Despite rising awareness of the risks associated with sports participation, overuse injuries continue to increase in youth athlete populations. Physeal injuries are one type of overuse injury exclusive to pediatric populations that are often sustained during athletic practice or competition. Overuse physeal injuries are, in theory, preventable; however, little consensus has been reached surrounding the risk factors, prevention, and treatment strategies.

Objective: This systematic review summarizes the best available evidence concerning overuse physeal injuries in youth and adolescent athletes. It can be used to develop prevention and treatment programs specific to this population.

Data Sources: PubMed and Academic Search Complete (EBSCOhost) were explored using the keyword physeal injuries from January 1950 through May 2015 to identify 24 studies.

Study Selection: Original research studies of athletic populations with mechanisms of injury related to sport were chosen.

Study Design: Systematic review.

Level of Evidence: Level 3.

Data Extraction: Data were extracted as available from 24 eligible studies. Study quality was rated using the Oxford Centre for Evidence-based Medicine (OCEBM) guidelines.

Results: Risk factors for injury include periods of accelerated growth, chronological age, body size, training volume, and previous injury. Injury prevention strategies currently emphasize participation limitations and sport-specific training programs in skeletally immature athletes. The most effective treatment after an overuse physeal injury was an extended period of active rest and joint immobilization when necessary.

Conclusion: Overuse physeal injuries are multifactorial in nature. Muscular imbalances after accelerated growth periods predispose young athletes to overuse injuries. Modifiable risk factors such as flexibility, strength, and training volume should be regularly monitored to prevent these injuries.

Keywords: physis; physeal injury; overuse; sports injuries; pediatric injuries
Overuse physeal injuries develop in response to excessive stress placed on immature bony and soft tissue structures. Rapid physical changes combined with repetitive sport-related tasks such as running and overhead throwing are frequently associated with the development of physeal injuries in youth athletes. The gradual nature of this injury progression provides clinicians with multiple opportunities for effective intervention. Overuse physeal injuries are, in theory, preventable. Prevention and treatment strategies should be population specific, taking into account risk factors and clinical impairments observed in youth athletes. The purpose of this work was to review the best available evidence concerning recommended prevention and treatment strategies for overuse physeal injuries in clinical practice.

METHODS

Literature Review and Article Identification

An electronic literature search was performed accessing papers published from January 1950 to May 2015 in the PubMed and all EBSCOhost databases. Search terms included epiphyseal injury, epiphyseal plate injury, pediatric sports injury, and physeal sports injury. Additional searches in the aforementioned databases were performed using the terms Little League shoulder, gymnast wrist, Little League elbow, lower extremity physeal injury, Osgood-Schlatter disease, Sever disease, and Sinding-Larsen-Johansson disease as they were the most commonly reported mechanisms of injury during the primary search. Only English-language articles published in peer-reviewed journals with an emphasis on human participants were initially included. Articles were also required to meet level 4 standards or higher based on criteria developed by the Oxford Centre for Evidence-based Medicine (OCEBM). Abstracts and nonpublished works were not included. Based on these search criteria, 3663 articles were located. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, studies were selected based on appropriateness of topic and full-text options. All clinical commentaries and review articles were omitted. A total of 24 original research studies were included in this systematic review (Figure 1).
Eligibility Criteria

Article selection was based on repetitive stress as a mechanism of injury in young athletes. Case reports, case series, and cohort studies that described non-sport-related mechanisms of injury, such as falls, were not included in this review. Acute sport-related injuries were also excluded. The scope of this systematic review was limited to overuse physeal injuries sustained during athletic competition.

RESULTS

Twenty-four studies were included in this systematic review (Tables 1 and 2). Thirty-three percent of studies included descriptions of known physeal injury risk factors while only 8% of studies used those factors to outline effective prevention strategies. Eighty-eight percent of studies included data describing treatment strategies after an overuse physeal injury. Review of current evidence suggests that more emphasis has been placed on the treatment of overuse physeal injuries and that further research is needed to establish effective prevention strategies for these diagnoses.

Risk factors common to both lower extremity (LE) and upper extremity (UE) physeal injuries include age, physical characteristics, growth patterns, and training volume. While limited evidence was available describing effective prevention strategies in this population, studies did emphasize that youth athletes should engage in minimum periods of active rest after their competition cycles. Adequate physical training and variation in sport-specific tasks were also encouraged. Treatment strategies after an overuse physeal injury included varying periods of active rest, and when necessary, immobilization of the affected joint. Gradual return to physical training and conditioning tasks was recommended prior to full return to sport.

