics noted 1 in 5 injuries in persons 18 years and younger reporting to EDs was sports-related.¹³ Similar proportions are also noted in the primary care office setting, in which sports-related incidents are the leading cause of pediatric visits, accounting for a comparable 19% of all injury-related outpatient visits.¹⁴

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DEHYDRATION AND HEAT-RELATED INJURY

An evaluation of athletes' injuries at the Seventh World Championships of the International Amateur Athletics Federation in Seville, Spain in August, 1999 noted heat-related illness accounted for 17% of all athlete injuries seen during that weeklong event.¹⁵ Even more concerning, the number of American high school and college deaths in football players due to heat stroke has doubled in the past decade, from 15 in the 1990s to 29 from the turn of the millennium to 2010.¹⁶

DENTAL INJURY

A random sampling of 6313 high school students between 15 and 18 years noted 19.9% of them to have suffered a traumatic dental injury at some point in the past.¹⁷ Approximately one-third of these cases (30.8%) were due to sports-related and leisure-related activities.¹⁷ Similarly Dr David Satcher, the United States' Surgeon General in 2000, reported that 1 in 5 head and face injuries in the United States were sports related, and that 33% of these were dental trauma.¹⁸ A British study of children 11 to 14 years noted sports injuries to account for 17.2% of dental trauma,¹⁹ implying that middle school athletes suffer about half as much sports-related dental trauma as do their high school colleagues.

NEUROLOGICAL INJURY AND CONCUSSION

As our awareness of acute and chronic pathologies associated with concussion matures, so too does our understanding of the incidence of concussion in pediatric populations.^{20,21} The CDC report that 200,000 athletes with concussions are seen in EDs each year, with 65% of these patients between 5 and 18 years.²² Approximately two-thirds of these are related to bicycling, playing football, playing basketball, and playground activity (and a full two-thirds of those being bicycling and football alone).²² Although an estimated 5.6% of high school football players suffer a concussion each season,²³ perhaps more alarming is the suggestion that this figure is likely closer to 15% when adjusting for underreporting.²⁴ Other sports with high concussion incidences include basketball, field hockey, lacrosse, soccer, and wrestling.^{25,26} The CDC estimates that 1 in 5 of the 1,500,000 head injuries evaluated each year in the United States is sports related.²⁷

SPINAL CORD INJURY

Spinal Cord Injury, General

Since 2005, 7.9% of all new cases of spinal cord injuries in the United States were related to sports.²⁸ Sports are the fourth most common cause of spinal cord injury in Americans behind motor vehicle accidents, falls, and violence (mainly gunshot wounds).²⁸ Neck and cervical spine injury comprised 4.1% of 517,726 American high school football injuries reviewed from the 2005 to 2006 season.²⁹ Cervical cord neuropraxia (eg, transient quadriplegia and transient hemiplegia) has an estimated prevalence of 7 per 10,000 football participants.³⁰ For the past 26 years the number of ED visits for cheerleading-related injuries has been on the rise; as of 2007, 15.1% of these injuries involved the head or neck.³¹

Spinal Cord Injury, Catastrophic

Anecdotally, the sports at greatest risk for catastrophic spinal cord injury are baseball, cheerleading, diving, football, ice hockey, rugby, skiing, snowboarding, and wrestling, although formal incidence comparisons are difficult because of differences in statistical reporting.^{32,33} Football has the highest incidence of severe cervical injuries per year of all high school sports.³² Fortunately, after intentional spearing was banned in 1976, the incidence of permanent quadriplegia decreased 88% (down to 4 from 34 annually) by 1995,³⁰ and is reportedly 0.52 per 100,000 high school football players per year as of the early 2000s.³² A study reviewing catastrophic injury in high school wrestlers throughout the 1980s and 1990s found an incidence of 1 per 100,000; almost all were cervical fractures and cervical ligament trauma.³⁴ A study of all downhill skiing deaths during a 5-year period in Vermont noted 37.5% to be in individuals aged 15 to 17 years.³⁵ Almost all of these were head and neck injuries.³⁵

CARDIOVASCULAR INJURY

Sudden Cardiac Death (SCD)

A study by the American Heart Association reviewed 1866 cases of sudden death in athletes aged 39 years and younger occurring between 1980 and 2006.³⁶ They found 56% (1049 of 1866 cases) of sudden death to be cardiovascular in nature.³⁶ SCD is often defined as death within an hour after cardiac symptom onset in an individual with no earlier history of cardiovascular pathology.³⁷ According to the National Center for Catastrophic Sport Injury Research, based at the University of North Carolina at Chapel Hill, the incidence of SCD in high school athletes (aged 12 to 19 y) is 0.66 per 100,000 per year.³⁸ It is interesting to note that male high school athletes have more than 5 times the risk of their female counterparts (0.75 and 0.13 per 100,000 per year, respectively).³⁸

