

The Association of Single Sport Specialization and Overuse Injury in Youth

Athletics

By

Danny Taylor, PA-S, MEd, LAT, ATC

A Capstone Paper submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Health Sciences in the Physician Assistant Program

Chapel Hill

December 2017

[Redacted]

Name and title of First Reader

11/16/17

Date

[Redacted]

Name and title of Second Reader

11/16/2017

Date

BACKGROUND

Youth sports in today's society has come to represent a microcosm of the highly visible and overtly publicized professional world of sports. Children and adolescents are inundated by an unprecedented and ubiquitous sociocultural saturation not experienced by previous generations; from the most recent current global news events trending on our Twitter feeds to the latest player to sign a \$200 million professional sports contract. While the former is newsworthy, the latter is what often catches the eyes of not only kids, but their parents, coaches, and other individuals that are involved with different athletic programs at the youth level. There is an evolving perception that if kids are put into the right situations at an early age, identifying a niche and "specializing" in a sport, they can advance and develop a skill set that will allow them to obtain higher social status, possibly receive college athletic scholarships, and even become professional athletes with high earning potential. This perception is not a geographically isolated concept. In China, there are over 3000 government-affiliated sports-based schools¹, of which there are approximately 100 boarding schools dedicated to allowing children ages 5-16 years old to work and develop sport-specific athletic skills in hopes of being selected to train at Olympic training facilities. The amount of pressure being placed on young athletes is certainly high, and has a large impact physically and mentally.

What is Sports Specialization?

There have been varying definitions of sport specialization in the literature. There are often discrepancies about level of intensity (practice versus competition) and volume of activity, as well as timeline and duration (hours per week or months per year). One clinical

review² discusses Cote's description of "deliberate practice" versus "deliberate play" in the framework of characterizing intensive training, with the former having a goal of improving performance and the latter with a goal of simply having fun. However, sports specialization is best defined as participation in intensive training and/or competition in a single sport at the exclusion of all others, often year-round, but at least 8 months of the year³. Jayanthi et al⁴ further sub-categorize the classification of specialization into low, moderate, or highly specialized based on a 3-point scale by providing answers to the following questions: "Can you pick a main sport?" (single sport – 1 point), "Did you quit other sports to focus on a main sport?" (exclusion of other sports – 1 point), and "Do you train > 8 months in a year?" (year-round training – 1 point). Low specialization is determined by a score of 0 or 1, moderate by a score of 2, and high by a score of 3. It can become even more refined, with early specialization occurring before puberty (7th grade or roughly 12 years old) and late specialization occurring after puberty^{3,5}.

The hopes of parents, coaches and other stakeholders of athletes capturing, excelling and capitalizing on the rare but lucrative opportunities such as athletic scholarships or professional recognition has provided the impetus behind single sport specialization and its ongoing prominence. Of all those that participate in high school sports, few go on to play their sport at the National Collegiate Athletic Association (NCAA) level. Of the 3-11% that do advance and play in college, only 1% of those will be offered a scholarship³. Taking it further still, a scarce 0.2-0.5% of high school athletes will make it to the professional ranks⁶. This would lead one to believe that while these goals are achievable for a select few, they are far more the exception rather than the rule. Evidence in the literature has been scarce as well, and has

shown that early sport specialization may or may not be necessary to achieve success and high skill level⁷. Additionally, the question has been asked, is single sport specialization safe for the young athlete?

PATHOPHYSIOLOGY

Overuse injuries can be defined as injuries that occur when repeated mechanical loads are placed on tissues that exceed the capability of those tissues to remodel over a period of time⁸. The child and adolescent athlete is much different from the skeletally mature athlete, and is more susceptible to overuse type injuries. Articular and epiphyseal cartilage in children is much more fragile and prone to injury due to a myriad of forces^{1,7-9}, including compressive, shear and traction, which can lead to osteochondrosis. Common locations of injury to the epiphysis include the proximal humerus (little leaguer's shoulder), capitulum (Panner's disease) and the distal radius⁹. During adolescent growth spurts, athletes are at particularly increased risk of apophyseal osteochondrosis due to increased tension of the myotendinous unit at the apophysis in conditions such as Osgood-Schlatter's (tibial tuberosity) and Sever's disease (calcaneus)⁹. During this time adolescents are also at increased risk of fracture due to extensive epiphyseal growth¹, which causes a relative decrease in bone density due to the lack of calcified and mature bone formation at the growing and developing epiphysis. Other intrinsic and extrinsic factors, such as biological versus actual age, anatomical variations, training technique, and training volume and intensity also illustrate how the risk for overuse injury in the child and adolescent athlete is complex and multifactorial.

