[Physical Therapy]

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Overuse Physeal Injuries in Youth Athletes: Risk Factors, Prevention, and Treatment Strategies

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Context: 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

An estimated 30 million children in the United States are involved annually in organized sport.[1,14] Despite rising awareness of the risks associated with sports participation, overuse injuries continue to increase in youth athlete populations.[1,13-16,18,37] Physeal injuries are overuse injuries exclusive to pediatric populations that are most often sustained during athletic practice or competition.[9,10,12-14,16-18,20,24,30,34-36,41,45,48,53,58,66,81-83,88] While specific mechanisms of injury are heterogeneous and differ by sport, the physis, as the weakest part of the bone, is a site highly prone to injury in youth athletes.[12,13,15,27]

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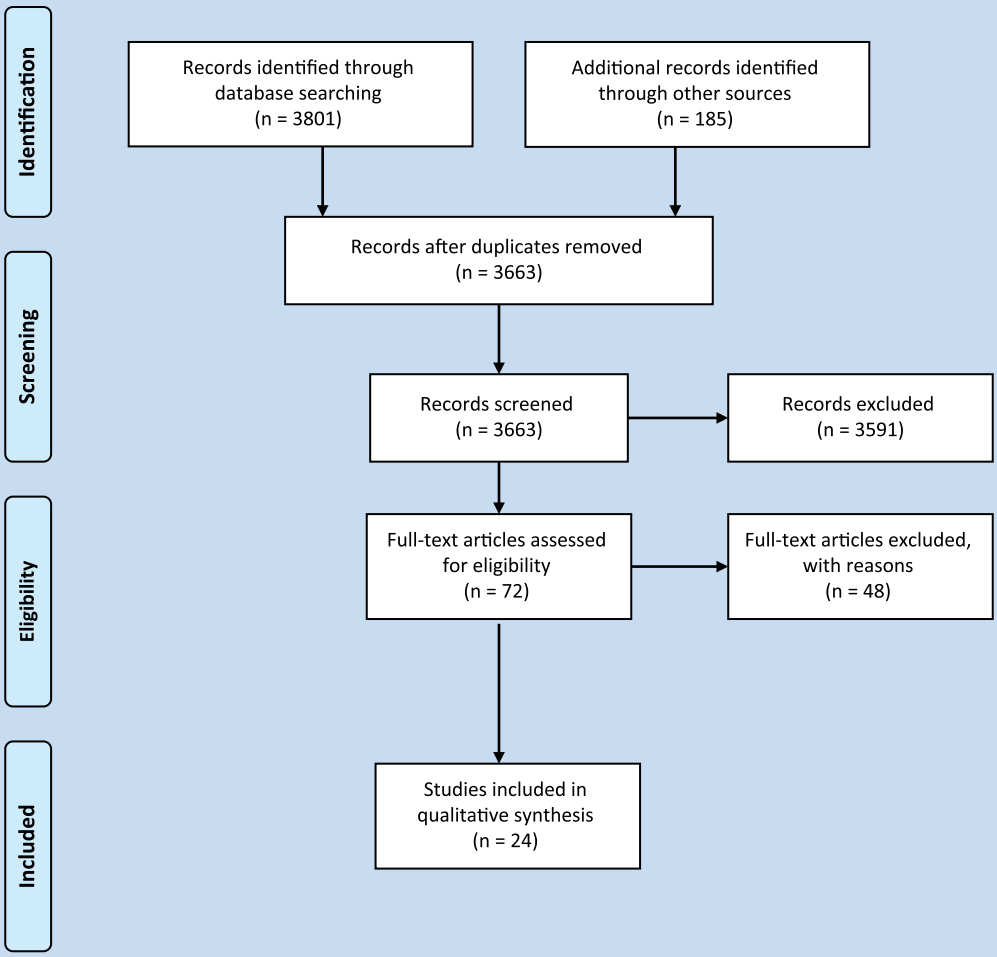

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[60] flow diagram.

