

Epidemiology of sports-related musculoskeletal injuries in young athletes in United States

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Abstract: Over the past several decades there has been increased participation in sports by children and adolescents at earlier ages in the United States, as well as more intense participation and specialization in sports at very early ages. This trend has also partly contributed to the patterns of injuries seen in young athletes, and especially in recent years, injuries previously seen in mature athletes are being seen in young athletes. Overall, the vast majority of sport-related musculoskeletal injuries in children and adolescents are due to repetitive overuse and acute macrotrauma is less frequently seen in young athletes. Epidemiological data on sports injuries are provided by several national surveys. Investigators have used different methods to define sports injuries and the most widely used definition is based on athlete-exposure time. Certain aspects related to adolescent growth and development modulate the pattern of injuries. This article provides an overview of the epidemiology of sports-related musculoskeletal injuries seen in children and adolescents.

Keywords: Epidemiology; athlete-exposure; overuse injury

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Introduction

Studies regarding the epidemiology of sports injuries in youth sports are often difficult to compare as the definition of a sport-related injury varies across studies (1-8). However, most definitions include one or more of the following descriptors: time loss from practice or game, decreased level of activity, and the need for medical attention (7). Limitations of some studies include reliability of the collected data, self-report recall bias, presence or absence of an athletic trained or other qualified professional to record the injury, difficulty in determining the denominator (population at risk), and insufficient information on actual time the athlete was exposed to the risk (7).

According to a study conducted by the Centers for Disease Control and Prevention (CDC), sports injuries were defined as those (I) resulting from participation in

an organized high school athletic practice or competition, (II) requiring medical attention from a certified athletic trainer or a physician, and (III) restricting the athlete's participation for 1 or more days beyond the day of injury (1). An athlete exposure was defined as one athlete participating in one practice or competition during which the athlete was exposed to the possibility of athletic injury (1).

Time loss from game or practice is a commonly used indicator for severity of injury (2). For example: non-reportable, no time lost, 1-7 days lost (minor), 8-21 days lost (moderate), more than 21 days lost, and severe injury resulting in permanent disability (2). In addition to the number of days lost, other factors have been considered in determining the severity of injury. These factors include the nature of the injury, duration of treatment, absence from school, and cost of treatment (2). Cumulative incidence of injuries refers to the number of injuries among a specific

Table 1 Factors of specific significance in adolescent athletes

Factor	Comments
Height and weight	Increase in rate of height and weight during adolescence contribute to increase in momentum and force during collision with another athlete; increased weight also increases stress and load to skeletal structures
Muscle growth and strength	There is increased muscle hypertrophy and associated increase in strength during adolescence. This is relatively more pronounced in males compared to females
Motor skills and performance	Motor skills generally improve during adolescence. This is associated with improved motor performance and may contribute to improved sport-specific task performance. Males and females follow a different trajectory in motor skills development
Body composition	There are inherent differences between males and females described in terms of fat mass and fat-free mass as well as body fat distribution. Some athletes may engage in unhealthy measures to manipulate body fat mass
Flexibility	There is a relative period of decreased overall musculotendinous flexibility during adolescent growth spurt. Generally females are more flexible when compared to males
Growth cartilage	The immature growth plate is vulnerable to stress injury
Bone structure	There is increased risk for tendon or ligamentous injury and bony avulsions because of relative weakness of growing bones
Psychological maturity	Psychosocial factors and development play an important role in how adolescents view participation in sports. This has direct implications for adherence to treatment recommendations and how they cope with injuries

group of athletes followed for a defined period (2,4,7). Cumulative incidence is an indicator for an individual athlete's risk for injury; whereas, the incidence of first injury is an indicator of any one athlete being injured (2,4,7).

A widely accepted definition of sport-related injury considers athlete-exposure time. An injury, for example, may be reported as rate per 1,000 athlete-exposures. This is considered to be a more accurate measure to define an injury. An athlete-exposure is defined as one athlete participating in one practice or game, in which there is the possibility of sustaining an injury (1,4,7).

Special considerations in adolescent athletes

The risk for sport-related musculoskeletal injuries is modulated to some extent in adolescents by certain aspects related to growth and development. These factors are summarized in *Table 1* (7).

