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# Pediatric and adolescent injury in adventure and extreme sports

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OVERVIEW



# Pediatric and adolescent injury in adventure and extreme sports

## Introduction

Participation in children's and youth sports and recreational activities is increasingly popular and widespread in Western culture. Trends over recent decades include increased numbers of participants, increased duration and intensity of training, earlier specialization and year-round training, and increased difficulty of skills practiced beginning at an early age. In addition to traditional sports, children and adolescents are increasingly visiting wilderness recreational destinations and participating in a growing number of adventure and extreme sports (AES) (Phit America, 2018; Outdoor Foundation, 2017; Heggie & Caine, 2012).

AES are broadly defined as individualistic sports containing structural components of real or perceived danger (Ewert & Hollenhorst, 1997). These activities often involve speed, height, a high level of physical exertion and highly specialized gear or spectacular stunts. Moreover, participants in these activities often train and compete in variable environmental conditions such as those that are weather- and terrain-related, including wind, snow, water and mountains. Some AES are practiced and performed in populated urban areas including streets, parking lots or designated locations such as skateboard parks, climbing walls and dirt tracks.

Examples of popular youth AES include indoor and outdoor rock climbing, scuba diving, surfing, personal water craft (PWC), whitewater canoeing, kayaking, rafting, extreme hiking, parkour, rodeo, skateboarding, mountain biking, bicycle motocross (BMX), in-line skating, alpine skiing, snowboarding, all-terrain vehicle (ATV) and motocross sports (Caine & Mei-Dan, 2016). Unlike many school- and club-related sports, participants in AES often have little or no access to immediate medical care (Mei-Dan & Carmont, 2013; Heggie & Heggie, 2012). Even if medical care is available, it may face challenges related to longer response and transport times, access to few resources, limited provider experience due to low patient volume and more extreme geographical and environmental challenges (Heggie & Heggie, 2009).

Mass media showcasing breathtaking stunts at the X-Games and the inclusion of skateboarding, in-line sports, mountain biking and rock climbing in the Youth Olympic Games are all helping to drive the popularity of AES among youth. In the United States in 2016, there were 33.4 million youth outdoor participants, aged 6–17 years, an increase from 31.4 million in 2015 (Outdoor Foundation, 2017). During 2016, youth participants, aged 6–17 years, recorded 2.2 billion annual outdoor recreation outings, or 66 average outings per participant (Outdoor Foundation, 2017). The most popular outdoor and favourite outdoor activities are shown in Table 1 (Outdoor Foundation, 2017).

**Table 1.** Outdoor activities among youth, ages 6–17 (Outdoor Foundation, 2017).

| Ranking | Most popular outdoor activities by participation rate | Favourite outdoor activities by frequency of participation |
|---|---|---|
| 1 | Road, Mountain and BMX Biking: 25% of American youth/12.9 million participants | Running, Jogging and Trail Running: 70 average outings per runner/884.5 million total outings |
| 2 | Running, Jogging and Trail Running: 21% of American youth/11.0 million participants | Road, Mountain and BMX Biking: 54 average outings per cyclist/355.1 million total outings |
| 3 | Freshwater, Saltwater and Fly Fishing: 21% of American youth/11.0 million participants | Freshwater, Saltwater and Fly Fishing: 14 average outings per angler/101.6 million total outings |
| 4 | Car, Backyard, Backpacking and RV Camping: 21% of American youth/10.7 million participants | Skateboarding: 36 average outings per skateboarder/ 97.2 million total outings |
| 5 | Hiking: 15% of American youth/7.4 million participants | Car, Backyard, Backpacking and RV Camping: 9 average outings per camper/93.2 million total outings |

## Balancing risks and benefits

Physical activity has important and wide-ranging health benefits which have become increasingly important given growing public health challenges related to physical inactivity (Blair, 2009). In particular, physical activity in children increases physical fitness (both cardiorespiratory fitness and muscular strength), reduces body fat, improves cardiovascular and metabolic disease risk profiles, enhances bone health and reduces symptoms of depression and anxiety (U.S. Department of Health and Human Services, 2008). However, engaging in sports and recreational activities at a young age also involves risk of injury which may adversely affect future health due to such factors as reduced levels of physical activity, greater adiposity, post-traumatic osteoarthritis and post-concussion syndrome (Carbone & Rodeo, 2017; Manley et al., 2017; Emery, Roy, Whittaker, Nettel-Aguirre, & Van Mechelen, 2015; Caine & Golightly, 2011; Maffulli, Longo, Gougoulias, Loppini & Denaro, 2010).

