The Association of Single Sport Specialization and Overuse Injury in Youth

Athletics

By

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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
review\textsuperscript{2} 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 year\textsuperscript{3}. Jayanthi et al\textsuperscript{4} 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 (7\textsuperscript{th} grade or roughly 12 years old) and late specialization occurring after puberty\textsuperscript{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 scholarship\textsuperscript{3}. Taking it further still, a scarce 0.2-0.5% of high school athletes will make it to the professional ranks\textsuperscript{6}. 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 level\textsuperscript{7}. 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 time\textsuperscript{8}. 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\textsuperscript{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 radius\textsuperscript{9}. 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)\textsuperscript{9}. During this time adolescents are also at increased risk of fracture due to extensive epiphyseal growth\textsuperscript{1}, 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 Associations\textsuperscript{10}, 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 recreationally\textsuperscript{7}. The National Council for Youth Sports also reports a 6% increase in children younger than 6 years old participating in recreational sports\textsuperscript{11}. While numbers have increased globally, there is still a significant attrition, with about 70% withdrawing from organized sport by the age of 13\textsuperscript{3}. 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 year\textsuperscript{12} 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\textsuperscript{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 running\textsuperscript{7}. 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 injuries\textsuperscript{13}. 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.

\textit{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 success\textsuperscript{14}. 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 counterparts\textsuperscript{14}. In a study of NCAA Division I athletes\textsuperscript{15}, 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. Jayanthi\textsuperscript{2} 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. Smucny\textsuperscript{15} 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\textsuperscript{2,14}. Early specialization is noted to be helpful in gymnastics, dance, tennis, and swimming and diving, where these parameters are often seen.

\textit{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\textsuperscript{7,8,16} and, along with prior injury, is the most consistent predictor of overuse injury\textsuperscript{17}. 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 hours\textsuperscript{18}
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 injury\textsuperscript{4}. 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 exceeded\textsuperscript{19}.

\textit{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 al\textsuperscript{20} 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 specialization\textsuperscript{20}. Bell et al\textsuperscript{21} surveyed 302 Wisconsin high school students aged 13-18, and those classified as highly specialized by Jayanthi’s 3-Point scale\textsuperscript{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 al\textsuperscript{22} 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 counterparts. 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 period. 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 category. 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 group. Finally, McGuine et al 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 scale4,19,21,22 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\textsuperscript{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\textsuperscript{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 younger\textsuperscript{26}. 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 5\(^2\). 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 competitions\(^5–7\), 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 practice\(^18\). While participating in multiple sports year-round accrues similar risk, single-sport specialized athletes may be more likely to participate in their sport year-round\(^18\). The NATA Position Statement on Prevention of Pediatric Overuse Injuries\(^17\) 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 movement\textsuperscript{7}, 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 injury\textsuperscript{5}. 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\textsuperscript{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 classes\textsuperscript{15}. 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 development\textsuperscript{14}. 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 performance\textsuperscript{14}. 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\textsuperscript{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>
<thead>
<tr>
<th>Author (Journal)</th>
<th>Date</th>
<th>Study Type/Level of Evidence</th>
<th>N</th>
<th>Main Measures</th>
<th>Findings</th>
<th>Recall Bias</th>
<th>Selection Bias</th>
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<tr>
<td>Jayanthi* et al., (J Med Sci Tennis)†</td>
<td>2011</td>
<td>Prospective cohort/III</td>
<td>519</td>
<td>Assoc. of practice volume/mth competed/SSS with injury risk/tournament withdrawal due to injury</td>
<td>SSS more likely to report sport-related injury; those with injury in past yr more likely to withdraw</td>
<td>Yes (1 yr) ++</td>
<td>No</td>
<td>Age of specialization, single sport (tennis)</td>
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<td>Jayanthi* et al., (Am J Sports Med)‡</td>
<td>2015</td>
<td>Case-Control/III</td>
<td>1190</td>
<td>Assoc. of SSS/growth rate w/incre. injury/overuse injury risk</td>
<td>SSS is independent RF for injury/serious overuse injury; growth rate not related to inj. risk</td>
<td>Yes +</td>
<td>Yes +++</td>
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<tr>
<td>Hall* et al., (J Sport Rehabil)§</td>
<td>2015</td>
<td>Retrospective Epi. Cohort/IV</td>
<td>546</td>
<td>Assoc. of SSS with anterior knee pain/PFP in female adolescent athletes</td>
<td>SSS increases risk of overall PFP 1.5x; SLJ/PF/OSD 4x as likely in SSS than multisport athletes</td>
<td>No</td>
<td>Yes ++</td>
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<td>Bell et al., (Am J Sports Med)¶</td>
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<td>Cross-sectional/III</td>
<td>302</td>
<td>Prevalence of SSS in high school settings; likelihood of reporting LEI in highly specialized athletes</td>
<td>School size influenced specialization rates; SSS highly spec. athletes more likely to report hx of overuse hip/knee injury</td>
<td>Yes (1 yr) ++</td>
<td>Yes ++</td>
<td>School size, sex</td>
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<td>Pasulka et al., (Phys Sportsmed)‖</td>
<td>2016</td>
<td>Case-Control/III</td>
<td>1190</td>
<td>Analyze relationship b/w SSS sport type (team vs individual) and age of spec./injury risk/training volume</td>
<td>Individual SSS athletes report increased rates of overuse/serious overuse injuries than team SSS athletes</td>
<td>Yes ++</td>
<td>Yes +++</td>
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<td>Post et al., (Am J Sports Med)¶</td>
<td>2017</td>
<td>Case-Control/III</td>
<td>2011</td>
<td>Assoc. of SSS w/injury hx; assoc. b/w sport volume and injury hx</td>
<td>Highly specialized athletes more likely to report any injury hx; &gt; 8mth/yr participation more likely to have overuse injury hx; &gt; hrs than age more likely to report any injury hx</td>
<td>Yes (1 yr) ++</td>
<td>Yes ++</td>
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<td>McGuine et al., (Am J Sports Med)¶</td>
<td>2017</td>
<td>Prospective Cohort/II</td>
<td>1544</td>
<td>Assoc. of SSS w/incidence of LEI in high school athletes</td>
<td>Moderate and Highly specialized athletes more likely to have LEI/non-acute LE than low specialized athletes</td>
<td>Yes (1 yr) ++</td>
<td>Yes +</td>
<td>Sports spec. Classification</td>
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SSS—Single sport specialization; RF—risk factor; PFP—patellofemoral pain; SLJ—Sinding Larsen Johannsen; 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, 2016®
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 checklist\textsuperscript{28} and Strength of Recommendation Taxonomy (SORT) criteria were used to evaluate the summary of the literature\textsuperscript{29}.

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)\textsuperscript{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.


23. McGuine TA, Post EG, Hetzel SJ, Brooks MA, Trigsted S, Bell DR. A prospective study on