Hypertrophic Cardiomyopathy (HCM) and Anomalous Coronary Arteries

Even when sudden death is attributed to cardiovascular causes (ie, SCD), the specific cardiovascular etiology is discovered in just 66% of the cases.³⁶ HCM is the most common cause (36%) of SCD in American athletes younger than 40 years (including teenagers) in cases where the etiology is known.³⁶ The prevalence of HCM in screened athletes (with 12-lead electrocardiogram) and echocardiogram³⁹ or exercise testing⁴⁰) younger than 35 years (including teenagers) is estimated to be 7 to 8 per 10,000.^{39,40} Anomalous coronary arteries is the second most common cause of SCD in American athletes, accounting for 17% of the cases with known etiologies.³⁶

Commotio Cordis and Brugada Syndrome

Two well-publicized, although extremely rare, etiologies of SCD in athletes are commotio cordis and Brugada syndrome. Commotio cordis is a condition in which a blunt precordial blow results in cardiac arrest and/or SCD.³⁶ Commotio cordis accounts for 3% of SCD cases with known etiologies.³⁶ Brugada syndrome is defined as characteristic electrocardiogram changes and an increased risk of ventricular fibrillation. Brugada syndrome accounts for 0.2% of SCD cases with known etiologies.³⁶

UPPER EXTREMITY INJURY

Fracture

A recent study reviewed sports injury data from 100 nationally representative American high schools from 2005 to 2009.⁴¹ In this 4-year span, 18,316 injuries were described occurring more than 7,740,400 athlete exposures (ie, a practice or a competition event).⁴¹ Fractures were the fourth most common diagnosis after (1) ligament/tendon sprains, (2) muscle strains, and (3) contusions.⁴¹ Using this data, the authors concluded an estimated 568,177 fractures occur annually in the high school athlete population, accounting for 1 in 10 of all injuries sustained by high school athletes.⁴¹ Of the 9 sports studied, football athletes had the highest fracture rate (4.61 fractures per 10,000 athlete exposures), followed by wrestling (2.64 per 10,000) and male soccer (2.17 per 10,000).⁴¹ The lowest fracture rate was female volleyball (0.52 per 10,000).⁴¹ In all sports except female volleyball, fracture was more likely in competition than in practice.⁴¹ Overall 16.1% of the fractures reviewed in this study required surgery.⁴¹ It is notable that while overall recurrence rates of fracture were low (just 3.7% of all fractures), these rates were highest for female in softball (8.7% recurrence) and female in basketball (6.2% recurrence).⁴¹

When data from all sports studied were compiled, the hand was the most commonly fractured body site, accounting for more than 1 in 4 fractures (28.3%).⁴¹ The second most commonly fractured site was the wrist (10.4%).⁴¹ The fourth most commonly fractured site was the forearm (8.2%).⁴¹ See below for the third and fifth most commonly fractured sites. In accordance with these conclusions is a study of 25,120 patients (of all age, approximately two-thirds of these under 25 y) seen in a Dutch ED for sports-related injury.⁴² The authors found half of all upper extremity injuries to be fractures (and two-thirds of these to be of the hand and wrist), whereas just 14% of lower extremity injuries were fractures.⁴²

A study of 408 sports-related fractures in children, age 10 to 19 years presenting to 2 Scottish Hospitals over a 12-month span further elucidates specific fracture location.⁴³ The authors observed that over one-quarter (28.7%) of all fractures were finger phalanges and 12.7% were of the metacarpals.⁴³ Wrist fractures of the distal radius and ulna comprised almost one-quarter of all fractures (23%).⁴³

Elbow Injury

Throwing sports are associated with the highest incidence of elbow pain.⁴⁴ One meta-analysis notes that 18% to 69% of all baseball players between 9 and 19 years have reported, or will report, elbow pain.⁴⁴ The elbow is the most common site of injury in youth baseball pitchers.⁴⁵ One study of 343 baseball players between 9.5 and 12 years found that an even higher percentage of catchers (63% or 25 of 40) than pitchers (58% or 69 of 120) reported elbow soreness in their throwing elbow over the course of a single season.⁴⁶ It is also noteworthy that, in this study, 47% (86 of 183) of all fielders (nonpitchers and noncatchers) reported elbow pain during the season.⁴⁶ Fortunately, the frequency of elbow injury seems to be reduced in those athletes trained in proper throwing technique, with a noted reduction in 1 study from 52% to just 6%.⁴⁷

Pediatric elbow injuries in many sports have an incidence of approximately 5% or less.⁴⁴ These include

football (2% to 6%), rugby (2.6%), snowboarding (5%), skiing (1.5% to 3%), and ice hockey (2% to 6%).⁴⁴