Young AES participants may be particularly vulnerable to injury due to such growth-related factors as the adolescent growth spurt, susceptibility to growth plate injury, differences in maturity status and greater head-to-body ratio (Caine & Caine, 2005; Caine & Purcell, 2016) and, relative to adults, increased vulnerability to concussion (Guskiewisz & McLeod, 2011; Huelke, 1998) and longer recovery and differing physiological response after concussion (Davis et al., 2017; McCrory, Collie, Anderson, & Davis, 2004). Children might also be at risk because of immature or underdeveloped coordination, skills and perception (National Center for Injury Prevention and Control, 2009) and because of reduced emotional maturity and judgment compared to adults, especially in the presence of peers (Malina, Bouchard, & Bar-Or, 2004).

By their very nature, participation in AES often takes place in variable and often unpredictable environmental conditions that may be associated with significant physical risks. The unusual and sometimes risky physical and cognitive demands of AES may create conditions under which potential risk factors can more readily exert their influence. Recent research suggests that the risk and severity of injury in some AES may be high (Heggie & Caine, 2012; Laver, Pengas, & Mei-Dan, 2017). For example, researchers reviewed 2000–2011 National Electronic Injury Surveillance System data for seven popular extreme sports featured at the Winter and Summer X Games: surfing, mountain biking, motocross, skateboarding, snowboarding, snowmobiling and snow skiing (Sharma et al., 2015). Of the four million injuries reported for these sports, 11.3% were head and neck injuries (HNI). In this study, HNI injuries included concussions, fractures and traumatic brain injuries (TBIs) which can result in outcomes such as chronic depression, headaches, paralysis and death (Sharma et al., 2015). The data included all ages; however, teens and young adults accounted for the highest percentage of extreme sports injuries (American Academy of Orthopedic Surgeons, 2014).

## The epidemiologic approach

The increased sports and recreational activity of children from an early age and continued through the years of growth, against a background of their unique vulnerability to injury, gives rise to concern about the risk and severity of AES injury. Parents are not interested in conjecture and want to know if AES are safe for their children (Lackman, 2015). Indeed, children and adolescents and everyone who works with them, whether they are parents, sports medicine personnel, sports governing bodies or coaches, need to understand the incidence and distribution of injury associated with participation in AES, and what measures might be taken to reduce unnecessary risk of injury (Caine & Caine, 1996). Many injuries in sports and recreation are considered preventable, and epidemiologic studies of their incidence, causes and demographic features can lead to targeted prevention strategies (Tator, 2008).

The epidemiologist in sports medicine is concerned with quantifying injury occurrence *(how much)* with respect to *who* is affected by injury, *where* and *when* injuries occur and *what* is their outcome, for the purpose of explaining *why* and *how* injuries occur and identifying strategies to control and prevent them. The study of the distribution of varying rates of injuries (i.e. who, where, when, what) is referred to as descriptive epidemiology. The study of the determinants of an exhibited distribution of varying rates of injuries (i.e. why and how) and the identification and implementation of preventive strategies are referred to as analytical epidemiology.

This overview illuminates the epidemiologic approach to understanding the incidence and characteristics of injury affecting paediatric and adolescent AES participants, and what is known about risk factors and preventive measures with the hope of generating understanding and further research. This is accomplished through reference to the in-depth, sport-specific reviews by content experts that are presented in this special issue of *Research in Sports Medicine*. A unique feature of this issue is that the articles included are laid out with the same basic headings so that the reader can easily find common information across articles.

## Descriptive epidemiology

Descriptive epidemiology is the most common type of epidemiologic research that has been published in the AES literature and arises primarily from observational research including ecological, case series, cross-sectional and cohort studies. Most published data on AES injuries arise from four general sources: government databanks, healthcare system records, sports organization surveillance and special studies done by academic research institutions (Hootman, 2010). A diagram illustrating important aspects of the descriptive epidemiology of sports-related injuries is shown in Figure 1 (Caine, Caine, & Maffulli, 2006).

These components are discussed below with the purpose of highlighting their various contributions to understanding the incidence and distribution of AES injuries.

## Injury occurrence

We often first learn of a youth injury suffered through participation in AES via media reports. For example, on 4 January 2014, a 15-year-old San Clemente, CA girl suffered a serious head injury, including skull fracture, when she was skateboarding down a steep street and lost control. She was not wearing a helmet at the time of the accident (KABC News, 4 January 2014). Reports like these and representing a variety of AES are not uncommon. However, typically no information is provided on the frequency or rate of such events.

