

Single Sport Specialization in the Skeletally Immature Athlete: Current Concepts

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Abstract

Youth sport participation patterns have drastically changed over the past two decades. Increasingly, young individuals are specializing in single sport while skeletally immature. Sport specialization in the growing athlete has profound effects on performance, short- and long-term injury risks, and joint health. Evidence continues to mount as the detrimental effects of this trend on the immature athlete. The knee, shoulder, and elbow of these young athletes are particularly affected by this emphasis on skill-based sporting activity as opposed to generalized fitness and participation. An understanding of the epidemiology of sport participation, particularly financial impacts, and the effects on elite sport performance are critical so that the clinician can effectively educate athletes, parents, and coaches.

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The culture of youth sport participation continues to change in the United States. A shift in athletic participation from unstructured free play/school-based activity has shifted to structured, skill-based/private club-driven activity. Concurrent with the increase in skill-based, structured sport has been an increase in the both injury risk and sports dropout. The purpose of this review will be to understand the implications of sport specialization in the skeletally immature athlete.

Background and Epidemiology

The location and structure of youth sport participation has dramatically shifted over the past 20 years. An increasing number of youth are specializing in a single sport, with published specialization rates among high school athletes from the past 10 years of 22% to 48%.^{1,2} A three-point system has been devised to

define low, moderate, and highly specialized athletes; athletes who are highly specialized are defined as participating in a single sport at the exclusion of other sport for more than 8 months per year.³ Concurrent with this shift in participation has been a tremendous increase in injury risk. Post et al⁴ examined injury data of high school athletes and demonstrated that club athletes and highly specialized athletes had more overuse injuries. In fact, athletes who participate in more hours of sport per week than their age in years (odds ratio 2.07) or whose ratio of organized sport to free play time was >2:1 hr/wk (odds ratio 1.87) have been shown to have an increased odd of serious overuse injury (requiring at least one month off from sports).³ This does not take into account the number of children who may simply drop out of participation because of burnout due to lack of enjoyment from intensive training regimens.

Although this change in participation patterns is multifactorial, it cannot be disputed that financial considerations play a major role in affecting participation profile. Youth sport represents a multibillion-dollar industry associated with notable costs to families. This background of spending is weighed against the perceived financial gain of parents, families, and coaches who may believe of the increased chance of collegiate scholarship, collegiate entrance, or professional success via sport specialization. However, the National Collegiate Athletic Association (NCAA) data demonstrate the difficulty in professional success (less than 2% of all NCAA athletes) and collegiate scholarship attainment in general (approximately 2% of all high school athletes).⁵ High cost has also created an economic barrier for many families to participate. According to the Aspen Institute in 2017, only 34.1% of children between the ages of 6 to 12 in families who make under \$25,000 per year will participate in team sport, whereas those with incomes \$100,000 per year had 69.0% participation rate.⁶ The implications of socioeconomic status were borne out in a recent analysis which demonstrated that the NCAA basketball scholarships are more likely to be obtained by individuals who are of a higher socioeconomic status than the average student and less likely to be given to a first generation college student.⁷

Given these trends, this article aims to provide clinicians with a summary of the knowledge to date regarding the impact of sport specialization on clinical, psychological, and performance outcomes in youth athletes.

Knee

The knee remains one of the most common sites for overuse injuries among youth athletes.

In two retrospective survey studies of youth athletes by the same study

group, a high degree of sport specialization and increased weekly hours of sport participation were correlated with a history of injury. In addition, knee overuse injuries in particular were more common in highly specialized athletes.^{1,4} The incidence of anterior knee pain disorders has also been correlated with single sport specialization in youth female soccer, basketball, and volleyball players.⁸ Furthermore, in a large case-control study comparing injured youth athletes from a sport clinic to uninjured youth athletes from primary care offices, sport-specialized training was found to be an independent risk factor for serious overuse injuries, with the knee being the most common site for injury.³ Although the above studies identify a link between sport specialization and overuse knee injuries, no causality can be determined because of their retrospective nature. There is a single prospective study of youth sport specialization and injury in which 1,544 high school athletes enrolled and were followed for one year of sports participation.⁹ Those classified as highly specialized on enrollment (based on the three-point system noted above) were 50% more likely to sustain a lower extremity injury during that year; knee injuries represented a quarter of all injuries between groups. In a subanalysis, no difference existed in acute lower extremity injuries between groups, but there was a stepwise increase in nonacute lower extremity injury incidence from low to moderate to highly specialized athletes. Taken together, the above studies suggest that a high degree of sport specialization and increased training volumes are associated with increased lower extremity and knee overuse injuries among youth athletes.