Single sport specialization brings with it a focus on defined skill sets in which there is opportunity for numerous repetitive movements over time to place stress on tissues and cause tissue breakdown. There is limited data thus far in the literature addressing the impact of single sport specialization on injury rates in youth sports participants. The specific focus of this paper is two-fold. Primarily, this paper will examine the impact of single sport specialization on injury rates, specifically musculoskeletal overuse injuries, in youth sports participants 18 years of age or younger when compared to those who do not specialize in a single sport. Additionally, it will review and discuss the most current evidence based recommendations for and areas of further interest regarding single sport specialization.

EPIDEMIOLOGY

In the 2015-2016 school year, there were approximately 7.9 million participants in high school sports per the High School Athletics Participation Survey, given by the National Federation of State High School Associations¹⁰, which is an increase of 1.2 million from 2000-2001. Considering youth aged 6-18 years, it is estimated that approximately 27 million play organized team sports outside of school, while roughly 60 million engage in at least some kind of organized sports recreationally⁷. The National Council for Youth Sports also reports a 6% increase in children younger than 6 years old participating in recreational sports¹¹. While numbers have increased globally, there is still a significant attrition, with about 70% withdrawing from organized sport by the age of 13³. This dropoff can be attributed to a multitude of factors, including overscheduling, financial burdens, burnout, loss of interest and injury.

In data taken from 2011-2012 school year¹² from 174 American high schools, the overall injury rate for high school athletes was shown to be 1.8 injuries per 1000 athlete exposures, where an athlete exposure represents either a single practice or competition for one participating athlete. Overuse injuries have increased along with increased participation, and an estimated 46-54% of all youth sports injuries^{3,7} are overuse type injuries. This has been shown to vary among sports, with ranges found between 37% in skiing and handball, to 68% in running⁷. The sheer volume of injuries incurred presents a substantial burden on the healthcare system, and can be seen in primary care, pediatric, orthopedic and hospital settings. SAFE Kids reports that 2.6 million children are seen in emergency departments every year for sports and recreational injuries¹³. Being able to implement preventive measures along the continuum of youth sports at all levels to help decrease injury risk would serve to decrease the physical burden on athletes and decrease the financial burden on families and the healthcare system as a whole.

Is specialization needed for success?

While there is a large movement and trend toward single sport specialization in youth athletics, one might ask if there is any benefit from this. Does specializing early, or at all, help achieve elite status in one's sport? The current evidence is suggestive of the contrary. In fact, numerous studies of Olympic level athletes from Germany and Russia have showed that early specialization or adolescent success did not increase odds of achieving elite level or international level status and did not predict senior-level success¹⁴. They also found that international level athletes participated on average in 2 other sports prior to specialization, and

specialized later in adolescence than their near elite counterparts¹⁴. In a study of NCAA Division I athletes¹⁵, 88% of athletes surveyed participated in 2-3 sports during childhood, and 70% of those did not specialize in their sport until after the age of 12. Jayanthi² discusses the transfer of pattern motor skills in high-level basketball, netball, and field hockey players and the less sport-specific work required to achieve expertise when exposed to more diverse activities in the developing years. Smucny¹⁵ references a study of boys aged 10 to 12 years of age that shows better performance on standing broad jump in those participating in multiple versus a single sport.

The exception to the advantages provided by multisport participation seems to be in sports that require high levels of technical skill and where the peak performance is reached before full maturation^{2,14}. Early specialization is noted to be helpful in gymnastics, dance, tennis, and swimming and diving, where these parameters are often seen.

Volume versus specialization: an independent risk factor

Training volume is a key component of the definition of single sport specialization. It is identified as an extrinsic risk factor for overuse injuries^{7,8,16} and, along with prior injury, is the most consistent predictor of overuse injury¹⁷. There are multiple ways that volume can be measured, frequently noting hours or days per week of participation, total practice or competition exposures, or even months of the year participated. While the most recent and comprehensive definition to date of single sport specialization recognizes a rather broad version of volume, participation for greater than 8 months of the year, others have been utilized in the literature. Number of hours per week of intense training, specifically 16 hours¹⁸

is consistently viewed as a marker for increased overuse injury risk. Another hour-based algorithm examined hours per week spent on sport based on age, where participating more hours per week than stated age demonstrated increased risk of serious overuse injury⁴. One recent case-control study of athletes age 12 to 18 showed increased likelihood of reporting history of any injury and overuse injuries of the upper and lower extremity in the previous year when any volume-based parameters (>8 months of the year, >16 hrs/week, >hours than age in years) were exceeded¹⁹.