The most basic measure of injury occurrence is a simple count of injured persons or fatalities. For example, Daniels et al. (2015) studied 248 competitive and recreational motocross riders <18 years of age who had been treated for 298 head and spine injuries during 2000–2007 (Daniels et al., 2015). Head injury or TBI was identified in 60 of 298 cases (20.1%) and spine fractures were identified in 13 patients (4.3%). Helmet use was confirmed among 43 (71.7%) of head-injured cases despite the use of protective gear.

Several AES studies report analyses of count data arising from national hospital-based studies and indicate a relatively high annual frequency of injury. For example, Shults, West, Rudd and Heitkamp (2013) report that during 2001–2010 in the United States, ~361,000 children aged 15 years were injured while riding ATVs, an average of 36,000 cases per year. Also, an estimated 1,226,868 children/adolescents, aged 5–19 years were treated in US hospital emergency departments (EDs) during 1990–2008 for nonfatal skateboarding-related injuries, an average of 64,500 cases per year (McKenzie, Fletcher, Nelson, Roberts, & Klein, 2016). Notably, skateboarding and ATV ranked fifth and sixth, respectively, among 39 sport, recreation and exercise activities ranked for annual frequency of TBI (CDC, 2011). These count data are useful in providing an estimate of the relative frequency of injuries as well as an estimate of the morbidity load on a clinic. They also raise concern that participation in AES is an important source of injury for children and adolescents.

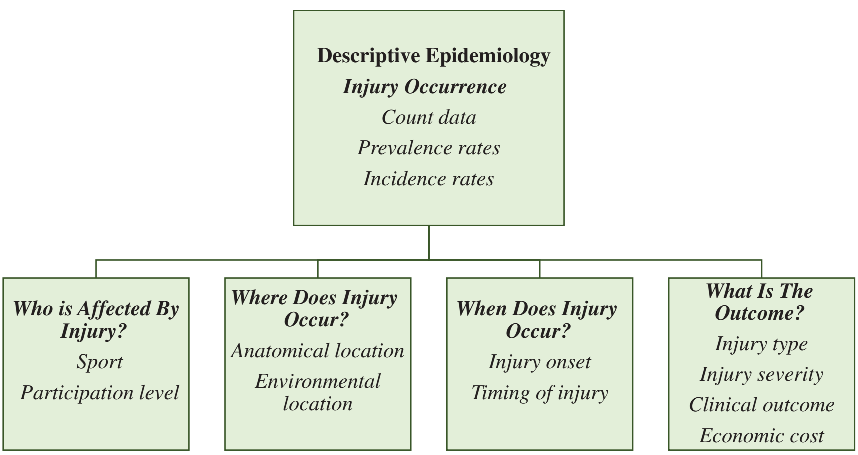


**Figure 1.** Descriptive epidemiology of paediatric and adolescent sports injuries.

The two most commonly reported injury rates in the AES literature are *prevalence* and *incidence*. Prevalence pertains to the proportion of individuals in a population who have an injury at a particular time. Most prevalence studies in the AES literature report prevalence rates for specific injury conditions. For example, Schöffl, Hochholzer and Imhoff (2004) conducted a radiographic survey which showed that 47% of the German Junior National climbing team and 28% of recreational climbers were characterized by stress reactions in the fingers.

Injury incidence refers to the number of new occurrences of injury that occurs during a specified *period* of time, such as from the start of a season (Knowles, Marshall, & Guskiewicz, 2006). Types of injury incidence commonly reported in the AES injury literature include incidence proportion, clinical incidence and incidence rate. Incidence proportion or "athlete rate" measures the average risk of at least one injury as the number of injured athletes divided by the total number of athletes participating or at risk during a specified time period (Caine & Caine, 1996; Knowles et al., 2006). For example, Ruedl et al. (2016) reported that the incidence proportion was highest in snowboard cross (11%), Nordic combined (9%) and alpine skiing (6%) during the 2015 Winter European Youth Olympic Festival. Incidence proportion is rarely used in the AES injury literature because it combines athletes with single as well as multiple injuries (Caine & Caine, 1996; Knowles et al., 2006).

In contrast, clinical incidence is widely used in sports medicine research and uses number of injuries sustained in its numerator and number of athletes at risk in its denominator (Knowles et al., 2006). For example, a range of 114–420 injuries per 1000 snowboard athletes has been reported in studies of injury occurrence during the Youth Winter Olympic games (Ruedl et al., 2016, 2012; Steffen et al., 2017). While these results provide a basis for comparison of average number of injuries per athlete within and across sports and as an indication of clinical or resource utilization, they do not account for the potential variance in exposure of participants to risk of injury (Knowles et al., 2006).