Acute injuries to the knee such as anterior cruciate ligament rupture have less robust evidence linking

injury to specialization, although some authors have implicated the increase in sport specialization as a potential contributor to the contemporary increase in anterior cruciate ligament injury among youth athletes.^{10,11} One possible explanation is that neuromuscular control pathways differ between single sport and multisport athletes. A study of 735 preadolescent boys in Belgium demonstrated that in boys aged 10 to 12 years, there was a positive correlation between sport sampling and gross motor coordination, in addition to strength, speed, and endurance.¹² DiStefano et al¹³ administered a jump-landing task test to over 350 youth athletes aged 8 to 14 years and found that multiple sport athletes were 2.5 times as likely to have good control during landing compared with single sport athletes. In a cohort study of specialized female soccer, volleyball, and basketball athletes compared with nonspecialized athletes, DiCesare et al¹⁴ demonstrated increased variability in hip and knee angular parameters during a drop-vertical-jump task among single sport athletes. The authors postulated that abnormal landing mechanics in single sport athletes may increase contact forces, diminish force-absorption strategies, and overall contribute to increased injury risk. In summary, many studies support the postulate that sport diversification may be injury protective by improving coordination and biomechanics during high-risk tasks such as jumping and landing in youth athletes (Table 1).

Elbow

Elbow injuries are the most common injuries for youth baseball pitchers with most of these injuries caused by overuse.¹⁵ Elbow injury rates have been reported at 0.86 per 10,000 athlete exposures,¹⁵ leading to a high

frequency of adolescent elbow injuries given the prevalence of youth baseball participation. Over 5 million children younger than eighth grade play organized baseball. Rates of young players reporting elbow pain during the season have been reported as greater than 50%.¹⁶ Structures at risk for injury in the elbow include the articular cartilage, ligaments, tendons, and the physes in the growing elbow.

The medial epicondyle serves as the origin of the flexor-pronator mass and ulnar collateral ligament. During the late cocking and acceleration phases of the throwing cycle, there is extreme tensile force at the medial aspect of the elbow, placing structures such as the medial epicondyle apophyses and ulnar collateral ligament at risk for injury. In skeletally mature throwing athletes, overuse injuries at the elbow include flexor-pronator tendinitis, apophysitis, and less commonly ulnar collateral ligament injuries. Known as little leaguer's elbow, the medial epicondylar apophyses may be injured with repetitive activity in the skeletally immature athlete. Owing to a varus moment at the elbow along with extension, patients may also develop posteromedial impingement and olecranon osteophyte formation, a rare development in children. Patients with an injury to the medial epicondyle or ulnar collateral ligament may present with an acute pop or sudden onset of pain with a single pitch. Alternatively, patients will commonly describe progressive and more vague elbow pain that is throwing-related and worsening over time. Patients may also note difficulty with pitch accuracy and declining pitch velocity.

There is also a high compressive force at the lateral aspect of the elbow during throwing, placing the articular cartilage of the capitellum and radial head at risk for injury. The lateral elbow also sees 60% of the applied load with the arm extended

as in gymnastics, predisposing these athletes to laterally-sided cartilage injury.¹⁷ Owing to the limited blood supply at the capitellum, the articular cartilage may be especially prone to breakdown with repetitive activity.¹⁸ Patients with articular cartilage injury describe aching pain, stiffness, and possible mechanical symptoms at the elbow.

