

The Influence of Pitch Count and Type on Elbow and Shoulder Injuries in Adolescent Baseball Pitchers: A Systematic Review

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Context: There is no one single risk factor causing shoulder or elbow injury. However, in adolescent baseball, rising pitch counts and specific pitch types influence risk of injury, but to what degree is still under investigation. **Objective:** To systematically review the current literature to determine to what degree baseball pitch count or pitch type continues to influence the risk of shoulder or elbow injuries in adolescent baseball players. **Data Sources:** Relevant articles were identified through *PubMed*, *MEDLINE*, *Science Direct*, *Cumulative Index to Nursing and Allied Health Literature (CINAHL)*, and single-citation matching from January 2000 through November 2013 using the following terms: "adolescent and baseball," "adolescent and pitch count or pitch type," and "shoulder or elbow and injuries and adolescent"; searching resulted in 10 articles. **Study Selection:** Studies were included if they met the following criteria: (1) used a peer-reviewed cohort, a descriptive epidemiology, a case control, a cross-sectional, or a controlled clinical trial study, (2) were written in English, (3) involved adolescents 13 to 18 years of age, (4) provided an abstract, and (5) included study outcomes measuring the influence of pitch count and/or pitch type on shoulder and/or elbow injuries. **Data Extraction:** Three reviewers independently assessed and graded studies according to the Strengthening in the Reporting of Observational Studies in Epidemiology (STROBE) and Physiotherapy Evidence Database (PEDro) checklists as applicable. Data of interest included subjects, groups when specified, methods of observation/clinical trial and descriptive data, odds ratios (OR), and 95% confidence intervals (CI) with reference to pitch count/type's influence on shoulder/elbow injuries. **Data Synthesis:** Three initial and one subsequent article found from single-citation matching met the inclusion criteria. The PEDro score for one clinical trial was 5.33 ± 0.94 (maximum=10). Two studies examined postgame complaints of

elbow and/or shoulder pain related to pitch count/type, finding that pitching >600 pitches per season increased risk of elbow pain (OR 2.61-3.34) while pitching >75 pitches per game increased risk of shoulder pain (OR 3.22, CI: 1.84-5.61). Increased age demonstrated a significant increased risk of elbow pain in two studies (OR 1.66-2.91) especially when throwing the slider (OR 3.49, P<0.01). An increased injury risk in adolescent pitchers (16.7-20.2 years old [yo]) was found when pitching >8 months (OR 5.05, CI: 1.39-18.32), when pitching >80 pitches per appearance (OR 3.83, CI: 1.36-10.77), and when regularly pitching through fatigue (OR 36.18, CI: 5.92-221.22). No significance was found at this time to support the claim that curveballs are more harmful than other pitches such as fastballs. **Conclusions:** Pitch counts and type continue to increase risk of shoulder and elbow injury and pain in adolescent baseball players. An increased pitch count and age-related use of specialty pitches appear associated with an increased frequency of joint pain. **Clinical Application:** Athletic trainers often work with adolescent pitchers and need to remain aware of potential modifiable risk factors causing injury. To spread awareness of these potential risks, athletic trainers should promote increased pitch tracking for their athletes and educate them, coaches, and parents about the implicit influences pitches have on injuries.

Introduction

Baseball is a generally safe sport, but injuries do occur. For a baseball pitcher, the majority of these injuries involve overuse of the elbow and/or shoulder.¹⁻³ These injuries are the result of repeated microtrauma sustained over the course of a baseball outing.⁴ Youth athletes are more susceptible to overuse injuries of the shoulder and elbow due to incomplete bone ossification, overloading stresses placed on the joints from full-speed throwing motions, and general instability of the glenohumeral joint with fatigue.^{1,4} In turn, this places pitchers especially at risk of injury.⁵

Research has identified several risk factors contributing to why certain baseball pitches may be more harmful than others.^{1-3,6} These risk factors often include the following: (1) height, (2) weight, (3) pitch count per outing, (4) pitch count per season or year, and (5) pitching outside of an organized league.⁷ The general consensus regarding which pitches are harmful and at what age they are harmful is mostly pure controversy at this point.⁶ Because of this uncertainty regarding the risks of certain pitch types and pitch counts, we conducted a systematic review of the current literature to review the existing influence that pitch count and type hold on shoulder and elbow injuries in adolescent baseball pitchers.