Overuse physeal injuries develop in response to excess stress placed on immature bony and soft tissue structures.[13-18,24,25,30-34,36,37,40,42,44,48,58,61,62,73] 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.[13,15,20] 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.[15] 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.[60] 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).[2,4-6,8,21,24,32,33,37-39,44,46,47,49,59,62,63,65,72,73,84,87] 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.[6,21,24,32,44,65,72,84] Eighty-eight percent of studies included data describing treatment strategies after an overuse physeal injury.[2,5,6,8,21,24,32,33,37,39,46,47,49,59,62,63,65,73,84,87] 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.[13,15,20] 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.[13,27] Adequate physical training and variation in sport-specific tasks were also encouraged.[13,28] Treatment strategies after an overuse physeal injury included varying periods of active rest, and when necessary, immobilization of the affected joint.[2,4-6,21,33,37,39,46,47,59,63,87] Gradual return to physical training and conditioning tasks was recommended prior to full return to sport.[4,5,44,46]

Lower Extremity Injuries

Overuse physeal injuries in the LE typically occur when excess stress is placed across areas with major tendon insertions.[7,13] Osgood-Schlatter disease, Sever disease, and Sinding-Larsen-Johansson syndrome are 3 of the most common overuse physeal injuries sustained during childhood.[10,53,56] The first 2 syndromes account for a staggering 18% of all pediatric overuse injuries reported in the literature.[53]

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 (Figure 2).[24] The same inflammatory process occurs with Sever disease but at the Achilles tendon insertion into the vertical calcaneal apophysis.[65] This condition appears to present more often in young boys between the ages of 8 and 12 years.[40] 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.[87] 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).[87]

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.[13,15,20,28,87] Programs designed to enhance cardiovascular endurance and correct physical training errors are also recommended to prevent these types of injuries.[24,27,44] 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.[5,37,39,46,59,65,87] 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.[5,46,65] 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.[24,44,65] 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.[37,39,47,59,62,65] 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.[75]

Upper Extremity Injuries

Overuse physeal injuries in the UE occur due to excess compression or traction forces placed across a joint during sport.[13,30] 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.[2,4,6,8,21,33,38,44,63,65,73,84] Seventy-nine percent of youth gymnasts report wrist pain during practice or competition, while 32% of youth baseball pitchers report arm pain while throwing.[30,51,52]

Gymnast wrist occurs in response to the premature closure of the distal radial physis after excessive compression loads during UE weightbearing.[18,49] Gymnastics is one of the few sports that repeatedly performs closed-chain weightbearing activities on both their upper and lower extremities.[3,11,14,16,17,25,30,31] This injury is typically seen in athletes between the ages of 10 and 14 years (Table 2).[30] 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.[2,4,6,9,21,33,63,84] "Little League elbow" is a term often used to describe a variety of physeal and cartilaginous injuries at the pediatric elbow.[12,13,15,35,38,42] By definition, Little League elbow is a repetitive traction injury to the medial epicondylar apophysis (Figure 4).[35] 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).[21,42,63]

Table 1. Studies that report lower extremity physeal injuries

Study	Level of Evidence (OCEBM)	Sample Size	Age Range, y	Injury Site	Sport	Treatment Options
Beovich[5]	3	22	9-18	Proximal tibial tubercle	Multiple	Activity modifications (20); active rest (2)
de Lucena et al[24]	3	954	12-15	Proximal tibial tubercle	Multiple	Stretching program
Doral et al[32]	4	1	16	Anterior superior iliac spine	Soccer	Surgical intervention
Hajdu et al[37]	4	7	13-16	Proximal tibial tubercle	Ball games, skiing	Active rest (1); surgical intervention (6)
Hussain and Hagroo[39]	3	261	11-18	Proximal tibial tubercle	Multiple	Active rest and NSAIDs (237); surgical intervention (24)
Kolt and Kirkby[44]	3	43	11-19	Multiple sites	Gymnastics	Physical conditioning program
Kujala et al[46]	3	68	9-18	Proximal tibial tubercle	Multiple	Active rest—3 mo; activity modifications—7 mo
Laor et al[47]	4	6	8-15	Distal femur, proximal tibia, proximal fibula	Football, basketball, gymnastics, other	Joint immobilization—1-5 wk
Liebling et al[49]	4	1	13	Distal femur, proximal tibia	Baseball	None
Mital et al[59]	3	118	9-18	Proximal tibial tubercle	Multiple	Active rest/joint immobilization (104); surgical intervention (14)
Nanni et al[62]	4	1	15	Proximal tibia	Rugby	Surgical intervention
Orava and Virtanen[65]	3	185	9-26	Multiple sites	Multiple	Varied
Rossi and Dragoni[72]	3	203	11-18	Pelvic apophyses	Soccer, gymnastics, fencing, tennis	None
Valentino et al[87]	4	1	13	Inferior patellar pole	Football	Active rest—5 mo

NSAIDs, nonsteroidal anti-inflammatory drugs; OCEBM, Oxford Centre for Evidence-based Medicine.