Catastrophic and acute macrotrauma are relatively less frequent injuries seen in children and adolescents. The vast majority of injuries seen in clinical practice are overuse injuries (*Table 2*) (2,7-12). An overuse injury is a result of repetitive and excessive stress from physical activity applied to normal musculoskeletal tissues and failure of normal adaptation of the tissue. Several factors have been identified that contribute to risk for overuse injuries (*Table 3*) (7,8,13,14).

Epidemiology

The CDC High School Sports-Related Injury Surveillance Study was conducted in June 2005 (1). There were 7.2 million students who participated in high school sports in June 2005 (1). It is estimated that high school sports account for 2 million injuries, 500,000 doctor visits, and 30,000 hospitalizations every year (1).

Based on the CDC study, the overall injury rate in all high school sports combined was 2.44 injuries per 1,000 athlete exposures. American football has the highest injury rate at 4.36 injuries per 1,000 athlete exposures. In each of the nine sports for which data were collected, approximately 80% of the injuries reported were new injuries. Overall the injury rates were higher for competition compared to practice. About 50% of injuries resulted in less than 7 days of time lost from participation. No deaths were reported in the study.

Sheu *et al.* (2016) reported on sports and recreation related injury episodes in the United States for the period of time between 2011 and 2014 (9). Their analysis showed an average annual estimate of 8.6 million sports and recreational related injury episodes with an age-adjusted rate of 34.1 per 1,000 population. Male and individuals between 5 and 24 years of age accounted for greater than 50% of all injury episodes. Overall, injury rates were higher among males and children between the ages of 5–14 years.

Table 2 Spectrum of overuse musculoskeletal injuries in young athletes

Structure affected	Injuries
Articular cartilage and subchondral bone	Juvenile osteochondritis dissecans
	Medial condyle of the femur
	Patella
	Talus
	Capitellum
Apophysis	Osgood-Schlatter disease (tibial tubercle)
	Severe disease (posterior calcaneus)
	Ishelin disease (fifth metatarsal)
	Iliac crest
Bone	Low-risk stress fractures
	Medial tibia
	Fibula
	Ribs
	Radius
	Second and third metatarsals
	High risk stress fractures
	Femoral neck
	Midanterior tibia
	Patella
	Medial malleolus
	Talus
	Tarsal navicular
	Fifth metatarsal
	Pars interarticularis (spondylolysis)
Bursa	Subacromial bursitis
	Olecranon bursitis
	Iliopectineal bursitis
	Trochanteric bursitis
	Prepatellar bursitis
	Pes anserine bursitis
Physis or growth plate	Distal radius physis
	Proximal humeral physis

Table 2 (continued)**Table 2** (continued)

Structure affected	Injuries
Tendons	Rotator cuff tendonitis
	De Quervain tenosynovitis
	Popliteus tendonitis
	Iliotibial band friction syndrome
	Patellar tendonitis
	Achilles tendonitis
	Other
Other	Medial and lateral epicondylitis
	Osteitis pubis (affecting symphysis pubis)
	Scheuermann disease (affecting vertebral endplates)
	Idiopathic anterior knee pain (patella femoral pain syndrome)
	Sinding-Larsen-Johansson syndrome (affecting distal pole of patella)
	Chronic exertional compartment syndromes of the leg
	Medial tibial stress syndrome (shin splints)

Approximately 50% of injuries required medical attention. General exercise was the most frequently reported activity associated with sports or recreation related injuries. Injuries to the lower extremities were most common (42%) followed by those of upper extremities (30%), and head and neck region (16%).

Another study conducted by Comstock *et al.*, analyzed high-school sports related injuries for the years 2015–2016 (Table 4,5) (10).

According to the National Institute of Arthritis and Musculoskeletal and Skin Diseases report there were more than 2.6 million children younger than 19 years of age who were treated in emergency departments for musculoskeletal injuries due to sport participation (11). Musculoskeletal injuries were also the most common reason for injury-related visits to primary care physicians. The most common injuries were sprains and strains, growth plate injuries, and repetitive motion injuries. Most injuries were reported in basketball followed by track and field, American football, baseball, softball, soccer and gymnastics.