Single Sport Specialization and Overuse Injury Risk

There is a paucity of literature analyzing the effect of single sport specialization and injury risk in youth athletes. In a 2016 systematic review, Fabricant et al²⁰ looked at youth sport specialization and association with risk of overuse and acute injury. They found significant associations not only between sports specialization and overall patellofemoral pain (OR = 1.5, p = 0.038) and total injury rate (OR = 1.27, p < 0.01), but also with overuse injuries, specifically Osgood-Schlatter disease and patellar tendinopathy (OR = 4.0, p < 0.005). Additionally, serious overuse injuries, classified as those requiring at least 1 month rest from sports and including spondylolysis, osteochondritis dissecans, elbow ligament injuries, stress fractures or physeal reactions, were also significantly associated (OR = 1.36, p < 0.01) with specialization²⁰. Bell et al²¹ surveyed 302 Wisconsin high school students aged 13-18, and those classified as highly specialized by Jayanthi's 3-Point scale^{2,4} were more likely to report history of overuse knee injuries when compared to those in moderate or low specialization groups (P = 0.048). In addition to studying association of sport specialization with injury risk, Pasulka et al²² looked

further at the relationship between team and individual sports specialization on injury risk. 1190 athletes were surveyed to assess level of sport specialization utilizing the 3-point scale, involvement in team or individual sport, and history of injury in their sport over the previous 6 months. Electronic medical records were made available for diagnosis evaluation and classification as acute, overuse, or serious overuse injuries. They found after adjusting for age, gender and weekly sport hours, single-sport-specialized athletes in individual sports proportionately suffered significantly more overuse (44.3% vs 32.2%, OR = 1.67, p = 0.037) and serious overuse (23.4% vs 11.6%, OR = 2.38, p = 0.011) injuries than compared with their team-sport counterparts²². In a study of athletes aged 12-18 participating in organized summer sports and active over the previous 12 months, authors examined the association of single sports specialization with injury history over the previous 12 month period¹⁹. Injury history was grouped regionally (upper and lower extremity and head/neck) and was placed categorically as overuse injury, acute contact injury or acute non-contact injury. Again, using the 3-point scale for specialization and adjusting for age, gender and weekly sport hours, athletes classified as highly specialized were more likely to report history of any injury (OR = 1.59, P < 0.001), overuse injury (OR = 1.45, P < 0.05), and upper extremity overuse injury (OR = 1.91, P < 0.05) when compared to those in the low specialization category¹⁹. Moderately specialized athletes were also more likely to report history of any injury (OR = 1.32, P < 0.05) and overuse injury (OR = 1.39, P < 0.05) when compared to the low specialization group¹⁹. Finally, McGuine et al²³ prospectively analyzed a cohort of over 1500 high school students and the association of sport specialization with the incidence of lower extremity injury (LEI). LEI was defined as any injury occurring to the lower extremity that required evaluation by a certified athletic trainer or

medical provider, occurred during interscholastic practice or competition, and was classified as acute, gradual or recurrent-onset injury. Lacerations, abrasions and contusions were excluded. The overall incidence of LEI was increased in moderate (Cox HR, 1.51 [CI 95%, 1.04-2.20], P = 0.03) and highly (Cox HR, 1.85 [CI 95%, 1.12-3.06], P = 0.02) specialized groups compared to the low specialized group, but the incidence of non-acute LEI was also increased in moderate (Cox HR, 2.61 [CI 95%, 1.34-5.07], P = 0.005) and highly (Cox HR, 4.74 [CI 95%, 2.04-11.05], P < 0.001) specialized groups compared to the low specialized group²³.