Methods

Data Sources

We conducted an initial search of articles using *PubMed*, *MEDLINE*, *Science Direct*, and the *Cumulative Index to Nursing and Allied Health Literature (CINAHL)* with the search terms “adolescent and baseball,” “adolescent and pitch count or pitch type,” and “shoulder or elbow and injuries and adolescent.” Included studies were published in English between January 2000 and November 2013 and pertained to adolescent baseball pitchers between the ages of 13 and 18. Cohort, descriptive epidemiology, case control, cross-sectional, and controlled clinical trials were the studies of interest. We cross-referenced the bibliographies of relevant studies to identify other applicable studies that would meet the inclusion criteria.

Study Selection

Studies identified in our search included outcomes measuring the influence of pitch count and/or pitch type on shoulder and/or elbow injuries. Study participants were excluded if they did not fall into the identified adolescent age range (13-18 years of age). Studies only had to have an available abstract to qualify for review as long as they met the inclusion criteria and provided key outcome measures to make an inference related to the clinical question. After all duplicate studies were removed, 10 articles were identified across the databases. Of these articles, four were assessed for eligibility based on the inclusion criteria. An additional article was single-citation matched and screened for use. Out of the five articles screened for eligibility, only one was excluded due to a lack of key outcome measures geared specifically

towards our clinical question. Four studies met the inclusion criteria; the process of article selection is displayed in Figure 1.

Data Extraction

Three readers individually reviewed and appraised the included articles according to the Strengthening in the Reporting of Observation Studies in Epidemiology (STROBE) scale and the Physiotherapy Evidence Database (PEDro) scale. Three articles were appraised according to the STROBE checklist, and one was graded according to the PEDro scale. The reviewers came together to discuss and compare discrepancies on their independent ratings of the studies when applicable. Extracted data included (1) subject demographics, (2) methods of observation, and (3) odds ratios (OR) and 95% confidence intervals (CI) in regards to the influence of pitch count and/or pitch type on the risk of shoulder and/or elbow injuries.

Results

Of the articles retrieved from the preliminary search, four were selected for inclusion in our review. Two studies evaluated the association between elbow pain, shoulder pain, and several factors, including pitch type and count.^{7,8} One study assessed the correlation between frequency of new injuries, pitching practices, and previous history of injury.⁵ The final study assessed the biomechanics of throwing fastballs, curveballs, and change-ups to discover the possible risks of throwing each pitch relative to joint injury.⁹ Key summary findings of the included studies are summarized in Table 1.

Olsen et al.⁵ surveyed adolescent pitchers 14-20 years of age concerning injury history, playing history, and potential risk factors in those participants who sustained severe pitching-related injury. Injury was defined as an elbow or shoulder injury in the dominant arm that resulted in surgery. High school and college pitchers were also surveyed for an age-matched control. The injury group included 95 adolescent male pitchers who underwent an elbow or shoulder surgery between September 2003 and September 2004. The injured group was further divided into subgroups of elbow injury and shoulder injury. Statistical Package for the Social Sciences (SPSS) 10.0.5 was used to analyze the statistical differences between the injured groups and the control group. A chi-square test was conducted to analyze categorical variables and a 2-tailed student *t* test to analyze continuous variables.

Researchers assessed the number of pitches per appearance and found a statistically significant effect ($p < 0.001$) on shoulder injury (93.6 ± 15.2 pitches) and elbow injury (85.2 ± 23.8 pitches). The number of pitches per year yielded a statistical significance ($p < 0.001$) on elbow and shoulder injuries (2608.4 ± 1587.3 and 2458.6 ± 1321.3 pitches respectively).