Lower Extremity Injuries

Overuse physeal injuries in the LE typically occur when excess stress is placed across areas with major tendon insertions. Osgood-Schlatter disease, Sever disease, and Sinding-Larsen-Johansson syndrome are 3 of the most common overuse physeal injuries sustained during childhood. The first 2 syndromes account for a staggering 18% of all pediatric overuse injuries reported in the literature. Osgood-Schlatter disease is described as chronic apophysitis of the patellar tendon where it inserts on the tibial tuberosity apophysis. It is typically observed in girls aged 8 to 13 years and boys aged 10 to 15 years. The same inflammatory process occurs with Sever disease but at the Achilles tendon insertion into the vertical calcaneal apophysis. This condition appears to present more often in young boys between the ages of 8 and 12 years. Sinding-Larsen-Johansson syndrome has a similar etiology but develops at the junction of the inferior pole of the patella and the proximal portion of the patellar tendon. While this syndrome appears less frequently in the literature than the previous 2, Sinding-Larsen-Johansson syndrome does occur in youth athletes between the ages of 10 and 15 years, limiting their function and participation levels (Table 1).

Prevention strategies in the literature emphasize the correction of modifiable risk factors such as deficits in trunk and LE flexibility, which is often attributed to rapid changes in physical growth common during childhood and adolescence. Programs designed to enhance cardiovascular endurance and correct physical training errors are also recommended to prevent these types of injuries. After an overuse physeal injury in the LE, 50% of studies recommend a 3- to 5-month period of active rest, with complete cessation of sport-specific activities. Twenty-one percent of studies suggest activity modifications may be appropriate based on the symptom presentation of the athlete, thereby limiting their total time away from sport.

Lower extremity stretching and conditioning programs were also used in 21% of the studies as either a stand-alone treatment or in conjunction with additional strategies. Several studies reported joint immobilization and surgical intervention for long-standing physeal injuries related to overuse; however, these strategies were only employed in severe cases. Irrespective of the treatment strategy used, an athlete should not fully return to sport until symptom resolution has occurred. No studies to date have examined or compared the effectiveness of these treatments in youth athlete populations.

Upper Extremity Injuries

Overuse physeal injuries in the UE occur due to excess compression or traction forces placed across a joint during sport. Gymnast wrist, Little League shoulder, and Little League elbow are 3 UE physeal injuries that are highly prevalent and described frequently in the pediatric sports literature. Seventy-nine percent of youth gymnasts report wrist pain during practice or competition, while 32% of youth baseball pitchers report arm pain while throwing.

Gymnast wrist occurs in response to the premature closure of the distal radial physis after excessive compression loads during UE weightbearing. Gymnastics is one of the few sports that repeatedly performs closed-chain weightbearing activities on both their upper and lower extremities. This injury is typically seen in athletes between the ages of 10 and 14 years (Table 2). Little League shoulder has been described in the literature as a widening of the proximal humeral epiphysis or epiphysiolysis (Figure 3). It is most often seen in the dominant shoulder and is thought to occur secondary to the repetitive rotational and traction stresses associated with overhead throwing. “Little League elbow” is a term often used to describe a variety of physeal and cartilaginous injuries at the pediatric elbow. By definition, Little League elbow is a repetitive traction injury to the medial epicondylar apophysis (Figure 4). Diagnoses of Little League shoulder and Little League elbow are most often made after reports of persistent arm pain and loss of function in youth baseball pitchers between the ages of 11 and 15 years (Table 2).
Risk factors associated with the development of gymnast wrist include consistent UE loading and timing of growth spurts. Studies suggest that participation in repetitive UE weightbearing tasks, especially during periods of rapid physical growth, is directly associated with this highly prevalent, population-specific injury. Risk factors related to the development of Little League shoulder and Little League elbow are similar. Excessive game, season, and yearly pitch counts and pitching