Physeal Injury

During the adolescent growth spurt, a child's epiphyseal plate is weaker than the surrounding ligaments, predisposing them to physeal injury, whereas his or her skeletally mature postpubertal counterpart is more prone to tendinous (strain) or ligamentous (sprain) injury.⁴⁸ A retrospective study of 195 baseball players during a single season noted just half of those with radiologic evidence of medial epicondyle separation reported elbow pain,⁴⁶ leading some to conclude that many physeal injuries of the elbow go unrecognized.⁴⁴

Shoulder Injury

One elegant study reported on pediatric athletes seen in an American sports medicine clinic over a 10-year span.⁴⁹ Of the athletes younger than 16 years, 15% of the injuries involved the upper extremity.⁴⁹ Almost half of these injuries (45%) involved the shoulder.⁴⁹

Another study followed 476 baseball pitchers aged 9 to 14 years over the course of a single season.⁵⁰ Over a third of these athletes (35%) reported shoulder pain over the course of that season.⁵⁰

A 2-year Swedish study of pediatric tennis players (mean age 16.1 y) noted rotator cuff injury to be the third most common pathology seen in these athletes.⁵¹

In high school wrestlers, the shoulder is the most common site of injury, as approximately 1 in 10 wrestling injuries is a shoulder sprain/strain.⁵² In addition, shoulder subluxation or dislocation is the most common reason for a high school wrestler to suffer long-term (> 3 wk) time off of sport.⁵²

LOWER EXTREMITY INJURY

When examining the Dutch ED study of 25,120 sports injuries discussed above,⁴² the authors noted that while sports-related fracture was more common in the upper extremity than the lower, the lower extremity had an overall higher rate of injury of all causes (53%, or 13,399 of 25,120 sports injuries). Athletes 14 years and younger were found more likely to injure their upper extremity, and athletes 15 years and older were found more likely to injure their lower extremity.⁴²

Ankle Injury

A review of 227 ankle injury studies found the ankle the most commonly injured body part in 24 of 70 sports, notably indoor volleyball, field events in track and field, and mountaineering.⁵³ Ankle sprain was the major ankle injury in 33 of 43 sports, notably football, basketball, cheerleading, indoor soccer, ice hockey, and lacrosse.⁵³ In all sports reviewed throughout several countries, the ankle was the second most frequently injured body part after the knee, and ankle sprains were the predominant ankle injury.⁵³ The authors of the review conclude that ankle injury and sprain have the highest incidence in court games and team sports.⁵³

Many of these same authors published an original study the year after their review article in which they evaluated 240 sports-related ankle injuries presenting to an ED during the 2005 calendar year.⁵⁴ They found the majority of these to be associated with basketball, soccer, and hiking.⁵⁴ Ankle fracture (10.4% of all ankle cases) was

second only to ankle sprain (81.3%) in frequency.⁵⁴ Soccer accounted for over half (52%) of all ankle fractures seen in this particular ED.⁵⁴

Anterior Cruciate Ligament (ACL) Rupture

A meta-analysis of 33 articles studying ACL rupture found female soccer and female basketball athletes to have roughly 3 times the rate of rupture compared with their male counterparts.⁵⁵ Year-round female athletes in these 2 sports have an ACL tear rate of 5%.⁵⁵ The highest incidence the authors found of ACL pathology was in recreational downhill skiers.⁵⁵ It is interesting to note that, the lowest incidence encountered was in expert downhill skiers.⁵⁵

Fracture

In the study of American high school athletes noted above, the hand was the most common site of fracture in all sports except male and female soccer, in which lower extremity fractures were most common in both instances.⁴¹ The third most common site of fracture in the sports reviewed was the tibia/fibula and the fifth was the foot/toe.⁴¹

CONCLUSIONS

Since the time of Dr Haddon, interest in sports injury epidemiology has grown both qualitatively and quantitatively. As of September 15, 2010, a search of “sports injury epidemiology” on PubMed yields 4372 results. Although sorting through these can be a daunting task, it is an enjoyable one nonetheless. We are treated to injury discussions of almost every sport imaginable. One example of which is Dr Akhter Nawaz’s thoughtful epidemiologic study of pediatric sports injury in camel racing.⁵⁶ Although such sport may be relatively unknown in the western world, it is refreshing to read Dr Nawaz’s conclusions—that public education and adequate protection are paramount in the health of these pediatric athletes—and to realize the commonality that these conclusions share with the protection of the child-athlete in almost any sport. Furthermore, his emphasis that appropriate epidemiologic study of such injuries is the cornerstone of their prevention is a common, recurring theme recognizable throughout the past 5 decades of studies that have followed carefully in the footsteps of Dr Haddon.^{9,56}

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