Table 3 Factors contributing to overuse musculoskeletal injuries

Relatively more consistently associated factors	Relatively less consistently associated factors
Sudden increase in the intensity, duration, and volume of physical activity	Anatomic variations, especially in lower extremities
Poor conditioning	Hard playing surfaces
Insufficient sport-specific training	Stress to the growth cartilage
Poor training techniques	Differential growth between bones and musculotendinous structures
Inappropriate equipment for the sport	Decreased musculotendinous flexibility
	Presence of associated neuromuscular conditions

Table 4 Injury rates by sport, High School Sports-Related Injury Surveillance Study, United States, 2015–2016 school year (only includes injuries resulting in more than 1 day of time loss)

Sport	Injury rate per 1,000 athlete-exposures
Overall total	2.32
Boys' American football	4.08
Boys' soccer	1.87
Girls' soccer	2.59
Girls' volleyball	1.19
Boys' basketball	1.48
Girls' basketball	2.14
Boys' wrestling	2.23
Boys' baseball	0.84
Girls' softball	1.30

Table 5 Injury diagnosis by type of exposure, High School Sports-Related Injury Surveillance Study, United States, 2015–2016 school year

Type of injury	During game (%)	During practice (%)
Sprain or strain	39	43
Contusion	11	7
Fracture	9	9
Concussion	28	20
Other	14	22

According to the Youth Sports Safety Statistics report of the National Athletic Trainers' Association there were 39 sports-participation-related deaths in young athletes in 2011 (12). Nationally, approximately 8,000 children per

day were seen in emergency departments for sports-related injuries, including musculoskeletal and other injuries. According to this report, the highest rate of sports-related injury occurred in teens between the ages of 15–17 years, in remote rural settings, playing American football, and during practice. A history of previous injury was a risk factor for subsequent injury. In 2011, sport-related traumatic brain injury accounted for 15% of all injuries in high school athletes. Other significant reasons for athletes to seek medical attention included exercise-induced asthma, heat illness, exertional sickling, and infrequently spinal cord injury.

Analysis by Rosendahl and Strouse (2016) of sports-related injuries showed that factors influencing the distribution of musculoskeletal injuries were age, sex, type of sport, intensity of participation, position played, and underlying congenital conditions (13). They reported a sports injury incidence of 1 in 10 children per year with higher overall incidence and greater severity of injury in boys. The report noted that younger athletes sustained relatively milder non-specific injuries compared to older athletes. The highest incidence of musculoskeletal injuries was reported in contact and jumping sports that included American football, wrestling, basketball, soccer, baseball, skiing and snowboarding. Children under the age of 10 years were most likely to have contusions, mild sprains, and injury to growth plates. During pre-pubertal years acute or repetitive stress fractures were reported more frequently. Ligamentous injuries were more likely after skeletal maturity was attained. Sport-related musculoskeletal injuries by location reported by Rosendahl and Strouse are listed in *Table 6*.

In a retrospective review, Stracciolini, *et al.* (2014) analyzed athletes aged 5–17 years old who presented to a sports medicine clinic over a period of 10 years (15). Results

Table 6 Sports-related MSK injuries by location

Location	Injuries
Shoulder	Most common in older youth from contact sports (wrestling, football, hockey); clavicular fracture occurs at all ages
Elbow	Supracondylar/lateral condylar fractures; throwing athletes prone to osteochondritis dissecans, stress injury, flexor tendinopathy, ulnar collateral ligament injury; note that dislocations are very rare
Wrist and hands	Salter-Harris type fractures of growth plates/plastic fractures of distal radial physis and metaphysis are most common, but if inciting activity is not decreased, premature physeal fusion or carpal impingement can occur; carpal bone injuries are rare
Pelvis and hips	Avulsion of apophyseal growth centers, especially at anterior superior iliac spine (kicking) and ischial apophysis (hurdling); slipped capital femoral epiphysis; femoral acetabular impingement
Knee	Physeal fracture at distal femur or proximal tibia are seen in younger children, whereas cruciate/collateral ligament and meniscal injury are more common after skeletal maturity is reached; extensor mechanism injury is also common in older adolescents
Ankle and foot	Juvenile Tillaux (Salter III) and triplane fractures in partially fused physes; ligamentous injury typically in skeletally mature athletes; tarsal coalition; posterior ankle impingement in dancers; avulsion fractures
Spine	Mostly from high-risk sports (football, diving, skiing, gymnastics); intervertebral disk herniation at L4/L5/S1; Scheuermann disease (gymnastics, rowing, weightlifting); spondylolysis and spondylolisthesis at L5/S1 (gymnastics, dance, cheerleading, football, weightlifting, running); all spine injuries are generally more common in older adolescent athletes

MSK, musculoskeletal.

showed higher incidence of overuse injuries compared to acute traumatic injuries in females, and the opposite in males. Females tended to injure the lower extremity and spine more frequently, whereas males tended to injure the upper extremity. Hip/pelvic injury tended to be overuse or soft tissue injury in females, as opposed to traumatic or bony injury in males. Females were more likely to suffer from patellofemoral knee pain, but males were more likely to develop osteochondritis dissecans and fractures. Anterior cruciate ligament sprains were equal among sexes. Differences between sexes may be due to differential movement patterns, sport participation, strength, flexibility, physiologic and anatomic factors (biomechanics of growing joints etc.).