Lyman et al.⁷ conducted a study to determine the correlation between elbow and shoulder pain and numerous variables. (See Table 2.) Researchers studied two youth baseball teams for two consecutive seasons and conducted a follow-up at the conclusion of each season. Postgame data was collected via a telephone interview from each of the pitchers to assess the incidence of pitching-related arm injuries. The ages of pitchers included in the study ranged from 9-12 years ($N=298$). The variables of interest included pitch count per game, pitch count per season, and pitch type. The researchers utilized a generalized estimating equation (GEE) to factor in significant variables when analyzing statistical data. This model yielded ORs and 95% CIs for all potential incidents of elbow and shoulder pain. P-values were set at < 0.05 .

The study found that subjects were more than twice as likely (OR 2.07, 95% CI: 0.68-6.26) to experience elbow pain when throwing 600 or more pitches in a season compared to throwing 300-599 pitches (OR 0.54, 95% CI: 0.32-0.92). A higher number of pitches per game showed more of an effect on shoulder rather than elbow pain. Throwing more than 75 pitches per game greatly increased the risk of shoulder pain (OR 3.22, 95% CI: 1.84-5.61) as opposed to only pitching 1-24 pitches per game. In regards to pitch type, only one pitch proved to be moderately substantial in producing elbow pain—the sinker. Use of the sinker proved to be nearly twice as likely to produce pain as opposed to only throwing fastballs.

Lyman et al.⁸ followed 476 baseball pitchers between the ages of 9 and 14 years of age for one complete baseball season to assess the effects of pitch type, count, and mechanics and how they affect

elbow and shoulder pain in youth baseball pitchers. (See Table 3.) A pre-season questionnaire was administered via telephone to collect baseball-related information and demographics. During the entire season, each team kept a log of pitches thrown by each pitcher in a game. After each pitching performance, participants were contacted via telephone by a university-based survey research unit for a postgame interview. Questions assessed fatigue, joint stiffness, joint tightness, and pain during or after pitching. After the season, all 476 participants were once again contacted via telephone to complete a follow-up interview. Interviewers inquired about pitch types thrown in previous games during the course of the year.

Pitch types were assessed for correlation to elbow and shoulder pain. The analysis found that, overall, there was a significant relationship between elbow pain and the slider pitch in pitchers 13-14 years of age (OR 3.49). Among pitchers who were 11-12 years of age, a significant relationship was found between shoulder pain and the slider (OR 3.38). There was an 86% increased risk of elbow pain overall when throwing the slider. A significant increase was found in shoulder pain among pitchers who were 9-10 years of age and who threw 100 or more pitches per game (OR 2.01). There was also a significant increase in shoulder pain in pitchers 13-14 years of age who threw 75 to 99 pitches per game (OR 2.17) as well as 100 or more pitches per game (OR 2.15). No statistically significant evidence was found in regards to the correlation between elbow pain and pitch count. Researchers found an increase in elbow pain with 601-800 pitches per season (OR 3.34) and a significant increase in shoulder pain with over 800 pitches per season (OR 3.29).

Dun et al.⁹ asked 29 pitchers (age 12.5 ± 1.7 years) to throw five fastballs, five curveballs, and five change-ups in a laboratory setting to examine the biomechanical differences between the three pitches. A three-dimensional motion analysis system was used to capture data from sensors on key anatomical structures associated with pitching mechanics. Parameters of interest included elbow varus torque, shoulder internal rotation, and elbow proximal force. To analyze the differences between the three pitches, researchers conducted a repeated-measures analysis of variance (ANOVA). Post hoc paired *t* tests were performed when an ANOVA detected a significant difference. Comparisons were made at $p < 0.01$.

The analysis found that, overall, the fastball produced the greatest values for factors related to elbow varus torque (34.8 ± 15.4 N·m) and shoulder internal rotation (35.2 ± 15.6 N·m). During the arm acceleration phase, the fastball yielded significantly higher numbers than the curveball and change-up for both elbow proximal force (461.9 ± 163.2 N) and shoulder proximal force (465.6 ± 169.9 N). For most parameters, the curveball produced the next highest values, and the change-up generated the lowest amounts of force and torque on the elbow and shoulder.