Table 1. Studies that report lower extremity physeal injuries

| Study                                      | Level of Evidence (OCEBM) | Sample Size | Age Range, y | Injury Site                           | Sport                          | Treatment Options                     |
|--------------------------------------------|----------------------------|-------------|--------------|---------------------------------------|-------------------------------|---------------------------------------|
| Beovich⁵                                   | 3                          | 22          | 9-18         | Proximal tibial tubercle               | Multiple                      | Activity modifications (20); active rest (2) |
| de Lucena et al²⁴                         | 3                          | 954         | 12-15        | Proximal tibial tubercle               | Multiple                      | Stretching program                    |
| Doral et al³²                              | 4                          | 1           | 16           | Anterior superior iliac spine         | Soccer                        | Surgical intervention                 |
| Hajdu et al³⁷                              | 4                          | 7           | 13-16        | Proximal tibial tubercle               | Ball games, skiing            | Active rest (1); surgical intervention (6) |
| Hussain and Hagroo⁹⁹                       | 3                          | 261         | 11-18        | Proximal tibial tubercle               | Multiple                      | Active rest and NSAIDs (237); surgical intervention (24) |
| Kolt and Kirkby⁴⁴                         | 3                          | 43          | 11-19        | Multiple sites                        | Gymnastics                    | Physical conditioning program          |
| Kujala et al⁴⁶                             | 3                          | 68          | 9-18         | Proximal tibial tubercle               | Multiple                      | Active rest—3 mo; activity modifications—7 mo |
| Laor et al⁴⁷                               | 4                          | 6           | 8-15         | Distal femur, proximal tibia, proximal fibula | Football, basketball, gymnastics, other | Joint immobilization—1-5 wk            |
| Liebling et al⁴⁹                           | 4                          | 1           | 13           | Distal femur, proximal tibia           | Baseball                      | None                                   |
| Mital et al⁶⁹                              | 3                          | 118         | 9-18         | Proximal tibial tubercle               | Multiple                      | Active rest/joint immobilization (104); surgical intervention (14) |
| Nanni et al⁶²                              | 4                          | 1           | 15           | Proximal tibia                        | Rugby                         | Surgical intervention                 |
| Orava and Virtanen⁶⁵                       | 3                          | 185         | 9-26         | Multiple sites                        | Multiple                      | Varied                                 |
| Rossi and Dragoni⁷²                        | 3                          | 203         | 11-18        | Pelvic apophyses                      | Soccer, gymnastics, fencing, tennis | None                                   |
| Valentino et al⁰⁷                          | 4                          | 1           | 13           | Inferior patellar pole                | Football                      | Active rest—5 mo                      |

NSAIDs, nonsteroidal anti-inflammatory drugs; OCEBM, Oxford Centre for Evidence-based Medicine.
while fatigue are factors that have been associated with shoulder and elbow dysfunction in youth baseball players.\textsuperscript{51,52} Pitch type and selection are also important for the health of this population. Youth baseball players who reported throwing breaking pitches such as curveballs or sliders over the course of the season were more at risk to develop shoulder and elbow pain when compared with those who did not.\textsuperscript{51} Anthropometric measures such as increased height and weight also impacted injury risk but were more significant to the development of elbow pathology than shoulder pathology.\textsuperscript{52}

Despite the lack of epidemiological data concerning gymnast wrist, multiple prevention strategies have been suggested in the literature.\textsuperscript{26,27,29} The gradual progression and variation of training loads is imperative to limit the volume of compressive forces sustained through the distal radial physis.\textsuperscript{26,28,29} Studies suggest that coaches and parents should be cognizant of rapid changes in growth, as the athlete is most at risk for overuse physeal injuries during this period.\textsuperscript{20,28} In an effort to prevent Little League shoulder and Little League elbow, USA Baseball implemented yearly, seasonal, and game pitch count limitations based on an athlete’s age at the time of competition.\textsuperscript{50-52,64} These recommendations were designed to decrease an athlete’s risk for injury by limiting excessive stress and fatigue during sports participation.\textsuperscript{50-52}

Treatment strategies for all 3 overuse physeal injuries center around an extended period of active rest. After an injury, 50% of studies recommend active rest from sport-specific training to ensure adequate healing and symptom resolution.\textsuperscript{2,4,21,33,63,65} Recommended periods of active rest range from 4 to 6 weeks for a diagnosis of gymnast wrist or Little League elbow and 3 to 5 months for athletes with Little League shoulder.\textsuperscript{2,21,29,63,80} In severe cases of Little League elbow, joint immobilization and/or surgical intervention have been employed to ensure optimal functional outcomes.\textsuperscript{43,66,69} However, an extended period of active rest remains the main treatment of choice for overuse physeal injuries in the UE.