DiFiori *et al.* (2014) conducted a systematic review of trends in competitive youth sports with regards to overuse injury and burnout (14). Overuse injury is often variable with the sport, ranging from 15% in soccer players up to 68% in running. Authors noted that the incidence of such injury is still underreported. Most define injury as loss of time from sports participation and many cases of overuse injury do not cause the athlete to miss playing time. Overuse injury also varies by age: younger athletes suffer more growth-related conditions (apophysitis, physeal stress injury) as opposed to older skeletally mature athletes. All

overuse injuries are not inherently benign, for example, high-risk injuries include stress fractures of the femoral neck/tarsal navicular/anterior tibial physis, as well as effort thrombosis.

Lykissas *et al.* (2013) conducted a cross-sectional epidemiological study of pediatric injuries presenting to the emergency department, using data collected from the National Electronic Injury Surveillance System database (16). It compares reports of sports and recreational injuries in children in the years 2000, 2005, and 2010, to determine the trends in the top eight causes of these injuries. The top eight causes of injury for children ages 5–14 years were bicycling, football, roller sports, playground equipment, baseball/softball, soccer, and trampoline. The study found that the incidence of all musculoskeletal injuries decreased over time for all eight activities (16.4 to 14.4/1,000 person-years); and sports-specific injuries were found to have decreased in 6 out of 8 activities. Maximal decrease was seen in bicycling, with a smaller decrease in football and soccer. Older children (10–14 years of age) sustained a greater proportion of injuries. This study concludes that although injury severity or overuse injury prevalence may have increased, the total incidence of acute sports/recreation-related injuries has been decreasing over the last decade.

Stracciolini *et al.* (2013) conducted a retrospective review of sports injuries in younger children (5–12 years of age) versus older children (13–17 years of age), to determine whether there was variation in location, severity, and diagnosis depending on age (17). The authors collected retrospective data from a sports medicine clinic over 10 years and found definitive differences between the age groups. Forty percent of the total cohort underwent surgery, which was disproportionately in older children. Younger children sustained more acute traumatic bony injuries of upper extremities. Older children sustained more overuse, soft tissue injuries of back and lower extremities.

To classify sports injuries by sex and sport, Schroeder *et al.* (2015) conducted a retrospective cohort study that focused on older children (approximately 14–18 years of age) with overuse injuries (18). The authors collected data from the High School Reporting Information Online study generated in the 2006–2007 and 2011–2012 school years to assess a large national sample. Authors noted that the incidence of overuse injuries in young athletes is increasing overall, attributed to increasing participation and intensity of high school sports. Their study found that incidence of acute traumatic injury was higher in boys compared to girls. They also found that girls had a higher rate of overuse injury, particularly within track and field and field hockey and girls sustained more overuse injuries of the lower extremities compared to boys. The greatest number of boys with overuse injury were seen in swimming and diving (18,19). In most sports, overuse injury was more likely to occur during practice rather than in a competition. Distinct differences were found between sexes with regards to class year—overuse injuries decreased with year in school in girls, but the trend was the opposite in boys. Although body site injured was variable, the most commonly injured areas were the lower leg, knee, and shoulder. Approximately half of all overuse injuries resulted in less than 1 week of playing time lost, with very few requiring more than 3 weeks off. Findings also were consistent with other studies reporting prior injury as a strong risk factor for subsequent injury.

Conclusions

Injuries sustained during physical activity, exercise, and sports activities are common in children and adolescents. While the majority of sport-related musculoskeletal injuries are secondary to repetitive overuse, patterns of injury can be modulated by growth and development and vary by age, gender, and type of sport or physical activity.

Individual studies highlight the variability in injuries, but in general, boys are more likely than girls to sustain injury during sports, lower extremity injuries are more common overall, and prior injury is a strong risk factor for future injury. It remains important for practitioners to understand the epidemiology and variance of injury for their patient populations.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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