Discussion

The results suggest that a cumulative pitch count of more than 600 pitches over the course of a season increases the occurrence of elbow pain compared to a cumulative season count between 300 and 599 pitches.⁷ Cumulative pitches per game appear to have more of an effect on shoulder pain as pain increases with 75 or more pitches per game,⁷ although a cumulative season count of over 800 correlated with an increased risk of shoulder pain.⁵ Overall, the data collected from the studies support a greater influence on elbow pain with increased season pitch count and a greater influence on shoulder pain with increased game pitch count.^{5,7,8}

The National Athletic Trainers' Association (NATA) recommends that a decrease in pitch volume serve as a preventative measure in overuse injuries for the pediatric thrower.¹⁰ As an additional preventative measure, the organization recommends that athletes, coaches, parents, and medical personnel watch for signs of arm pain, fatigue, and decreased performance as these may indicate the potential for overuse injuries.¹⁰ In this age of competitive sports, it is easy for coaches, parents, and even the athletes themselves to ignore pain and fatigue. If decreased performance is seen, coaches and parents often push the athlete to work harder to improve their performance despite any pain or fatigue. In fact, a survey conducted by Ahmad et al.¹¹ found that only half of youth pitchers believed pitch count to be a risk factor for injury. The other groups surveyed—high school pitchers, collegiate pitchers, coaches, and parents—showed a significantly increased awareness that pitch count is an important risk factor, specifically in elbow injuries.

It is more difficult to discern an association between pitch count and injury due to the differences in biomechanics between pitches and the athletes themselves, as well as a general controversy regarding which pitch causes the most harm.⁶ Of the pitches studied, the fastball appeared to place the most stress on the joints.⁹ The sinker was found to have a greater effect on elbow injuries than the fastball.⁷ The slider was especially influential on pitchers 13-14 years of age in regards to elbow pain and in pitchers 11-12 years of age in regards to shoulder pain.⁸ In general, the fastball was found to be the most harmful for both the elbow and shoulder, and the sinker specifically for the elbow.^{7,9}

The NATA thus recommends a restriction on the use of breaking pitches until an athlete can demonstrate frequent pitching of such a pitch without any signs or symptoms of injury.¹⁰ When surveyed,¹¹ half of youth pitchers believed pitch type is a risk factor for injury while high school and collegiate pitchers, coaches, and parents did not. There was also a low consensus among the different pitching levels that high-velocity pitching was a significant risk factor. The data supporting that faster velocity pitches like the fastball and sinker^{7,9} are more harmful make this survey response especially noteworthy. Another NATA recommendation limits the full-effort pitching of those 9 to 14 years of age to the following: throwing 75 pitches per game, 600 pitches per season, and 2,000-3,000 pitches per year.¹⁰ The organization also recommends that pitchers 15-18 years of age pitch no more than 90 pitches per game in no more than two games per week.⁵

These recommendations are in line with the data found by Lyman et al.⁸ However, the reality of actually enforcing these recommendations is not evident at present. We believe that further research is necessary for the harm of increased pitch count and increased use of harmful pitches to be evident to the entire population involved—coaches, parents, and athletes. Although the necessity of further research investigating the influence of pitch count and pitch type on injuries exists, it is difficult to do such research with adolescents and youth. They are still developing, and the degree of pitch influence on injury for a specific age is still unclear beyond the fact that youth and adolescents are more susceptible to injury than older individuals due to incomplete ossification and overloading joint stresses.^{1,4}

The developmental differences in biomechanics present a large gray area as to when a pitcher is able to throw a certain pitch. Although it is possible to make recommendations for certain age ranges, there will always be outliers to these ranges as rates of development can differ greatly amongst children. It is impractical to pinpoint a certain age or stage of development, as work would have to be done with children on an individual basis to determine where that child stands developmentally and what his or her joints are able to handle. In general, we believe it is not necessarily what one pitches that is harmful, but rather the amount of force with which one pitches on a regular basis. The more effort behind a pitch, the more potential it has to be harmful. We also agree that individually tracking pitch counts and types is an important step to determine individual risk factors for elbow and shoulder injury.

