Proposed Musculoskeletal Examination of Youth and Adolescent Baseball Players

Nathan Allen Kindstrand, PT, DPT, OCS, ATC, CSCS;[1] Brian T. McNeill, PT, DPT, OCS;[2] Scott B. Dickenson, PT, DPT, ATC;[3] Nick Magnusson, PT, DPT, OCS, CSCS;[4] and Jonathan C. Sum, PT, DPT, OCS, SCS[1]

Abstract

With a wide range of injuries in youth baseball, and more than 12 million amateur baseball players in the United States, a comprehensive list of tests and measures may be helpful to assess strength, mobility, and motor control throughout the kinetic chain to reduce risk of injury in this population. Many studies have looked at youth baseball players using a single test or a small number of tests to determine the prevalence of specific injuries in youth baseball, but to this author's knowledge, there is no comprehensive musculoskeletal screen published at this time specific to youth baseball. The purpose of this article is to review literature published over the last year relative to injury in youth and adolescent baseball players in an effort to update the reader on current concepts, risk factors in this population, and to provide an updated systematic screening process that may be used in reducing injury rates.

Introduction

Musculoskeletal screening has become more prevalent in athletics with a focus on both performance enhancement and injury risk reduction. As research continues to investigate variables linked with injury in the youth and adolescent baseball population, it is important to identify demographic characteristics and related tests and measures for sport-specific screening. Multiple studies have looked at injury prevalence in youth and adolescent baseball players (1,2) suggesting this age as an optimal time to introduce screening for musculoskeletal impairments and intervention directed at reducing the risk of injury. For the purpose of this article, adolescents and young people will be defined as ages 10 to 24 years and youth will be defined as the ages of 15 to 24 years per the Society for Adolescent Health and Medicine (3). To the authors' knowledge, there is currently no systematic musculoskeletal screening tool available specific to the youth and adolescent baseball population. With a wide range of injuries in baseball, and more than 12 million amateur baseball players in the United States (4), a comprehensive list of tests and measures may be helpful in identifying strength, mobility, and motor control deficits throughout the kinetic chain that influence an athlete's injury risk.

The lower extremities and trunk play a significant role in transmission of force through the kinetic chain during the throwing motion, and pain in these regions may impair throwing efficiency resulting in increased stress to the shoulder and elbow (5–7). Research has linked reports of elbow and shoulder pain with concurrent low back and knee pain (8) supporting examination of the trunk, lower, and upper extremities in overhead throwing athletes. Furthermore, increasing evidence indicates baseball pitchers are susceptible to femoroacetabular impingement, sports hernias, and groin injuries (9). With lower extremity and trunk injuries prevalent in the baseball population, it is necessary to examine these body regions as part of the screening process. As recent research has identified an increased rate of elbow and shoulder injuries in adult throwers (10,11), early intervention in youth throwers may help to reduce injury rates. The information gathered can be used to direct individualized sport performance enhancement and injury risk reduction programs through identification of musculoskeletal impairments and effective implementation of corrective exercise programs.

The purpose of this article is to review literature published over the last year relative to injury in youth and adolescent baseball players in an effort to update the reader on current concepts, risk factors in this population and to provide an updated systematic screening process that may be used in reducing injury rates.

Literature Review

A number of studies have looked at factors related to injury in the youth baseball population over the past year ranging in topics from; early sport specialization (ESS) (12–16), pitch

[1]Tustin Physical Therapy Specialists, Tustin, CA; [2]USC Division of Biokinesiology and Physical Therapy, Los Angeles, CA; [3]Excel Physical Therapy, Chalfont, PA; and [4]Doctor of Physical Therapy, Los Angeles, CA

Address for correspondence: Nathan Allen Kindstrand, PT, DPT, OCS, ATC, CSCS, Tustin Physical Therapy Specialists, 15000 Kensington Park Dr #110, Tustin, CA 92782; E-mail: nathankindstrand@gmail.com.

1537-890X/2110/376–382
Current Sports Medicine Reports

counts (17–23), prethrowing protocols (24,25), imaging findings (26), to body region-specific inquiries (27–43) in search for opportunities to reduce the risk of injury in this population. We will review a wide range of articles and their relevance to injury risk in this population.

Early Sport Specialization

ESS has become an increasingly common trend in youth athletics over the past several decades and is defined as "intense, year-round training in a single sport at the exclusion of other sports" (44). The degree of ESS can be measured via a point system with one point awarded for each "yes" answer to the questions listed below (13).

1. Does the athlete participate in the sport more than 8 months per year?
2. Has the athlete quit other sports to focus on one primary sport?
3. Is your primary sport more important than other sports?