Elevated pitch counts and more frequent pitching have been consistently linked to an increased risk of serious elbow injury.¹⁹ Fleisig et al¹⁹ reported that players who threw greater than 100 innings per year had a greater than threefold risk of serious injury relative to players who threw less frequently. In addition, the authors report that pitchers had a 5% overall risk of serious elbow injury during this 10-year prospective study. Importantly, catchers have a similar rate of elbow soreness as pitchers.¹⁹ Participation with multiple teams and year-around throwing have both been linked to an increase in injury risk.²⁰

Multiple organizations have established pitch count guidelines and recommendations for maximum number of games pitched per week. Major League Baseball and a multidisciplinary group of health professionals have developed Pitch Smart to provide age-based recommendations on pitch limits and rest between pitching (Table 2).²¹ Fatigue also contributes to injury risk, and players should be encouraged to not continue throwing when fatigued.²² In addition to overhead throwing athletes, the elbow is at risk for injury, and especially overuse injury, in athletes participating in gymnastics, racquet sport, and other throwing sport such as shotput.²³ Although similar guidelines are not as established for other sport, the concepts may be extrapolated to hopefully decrease overuse injury in gymnastics, racquet sport, shotput, javelin, and other sports that place stress on the elbow.

Limiting activity when soreness is present, allowing for appropriate rest between athletic exposures, and ensuring periods of the year where athletes rest or play other sports should all be encouraged to hopefully minimize the risk of overuse injury to the elbow. Importantly, the throwing mechanics of young athletes are more variable than older throwers, which may contribute to higher potential for overuse injury.²⁴ Following these pitch count guidelines may allow for a reduction in overuse injury. Unfortunately, however, other studies have demonstrated that less than half of coaches can demonstrate familiarity with pitch count recommendations and more than 25% of coaches may not follow them.²⁵ Further work is needed to emphasize the importance of pitch counts in limiting risk of serious injury in young athletes.

Shoulder

Much of the same literature that has been used in little league to decrease elbow injuries has also been used for shoulder injuries. Two characteristic findings have been shown to occur in youth throwers—Little Leaguer's Shoulder (LLS) and increased humeral retroversion. LLS is a diagnosis that includes shoulder pain at the proximal shoulder and widening of the proximal humeral epiphysis or epiphysiolysis. Although the diagnosis of LLS can be made clinically, it is usually confirmed with radiographic imaging.

It is theorized that too many pitches thrown before skeletal maturity may result in anatomic changes including increased humeral retroversion. Sabin et al²⁶ evaluated 14 elite youth baseball pitchers with a mean age of 12 years. The authors demonstrated that the amount of shear stress arising from the high torque late in the arm-cocking phase was large

Table 1**Sport Specialization and Lower Extremity Injury Risk Studies^{3-5,8,18,19}**

Study	Design	Data Collection	Size (n); Patient Population	Findings
Prevalence of sport specialization in high school athletics: A 1-year observational study. ³	Cross-sectional study; LOE 3	Survey	302; high school athletes	High specialization correlated to overuse knee injuries Playing 1 sport > 8 mo/yr more likely to report knee injuries (OR 2.3), overuse knee injuries (OR 2.9), hip injuries (OR 2.7)
Specialization patterns across various youth sports and relationship to injury risk. ⁴	Case-control study; LOE 3	Survey; electronic medical record data collection	1,190; injured and healthy athletes aged 7-18	Individual sport athletes playing single sport more likely to have overuse (OR 1.7) and serious overuse injuries (OR 2.4) than team sport athletes playing single sport
The association of sport specialization and training volume with injury history in youth athletes. ⁸	Case-control study; LOE 3	Survey	2011; youth athletes age 12-18	Athletes with high level of specialization more likely to have any injury (OR 1.6) and overuse injury (OR 1.4) in past year Playing >8 mo per year = more LE overuse injury (OR 1.7) Playing more hr/wk than age = increase injury rate (OR 1.3)
Sport-specialized intensive training and the risk of injury in young athletes: A clinical case-control study. ⁵	Case-control study; LOE 3	Survey; electronic medical record data collection	1,190; injured and healthy athletes age 7-18	Injured athletes older, played more hr/wk Sport specialized training independent risk factor for injury (OR 1.3) and serious overuse injury (OR 1.4), controlling for age, hr/wk Youth athletes playing more hr/wk than age in years, had increased odds of serious overuse injury (OR 2.1)
Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. ¹⁸	Retrospective cohort study; LOE 3	Clinical history and examination; survey	546; female middle and high school basketball, soccer, volleyball players	Single sport specialization increases RR of patellofemoral pain 1.5-fold 4-fold increase in Osgood Schlatter and patellar tendinopathy in single sport athletes
A prospective study on the effect of sport specialization on lower extremity injury rates in high school athletes. ¹⁹	Cohort study; LOE 2	Survey; prospective injury/exposure data collection	1,544; high school male and female athletes	Increased incidence in lower extremity injuries in high (HR 1.58) and moderately (HR 1.51) specialized athletes than low specialization athletes