Incidence rate refers to the number of incident injuries divided by the total time-at-risk and usually multiplied by some *k* value (e.g. 1000) (Knowles et al., 2006). It is the preferred measure of incidence in research studies because it can account for variations in time-at-risk among athletes. Different units of time-at-risk, varying in precision, have been used to calculate incidence rates in the AES literature. Time-at-risk can be calendar time (in days, months, years), time spent active in training or competition (hours), the number of practices or games or simply part or all of a season (Hopkins, Marshall, Quarrie & Hume, 2007). For example, Becker et al. (2013) reported a rate of 16.8 injuries per 1000 h of exposure (training and competition) among downhill mountain bikers (aged 14–53 years).

A more sensitive measure of person-time-at-risk is the use of athlete exposure where the total number of injuries over a period of time is divided by *k* time exposures where one time exposure is defined as one individual participating in 1 h of activity in which there is the possibility of sustaining a sport-related injury. For example, Westin, Alricsson and Werner (2012) reported an incidence rate among adolescent male alpine skiers of 1.62 injuries per 1000 h exposure.

Element exposures are also appropriately used in epidemiological studies of injury in AES. One element exposure is defined as one individual participating in one element of activity in which there is the possibility of sustaining an athletic injury (Caine & Caine, 1996). Examples of element exposures in AES include number of climbs, surfing days, snowboard runs, personal watercrafts in operation, competitive exposures (rodeo) and scuba dives. For example, Russell et al. (2014) reported a rate of 0.8 injuries per 1000 runs (CI, 0.7–0.9) among 12–17-year-old snowboarders.

Review of the epidemiologic literature on paediatric and adolescent injury in AES thus reveals a variety of approaches to reporting injury occurrence and perhaps, above all, a difficulty in systematically obtaining injury data from participants who often train and compete in variable and remote environmental conditions. Because the approaches vary in precision of quantifying injury occurrence, they are not easily compared within and especially across sports.

## *Who is affected by injury?*

Injury rates in AES are often reported relative to sport participation and the way in which participants are organized for sports. For example, Sharma et al. (2015) reported that skateboarding had the highest risk of HNI for extreme sports participants (10.21 per 10,000 person-years), while mountain bicycling had the lowest risk (1.08 per 10,000 person-years). Yet, because the population of the study included both recreational and competitive sports participants, their respective injury rates cannot accurately reflect the risk of individuals participating in these AES.

Comparison of injury rates among various events within a discipline may yield different results. For example, research conducted during the Lillehammer 2016 Youth Olympic winter games shows variable injury rates in alpine (12.9 per 100 participants) and freestyle (17.4 injuries per 100 participants) skiing (Steffen et al., 2017). These results may be misleading, however, since they do not account for variable exposure of participants to risk of injury.

## *Where does injury occur?*

Determination of *where* injury occurs involves identification of the anatomical and situational locations of injury. Anatomical locations include body region of injury (e.g. upper extremity) as well as specific body parts (e.g. shoulder, ankle). Identifying the anatomical location of injury highlights the body parts in need of special attention and may also assist in the development of preventive measures to reduce the number and severity of these injuries. For example, a national study of ATV-related nonfatal injuries showed that among children aged 0–5 years, face or mouth injuries were most common, accounting for 31% of ED visits, whereas among older children upper and lower extremity injuries accounted for >50% of all injuries (Shults et al., 2013).

Environmental location provides information on the distribution of injury by where in the environment the injury occurred. Environmental locations reported in AES injury literature include surface or terrain on which the activity takes place, such as indoor or outdoor climbing or grade of terrain associated with mountaineering, and whether the injury occurred in practice or competition. Information on high risk settings is of course useful in identifying morbidity load for healthcare facilities as well as important targets for application of preventive measures. For example, Larson et al. (2009) reported that the majority of patients presenting for medical evaluation at a level 1 regional trauma centre sustained the injury at a formal motocross course.

## When does injury occur?

The next characteristic of injury distribution is the *when* of injury occurrence. Temporal factors are typically expressed in terms of injury onset and timing of injury. There are two broad categories of injury onset that differ markedly in aetiology. Injuries that occur suddenly are termed acute injuries and are usually the result of a single, traumatic event. Overuse injuries are subtle and develop gradually over time. They are the result of repetitive micro-trauma to the tendons, bones and joints. Most studies in the AES injury literature report only acute injuries or otherwise do not distinguish between acute and overuse injuries. An exception is reported among young climbers who commonly experience overuse injuries, particularly epiphyseal stress fractures of the finger (Schöffl, Lutter, Woollings, & Schöffl, 2018).

Examples of timing of injury include time into training, time of day and time of season or year when injury occurs. It stands to reason that if rates are higher during a particular time period, then efforts to better understand the risk factors for the elevated risk are in order and appropriate preventive measures should be applied to reduce risk during this time. For example, in a 2-year study of recreational activities in U.S. National Parks, Heggie, Heggie and Kliewer (2008) identified the northern hemisphere summer months of June, July and August as peak fatality months and the winter months of November through February as the lowest.