DISCUSSION

The role of single sport specialization and musculoskeletal overuse injury risk is multifactorial and complex. Current research in the literature is superficial and suffers from methodological flaws in its design and focus and leaves many unanswered questions regarding its overall effects. One must consider many variables when analyzing these associations. For instance, it has not been until recently that there has been a widely-accepted definition of sport specialization. Within the individual studies and systematic review that were evaluated in this paper, defining specialization varied. Most recent studies utilized a 3-point scale^{4,19,21,22} to classify athletes as low, moderate, or highly specialized. Others assessed specialization based on playing only a single sport²⁴, or by volume (hours per week, number of exposures) or age of specialization²⁵. Even when utilizing the 3-point scale, there is a possibility of exclusion of a subset of athletes who may be highly specialized, but would not be considered so because they have never quit a sport to participate in their primary sport simply due to lack of exposure. This heterogeneity can lead to confusing and inaccurate associations. Additionally, much of the

research to date has been observational in nature, utilizing survey tools and self-report measures. Studies of focus in this paper included case-control, cross-sectional, and cohort studies and often relied on self-report measures^{4,19–22,24,25}. Study design and methodology again contributes to heterogeneity within the sample population. Many of the studies evaluated in this paper produce sample and recall bias based on survey methods and recall of previous injury history as well as previous participation (see Table 1). Ultimately, the nature of the studies also allow only association without causation. While variables such as age, gender and sport hours were often adjusted for, consistent analysis of other potential confounders such as age of specialization, socioeconomic status, athletic setting or sport type would be helpful to elucidate the extent and impact of specialization on injury risk. Further research would also be most beneficial if conducted prospectively.

Risk of injury is inherent in participation in all types of sporting activities. While there seems to be a logical connection between single sport specialization and increasing injury risk, this has not been fully established in the literature. Despite this fact, medical societies and other physician organizations have made best practice recommendations based largely on empirical evidence and concerns over increasing injury rates and an accumulation of epidemiological information. Of major concern is age of specialization. It is known physiologically that adolescent athletes are at higher risk of overuse injury, especially during the adolescent growth spurt, due to changes and imbalances in bone and tendon growth^{1,7–9}. One study of young gymnasts supports this, showing more prevalence of wrist pain in gymnasts between 10 and 14 years of age than groups older and younger²⁶. This is echoed in another study that found pre-pubertal gymnasts in Tanner stages 2 and 3 were more likely to be injured

than in stages 1, 4, or 5². There is little evidence to support increased levels of success in those who specialize at a young age, and it is also thought that early specialization in a single sport can prevent proper motor skill development^{7,14}. This series of findings has led to the recommendation that young athletes diversify their sport participation and delay specialization until late adolescence in sports where peak performance occurs in adulthood^{2,5,7,17}.

Another issue of concern is volume and time spent participating in sports. Increased workload and higher intensity of sport activities are well-known risk factors for injury. Numerous investigations into little league baseball pitchers have shown increased likelihood of time-loss injury with increased number of pitches per game, innings pitched per year and months of the year playing the sport^{7,27}. While there is evidence to support implementation of pitch counts and restrictions on innings pitched, there has not been evidence to date that shows a significant decrease in injury rates or that recommendations already in place have been successful. Thought to contribute significantly to single sport specialization is the abundance of external opportunities for young athletes to play their chosen sport in the form of travel, challenge, and AAU teams. Playing on multiple teams in a single sport may predispose to overscheduling of competitions⁵⁻⁷, which presents issues not only from the standpoint of hours of sport per week but also intensity of participation, as intensity is expected to be higher during competition when compared to practice¹⁸. While participating in multiple sports year-round accrues similar risk, single-sport specialized athletes may be more likely to participate in their sport year-round¹⁸. The NATA Position Statement on Prevention of Pediatric Overuse Injuries¹⁷ recommends limiting the amount of repetitive loads placed on the pediatric athlete and that they participate in no more than 16-20 hours per week of vigorous sport activity. The

American Medical Society for Sports Medicine and the American Orthopaedic Society for Sports Medicine follow suit with similar guidelines, recommending weekly and yearly time limits and volume limits be placed on sport-specific repetitive movement⁷, and that children specializing in a single sport and participating more than 16 hours per week or more hours per week than their age should be monitored for overuse injury⁵. The American Academy of Pediatrics council on Sports Medicine and Fitness varies slightly, recommending 1-2 days off per week from organized, competitive or sport-specific activity, and 2-3 months off during the course of the year^{3,6}.