0 to 1 points, low specialization
2 points, moderate specialization
3 points, high specialization

Although most parents of adolescent athletes believe early specialization will increase their child's baseball abilities "quite a bit" or "a great deal" (12), ESS has been shown to increase injury risk, increase rates of burnout, and lower rates of lifelong sports participation (13). Croci et al. (14) identified those college baseball players who had highly specialized by 13 years were more likely to have a history of upper extremity injury than players who were low/moderate specialization and reported worse subjective throwing arm function. This has been observed in the Little League population and high school population, as well as with players of high sport specialization demonstrating worse throwing arm health compared with low-specialization players (15,16).

Pitch Counts

Pitch counts have been heavily researched in the amateur overhead athlete population relative to injury risk. Traditional pitch count models tracking in game number of pitches leave a large amount of room for error in objectively measuring stress to the throwing arm not including volume and intensity of throws during warm-up, plyocare, long toss, bullpen, flat grounds, and pitches between innings (17,45). Wearable inertial measurement units (IMUs) have been popularized over recent years to improve accuracy in tracking throws and will likely play an important role in measuring workloads in the amateur thrower going forward (22). High speed motion capture systems have been used traditionally in the evaluation of baseball biomechanics, but IMUs, which contain gyroscopes, accelerometers, and sometimes magnetometers, are less intrusive, less expensive, enable measurement of human movement in real-world, nonlaboratory environments and allow the user to quantify both basic information, including throw counts and advanced metrics, such as peak valgus torque (22). While it is widely accepted that high baseball loads induce higher rates of shoulder and elbow injuries in youth throwers (19), one recent study by Shitara et al. (18) identified a significantly higher risk, 2.3× greater risk for shoulder/elbow injury, in athletes with a lower number of pitches per day (<30) compared with individuals who threw >30 pitches per day arguing for maintenance of the physical condition necessary to remain healthy through consistent workloads. This article offers a counter argument to the recommendation for increased rest time between bouts of pitching as acute spikes in pitch counts may place an athlete at increased risk for shoulder and elbow injury compared to an athlete undergoing gradual progressive overload in workload. Matsuura et al. 2021 identified higher risk of elbow pain correlated with a group of 8- to 12-year-old baseball players using inning limits of ≤7 innings compared with a group limited to ≤70 pitches in a single day suggesting pitch counts instead of inning limits may be more valuable when guiding decision making relative to throwing volume (20). Although implementation of throwing volume guidelines are underway, surveys evaluating adherence to these guidelines show poor awareness and noncompliance to these programs in the parent and coaching circles (21,23).

Prethrowing Protocols

Prethrowing protocols have been implemented to prepare the thrower for participation in practice and game competition with focus on reducing injury risk by addressing flexibility and motor control patterns. Specifically motor control or activation of the lumbopelvic complex has been targeted in high school baseball players with the incorporation of a four-exercise warm-up regiment (25). Results of the protocol demonstrated improved isometric strength and better ability to maintain shoulder ROM compared with a control group (25). A clinical review of exercise programs targeting strength and flexibility of the throwing arm to prevent injury identified a 36% risk reduction of shoulder and elbow injuries after stretching the posterior shoulder muscles daily and 50% reduced risk of elbow injury when a multimodal group-based arm care program called the Yokohama Baseball-9 (YKB-9) was completed addressing multiple musculoskeletal impairments (nine strengthening; nine stretching) (24). The YKB-9 was completed two times per week and consisted of 18 exercises, whereas the modified YKB-9 (mYKB-9) consisted of nine exercises and demonstrated significantly increased adherence (24). The mYKB-9 (Fig. 1) consists of stretching for the elbow, shoulder, and hip, dynamic mobility for the scapula and thorax, and lower body balance (24). Implementation of systematic multimodal prethrowing protocols or dynamic warm-ups should be included in the youth and adolescent throwing population targeting the entire kinetic chain in preparation for athletic movement patterns.

Imaging

Imaging studies have been used to determine the effect of valgus torque on the medial elbow relative to ulnar nerve subluxation and neuropathy. While studies regarding ulnar nerve damage/displacement have been performed primarily in adults, a study by Kawabata et al. (26) examined a group of 57 youth baseball players age 10 to 12 years, 31.6% identifying sonographic findings of ulnar nerve displacement correlating more commonly with the dominant hand and with tenderness to palpation of the arcade of Struther's. With these findings in mind diagnostic ultrasound may be a valuable tool in identifying risk for injury in the throwing population.