It is also of interest to consider reasons for observed change in incidence and distribution of injury over time. For example, a national study of injury rates (per 100,000 youth) for paediatric ATV-related injuries showed an increased rate from 50 to 67 (2001 vs. 2004) followed by a decrease to 42 by 2010 (Shults & West, 2015). The reasons for the decrease in deaths and injuries seen after the peak years remain unknown but may reflect the growing popularity of recreational off-road vehicles (Denning & Jennissen, 2018).

## What is the outcome?

Injury outcome in AES can span a broad spectrum from abrasions to fractures, to those injuries that result in severe permanent functional disability (i.e. catastrophic injuries) or even death. In the epidemiologic literature on AES injuries, injury outcome is typically represented by data on injury type, injury severity, clinical outcome and economic cost. Assessment in each of these areas is important to understanding the individual and public health impact of injuries.

### Injury type

Most AES studies report injury types using percent values and in general terms such as contusion or fracture, with few specifics on type of fracture, grade of injury and so forth. For example, a national study reported that patients, aged 14–19 years, treated for mountain-biking injuries in EDs in the United States during 1994–2007 sustained a greater proportion of TBIs (8.4%) than did patients aged 8–13 years and ≥20 years combined (4.3%) (Nelson & McKenzie, 2011). In this example, "TBIs" include cases with concussion, fractures to the head and internal organ injuries to the head (Nelson & McKenzie, 2011).

### *Injury severity*

Indicators of injury severity reported in the paediatric and adolescent AES literature include duration of restriction from athletic performance subsequent to injury, hospital admission and length of hospital stay, surgical intervention and injury severity scores (ISS). For example, Larson et al. (2009) reported that 30% of motocross injuries seen at a regional trauma centre required surgery. In contrast, Milan, Jhajj, Stewart, Pyle and Moulton (2017) found only 6% of injuries sustained by 549 young skiers and snowboarders (mean age 11 ± 3 years) treated at a level 1 paediatric trauma centre during 1999–2014 had an ISS >15 and 87% of injuries were mild (ISS 1–9).

### *Clinical outcome*

A concern often registered regarding youth participation in AES is the potential for serious, life-threatening injury (Caine & Mei-Dan, 2016; Heggie & Caine, 2012; Lackman, 2015). Indeed, the worst-case scenario in paediatric and adolescent AES is catastrophic injury. Catastrophic sports injuries are categorized by the National Center for Catastrophic Sports Injury Research (NCCSIR) as fatalities, nonfatal injuries (permanent severe functional disability) and serious injuries (no permanent disability but significant initial injury, such as vertebral fracture without paralysis) (Kucera, Yau, Thomas, Wolff, & Cantu, 2015).

The NCCSIR has collected injury data since 1965 on deaths and disability from brain and/or spinal cord injury attributed to high school and college sports participation in the Unites States. However, despite the real and perceived risks and increasing attention to catastrophic injuries in AES, no organization with the exception of the Rodeo Catastrophic Injury Registry (in operation during 1989–2009) has systematically collected such information nationally (Butterwick, Lafave, Lau, & Freeman, 2011).

We typically first learn of a catastrophic injury suffered through participation in AES via media reports. For example, on 2 September 2017, Valley News Live reported that the North Dakota Highway Patrol and the Burke County Sheriff's office are investigating an ATV accident that claimed the life of an 11-year-old child (Valley News Live, 2017). Apparently, the boy was riding the ATV when it flipped trapping the child underneath. Media reports like this attest to the potential for severe and sometimes fatal paediatric and adolescent injuries in AES.

Unfortunately, few data illuminate the nature and extent of catastrophic injury among children and adolescents involved in AES. The data on catastrophic injuries, like most injury data for AES, arise primarily from government surveys, healthcare systems, registries and special studies where exposure data are rarely collected. Design and report limitations notwithstanding, a concerning account related to the existence of catastrophic injury – including fatal, nonfatal and serious injuries – emerges in the paediatric and adolescent AES literature reviewed in this theme issue. Some AES appear to carry a greater risk for catastrophic injuries than others.

***Fatal injuries.*** Relative to other youth AES, the reported frequency of fatality appears to be greatest among young ATV riders. Denning and Jennissen (2018) note that there are currently more than 150 paediatric ATV-related fatalities each year. In contrast, during 1982–2013 there were 177 direct fatalities in all high school sports combined in the United States, both male and female, or about six fatalities per year (Zemper, Roos, & Caine, 2016). In this issue, evidence of paediatric and adolescent fatalities is provided in several additional articles including rodeo, skiing, and wilderness sports and recreational activities.