Limitations

The quantifiable data that was deemed significant included a wide CI range, making it difficult to determine at what age a pitcher is most susceptible to certain variables surrounding shoulder and/or elbow injury. There was also a lack of current research to utilize because most studies analyzing pitch count and pitch type were conducted earlier than our search parameters allowed us to include.

Clinical Relevance

Athletic trainers often cover baseball and work with pitchers at all levels of play. Athletic trainers can promote increased awareness of the influences of pitch count and pitch type to coaches, parents, and athletes at both small-scale team locker room chats and at large-scale community events. Athletic trainers can help promote pitch tracking and even keep their own records of pitch count and type to identify those athletes most at risk of injury. After identification occurs, athletic trainers can then work with the athlete, coaches, and parents to determine the best course of action for the athlete.

Conclusions

Pitch count and pitch type have a definite influence on shoulder and elbow injuries. The evidence found from our review suggests an overall increase in elbow pain with increased pitches over the course of a season and an overall increase in shoulder pain with increased pitches per game. The fastball, slider, and sinker were found to have an influence on increased joint pain. A lack of congruency in biomechanical development rates among children limits the ability to draw concrete conclusions about the degree of influence that pitch count and pitch type hold on shoulder and elbow injuries. Pitching should be monitored for injury risk on an individual basis until further research can uncover a more precise correlation among pitch count, pitch type, and age-specific shoulder and elbow injury.

References

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Figure 1. Study Inclusion and Exclusion Flowchart