Table 2. Studies that report upper extremity physeal injuries

| Study | Level of Evidence (OCEBM) | Sample Size | Age Range, y | Injury Site | Sport | Treatment Options |
|-------|---------------------------|-------------|--------------|-------------|-------|------------------|
| Akgul et al\textsuperscript{2} | 4 | 1 | 13 | Proximal humerus | Nonathlete | Active rest—4 mo |
| Anton and Podberesky\textsuperscript{4} | 4 | 1 | 13 | Proximal humerus | Baseball | Active rest, physical therapy |
| Binder et al\textsuperscript{6} | 3 | 72 | 8-13 | Proximal humerus | Unknown | Joint immobilization—1-4 wk (57); surgical intervention (15) |
| Boyd and Batt\textsuperscript{8} | 4 | 1 | 15 | Proximal humerus | Badminton | None |
| Carson and Gasser\textsuperscript{21} | 3 | 23 | 14 | Proximal humerus | Baseball | Active rest—3 mo |
| Drescher et al\textsuperscript{33} | 4 | 1 | 12 | Proximal humerus | Cricket | Joint immobilization—3 wk; active rest—3 mo |
| Hang et al\textsuperscript{38} | 3 | 343 | 8-12 | Distal humerus | Baseball | None |
| Kolt and Kirkby\textsuperscript{44} | 3 | 43 | 11-19 | Multiple sites | Gymnastics | Physical conditioning program |
| Obembe et al\textsuperscript{63} | 4 | 4 | 11-15 | Proximal humerus | Baseball, tennis | Active rest—3 mo |
| Orava and Virtanen\textsuperscript{65} | 3 | 185 | 9-26 | Multiple sites | Multiple | Varied |
| Roy et al\textsuperscript{73} | 4 | 21 | 11-18 | Distal radius | Gymnastics | None |
| Torg et al\textsuperscript{84} | 4 | 1 | 12 | Proximal humerus | Baseball | None |
Physeal injuries represent approximately 15% of all pediatric sports injuries. The physis, as the weakest physiologic structure of the bone in a young athlete, is particularly susceptible to overuse injuries. As participation in youth sports continues to increase, clinicians should know the risk factors, prevention strategies, and treatment options associated with overuse physeal injuries.

Risk Factors

Risk factors associated with participation in youth sports have been reported; however, none have examined injury risk with respect to physeal injuries. Physeal injuries are exclusive to skeletally immature individuals, suggesting that modifiable and nonmodifiable risk factors are specific to this population.

Nonmodifiable risk factors for overuse injuries can include timing of accelerated growth spurts, chronological age, body size, and history of previous injury. Previous injury is the strongest predictor for the development of future injuries. Studies show that athletes with a prior injury were at a much greater risk to sustain an injury when compared with a previously healthy cohort. Modifiable risk factors such as flexibility, strength, training volume, and coaching styles also impact overall injury risk in youth and adolescent athletes. Multiple studies suggest that excessive training loads often lead to physical fatigue in youth athletes. Continued participation in sport once fatigued can damage an athlete’s physical development, thereby illustrating the importance of responsible coaching, especially during the early years of sport.

Prevention and Treatment Strategies

Injury prevention strategies for youth and adolescent athletes focus on limiting time spent participating in sport as well as encouraging 2 to 3 months of scheduled rest away from training and competition. This is designed to mediate the effects of repetitive risk-prone activities on physically maturing bodies. Pitch count regulations, which are enforced by the governing bodies in youth baseball, are one notable attempt at preventing upper extremity overuse injuries at the policy level. Multiple studies have also recommended that clinicians monitor known risk factors such as anthropometric (eg, height and weight) and physical characteristics (eg, range of motion and strength) as youth athletes mature over time. Multiple programs designed to improve flexibility, strength, and balance deficits have protective effects against injuries in this population.
The most widely accepted treatment strategy after any physeal injury is an extended period of active rest.\textsuperscript{3,6,13,21,23,40,42,62,63,75} Recommended durations of active rest vary from 4 to 6 weeks to 3 to 5 months depending on diagnosis, sport, and severity of symptoms.\textsuperscript{20,21,42} During this time, strategies can include field position changes to limit throwing in the cases of Little League shoulder and Little League elbow or no running for a specified period of time in athletes with Osgood-Schlatter disease, Sinding-Larsen-Johansson syndrome, or Sever disease. In most cases, nonsymptomatic activities such as hitting a baseball or footwork drills in soccer can be continued, allowing young athletes to continue training without prolonging their recovery by reaggravating the affected joint.

During a period of active rest, conservative measures such as physical therapy may be beneficial. Once the pain has subsided, the necessary flexibility, strength, and neuromuscular control required to participate safely in sport can be restored.\textsuperscript{2-4,8,11,16-19,21,22,25,20,30,31,33,43,44,63,74,80} Progressive strength training programs, lasting approximately 6 to 8 weeks, can augment return to throwing or running programs when appropriate.\textsuperscript{42} The rehabilitation programs in the literature were vague and lacked return-to-sport criteria.\textsuperscript{42,80} Future research should focus on the development of age- and injury-specific return-to-sport progressions designed to provide clinicians with evidence-based guidelines to return their athletes safely back to sport.