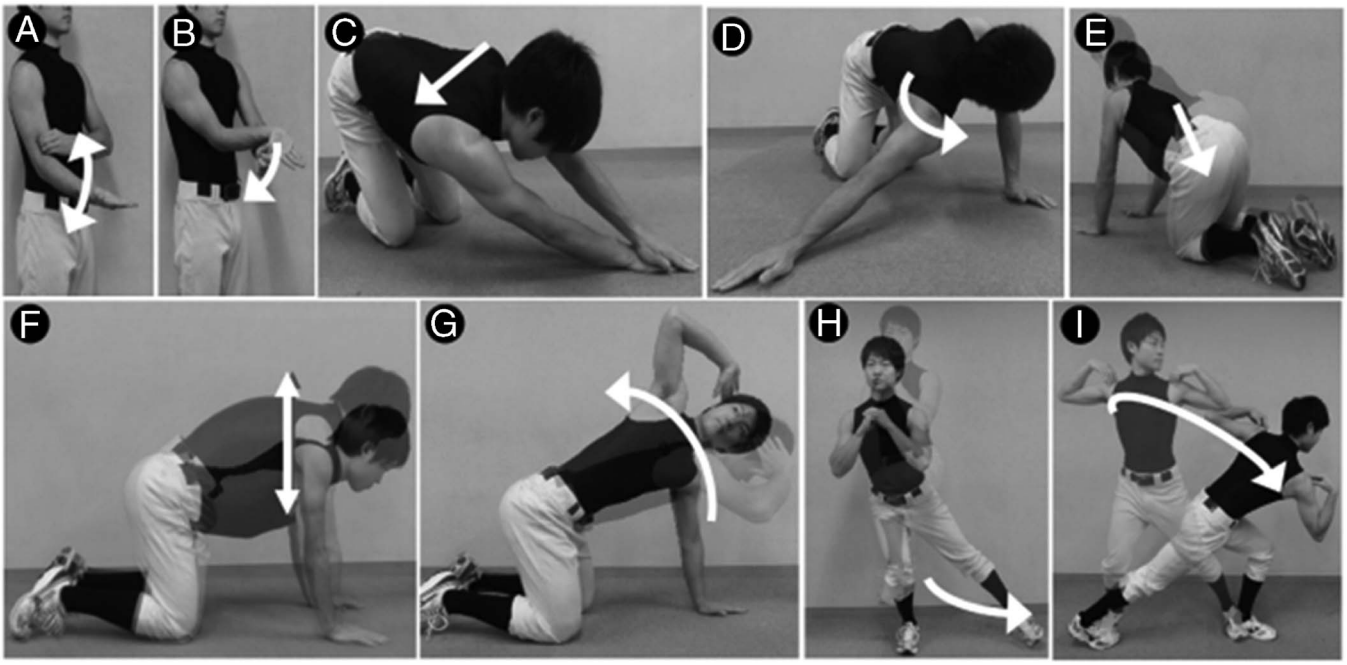

Figure 1: Nine exercises of the modified Yokohama Baseball-9: (A) Massage of brachial muscles: grip the distal brachial muscles and extend the elbow (dominant side, 10 times). (B) Stretch of pronator muscles: with the palm facing upward, hold the thumb and pull down while supinating the forearm and extending the wrist (dominant side, 10 s). (C) Posterior shoulder stretch: start on all fours, put one hand in front of the other and slide the trunk posterolaterally (nondominant side, 10 s). (D) Anterior shoulder stretch: start on all fours, put the hand on the lateral side, and rotate the trunk with horizontal shoulder abduction (dominant side, 10 s). (E) Posterior hip stretch: start on all fours and slide the hip posterolaterally (nondominant side, 10 s). (F) Cat and dog exercise: start on all fours, extend the spine with scapular retraction, and roll the spine with scapular protraction, making a C curve (10 times). (G) Trunk rotation exercise: start on all fours, put the hand on the head, and rotate the trunk with scapula retraction (both sides, 10 times). (H) Lateral slide exercise: assume a single-legged stance on the dominant leg and reach laterally with the nonweight bearing (nondominant) leg (10 times). (I) Elbow-to-knee exercise: step forward with the hand on the shoulder and rotate the pelvis to touch the elbow to the knee (nondominant side, 10 times). Reprinted with permission from Matsel KA, Butler RJ, Malone TR, et al. Current concepts in arm care exercise programs and injury risk reduction in adolescent baseball players: a clinical review. *Sports Health*. 2021; 13:245–50.