HR = hazard ratio, LOE = level of evidence, OR = odds ratio

enough to lead to chronic deformation of the proximal humeral epiphyseal cartilage, resulting in either humeral retroversion or proximal humeral epiphysiolysis over time. Hibberd et al²⁷ found that increased humeral retrorsion accounted for an age-related increase in glenohumeral internal rotation deficit in over 200 youth and high school pitchers. A recent study also demonstrated that

MRI changes of the shoulder were most likely associated with year-around play, single sports participation, and all-star team selection.²⁸ These studies and others suggest that since the biomechanical factors are non-modifiable with throwing, the primary way to limit is with pitch counts and year-around pitching.

In the most comprehensive recent analysis of Little Leaguer's Shoulder,

Heyworth et al²⁹ investigated the etiology, natural history, and associated factors with Little Leaguer's Shoulder. The authors investigated 95 athletes with LLS with an average age of 13.1 years, and they found that over the course of the study, the incidence increased annually. Most athletes were pitchers, but 8% were catchers. On examination, 30% had glenohumeral internal rotation deficit, which was the

Table 2**Major League Baseball Pitch Smart Guidelines³³**

Age	Daily Max (Pitches/Game)	0 Days Rest	1 Days Rest	2 Days Rest	3 Days Rest	4 Days Rest	5 Days Rest
<8 yr	50	1-20	21-35	36-50	N/A	N/A	N/A
9-12 yr	9-10: 75 11-12: 85	1-20	21-35	36-50	51-65	66+	N/A
13-14 yr	95	1-20	21-35	36-50	51-65	66+	N/A
15-18 yr	15-16: 95 17-18: 105	1-30	31-45	46-60	15-16: 61-75 17-18: 61-80	15-16: 76+ 17-18: 81+	N/A
19-22 yr	120	1-30	31-45	46-60	61-80	81-105	106+

N/A = not applicable

primary physical examination finding. Importantly, 13% of these athletes had concomitant elbow pain as well. This is critically important because it seems that alterations in the kinetic chain with increased shoulder pain and loss of internal rotation may also increase elbow forces and risk for elbow injury. In support of this theory, Wilk et al³⁰ found that loss of internal rotation increased the risk of pain and elbow injury.

The treatment of LLS and shoulder pain in the youth thrower is uniformly active rest. In the study by Heyworth et al, 99% of athletes were treated with rest. Approximately 80% of athletes were treated with physical therapy. The outcomes in this study and others were uniformly good and encouraging. The average time to full resolution of symptoms was only 2.6 months, whereas average time to return to competition was 4.2 months. However, 26% of athletes required a position change to return. Earlier cessation of throwing at the onset of shoulder pain correlated to better outcomes. Although the treatment of these athletes is successful, it is often a challenge to get compliance from athletes, coaches, and parents.

Sex and Specialization

Both girls and boys youth sport participation has steadily increased over the past 30 years. A number of studies

have examined differences between the sex regarding the rate of sport specialization. In an observational study of high school athletes, Bell et al found that a greater proportion of female athletes were classified as single sport athletes (34% versus 22%), although rates of low, moderate, and high specialization were similar between genders.¹ In a larger study of over 1,500 high school athletes of whom half were girls, high competition volume, club participation, and high sport specialization were all more common among female athletes.³¹ The trend toward sport specialization in female athletes may, in part, be explained by sport played by male versus female athletes. For example, baseball and football, predominated by boys, have lower rates of specialization.² This is supported by a study of collegiate athletes which found no difference in specialization rates for sex-equivalent sport between the genders.³²