**Limitations**

The main limitation of this systematic review was the lack of experimental and epidemiological data concerning overuse injuries in youth sports. Review studies typically described pediatric sports injuries in general terms with little respect to injury type. The current evidence surrounding risk factors, prevention, and treatment strategies for overuse injuries in youth sports was primarily limited to review studies and level 3 and 4 publications. The paucity of high-quality evidence combined with strict inclusion criteria appeared to impact the study selection process. A variety of search terms were used; however, a disproportionate number of studies featured Little League shoulder as the diagnosis. This selection bias toward overuse physeal injuries in the UE may have influenced the generalizability of the clinical recommendations made in this systematic review.

The lack of high-quality, patient-oriented research in younger athlete populations and the absence of research on physeal injuries pose notable gaps in the literature. These gaps include minimal data establishing the incidence, prevalence, and severity of overuse injuries in youth athletes, especially with respect to physeal involvement.\textsuperscript{42,64} No original research studies have clearly defined physeal injuries at this time. Also, little is known about the effects of population-specific risk factors, like growth-related changes and training volume, on the development of injuries in skeletally immature individuals. Future studies should establish a clear definition of physeal injuries in sport and determine the mechanisms and risk factors associated with their development. This will provide the foundation for more effective prevention and treatment strategies at the policy level, including the paradigm-shifting concept of scheduled periods of rest from sport.

**CONCLUSION**

Overuse physeal injuries are multifactorial in nature.\textsuperscript{55} Periods of accelerated growth, chronological age, skeletal maturity, and history of previous injury can predispose young athletes to repetitive stress injuries.\textsuperscript{55} Modifiable risk factors such as flexibility, strength, and training volume should be regularly monitored in an effort to limit risk-prone activities and prevent injuries when possible.\textsuperscript{35,30,24,25,36,44,75,86}

The most effective treatment strategy after overuse physeal injuries is an extended period of active rest. After symptom resolution, athletes should restore function through improvements in flexibility, strength, and neuromuscular control.\textsuperscript{24,30,44,74} Progressive strength training programs should include gradual return to throwing or running programs when appropriate.\textsuperscript{42} Return-to-sport timelines typically range from 4 to 6 weeks in most cases but can extend to 3 to 5 months when symptoms persist.\textsuperscript{21,42,47}
Clinical Recommendations

SORT: Strength of Recommendation Taxonomy Grade
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

Clinical Recommendation | SORT Evidence Rating
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The most widely accepted treatment option after any physeal injury is an extended period of active rest, and when necessary, joint immobilization. Once the pain has subsided, emphasis on the restoration of flexibility, strength, and sport-specific endurance is appropriate. | C
Modifications such as implementing sport-specific flexibility and strength programs as well as limiting training and competition volumes (eg, pitch counts) may avoid overuse and fatigue-related injuries. This is especially important during periods of rapid growth. | B
Regular monitoring of anthropometric (eg, height and weight) and physical characteristics (eg, range of motion and strength) in youth athletes may prove preventative as deficits have been linked to both upper and lower extremity injuries in multiple sporting events. | C