***Nonfatal and serious catastrophic injuries.*** Research documenting serious head and spinal cord injuries affecting paediatric and adolescent AES participants is also provided in the following articles, also included in this theme issue: adventure aquatic sports, ATV, mountain biking, motocross, skateboarding, skiing and snowboarding. For example, Caine and Provance (2018) describe a report on mountain bike injuries sustained during 1995–2007, where 17 of 107 patients (15.9%), aged 14–20 years, suffered spine fracture and/or spinal injury (Dodwell et al., 2010). Although mountain biking had the lowest number of HNI among seven extreme sports, it was the second riskiest sport in a national study with respect to neck fractures, with an incidence rate of 12.8 per 1,000,000 person-years (Sharma et al., 2015).

### *Economic cost*

Financial costs of injury provide insight into public health burden. Direct costs are those incurred in conjunction with medical treatment (e.g. treatment, medication). For example, between 2000 and 2005 the annual direct medical costs for youth <16 years old injured in ATV crashes increased from $1.8 to $2.2 million, and annual fatality costs rose from $805 to $924 million (Helmkamp, Aitken, & Lawrence, 2009).

Indirect costs are those associated with the loss of productivity because of increased morbidity and mortality levels and may include lost wages from time lost from work when parents are required to stay home to care for their injured children. For example, Vaca, Mai, Anderson, Fox and Ferrarella (2007) found that skatepark-related injuries resulted in mean total injury cost of $3167, of which 64% were medical costs and 28% were wages lost by the subject and family.

## Analytical epidemiology

Analytical epidemiology focuses on *why* and *how* injuries occur and identifying strategies to control and prevent them. There is an increasing body of rigorous evidence (including randomized controlled trial evidence) to inform best practice in injury prevention in youth sport (Emery, Thierry, Hagel, MacPherson, & Nettel-Aquirre, 2016). With a few exceptions, however, research approaches in the AES literature have been primarily descriptive in nature with few studies designed to test risk factors or to determine the effectiveness of preventive measures.

### *Risk factors*

The epidemiological approach to sports injuries is rooted in the assumption that injuries do not happen purely by chance, so an important part of AES injury epidemiology is the identification of factors that contribute to the occurrence of injury. Analysis of injury risk factors in youth sport has produced multiple significant predictors including age, balance, body size, maturity status, gender, previous injury, stressful life events, volume of training and fatigue (Caine & Goodwin, 2016). There is also an increasing body of scientific evidence to inform both intrinsic and extrinsic risk factors for paediatric and adolescent injury in AES (Emery, 2018).

Intrinsic risk factors that have been analysed in the paediatric and adolescent AES literature include ability/skill level (rock climbing, skateboarding, skiing), adolescent growth spurt (rock climbing), chronological age (ATV, rock climbing, mountain biking, skateboarding and snowboarding), concurrent risk-taking behaviour (ATV, rock climbing, skateboarding), gender (mountain biking, skateboarding, skiing), experience (rock climbing, skiing, snowboarding), and previous injury (wilderness). In mountain biking, for example, Nelson and McKenzie (2011) report that patients aged 14–19 years (8.4%) sustained a greater proportion of TBIs than did patients aged 8–13 and ≥20 years combined (4.3%) (IPR, 2.0; 95% CI, 1.6–2.5).

Extrinsic risk factors that have been analysed in the paediatric and adolescent AES include carrying a passenger (ATV), lack of protective equipment (aquatic adventure, mountain biking, skateboarding, snowboarding, skiing, wilderness), lack of supervision (ATV, skateboarding), inclement weather (skiing, snowboarding), inappropriate vehicle design (ATV), speed (mountain biking, ATV), training technique (rock climbing), vehicle design (ATV) and weather conditions (skiing, snowboarding). In rodeo, for example, not using a helmet is an independent predictor of TBI (Odds ratio, 2.5; 95% CI, 1.1–6.3) in paediatric patients who experienced an equestrian- or rodeo-related injury (i.e. horse, bull, sheep or calf) (Short, Fenn, Scaife, & Bucher, 2017).

### *Inciting events*

Although risk factors may render the sport participant more susceptible to injury, they are not usually sufficient for an injury to occur. An inciting event is more obviously (or visually) related to the injury than a risk factor and may be viewed as a precipitating factor associated with the definitive onset of injury (Meeuwisse, 1994). In AES, inciting events are varied but often tend to stem from a fall. In skateboarding, for example, most injuries follow a loss of balance, failed trick attempt or an abrupt stop of the skateboard by an irregularity on the ride surface, projecting the skateboarder in the direction of travel (Feletti & Brymer, 2018). Examples of other inciting events include collision with stationary objects such as trees, contact with or others in the environment (e.g. people, animals), vehicle rollovers (ATV) and rapid ascent and out-of-air (during scuba diving).