Foundational movement development is key for success in competitive athletics, and is also paramount in physical fitness and injury prevention. However, while there has been a marked increase in organized athletics as a whole, there has simultaneously been a vast decrease in school based physical education programs, with only 29% of high school students participating in daily PE classes¹⁵. When combined with a generally sedentary lifestyle, this can impact not only cardiovascular and muscular fitness levels, but can leave athletes susceptible to injury. Integrative neuromuscular training (INT) is a combination of general strengthening exercises and movement-specific conditioning activities that has been shown to improve overall fitness and motor skill development¹⁴. It is applied in an age-related manner and can be utilized as part of a normal physical activity regimen or as an adjunct. INT has been shown to provide benefits to all youth athletes, including the single-sport specialized athlete, by reducing injury risk and improving performance¹⁴. The NATA and AOSSM have both endorsed INT and INT-based programming as beneficial to all youth and recommend incorporating it as a preseason or in-season regimen to help reduce the risk of overuse injuries^{5,17}.

The effects and ramifications of single sport specialization are poised to be at the forefront of sports medicine and beyond for the foreseeable future. Organized youth athletics continues to grow, while at the same time the American youth lifestyle continues to be rather sedentary, creating more opportunity for injury. In summary, youth athletes are physiologically at increased risk of injury, specifically overuse injury, when compared to fully developed adults. The fact that overuse injuries alone account for roughly half of all youth sports injuries supports this statement. While the notion that specialization increases the chances of reaching elite status is prevalent, the evidence has been equivocal, and in some instances in opposition to that stance. Even though the majority of literature has been observational in nature, there appears to be a significant association between single sport specialization and increased injury rates, specifically overuse injuries, in youth athletes. In addition, levels of specialization and volume of participation also appear to be very influential in increasing the likelihood of sustaining an overuse injury. This information can be valuable for medical providers and parents and youth athletes alike for use in the prevention of musculoskeletal overuse injuries. Further future research of prospective design, utilizing universal definitions of sport specialization, and including more objective outcome measures is certainly warranted. Focused studies further analyzing aspects of training volume and endpoints for hours per week or weeks per year played could be advantageous in helping delineate more appropriate limitations for preventing injury. Whether recreational or interscholastic, quantifying playing time in competition versus practice could help identify subgroups of individuals within specialized athlete populations that may be at increased overuse injury risk. All of these could

improve our understanding of the effect of single sport specialization on musculoskeletal overuse injuries in youth athletes.

Table 1. Evaluation of Bias

Author (Journal)	Date	Study Type/Level of Evidence	N	Main Measures	Findings	Recall Bias	Selection Bias	Confounding
Jayanthi* et al., (<i>J Med Sci Tennis</i>) ²⁵	2011	Prospective cohort/III	519	Assoc. of practice volume/mth competed/SSS with injury risk/tournament withdrawal due to injury	SSS more likely to report sport-related injury; those with injury in past yr more likely to withdraw	Yes (1 yr) ++	No	Age of specialization, single sport (tennis)
Jayanthi* et al., (<i>Am J Sports Med</i>) ⁴	2015	Case-Control/III	1190	Assoc. of SSS/growth rate w/incr. injury/overuse injury risk	SSS is independent RF for injury/serious overuse injury; growth rate not related to inj. risk	Yes +	Yes +++	Sport type
Hall* et al., (<i>J Sport Rehabil</i>) ²⁴	2015	Retrospective Epi. Cohort/IV	546	Assoc. of SSS with anterior knee pain/PFP in female adolescent athletes	SSS increases risk of overall PFP 1.5x; SJU/PF/OSD 4x as likely in SSS than multisport athletes	No	Yes ++	Sex, team vs individual sport
Bell et al., (<i>Am J Sports Med</i>) ²¹	2016	Cross-sectional/III	302	Prevalence of SSS in high school settings; likelihood of reporting LEI in highly specialized athletes	School size influenced specialization rates; SSS highly spec. athletes more likely to report hx of overuse hip/knee injury	Yes (1 yr) ++	Yes ++	School size, sex
Pasulka et al., (<i>Phys Sportsmed</i>) ²²	2016	Case-Control/III	1190	Analyze relationship b/w SSS sport type (team vs individual) and age of spec./injury risk/training volume	Individual SSS athletes report increased rates of overuse/serious overuse injuries than team SSS athletes	Yes ++	Yes +++	Sport type
Post et al., (<i>Am J Sports Med</i>) ¹⁹	2017	Case-Control/III	2011	Assoc. of SSS w/injury hx; assoc. b/w sport volume and injury hx	Highly specialized athletes more likely to report any injury hx; > 8mth/yr participation more likely to have overuse injury hx; > hrs than age more likely to report any injury hx	Yes (1 yr) ++	Yes ++	Age of specialization
McGuire et al., (<i>Am J Sports Med</i>) ²³	2017	Prospective Cohort/II	1544	Assoc. of SSS w/incidence of LEI in high school athletes	Moderate and Highly specialized athletes more likely to have LEI/non-acute LE than low specialized athletes	Yes (1 yr) ++	Yes +	Sports spec. Classification