REFERENCES
1. Adirim TA, Cheng TL. Overview of injuries in the young athlete. *Sports Med*. 2005;35:75-81.
2. Akgul S, Dilsicik U, Kanbur NO, Kaya D, Dommez G, Doral MN. Proximal humeral physeal widening: little leaguer's shoulder or a variation of normal development? *Turk J Pediatr*. 2011;53:711-714.
3. Albanese SA, Palmer AK, Kerr DR, Carpenter CW, Lisi D, Levinson EH. Wrist pain and distal growth plate closure of the radius in gymnasts. *J Pediatr Orthop*. 1989;9:23-28.
4. Anton C, Podberesky DJ. Little League shoulder: a growth plate injury. *Pediatr Radiol*. 2010;40(suppl 1):S55.
5. Beovich RF. Osgood-Schlatter's disease: a review of the literature and an Australian series. *Aus J Sci Med Sport*. 1980;20:11-15.
6. Binder H, Schurz M, Aldrian S, Fialka C, Vecsei V. Physeal injuries of the proximal humerus: long-term results in seventy-two patients. *Int Orthop*. 2011;35:197-202.
7. Bloom OJ, Mackler L, Barbee J. Clinical inquiries. What is the best treatment for Osgood-Schlatter disease? *J Fam Pract*. 2004;53:153-156.
8. Boyd KT, Batt ME. Stress fracture of the proximal humeral epiphysis in an elite junior badminton player. *Br J Sports Med*. 1997;31:252-255.
9. Brooks MA, Schiff MA, Rivara FP. Identifying previous sports injury among high school athletes. *Clin Pediatr (Phila)*. 2009;48:548-550.
10. Bruns W, Maffulli N. Lower limb injuries in children. in *Sports Med*. 2000;19:67-662.
11. Butler TA, Yingling VR. The effects of delayed puberty on the growth plate. *J Pediatr Orthop*. 2013;33:99-105.
12. Caine D, Caine C, Maffulli N. Incidence and distribution of pediatric sport-related injuries. *Clin J Sport Med*. 2000;16:500-515.
13. Caine D, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? *Br J Sports Med*. 2006;40:749-760.
14. Caine D, Lewis R, O'Connor P, Howe W, Bass S. Does gymnastics training inhibit growth of females? *Clin J Sport Med*. 2001;11:260-270.
15. Caine D, Maffulli N, Caine E. Epidemiology of injury in child and adolescent sports: injury rates, risk factors, and prevention. *Clin J Sport Med*. 2002;12:97-108.
16. Caine D, Roy S, Singer KM, Broekhoff J. Stress changes of the distal radial growth plate. A radiographic survey and review of the literature. *Am J Sports Med*. 1992;20:290-298.
17. Caine DB, Bass S, Daly R. Does elite competition inhibit growth and delay maturation in some gymnasts? Quite possibly. *Pediatr Exerc Sci*. 2003;15:560-572.
18. Caine DH, Howe W, Ross W, Bergman R. Does repetitive physical loading inhibit radial growth in female gymnasts. *Clin J Sport Med*. 1997;7:302-308.
19. Caine D, Golightly YM. Osteoarthrthritis as an outcome of paediatric sport: an epidemiological perspective. *Br J Sports Med*. 2011;45:298-303.
20. Caine D, Maffulli N. Epidemiology of children's individual sports injuries. An important area of medicine and sport science research. *Med Sci Sports*. 2005;48:1-7.
21. Carson WG Jr, Gasser SI. Little Leaguer's shoulder: a report of 23 cases. *Am J Sports Med*. 1998;26:575-580.
22. Carter SR, Aldridge MJ, Fitzgerald R, Davies AM. Stress changes of the wrist in adolescent gymnasts. *Br J Radiol*. 1988;61:119-112.
23. Cohen E, Sala DA. Rehabilitation of pediatric musculoskeletal sport-related injuries: a review of the literature. *Eur J Phys Rehabil Med*. 2010;46:135-145.
24. de Lucerna GL, dos Santos Gomes C, Guerra RO. Prevalence and associated factors of Osgood-Schlatter syndrome in a population-based sample of Brazilian adolescents. *Am J Sports Med*. 2011;39:415-420.
25. De Smet L, Claessens A, Lefevre J, Beenen G. Gymnast wrist: an epidemiologic survey of ulnar variance and stress changes of the radial physis in elite female gymnasts. *Am J Sports Med*. 1994;22:846-850.
26. DiFiori JP. Overuse injury and the young athlete: the case of chronic wrist pain in gymnasts. *Curr Sports Med Rep*. 2006;5:165-167.
27. DiFiori JP, Benjamin HJ, Brenner J, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Clin J Sport Med*. 2014;24:2-10.
28. DiFiori JP, Benjamin HJ, Brenner J, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Clin J Sport Med*. 2014;24:2-10.
29. DiFiori JP, Caine DJ, Malina RM. Wrist pain, distal radial physeal injury, and ulnar variance in the young gymnast. *Am J Sports Med*. 2006;34:80-89.
30. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain, distal radial physeal injury, and ulnar variance in young gymnasts: does a relationship exist? *Am J Sports Med*. 2002;30:879-885.
31. DiFiori JP, Puffer JC, Mandelbaum BR, Doney F. Distal radial growth plate injury and positive ulnar variance in nonelite gymnasts. *Am J Sports Med*. 1997;25:765-768.
32. Doral MN, Aydog ST, Telik O, Atay OA, Turhan E, Demrel HA. Multiple osteochondroses and avulsion fracture of anterior superior iliac spine in a soccer player. *Br J Sports Med*. 2005;39:e16.
33. Drescher WR, Falliner A, Zantop T, Oehlert K, Petersen W, Hassennflug J. Little league shoulder syndrome in an adolescent cricket player. *Br J Sports Med*. 2004;38:E14.
34. Eastwood DM, de Gheldere A, Bijlsma P. Physeal injuries in children: a review of the literature. *Eur J Phys Rehabil Med*. 2010;46:135-145.
35. Fahl W, Collin JF, Caine C, Caine D. Apophyseal injuries of the apophyses of the ilium and ischium in a female high school athlete. *J Pediatr Orthop*. 2005;25:763-768.
36. Garrett SE, Shrivastava M, Meurer WJ, et al. The peroneal entrapment syndrome in the athlete. *Am J Sports Med*. 2009;37:813-818.
37. Gentili C, Agnello A, Di Fazio G, Di Sano G. Osteochondrosis in the bicipital tuberosity: a case report. *Sports Med Arthrosc*. 2014;22:277-281.
38. Hang DW, Chao CM, Hang YS. A clinical and roentgenographic study of Little League elbow. *Am J Sports Med*. 2004;32:79-84.
39. Hanssen AH, Hagego GA. Osgood-Schlatter disease. *Sports Exerc Inf*. 1996;2:202-206.
40. Kennedy JG, Knowles B, Dolan M, Bohne W. Foot and ankle injuries in the adolescent runner. *Curr Opin Pediatr*. 2005;17:34-42.
41. Kerssemakers SP, Fotiadou AN, de Jonge MC, Karantanas AH, Maas M. Sports injuries in the paediatric and adolescent patient: a growing problem. Pediatr Radiol. 2009;39:471-484.