Upper Extremity

Shoulder

Numerous studies have investigated normative values for shoulder strength and range of motion in the throwing shoulder and their relation to upper extremity injury (30–32,34). Descriptive profiles of youth baseball players (ages 5 to 12.9 years) have been established for shoulder internal rotation and external rotation passive range of motion, total arc and shoulder internal and external rotation strength at neutral and 90 degrees abduction (34). Recently, differences in shoulder passive range of motion, external rotation, and total range of motion (TRM) or total arc have been identified in youth baseball players (age, 17.2 ± 2.3 years) presenting with neurogenic thoracic outlet syndrome when compared with healthy controls (31). A recent study by Rosen et al. (30) reported glenohumeral internal rotation deficits (GIRD) in throwers with elbow pain average 32.7 degrees compared with 14.5 degrees in a nonpainful group of youth pitchers. Total arc of motion difference (TAMD) in the elbow pain group was 28.3 degrees compared with 6.7 degrees in the nonpainful group (30). In addition, GIRD and TAMD were observed in 88% and 96% of the elbow pain group versus 33.3% and 55.6% of the nonpainful group, respectively (30). Cheng et al. (32) investigated the effects of GIRD on lower extremity kinematics identifying significantly high knee torsion of the leading leg in the experimental group (GIRD, 13.67 ± 0.9 degrees) compared with the control group (4.25 ± 1.369 degrees). Shoulder strength and range of motion have been commonly evaluated in this population in determining risk for injury and recent literature suggests we continue to monitor these variables because of their strong correlation with pain in overhead throwers.

Elbow

A systematic review of the incidence and risk factors for musculoskeletal disorders of the elbow in baseball players was published by Grant et al. (42) reporting 2.2 disorders per 1000 athletic-exposures in youth baseball pitchers (ages 6 to 12 years). Furthermore, 40.6% of the pitchers sustaining an elbow disorder requiring medical attention per year, and elbow pain resulted in youth throwers (pitchers younger than 13 years) missing 21.3% of the season on average (42). Time loss due to elbow pain in adolescent and high school baseball pitchers is reported as significantly less than compared with youth and professional athletes ranging from 2.3% to 11.8% incidence in this population (42). Ulnar collateral ligament laxity and elasticity of the flexor-pronator muscle mass was recently studied in youth baseball pitchers due to the incidence of medial elbow injury (40,43). Hattori et al. (40) identified increased elasticity of the UCL following 100 pitches without increased elasticity of the flexor-pronator muscles in a group of 30 high school baseball pitchers. These authors concluded that

pitchers should be limited to <100 pitches per game to reduce laxity of the UCL (40). Strain ratios of the dominant arm flexor carpi ulnaris and bilateral pronator teres were significantly higher in a group of 89 youth baseball players with medial epicondylar fragmentation compared with 142 healthy baseball players supporting the argument for increased wrist/forearm muscle mass and stiffness in the throwing population (40,43). Successful return to play following ulnar collateral ligament reconstruction was investigated in a systematic review by Haley et al. 2021 reporting return to prior level of performance ranging between 66.67% and 91.4% with an average of 84.4% (39). Glogovac et al. (41) reports patient-reported outcome scores and rates of return to sport were comparable in adolescent baseball players when compared with those reported in adult athletes. While return to sport following UCL reconstruction has been moderately successful in this population, identification of increased strain ratios and elasticity of the UCL may help identify athletes at risk for UCL injury in an attempt to avoid injury and subsequent surgical repair.

Lower Extremity

Sacroiliac joint

Sacroiliac joint (SIJ) dysfunction as a contributing factor for low back pain in 891 high school baseball players was investigated by Kato et al. (29) examining flexibility of the spine and lower extremities through finger-to-floor distance, straight-leg-raising angle, heel-buttock distance, Thomas test, and passive range of motion of the hip. Twenty-two subjects (2.5%) met the criteria for SIJ dysfunction and 12 subjects (55% of SIJ dysfunction group) exhibited throwing arm side symptoms more commonly than in the nonthrowing arm side of bilaterally (29). Those individuals who were categorized as positive for SIJ dysfunction experienced significantly more prior episodes of low back pain than the group without SIJ dysfunction, and the prevalence of low back pain interfering with play was significantly higher in the SIJ dysfunction group (29). This study criteria defined SIJ dysfunction as fulfilling the following two conditions: 1) tenderness of the posterior superior iliac spine (a); and 2) low back and/or buttock pain during the Gaenslen test (b) or Patrick test (c) on the same side as the tenderness (36). These authors additionally reported significant association between a limitation in hip internal rotation on the throwing arm side and SIJ dysfunction (29).

Hip

Hip strength, range of motion, and lower extremity flexibility is hypothesized to influence throwing mechanics and injury risk for the adolescent thrower (36–38). Bullok et al. (38) contributed to established hip range of motion testing as a reliable testing strategy to be performed on field or in the clinic with excellent inter and intra-rater reliability with no rater bias. Hamano et al. (37) examined the relationship between hip abduction strength and hip range of motion and throwing-related shoulder/elbow injuries in 135 high school baseball pitchers. Hip external range of motion on the dominant side and hip abduction strength in both the dominant and nondominant sides were significantly lower in the injured group than in the noninjured group highlighting this as possible predictive characteristics for injury in adolescent throwers (37), and Kato et al. 2021 identified hamstring tightness on the nonthrowing arm side as a potential risk factor for low back pain in 335 high school baseball players. Hip abduction strength, hip external rotation on the dominant side, and hamstring length should be considered as possible impairments related to injury risk in this population.