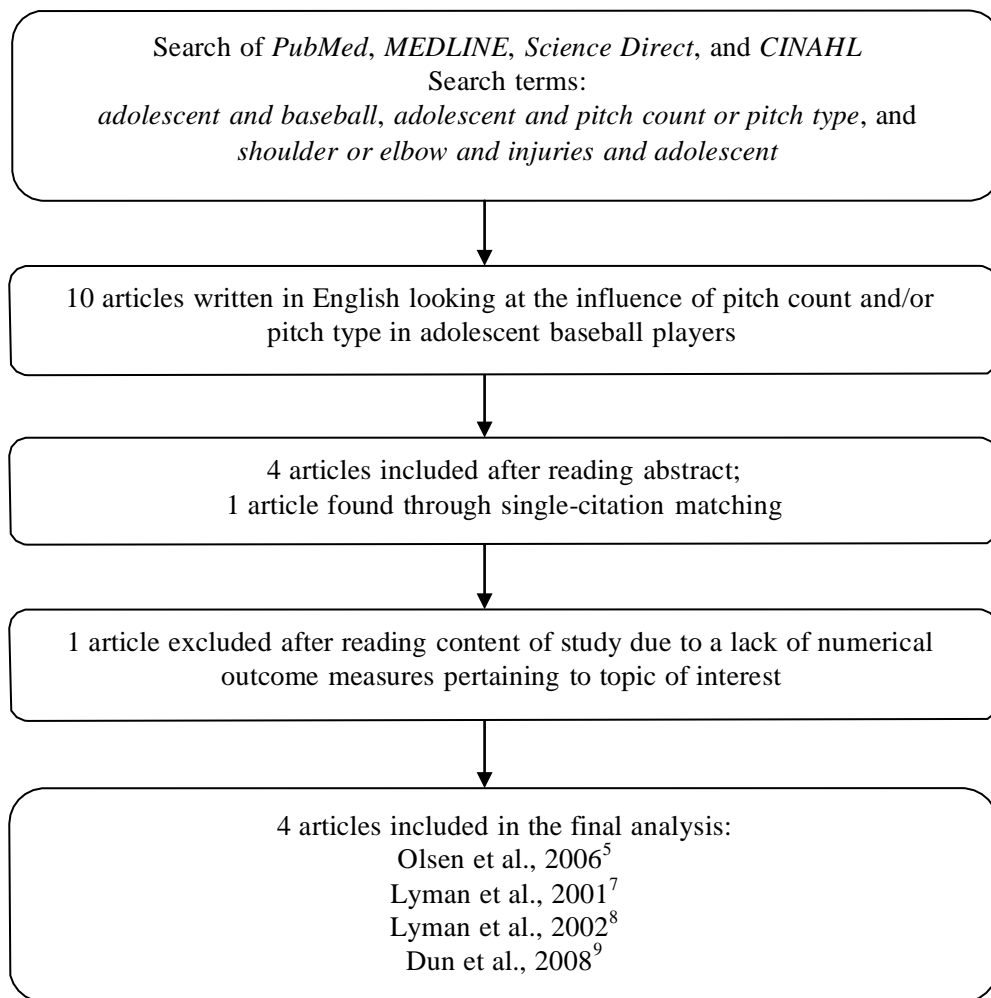


Table 1 Summary Data for the Reviewed Articles

References	Subjects/Groups	Methods	Outcome Measures	Results
Dun et al. ⁹	<ul style="list-style-type: none"> • 29 volunteer active youth baseball pitchers claiming to throw the fastball, curveball, and change-up • Order of fastball, curveball, and change-up pitch sets randomized 	<ul style="list-style-type: none"> • No proper biomechanical instruction given • Markers placed on bony landmarks • Subjects followed own personal warm-up routine, pitched three sets of pitches with maximum effort from indoor artificial mound • Motion data and ball velocity recorded • ANOVA with post hoc <i>t</i>-test used 	<ul style="list-style-type: none"> • Kinetic, kinematic, and timing parameters of the fastball, curveball, and change-up 	<ul style="list-style-type: none"> • Fastball produced greatest elbow varus torque (34.8 ± 15.4 N·m), shoulder internal rotation torque (35.2 ± 15.6 N·m), and elbow and shoulder proximal forces (461.9 ± 163.2 N, 465.6 ± 169.9 N) • Curveball had next highest values • Change-up had lowest values
Lyman et al. ⁷	<ul style="list-style-type: none"> • 298 youth baseball pitchers in 9-10 year old and 11-12 year old leagues from 2 large youth baseball parks in metro-Birmingham, Alabama • 180 followed from first season, 218 from second, 100 followed in both • Data from both seasons analyzed together 	<ul style="list-style-type: none"> • Prospective cohort conducted over two seasons • Each pitcher contacted via telephone after every game pitched to identify arm complaints and general performance • Generalized estimating equation used to assess associations 	<ul style="list-style-type: none"> • Complaint frequency • Pain location • Pain severity • Elbow pain as associated with pitches, innings, games, and pitch types • Shoulder pain as associated with pitches, innings, games, and pitch types 	<ul style="list-style-type: none"> • 600+ pitches/season increased elbow pain (OR 2.07; 95% CI: 0.68, 6.26) compared to 300-599 pitches/season (OR 0.54; 95% CI: 0.32, 0.92) • 75+ pitches/game increased shoulder pain (OR 3.22; 95% CI: 1.84, 5.61) compared to 1-24 pitches • Sinker twice as likely for increased elbow pain compared to fastball
Lyman et al. ⁸	<ul style="list-style-type: none"> • 476 youth baseball pitchers from 15 youth baseball parks in Alabama during 1999 spring season • All analyzed for pain • 240 analyzed for mechanics, 288 for change-up, 252 for curveball, and 65 for slider 	<ul style="list-style-type: none"> • Mechanics videos analyzed • Pitch count logs analyzed • Telephone interview involving simplified questions after every game pitched • Statistical analyses including descriptive and inferential analyses, 	<ul style="list-style-type: none"> • Postgame complaints of elbow or shoulder pain • Independent variables such as pitch count, type, and mechanics 	<p>Pitch Type</p> <ul style="list-style-type: none"> • Slider increased elbow pain in those 13-14 yo (OR 3.49) and shoulder pain in those 11-12 yo (OR 3.38) <p>Pitches/Game</p> <ul style="list-style-type: none"> • 100+ pitches/game increased shoulder pain in youth 9-10 yo (OR 2.01)