SSS – Single sport specialization; RF – risk factor; PFP – patellofemoral pain; SJU – Sinding Larsen Johanssen; PT – patellar tendinopathy; OSD – Osgood Schlatter Disease; LEI – lower extremity injury; For recall and selection bias: + mild, ++ moderate, +++ high

*Individual studies from systematic review by Fabricant et al., *Phys Sportsmed*, 2016²⁰

Appendix A: Methods

Data Sources: PubMed, Cochrane Database of Systematic Reviews, and the TRIP medical database were queried using search terms sports specialization, youth sport specialization, overuse injury, pediatric overuse injury, youth sport specialization and injury, youth sport specialization and overuse injury, sports specialization and overuse injury, sport specialization and pediatric overuse injury, youth sports and epidemiology, and overuse and youth injury and specialization. Included in the search were systematic reviews, randomized controlled trials, case reports, cohorts and clinical reviews. Search dates were from January 2000 – Dec 2017. Additional resources were sought from the citation lists of the articles found in the original search. All studies were evaluated for individual quality using the STROBE Statement checklist²⁸ and Strength of Recommendation Taxonomy (SORT) criteria were used to evaluate the summary of the literature²⁹.

Appendix B: Results:

STROBE Checklist scores (in descending order beginning with most recent): 18, 21, 19, 17, 17, 13, 11 (maximum of 22 points)

Strength of Recommendation Taxonomy (SORT)²⁹

A: consistent, good-quality, patient oriented evidence

B: inconsistent or limited-quality patient-oriented evidence

C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

The strength of recommendation grade pertaining to single sport specialization and increased musculoskeletal overuse injury rates in youth sports participants is SORT grade **B**: based on inconsistent or limited quality patient-oriented evidence.

Bibliography

1. Caine D, Maffulli N, Caine C. Epidemiology of injury in child and adolescent sports: injury rates, risk factors, and prevention. *Clin Sports Med* 2008;27(1):19-50, vii. doi:10.1016/j.csm.2007.10.008.
2. Jayanthi N, Pinkham C, Dugas L, Patrick B, Labella C. Sports specialization in young athletes: evidence-based recommendations. *Sports Health* 2013;5(3):251-257. doi:10.1177/1941738112464626.
3. Brenner JS, COUNCIL ON SPORTS MEDICINE AND FITNESS. Sports specialization and intensive training in young athletes. *Pediatrics* 2016;138(3). doi:10.1542/peds.2016-2148.
4. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. *Am J Sports Med* 2015;43(4):794-801. doi:10.1177/0363546514567298.
5. LaPrade RF, Agel J, Baker J, et al. AOSSM early sport specialization consensus statement. *Orthop J Sports Med* 2016;4(4):2325967116644241. doi:10.1177/2325967116644241.
6. Brenner JS, American Academy of Pediatrics Council on Sports Medicine and Fitness. Overuse injuries, overtraining, and burnout in child and adolescent athletes. *Pediatrics* 2007;119(6):1242-1245. doi:10.1542/peds.2007-0887.
7. DiFiori J, Benjamin H, Brenner J, et al. Overuse Injuries and Burnout in Youth Sports: A Position Statement from the American Medical Society for Sports Medicine. *Clinical Journal of Sports Medicine* 2014;24(1):3-20.
8. DiFiori JP. Evaluation of overuse injuries in children and adolescents. *Curr Sports Med Rep* 2010;9(6):372-378. doi:10.1249/JSR.0b013e3181fdb58.
9. Launay F. Sports-related overuse injuries in children. *Orthop Traumatol Surg Res* 2015;101(1 Suppl):S139-47. doi:10.1016/j.otsr.2014.06.030.
10. 2015-16 HIGH SCHOOL ATHLETICS PARTICIPATION SURVEY. Available at: http://www.nfhs.org/ParticipationStatistics/PDF/2015-16_Sports_Participation_Survey.pdf.
11. National Council of Youth Sports Report on Trends and Participation in Organized Youth Sports 2008 Edition. National Council of Youth Sports (NCYS). Available at: <http://www.ncys.org/pdfs/2008/2008-ncys-market-research-report.pdf>. Accessed May 23, 2017.