Youth and Adolescent Baseball
Injury Risk Questionnaire

Name: _____

Age: _____ Height: _____ Weight: _____

# of teams playing for: _____

# of hours training per week: _____

Avg. Pitch Velocity: _____

Positions Played: _____

Types of Pitches: _____

Sport Specialization

1. Does the athlete participate in the sport more than 8 months per year?
2. Has the athlete quit other sports to focus on one primary sport?
3. Is your primary sport more important than other sports?

YES = 1 point
0-1 points = Low specialization
2 points = Moderate Specialization
3 points = High Specialization

Average number of pitches per outing:
0-25 26-50 51-75
76-100 >100

Average number of outings per week:
1 2 3+

Do you participate in a structured pre-throwing protocol addressing strength and flexibility of the upper extremity, trunk and lower extremity?
YES NO

Do you pitch more than 100 inning per year?
YES NO

Have you had shoulder or elbow pain in the past?
YES NO

Do you continue to throw when your arm is fatigued (tired)?
YES NO

Figure 2: Youth and Adolescent Baseball Injury Risk Questionnaire.

Knee

Advancements in return to hitting protocols have been suggested by Giordano et al. (35) following ACL reconstruction in 19 high school baseball athletes. Bilateral knee kinetic values were analyzed using knee extension torque, knee internal and external rotation torque, knee varus and valgus torque, and knee anterior force (35). Comparing kinetics of the baseball swing with those of rehabilitation exercises, it is suggested that tee hitting may be initiated at 13 wk postoperatively following ACL reconstruction on the front knee and 17 wk postoperatively on the back knee (35).

Spine

Yokoe et al. 2020 retrospectively reviewed 267 young athletes who underwent MRI scans to evaluate low back pain following negative radiographic findings for spondylolysis. One hundred and thirty-three of these athletes were positive for spondylolysis with 49 of these athletes defined as baseball players (mean age 15.4 ± 1.6 years) with reported pain with extension-based movement patterns (28). Of these 49 baseball players, 60 lesions were identified in total with spondylolysis located at L5 in 55.4% of these individuals, and players pitching or batting with their dominant hand were associated with lesions located at the contralateral side of the pars interarticularis (28). Spinal alignment in single-leg standing positions in youth baseball players, specifically high thoracic kyphosis and backward trunk inclination angles, have been reported as characteristics of youth baseball players with medial elbow injuries (27). Single limb stance as part of a baseball specific screen may help in identifying those at risk for medial elbow pain in youth baseball.

A. Active Range of Motion **Initials:** _____ **Completed: [ ]**

	Left	Right
- C/S Rotation:	_____	_____
- T/S Rotation:	_____	_____
- Shoulder Flexion:	_____	_____

Comments: _____

B. Strength **Initials:** _____ **Completed: [ ]**

	Left	Right
- Shoulder ER Strength Midline:	_____	_____
- Shoulder IR Strength Midline:	_____	_____
- Shoulder ER Strength 90/90:	_____	_____
- Shoulder IR Strength 90/90:	_____	_____
- Hip Abduction Strength:	_____	_____

Comments: _____

C. Passive Range of Motion UE **Initials:** _____ **Completed: [ ]**

	Left	Right
- Shoulder Internal Rotation @90	_____	_____
- Shoulder External Rotation @90	_____	_____
- Total Arc (IR + ER)	_____	_____

Comments: _____

D. Passive Range of Motion LE **Initials:** _____ **Completed: [ ]**

	Left	Right
- Hip Internal Rotation	_____	_____
- Hip External Rotation	_____	_____
- Straight Leg Raising Angle (Hamstring Length)	_____	_____

Comments: _____

E. Special Tests **Initials:** _____ **Completed: [ ]**

	Left	Right
- Thomas Test	Positive/Negative	Positive/Negative
- Gaenslen Test	Positive/Negative	Positive/Negative
- Patrick Test	Positive/Negative	Positive/Negative

Comments: _____

F. Balance **Initials:** _____ **Completed: [ ]**

	Left	Right
- Single Leg Balance (seconds)	_____	_____
Lumbopelvic Control:	Poor/Fair/Good	Poor/Fair/Good
High Thoracic Kyphosis:	Yes	No
Backward Trunk Inclination:	Yes	No

Comments: _____

Figure 3: Orthopedic tests used in the youth and adolescent throwing population to identify injury risk.

Discussion

A number of characteristics have been previously reported to contribute to increased risk for injury in the youth and adolescent baseball player, including, but not limited to, age, height, playing for multiple teams, pitch velocity, pitching greater than 100 innings per year, being aged 9 to 11 years, being a pitcher or a catcher, training greater than 16 $h \cdot wk^{-1}$, having a history of elbow pain, and pitching with arm fatigue (42). In addition, greater average velocity and percent of fastballs thrown increased risk of UCL tear requiring surgical reconstruction while greater variety of unique pitch types, more days between games pitched, being of greater height and having greater normalized horizontal release location decreased odds of sustaining a UCL injury requiring surgery (42).