### *Injury prevention*

Once the analytical evidence points to an association between certain risk factors and injury, thereby establishing a degree of predictability for those participants who are likely to sustain injury, the next step in epidemiologic research is to seek ways to prevent or reduce the occurrence of such injury. Testing the suggested preventive measure to determine its effectiveness is an important aspect of the analytical epidemiologic process and fulfils the ultimate goal of epidemiology – that is, prevention.

Our thematic issue concludes with Emery's evidence-informed overview on what is known about injury prevention strategies which have been evaluated in youth AES. While there is an increasing body of scientific evidence to inform risk factors for paediatric and adolescent injury in AES, there is a gap in the literature with respect to evaluation of injury prevention strategies in these sports (Emery, 2018).

The results of recent investigations of youth sports injury prevention strategies have been encouraging and may serve to inform injury prevention in AES (Emery et al., 2016). For example, there is rigorous scientific evidence for the effectiveness of the use of protective equipment such as helmets in the reduction of injury in youth sport, including skiing and snowboarding (Emery et al., 2016). In addition to skiing and snowboarding, for example, the use of helmets in youth AES is pertinent to ATV, aquatic adventure sports, motocross, mountain biking, motocross, rodeo and skateboarding (Emery, 2018).

## Further research

While valuable insights into paediatric and adolescent injury in AES have been gained, efforts to present an epidemiological picture of injury in AES have been constrained due to the limited scope of relevant research literature. Given the life-changing impact injury can have in sports, the current paucity of well-designed epidemiological studies specifically targeting paediatric and adolescent injury in AES is troubling, especially given the relatively high frequency of injury, including catastrophic injury, in many of these sports.

Further research specifically targeting children and adolescents, and using more rigorous study designs, is required to develop a clear perspective of the incidence and distribution of injury, and to further identify risk factors and viable injury countermeasures. In these regards, the importance of denominator-based longitudinal data collection cannot be over-emphasized. Research looking into injury of competitive AES athletes in and out of competition would be a welcome addition to the landscape of information in AES.

In closing, we feel that there is an ethical imperative for AES governing bodies, both nationally and internationally, to provide incentive and guidance for epidemiological research on paediatric and adolescent injury in AES. It is also essential for these organizations to provide follow-up evaluation of the efficacy and cost-effectiveness of such programs.

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# Children and extreme sports: a parent's perspective

Omer Mei-Dan

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EDITORIAL



# Children and extreme sports: a parent's perspective

Adventure and extreme sports (AES) have gained enormous popularity over the past two decades and are now performed not only by adventurous elite athletes, including youth, but are very common amongst weekend warriors and relatively inexperienced active individuals. Social media tools and global spread of the World Wide Web, connecting people at real time, 24/7, without geographical, age or time-zone boundaries have resulted in an ever-growing inspiration and motivation for, especially, young generations to participate in AES. This, alongside dedicated media outlets (with their financial interest), fuelled by impressive film footage of breath-taking stunts, has created a young generation that is up for the game. The "bring it up, step it up" generation is like nothing before, willing to go higher, faster, stronger, with 10 camera angles and live feed.

AES, by definition, involve an element of increased risk and are usually performed in beautiful, exciting and remote locations or in extreme environments, where timely and experienced medical assistance is not always readily available. A wide variety of sport and recreational activities fall into the category of the ever-expanding AES field. New disciplines are invented and developed regularly, thanks to a rapidly evolving creative and financially stronger industry, improved technology and the fast-paced idea-to-market era we live in.

The American Ninja Warrior and X-games cultures are also helping to navigate teens' energy and spare time into healthier and confidence-building lifestyles, which open new doors and opportunities. Football and basketball are considered All-American sport outlets, which carry the opportunity for college education and a better life. Today's young extreme sports heroes jump straight into the centre of the media stage, inspiring and building up huge fan bases, attracting sponsors and generating economic benefits. In the past, a landlocked individual had to follow where the swell and the remote reef breaks led them to learn and improve their surfing skills, requiring significant financial capacity and time. In the near future, by contrast, wave pools and indoor ski domes may be the place where new champions are born, similar to what has happened in the rock-climbing world. During the last 20 years, adolescents have become the best climbers in the world, developing their skills in the indoor climbing gym during years of dedicated practice. Making these sports accessible to the crowds, eliminating the financial barrier, geographical proximity and culture or the "second-generation" factor are all changing the way young adventure superstar athletes are born.