42. Klingele KE, Kocher MS. Little league elbow: valgus overload injury in the paediatric athlete. Sports Med. 2002;32:1005-1015.

43. Kocher MS, Waters PM, Micheli LJ. Upper extremity injuries in the paediatric athlete. Sports Med. 2000;30:117-135.

44. Kolt GS, Kirkby RJ. Epidemiology of injury in elite and subelite female gymnasts: a comparison of retrospective and prospective findings. Br J Sports Med. 1999;33:512-518.

45. Krueger-Franke M, Siebert CH, Ploeminger W. Sports-related epiphyseal injuries of the lower extremity. An epidemiologic study. J Sports Med Phys Fitness. 1992;32:106-111.

46. Kuja-Jaaskelainen M, Heinonen O. Osgood-Schlatter’s disease in adolescent athletes: retrospective study of incidence and duration. Am J Sports Med. 1985;13:236-241.

47. Lanor, Wall EJ, Yu LP. Physeal widening in the knee due to stress injury in child athletes. J Pediatr Orthop. 2000;186:1260-1264.

48. LeVeau BF, Bernhard DB. Developmental biomechanics. Effect of forces on the growth, development, and maintenance of the human body. Phys Ther. 1984;64:1874-1892.

49. Liebling MS, Berdon WE, Ruzal-Shapiro C, Levin T, Royle DJ, Wilkinson R. Gymnast’s wrist (pseudoedgyrectoid plate abnormality) in adolescent athletes: findings on plain films and MR imaging. J Pediatr Orthop. 1995;15:157-159.

50. Lyman S, Fleisig GS. Baseball injuries. Med Sci Sports Exerc. 2000;32:93-99.

51. Lyman S, Fleisig GS, Andrews JR, Ousinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in young baseball pitchers. Am J Sports Med. 2002;30:463-468.

52. Lyman S, Fleisig GS, Watertower JW, et al. Longitudinal study of elbow and shoulder pain in young baseball pitchers. Med Sci Sports Exerc. 2001;33:1803-1810.

53. Maffulli N, Bruns W. Injuries in young athletes. Eur J Pediatr. 2000;159:59-63.

54. Maffulli N, Longo UG, Gougoulias N, Caine D, Denaro V. Sport injuries: a review of the literature on normal physiology and balance ability. Am J Sports Med. 1985;13:301-308.

55. Maffulli N, Longo UG, Spiezia F, Denaro V. Sports injuries in young athletes: long-term outcome and prevention strategies. Sports Med. 2010;38:29-34.

56. McHugh MP, Tyler TF, Tetro DT, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school athletes: the role of hip strength and balance ability. Am J Sports Med. 2006;34:661-670.

57. Mirtz TA, Chandler JP, Eyers CM. The effects of physical activity on the growth, development, and remodeling after fracture. J Bone Joint Surg Br. 1996;78:2178.

58. Mirtz TA, Chandler JP, Eyers CM. The effects of physical activity on the growth, development, and remodeling after fracture. J Bone Joint Surg Br. 1996;78:2178.

59. Mirtz TA, Chandler JP, Eyers CM. The effects of physical activity on the growth, development, and remodeling after fracture. J Bone Joint Surg Br. 1996;78:2178.

60. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Syst. 2010;8:536-541.

61. Murray DW, Wilson-MacDonald J, Moshcer E, Rahn BA, Kaslin M. Bone growth and remodeling after fracture. J Bone Joint Surg Br. 1996;78:42-50.

62. Moyer D, Libby L, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Syst. 2010;8:536-541.

63. Moyer D, Libby L, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Syst. 2010;8:536-541.

64. Naun M, Butt S, Mansour R, Muthukumar T, Cassar-Pullicino VN, Roberts A. Stress-induced Salter-Harris I growth plate injury of the proximal tibia: first report. Skeletal Radiol. 2005;34:405-410.