In the literature, rates of overuse injury among female youth athletes have been reported to be higher than in male athletes. Higher rates of sport specialization may be a contributing factor. As previously discussed, anterior knee pain was found to be more common among single sport adolescent female athletes than multisport athletes.⁸ In a retrospective study of specialization and injury among high school athletes, girls were more both

more likely to be highly specialized and also more likely to report a previous lower extremity injury, even when corrected for sex-equivalent sports.³¹ Post et al specifically examined the impact of sex and specialization in youth basketball, soccer, and volleyball players aged 12 to 18 years and found that specialization predicted overuse injury among volleyball players, but female sex predicted overuse injury among basketball players. In summary, female athletes are more likely to be highly specialized, and this correlates with higher rates of overuse injury; sport played likely modulates this effect. Further study is needed to determine how sex and skeletal maturity interact regarding injury risk in this cohort.

Burnout

Burnout has been widely discussed but sparsely studied contemporarily regarding youth sport specialization. Athletic burnout can be defined as “a cognitive-affective syndrome comprising emotional and physical exhaustion, a reduced sense of accomplishment, and sport devaluation.”³³ Gustafsson et al³⁴ described patterns of psychological stress and burnout among highly competitive youth athletes in Scandinavia and found that fear of failure and perfectionism were linked to higher levels of burnout. Other factors which

have been associated with burnout among athletes are overtraining and participation in an individual sport.³⁵ A recent meta-analysis compiling data from eight studies which involved administration of the Athlete Burnout Questionnaire to adolescent athletes found that specialized athletes were more likely to be burnt out than sport samplers.³⁶ Of note, most of the literature includes adolescent rather than prepubescent athletes, highlighting an area for future study.

Effects on Future Performance

Although there are a notable amount of data which has connected the risk of sport specialization with injury risk and sport dropout, there has been limited examination of the implications on athletic performance. There is a misconception that even with injury risk, sport specialization is necessary to achieve athletic success, particularly in team sports.

Buckley et al³⁷ reviewed 3,090 athletes (high school, college, and professional). The age of specialization was found to be markedly lower for high school athletes (12.7 ± 2.4 years) versus collegiate (14.8 ± 2.5 years) and professional (14.1 ± 2.8 years) athletes. Of professional athletes surveyed, 61.7% indicated that they believed specialization helped them play at a higher level, but only 22.3% would want their own child to specialize.

When looking further at elite sport data, single sport specialization does not again seem to be a prerequisite for achievement, and in fact may be detrimental. In a study of 237 National Basketball Association first round draft picks over 7 years, Rugg et al³⁸ found that those who participated in multiple sport in high school played a greater percentage of total games, were less likely to sustain a major injury during their career, and had

increased longevity in the league. In MLB, Confino et al³⁹ examined 746 athletes and found that single sport athletes played in less games and had a higher prevalence of upper extremity injuries, particularly shoulder and elbow injuries. Wilhelm et al⁴⁰ also found in their cohort of current professional baseball players that those who specialized early reported more serious injuries than those that did not. In addition, 63.4% of players did not believe that specialization is required to play professional baseball. These studies demonstrate that sports specialization is both not necessary for elite athletic performance and in fact is associated with negative impacts on success as measured by injury risk at the elite level.

Summary

The landscape of youth sport has changed dramatically in recent years, with a movement toward skills-based, structured activity. The increase in sport specialization among skeletally immature athletes has implications for both the physical and emotional well-being of children. Injury prevention efforts should focus on the knee, shoulder, and elbow; sport, and sex modulate overuse injury risk for these anatomic areas. Psychological burnout is a challenging topic to study in children but should be a focus moving forward to improve the youth athletic experience.

References

Levels of evidence are described in the table of contents. In this article, references 9, 28, and 30 are level II studies. References 1-4, 8, 12-14, 19, 20, 22, 24, 25, 27, 31, and 37 are level III studies. References 10, 11, 15-18, 26, 29, 32-36, and 38-40 are level IV report or expert opinion. Reference 23 is level V report or expert opinion.

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