	<ul style="list-style-type: none"> • Groups divided by age 	<p>generalized estimating equations, and logistic regression analysis</p>		<ul style="list-style-type: none"> • 75-99 pitches/game increased shoulder pain in those 13-14 yo (OR 2.17) as well as 100+ pitches/game (OR 2.15) <p>Pitches/Season</p> <ul style="list-style-type: none"> • 601-800 pitches/season increased elbow pain (OR 3.34) • 800+ pitches/season increased shoulder pain (OR 3.29)
Olsen et al. ⁵	<ul style="list-style-type: none"> • 95 adolescent male pitchers who had surgery by author categorized by joint injury: 66 for elbow, 29 for shoulder • 45 pitchers recruited through survey of school ATs used for control 	<ul style="list-style-type: none"> • Case control survey with retrospective cohort • Questions about injury history, playing history, and possible risk factors • Chi-square and 2-tailed <i>t</i> tests • Multivariate ANOVA for pitch type/injury association 	<ul style="list-style-type: none"> • Risk factors predisposing pitcher to significant shoulder or elbow injury • Differences in pitching practices 	<ul style="list-style-type: none"> • Increased number of pitches/appearance influenced shoulder injury 93.6 ± 15.2 pitches, elbow injury 85.2 ± 23.8 pitches • Increased pitches/year influenced shoulder injury 2458.6 ± 1321.3 pitches, elbow injury 2608.4 ± 1587.3 pitches

Table 2 Elbow and Shoulder Pain in Youth Baseball Pitchers by Age and Cumulative Pitches⁷

Cumulative Pitches	Elbow Pain OR (95% CI)	P	Shoulder Pain OR (95% CI)	P
<300	Referent	---	Referent	<0.01
300-599	0.54 (0.32, 0.92)	0.02	0.40 (0.24, 0.65)	
≥600	2.07 (0.68, 6.26)	0.20	0.13 (0.01, 1.10)	
Age (M=10.8 years)				
<10 yo	Referent	0.02	Referent	0.13
10 yo	1.66 (0.71, 3.88)		0.55 (0.29, 1.03)	
11 yo	2.60 (0.99, 6.81)		0.68 (0.28, 1.65)	
≥12 yo	2.91 (1.14, 7.41)		0.41 (0.14, 1.15)	

Table 3 Pitch Type, Pitch Count, and Pitching Mechanics on Risk of Elbow and Shoulder Pain in Youth Baseball Pitchers⁸

Season Pitches to Date	Elbow OR	P	Shoulder OR	P
1-200	Referent	<0.01	Referent	<0.01
201-400	1.63		1.65	
401-600	2.81		2.34	
601-800	3.34		2.90	
800+	2.61		3.29	
Game Pitch Counts				
9-10 yo 1-24	Referent	0.67	Referent	0.01
25-49	1.20		0.97	
50-74	1.40		1.11	
75-99	0.91		1.32	
100+	1.33		2.01	
11-12 yo 1-24	Referent	0.60	Referent	0.94
25-49	0.84		0.98	
50-74	0.83		1.10	
75-99	1.30		1.14	
100+	0.87		0.76	
13-14 yo 1-24	Referent	0.06	Referent	0.06
25-49	1.12		1.51	
50-74	1.38		1.65	
75-99	1.59		2.17	
100+	2.22		2.15	
Pitch Type and Age				
Change-up				
9-10 yo	1.41	0.36	0.65	0.20
11-12 yo	0.59	0.14	0.67	0.26
13-14 yo	0.69	0.37	1.10	0.83
Curveball				
9-10 yo	1.35	0.44	1.62	0.16
11-12 yo	1.06	0.86	1.54	0.22
13-14 yo	0.73	0.49	1.47	0.41
Slider				
9-10 yo	1.57	0.39	1.14	0.79
11-12 yo	0.74	0.61	3.38	0.02
13-14 yo	3.49	<0.01	1.80	0.17