Unfortunately, as more and more children and adolescents are enjoying AES, increased numbers are becoming injured as a result. Social media postings and readily available footage of extreme sports events frequently show spectacular crashes and near misses but rarely show the actual injuries or fatalities. This may generate a false confidence in some young athletes who, at times, may lack a realistic understanding of the implications associated with these pursuits as well as dedication to mastering the skills required to perform them safely and consistently.

Epidemiological research is progressing alongside the sports' development to create a better understanding of the distribution and determinants of AES injury. However, this research is still at its infancy, considering that youth participation in some AES is relatively new. We all hope to make these sports safer for young athletes without detracting from their adventurous nature. The risks involved in AES and the way youth handle those risks help to develop their character and confidence and is one of the main reasons they are attracted to them.

Injury epidemiology of many traditional sports is being increasingly understood, with national surveillance databases, injury-reporting programmes and evidence-based countermeasures implemented to prevent injuries. In traditional sports, the mechanism of many injuries has been established, and when sustained, young athletes tend to follow a management algorithm featuring non-operative care or surgical intervention and rehabilitation before returning to play. By comparison, the epidemiology of AES injury is far less researched and understood, which makes the diagnosis, treatment and rehabilitation more challenging for the healthcare provider, the athlete and his/her family.

It has been shown that many adult extreme sports athletes self-select for their sport (Monasterio et al., 2016; Monasterio, Mulder, Frampton, & Mei-Dan, 2012). They are more capable of responding appropriately in an adverse situation and do not perceive the situation as dangerous compared to the perception of the non-participating population. This may be slightly different with adolescent athletes where accessibility to a type of sport, or family direction, may play a stronger role in the activity performed. We should be open and sensitive to how children respond to the hours of training and the stress of competition and make sure they are participating because they truly enjoy it and see the yield rather than fulfilling their parents' will. This is even more relevant in AES when suboptimal "fit" can result not only in the athlete's being sidelined by the coach or by self-confidence challenges or by lack of joy, but also as a result of significant injury.

As a lifelong extreme sports athlete, a father of three active children (Figure 1) and an orthopaedic sports medicine surgeon, I carry an inherent passion for the topic and a well-established personal approach regarding child and adolescent involvement in AES. Participation in AES is a way of life in our family, with all the implications and consequences associated with it, both good and bad. My wife and I have learned to live in acceptance, have embraced and have become accustomed to the physical price that is associated with the love for these sports. It is a different thing altogether when this price is borne by your children. We try to raise them without inhibitions or limits to their sports pursuits, but as every parent, this does not come easily. Sharing with my 10-year-old son the love for backcountry skiing, multi-pitch climbing or downhill mountain biking is a huge privilege that results in pure happiness, but also comes with a valid share of concerns. Following him as he rides quickly down a steep rocky mountain bike trail, for example, is scarier for me than jumping off a cliff with a parachute. Understanding the risk involved, from all aspects, how fragile the human body is and how fast things can flip flop on you with the slightest mistake is not an easy thought to consider. However, as parents we eventually need to let go and trust that we provided our children with the appropriate protection, tools and ability to make the right


**Figure 1.** Three active kids, plenty to be worried about, lots of joy. Image © Dr Omer Mei-Dan. Reproduced with permission.

A – Airborne, Vail's terrain park, age 9.
B – Ready for cruising down the slopes, age 3.
C – Surfing Hawaii, age 6.
D – Scuba with dolphins, Red-Sea, age 10.
E – Ski racing in Vail, age 11.
F – Dropping in, Whistler bike park B.C, age 9.
G – Downhill MBK in Crested Butte Co, age 9.
H – Climbing the 1000 ft route up the 1st Flatiron, Boulder Co, age 6.
F – Ice climbing Vail falls, age 10.

decision, even if this relates to a split second call on how to avoid an avalanche in the backcountry. The grin on their faces is worth it, even if occasionally it comes with a few scratches and bruises.

Dennis Caine and Aaron Provance assembled a comprehensive theme issue on the epidemiology of youth injury in AES in a very unique cohort – children and adolescents – that is rarely studied or discussed. Each article is authored or co-authored by an expert in paediatric and adolescent sports medicine, including many who themselves are actively involved in AES. The public health model is used by the authors to describe the scope of the injury problem and associated risk factors in a variety of popular child and adolescent AES and to evaluate the research on sport-specific injury prevention strategies. This special issue delivers valuable information to healthcare providers treating or interested in better understanding the young AES athlete and their parents.

## Disclosure statement

No potential conflict of interest was reported by the author.

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