Review of literature from the past year indicates consideration of high specialization in sports using the sport specialization questionnaire and grading scale, high pitch counts, poor coach/parent understanding of pitch count guidelines, prethrowing protocols, and morphologic change when considering injury risk for this population. While some degree of sports specialization is helpful in attaining elite-level sport specific skills, it is advised that intense training in a single sports should be delayed until late adolescence to reduce risk of injury and psychological stress (44). Numerous topics relative to pitch counts have been explored to identify strategies effective in reducing injury risk including; utilization of IMUs to monitor pitch counts with improved accuracy, consistent workloads in throwing to decrease frequency of acute spikes in workload increasing injury risk, and limiting pitches thrown per day instead of innings thrown per day to decrease risk of elbow pain. Poor coach/parent understanding of pitch count guidelines has delayed the effectiveness of new guidelines established to improve the health and safety of youth and adolescent baseball players. Continued focus on education of parent and coaches regarding current guidelines is necessary to decrease injury risk. Sonographic differences on ultrasound indicating ulnar nerve displacement in the dominant arm with associated increased tenderness to palpation of the arcade of Struther's may indicate further evaluation of the athlete's injury risk factors is necessary to reduce risk of medial elbow discomfort.

A questionnaire has been constructed using characteristics discussed in this article and is listed in Figure 2. The information gathered in this section of the screening process may be helpful in identifying additional factors related to the creation of an athletes' individualized exercise program as well as provide an opportunity for education of athletes and parents on guidelines for the youth and adolescent thrower.

Many studies have looked at youth and adolescent baseball players using a single test or a small number of tests to determine the prevalence of specific injuries in youth baseball, but to this author's knowledge there is no comprehensive musculoskeletal screen published at this time that is specific to youth and adolescent baseball players. A musculoskeletal screen designed to assess orthopedic impairments throughout the kinetic chain and identify characteristics in youth and adolescent baseball players may be helpful in reducing injury risk in this population. Orthopedic tests highlighted over the research summarized in this article and tests previously used by this author in the youth and adolescent throwing population to identify injury risk have been combined and listed in Figure 3. Deficits in cervical spine rotation may contribute to altered mechanics including early trunk rotation to maintain visibility of the desired location of the pitch during the throwing motion placing undue stress throughout various components of the kinetic chain as a result. College baseball players with decrease neck motion during the preseason have an increased risk of time loss and shoulder/elbow disability during the season (46). Similarly, the relationship of poor thoracic spine mobility to injury in baseball has been observed clinically with correlation to pathology in the shoulder, cervical spine, and lumbar spine. Thoracic spine rotation as a component of overall trunk rotation plays a significant role in allowing the body to store potential energy during sport-specific rotational movement patterns in overhead throwers (47). Due to these potential contributions to injury risk, cervical and thoracic spine active range of motion in rotation have been included in the screen.

Completion of screening immediately following the competitive season or at minimum 6 wk before a competitive season will allow providers ample time to implement a corrective exercise program that can be tailored to each individual athlete based on the findings from their screen to decrease risk of injury and improve sport performance. Alternatively, the screen may be used to test youth and adolescent baseball players during the preseason, mid-season, and postseason to identify baseline data and analyze the effect of competition on orthopedic measures throughout the competitive season.

Conclusions

Musculoskeletal injuries in the youth and adolescent baseball population have been well studied as of late with increased attention toward identifying risk factors and orthopedic impairments associated with increased risk for injury. This article highlights significant findings in the research relative to this population over the past year and provides an updated questionnaire and screening protocol to mitigate musculoskeletal disorders in this population. In addition, current concepts in early sports specialization, pitch counts, prethrowing protocols and imaging studies in the youth and adolescent baseball population are reviewed to update the reader on advancements in research for this population over the past year.

The authors declare no conflict of interest and do not have any financial disclosures.