12. Injury Research and Policy RIO™ Study Reports :: Nationwide Children's Hospital, Columbus, Ohio. Available at: <http://www.nationwidechildrens.org/cirp-rio-study-reports>. Accessed July 1, 2017.
13. Safe Kids Worldwide: Sports and Recreation Safety Fact Sheet (2015). Available at: https://www.safekids.org/sites/default/files/documents/skw_sports_fact_sheet_feb_2015.pdf.
14. Myer GD, Jayanthi N, DiFiori JP, et al. Sports specialization, part II: alternative solutions to early sport specialization in youth athletes. *Sports Health* 2016;8(1):65-73. doi:10.1177/1941738115614811.
15. Smucny M, Parikh SN, Pandya NK. Consequences of single sport specialization in the pediatric and adolescent athlete. *Orthop Clin North Am* 2015;46(2):249-258. doi:10.1016/j.ocl.2014.11.004.
16. Magrini D, Dahab KS. Musculoskeletal overuse injuries in the pediatric population. *Curr Sports Med Rep* 2016;15(6):392-399. doi:10.1249/JSR.0000000000000303.
17. Valovich McLeod TC, Decoster LC, Loud KJ, et al. National Athletic Trainers' Association position statement: prevention of pediatric overuse injuries. *J Athl Train* 2011;46(2):206-220. doi:10.4085/1062-6050-46.2.206.
18. Myer GD, Jayanthi N, DiFiori JP, et al. Sport specialization, part I: does early sports specialization increase negative outcomes and reduce the opportunity for success in young athletes? *Sports Health* 2015;7(5):437-442. doi:10.1177/1941738115598747.
19. Post EG, Trigsted SM, Riekena JW, et al. The association of sport specialization and training volume with injury history in youth athletes. *Am J Sports Med* 2017;45(6):1405-1412. doi:10.1177/0363546517690848.
20. Fabricant PD, Lakomkin N, Sugimoto D, Tepolt FA, Straccolini A, Kocher MS. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. *Phys Sportsmed* 2016;44(3):257-262. doi:10.1080/00913847.2016.1177476.
21. Bell DR, Post EG, Trigsted SM, Hetzel S, McGuine TA, Brooks MA. Prevalence of Sport Specialization in High School Athletics: A 1-Year Observational Study. *Am J Sports Med* 2016;44(6):1469-1474. doi:10.1177/0363546516629943.
22. Pasulka J, Jayanthi N, McCann A, Dugas LR, LaBella C. Specialization patterns across various youth sports and relationship to injury risk. *Phys Sportsmed* 2017:1-9. doi:10.1080/00913847.2017.1313077.
23. McGuine TA, Post EG, Hetzel SJ, Brooks MA, Trigsted S, Bell DR. A prospective study on

the effect of sport specialization on lower extremity injury rates in high school athletes. *Am J Sports Med* 2017;363546517710213. doi:10.1177/0363546517710213.

24. Hall R, Barber Foss K, Hewett TE, Myer GD. Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. *J Sport Rehabil* 2015;24(1):31-35. doi:10.1123/jsr.2013-0101.
25. Jayanthi N, Dechert A, Durazo R, Dugas L, Luke A. Training and Sports Specialization Risks in Junior Elite Tennis Players. *J Med Sci Tennis* 2011;16(1):14-20.
26. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain in young gymnasts: frequency and effects upon training over 1 year. *Clin J Sport Med* 2002;12(6):348-353.
27. Olsen SJ, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med* 2006;34(6):905-912. doi:10.1177/0363546505284188.
28. Elm E von, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Epidemiology* 2007;18(6):800-804. doi:10.1097/EDE.0b013e3181577654.
29. Ebell M, Siwek J, Weiss B, et al. Strength of Recommendation Taxonomy (SORT): A Patient-Centered Approach to Grading Evidence in the Medical Literature. *Am Fam Physician* 2004;69(3):548-556.