65. Obembe OO, Gaskin CM, Taffollini MJ, Anderson MW. Little League’s shoulder (proximal humeral epiphyseolysis): MRI findings in four boys. Pediatr Radiol. 2007;37:885-889.

66. Olsen SJ, Fleisig GS, Dun S, Loitico J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. Am J Sports Med. 2006;34:985-912.

67. Paterno MV, Taylor-Haas JA, Myer GD, Hewett TE. Prevention of overuse sports injuries in the young athlete. Orthop Clin North Am. 2013;44:553-561.

68. Petty DH, Andrews JR, Fleisig GS, Cain EL. Ulnar collateral ligament reconstruction in high school baseball players: clinical results and injury risk factors. Am J Sports Med. 2004;32:1159-1161.

69. Rauk BC, LaMont LE, Doyle JM. Pediatric upper extremity stress injuries. Curr Opin Pediatr. 2013;25:40-45.

70. Rauh MJ, Keopple TD, Rivara FP, Margheriti AJ, Rice SG. Epidemiology of musculoskeletal injuries among high school cross-country runners. Am J Epidemiol. 2006;163:151-159.

71. Ray TR. Youth baseball injuries: recognition, treatment, and prevention. Curr Sports Med Rep. 2010;9:294-298.

72. Rossi F, Dragoon S. Acute avulsion fractures of the pelvis in adolescent competitive athletes: prevalence, location and sports distribution of 205 cases collected. Skeletal Radiol. 2001;30:127-131.

73. Roy S, Caine D, Singer KM. Stress changes of the distal radial epiphysis in young gymnasts. A report of twenty-one cases and a review of the literature. Am J Sports Med. 1985;15:501-508.

74. Sabich MB, Kim YK, Torry MB, Keimans MA, Hawkins RJ. Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal humeral epiphyseolysis and humeral retroversion. Am J Sports Med. 2005;33:1716-1722.

75. Scharbllig RW, Jones S, Scudder SD. Sever’s disease: what does the literature really tell us? J Pediatr Orthop. 2008;28:212-225.

76. Severini GC, Caccioc A, Campuna V, Milano G. Prevention strategies of shoulder injuries. In: Doral MN, Karlsson J, eds. Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation. New York, NY: Springer; 2015:279-290.

77. Shanley E, Kissenbreth MJ, Thigpen CA, et al. Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers. J Shoulder Elbow Surg. 2015;24:1005-1013.

78. Shanley EB, Bailey L, Rauh MJ, et al. Influence of a prevention program on arm injury risk: an RCT in adolescent pitchers. Orthop J Sports Med. 2014;2 suppl 2:215255691450009.

79. Shanley E, Rauh MJ, McChenner LA, Elleneckersh TS, Garrison JC, Thigpen CA. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. Am J Sports Med. 2011;39:1997-2006.

80. Shanley E, Thigpen CA. Throwing injuries in the adolescent athlete. Int J Sports Phys Ther. 2013;8:530-540.

81. Sharma P, Luscomb KE, Maffulli N. Sports injuries in children. Trauma. 2003;5:245-259.

82. Straccioli A, Casciano R, Levey Friedman H, Meehan WP 3rd, Micheli LJ. Pediatric sports injuries: an age comparison of children versus adolescents. Am J Sports Med. 2013;41:1922-1929.

83. Straccioli A, Casciano R, Levey Friedman H, Stein GJ, Meehan WP 3rd, Micheli LJ. Pediatric sports injuries: a comparison of males versus females. Am J Sports Med. 2014;42:95-972.

84. Torg JS, Pollack H, Sweetditch P. The effect of competitive pitching on the shoulders and elbows of preadolescent baseball pitchers. Pediatrics. 1972;49:267-272.

85. Traks JE, McHugh MP, Caracolizza PA, Buscicco A, Mullanyen M, Nicholas SJ. Muscle strength and range of motion in adolescent pitchers with throwing-related pain: implications for injury prevention. Am J Sports Med. 2008;36:2173-2178.

86. Tyler TF, McHugh MP, Mirabella MR, Mullanyen M, Nicholas SJ. Risk factors for noncontact ankle sprains in high school football players: the role of previous ankle sprains and body mass index. Am J Sports Med. 2006;34:471-475.

87. Valenti M, Quiligotti C, Buggirello M. Sinding-Larsen-Johansson syndrome: a clinical review. Pediatr Radiol. 2000;30:117-135.

88. Vandervliet EJ, Vanhoenacker FM, Snoeckx A, Gielen JL, Van Dyck P, Pirez PM. Sports-related acute and chronic avulsion injuries in children and adolescents with special emphasis on tennis. Br J Sports Med. 2007;41:827-831.