References

1. Sakata J, Nakamura E, Suzukawa M, *et al.* Physical risk factors for a medial elbow injury in junior baseball players. *Am. J. Sports Med.* 2017; 45:135–43.
2. Matsuura T, Suzue N, Kashiwaguchi S, *et al.* Elbow injuries in youth baseball players without prior elbow pain: a 1-year prospective study. *Orthop. J. Sports Med.* 2013; 1:232596711350994.
3. Society for Adolescent Health and Medicine. Young adult health and well-being: a position statement of the society for adolescent health and medicine. *J. Adolesc. Health.* 2017; 60:758–9.
4. Yen KL, Metzl JD. Sports-specific concerns in the young athlete: baseball. *Pediatr. Emerg. Care.* 2000; 16:215–20.
5. Kageyama M, Sugiyama T, Takai Y, *et al.* Kinematic and kinetic profiles of trunk and lower limbs during baseball pitching in collegiate pitchers [Internet]. *J. Sports Sci. Med.* 2014; 13:742–50.
6. Milewski MD, Ounpuu S, Solomito M, *et al.* Adolescent baseball pitching technique: lower extremity biomechanical analysis. *J. Appl. Biomech.* 2012; 28:491–501.
7. Robb AJ, Fleisig G, Wilk K, *et al.* Passive ranges of motion of the hips and their relationship with pitching biomechanics and ball velocity in professional baseball pitchers. *Am. J. Sports Med.* 2010; 38:2487–93.
8. Sekiguchi T, Hagiwara Y, Momma H, *et al.* Youth baseball players with elbow and shoulder pain have both low back and knee pain: a cross-sectional study. *Knee Surg. Sports Traumatol. Arthrosc.* 2018; 26:1927–35.