Risk factors associated with the development of gymnast wrist include consistent UE loading and timing of growth spurts.[29] 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.[13,26,29-31] 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 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[2]	4	1	13	Proximal humerus	Nonathlete	Active rest—4 mo
Anton and Podberesky[4]	4	1	13	Proximal humerus	Baseball	Active rest, physical therapy
Binder et al[6]	3	72	8-13	Proximal humerus	Unknown	Joint immobilization—1-4 wk (57); surgical intervention (15)
Boyd and Batt[8]	4	1	15	Proximal humerus	Badminton	None
Carson and Gasser[21]	3	23	14	Proximal humerus	Baseball	Active rest—3 mo
Drescher et al[33]	4	1	12	Proximal humerus	Cricket	Joint immobilization—3 wk; active rest—3 mo
Hang et al[38]	3	343	8-12	Distal humerus	Baseball	None
Kolt and Kirkby[44]	3	43	11-19	Multiple sites	Gymnastics	Physical conditioning program
Obembe et al[63]	4	4	11-15	Proximal humerus	Baseball, tennis	Active rest—3 mo
Orava and Virtanen[65]	3	185	9-26	Multiple sites	Multiple	Varied
Roy et al[73]	4	21	11-18	Distal radius	Gymnastics	None
Torg et al[84]	4	1	12	Proximal humerus	Baseball	None

while fatigued are factors that have been associated with shoulder and elbow dysfunction in youth baseball players.[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.[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.[52]

Despite the lack of epidemiological data concerning gymnast wrist, multiple prevention strategies have been suggested in the literature.[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.[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.[26,28] 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.[51,52,64] These recommendations were designed to decrease an athlete's risk for injury by limiting excessive stress and fatigue during sports participation.[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.[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.[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.[43,66,69] However, an extended period of active rest remains the main treatment of choice for overuse physeal injuries in the UE.

Figure 2. Radiograph of a 13-year-old male football player with Osgood-Schlatter disease.

Figure 3. Radiograph of a 14-year-old male baseball player with Little League shoulder.

DISCUSSION

Physeal injuries represent approximately 15% of all pediatric sports injuries.[13] The physis, as the weakest physiologic structure of the bone in a young athlete, is particularly susceptible to overuse injuries.[9,10,12-20,24,29,34-36,41,45,48,53,58,66,81-83,88] As participation in youth sports continues to increase, clinicians should know the risk factors, prevention strategies, and treatment options associated with overuse physeal injuries.[9,10,13,15,16,35,82,83]

Risk Factors

Risk factors associated with participation in youth sports have been reported; however, none have examined injury risk with respect to physeal injuries.[15] Physeal injuries are exclusive to skeletally immature individuals, suggesting that modifiable and nonmodifiable risk factors are specific to this population.[15,20,24,25,36,44,57,75]

Nonmodifiable risk factors for overuse injuries can include timing of accelerated growth spurts, chronological age, body size, and history of previous injury.[15,27,29] Previous injury is the strongest predictor for the development of future injuries.[15,20,70,86] 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.[86] 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.[13,15,41] 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.[15,27,29,41]

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.[27,68] 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.[51,52,76,79] 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.[24,26,27,77,85] Multiple programs designed to improve flexibility, strength, and balance deficits have protective effects against injuries in this population.[15,19,54,55,67,78]

Figure 4. Radiograph of a 13-year-old male baseball player with Little League elbow.

The most widely accepted treatment strategy after any physeal injury is an extended period of active rest.[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.[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.[2-4,8,14,16-19,21,22,25,29,31,33,43,44,63,74,80] Progressive strength training programs, lasting approximately 6 to 8 weeks, can augment return to throwing or running programs when appropriate.[42] The rehabilitation programs in the literature were vague and lacked return-to-sport criteria.[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.[52,64] 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.[55] Periods of accelerated growth, chronological age, skeletal maturity, and history of previous injury can predispose young athletes to repetitive stress injuries.[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.[15,20,24,25,36,44,75,86]

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.[2-4,8,14,16-18,20-22,25,30,31,33,43,44,74,80] Progressive strength training programs should include gradual return to throwing or running programs when appropriate.[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.[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
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.[3,6,13,21,23,40,41,62,63,75]	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.[15,19,20,42,51,52,55,64,67,71,76,78,80,85]	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.[23,42,64,85,88]	C

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