9. McCulloch PC, Patel JK, Ramkumar PN, *et al.* Asymmetric hip rotation in professional baseball pitchers. *Orthop. J. Sports Med.* 2014; 2:232596711452157.
10. Lyle Cain E Jr., Andrews JR, Dugas JR, *et al.* Outcome of ulnar collateral ligament reconstruction of the elbow in 1281 athletes results in 743 athletes with minimum 2-year follow-up. *Am. J. Sports Med.* 2010; 38:2426–34.
11. Erickson BJ, Nwachukwu BU, Rosas S, *et al.* Trends in medial ulnar collateral ligament reconstruction in the United States a retrospective review of a large private-payer database from 2007 to 2011. *Am. J. Sports Med.* 2015; 43:1770–4.
12. Post EG, Rosenthal MD, Pennock AT, Rauh MJ. Attitudes and beliefs of little league baseball parents regarding sport specialization and college scholarship availability. *Phys. Sportsmed.* Published online ahead of print July 12, 2021. doi:10.1080/00913847.2021.1949251.
13. Anderson FL, Knudsen ML, Ahmad CS, Popkin CA. Current trends and impact of early sports specialization in the throwing athlete. *Orthop. Clin. N. Am.* 2020; 51:517–25.
14. Croci J, Nicknair J, Goetschius J. Early sport specialization linked to throwing arm function and upper extremity injury history in college baseball players. *Sports Health.* 2021; 13:230–6.
15. Post EG, Rosenthal MD, Pennock AT, Rauh MJ. Prevalence and consequences of sport specialization among little league baseball players. *Sports Health.* 2021; 13:223–9.
16. Post EG, Struminger AH, Hibberd EE. Sport specialization is associated with upper-extremity overuse injury in high school baseball players. *J. Shoulder Elb. Surg.* 2020; 29:1775–82.
17. Dowling B, McNally MP, Chaudhari AMW, Oñate JA. A review of workload-monitoring considerations for baseball pitchers. *J. Athl. Train.* 2020; 55:911–7.
18. Shitara H, Tajika T, Kuboi T, *et al.* A small number of daily pitches induces shoulder and elbow injuries among high school baseball pitchers: a prospective study. *Sci. Rep.* 2020; 10:21955.
19. Shitara H, Tajika T, Kuboi T, *et al.* High baseball loads induce shoulder and elbow injuries among high school baseball pitchers: a prospective study. *Sci. Rep.* 2021; 11:351.
20. Matsuura T, Takata Y, Iwame T, *et al.* Limiting the pitch count in youth baseball pitchers decreases elbow pain. *Orthop. J. Sports Med.* 2021; 9:232596712198910.
21. Eichinger JK, Goodloe JB, Lin JJ, *et al.* Pitch count adherence and injury assessment of youth baseball in South Carolina. *J. Orthop.* 2020; 21:62–8.
22. Rose MJ, McCollum KA, Freehill MT, Cain SM. Quantifying throw counts and intensities throughout a season in youth baseball players: a pilot study. *J. Biomech. Eng.* 2021; 143:034502.
23. Reintgen C, Zeppieri G Jr., Bruner M, *et al.* Youth baseball caregiver understanding of safe pitching guidelines and player injury. *Int. J. Sports Phys. Ther.* 2021; 16:807–15.
24. Matsel KA, Butler RJ, Malone TR, *et al.* Current concepts in arm care exercise programs and injury risk reduction in adolescent baseball players: a clinical review. *Sports Health.* 2021; 13:245–50.
25. Downs J, Wasserberger K, Oliver GD. Influence of a pre-throwing protocol on range of motion and strength in baseball athletes. *Int. J. Sports Med.* 2021; 42: 183–90.
26. Kawabata M, Miyata T, Tatsuki H, *et al.* Ultrasonographic prevalence of ulnar nerve displacement at the elbow in young baseball players. *PM R.* 2022; 14:955–62.
27. Saito A, Okada K, Sato H, *et al.* High thoracic kyphosis and backward trunk inclination angles in the single-leg standing position associate with medial elbow injuries in youth baseball players: a cross-sectional study. *J. Sport Rehabil.* 2021; 30:786–93.
28. Yokoe T, Tajima T, Sugimura H, *et al.* Comparison of symptomatic spondylolysis in young soccer and baseball players. *J. Orthop. Surg. Res.* 2020; 15:378.
29. Kato K, Otoshi KI, Tominaga R, *et al.* The prevalence and clinical characteristics of sacroiliac joint dysfunction in adolescent baseball players. *J. Orthop. Sci.* 2022; 27:335–41.
30. Rosen M, Meijer K, Tucker S, *et al.* Shoulder range of motion deficits in youth throwers presenting with elbow pain. *Sports Health.* 2022; 14:478–82.
31. Garrison JC, Hannon JP, Conway JE. Differences in passive shoulder range of motion between baseball players with neurogenic thoracic outlet syndrome and matched healthy controls. *Orthop. J. Sports Med.* 2021; 9:23259671211000764.
32. Cheng SC, Lin SM, Lin WJ. The potential impact from glenohumeral internal rotation deficit to the knee kinematics in baseball pitchers: a case-control study. *Medicine.* 2021; 100:e24066.
33. Oliver GD, Downs JL, Barbosa GM, Camargo PR. Descriptive profile of shoulder range of motion and strength in youth athletes participating in overhead sports. *Int. J. Sports Phys. Ther.* 2020; 15:1090–8.
34. Nakaji RM, Ellenbecker TS, McClenahan KM, *et al.* Descriptive strength and range of motion in youth baseball players. *Int. J. Sports Phys. Ther.* 2021; 16:195–206.
35. Giordano K, Chaput M, Anz A, *et al.* Knee kinetics in baseball hitting and return to play after ACL reconstruction. *Int. J. Sports Med.* 2021; 42:847–52.
36. Kato K, Otoshi KI, Tominaga R, *et al.* Influences of limited flexibility of the lower extremities and occurrence of low back pain in adolescent baseball players: a prospective cohort study. *J. Orthop. Sci.* 2021; 27:355–9.
37. Hamano N, Shitara H, Tajika T, *et al.* Relationship between upper limb injuries and hip range of motion and strength in high school baseball pitchers. *J. Orthop. Surg.* 2021; 29:23094990211003347.
38. Bullock GS, Beck EC, Collins GS, *et al.* Hip internal and external rotation range of motion reliability in youth baseball players. *J. Sports Med. Phys. Fitness.* 2021; 61:75–9.
39. Hadley CJ, Edelman D, Arevalo A, *et al.* Ulnar collateral ligament reconstruction in adolescents: a systematic review. *Am. J. Sports Med.* 2021; 49:1355–62.
40. Hattori H, Akasaka K, Otsudo T, *et al.* Ulnar collateral ligament laxity after repetitive pitching: associated factors in high school baseball pitchers. *Am. J. Sports Med.* 2021; 49:1626–33.
41. Glogovac G, Kakazu R, Aretakis AC, Grawe BM. Return to sport and sports-specific outcomes following ulnar collateral ligament reconstruction in adolescent athletes: a systematic review. *HSS J.* 2020; 16:242–9.
42. Grant C, Tuff T, Corso M, *et al.* Incidence and risk factors for musculoskeletal disorders of the elbow in baseball pitchers: a systematic review of the literature. *J. Can. Chiropr. Assoc.* 2020; 64:165–79.
43. Saito A, Okada K, Shibata K, *et al.* High elasticity of the flexor carpi ulnaris and pronator teres muscles is associated with medial elbow injuries in youth baseball players. *Phys. Sportsmed.* 2021; 1–8.
44. Jayanthi N, Pinkham C, Dugas L, *et al.* Sports specialization in young athletes: evidence-based recommendations. *Sports Health.* 2013; 5:251–7.
45. Zaremski JL, Zeppieri G Jr., Jones DL, *et al.* Unaccounted workload factor: game-day pitch counts in high school baseball pitchers-an observational study. *Orthop. J. Sports Med.* 2018; 6:2325967118765255.
46. Devaney LL, Denegar CR, Thigpen CA, *et al.* Preseason neck mobility is associated with throwing-related shoulder and elbow injuries, pain, and disability in college baseball pitchers. *Orthop. J. Sports Med.* 2020; 8:232596712092055.
47. Stodden DF, Fleisig GS, McLean SP, *et al.* Relationship of pelvis and upper torso kinematics to pitched baseball velocity. *J. Appl. Biomech.* 2001; 17:164–72.