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Risk of Serious Injury for Young Baseball Pitchers

A 10-Year Prospective Study

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Investigation performed at the American Sports Medicine Institute, Birmingham, Alabama

Background: The risk of elbow or shoulder injury for young baseball pitchers is unknown.

Purpose/Hypothesis: The purpose of this study was to quantify the cumulative incidence of throwing injuries in young baseball pitchers who were followed for 10 years. Three hypotheses were tested: Increased amount of pitching, throwing curveballs at a young age, and concomitantly playing catcher increase a young pitcher's risk of injury.

Study Design: Cohort study; Level of evidence, 3.

Methods: In sum, 481 youth pitchers (aged 9 to 14 years) were enrolled in a 10-year follow-up study. Participants were interviewed annually. Injury was defined as elbow surgery, shoulder surgery, or retirement due to throwing injury. Fisher exact test compared the risk of injury between participants who pitched at least 4 years during the study and those who pitched less. Fisher exact tests were used to investigate risks of injury for pitching more than 100 innings in at least 1 calendar year, starting curveballs before age 13 years, and playing catcher for at least 3 years.

Results: The cumulative incidence of injury was 5.0%. Participants who pitched more than 100 innings in a year were 3.5 times more likely to be injured (95% confidence interval = 1.16 to 10.44). Pitchers who concomitantly played catcher seemed to be injured more frequently, but this trend was not significant with the study sample size.

Conclusion: Pitching more than 100 innings in a year significantly increases risk of injury. Playing catcher appears to increase a pitcher's risk of injury, although this trend is not significant. The study was unable to demonstrate that curveballs before age 13 years increase risk of injury.

Clinical Relevance: The risk of a youth pitcher sustaining a serious throwing injury within 10 years is 5%. Limiting the number of innings pitched per year may reduce the risk of injury. Young baseball pitchers are encouraged to play other positions as well but might avoid playing catcher.

Keywords: shoulder; elbow; Little League; high school; throwing; ulnar collateral ligament reconstruction

For decades, the sports medicine community has reported elbow and shoulder injuries resulting from youth baseball pitching.^{3,5-7,10,14} By the late 1990s, sports medicine physicians perceived an increase in the number of adolescent pitchers requiring elbow and shoulder surgery. The general public became aware of this "epidemic" from

numerous television, print, and online stories featuring young pitchers recovering from surgery. Many of these stories focused on the rise in "Tommy John surgery" (ulnar collateral ligament reconstruction) in youth baseball. No national data for elbow and shoulder surgical rates were documented, but increased rates at one prominent sports medicine practice have been shown.^{3,5,14} At that practice in the late 1990s, few of the ulnar collateral ligament reconstructions were for youth or high school pitchers; however, rates in youth and high school-age pitchers have risen to approximately one-fourth of these surgeries in the 21st century. Whether this represents a referral bias or a true epidemic remains a question.

In previous generations, boys tended to play organized baseball in only large programs, such as Little League Baseball and high school baseball; however, in the 1990s, there was a sharp rise in independent baseball and travel teams, giving kids the opportunity to play organized

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baseball more months of the year and often with overlapping team schedules.

In 1999, Lyman et al¹¹ followed 481 youth baseball pitchers (aged 9 to 14 years) during one spring baseball season. Each pitcher was contacted the day after each game and interviewed regarding any arm fatigue or arm pain that he was feeling. Pitch counts were also kept by each team with players participating in the study. At the end of the season, each pitcher was interviewed regarding what types of pitches he had thrown during the season, as well as any injuries sustained. This study showed significant associations between number of pitches thrown and both elbow and shoulder pain.

In 2004, the USA Baseball Medical & Safety Advisory Committee released guidelines for youth pitcher safety.⁹ In 2007, Little League Baseball replaced their decades-old inning limits with pitch counts. Numerous other youth baseball organizations have followed and now adhere to pitch count limits.

Thus, the seminal study by Lyman et al¹¹ has led to overuse prevention guidelines and rules for youth baseball throughout the United States. The rationale leading to rule changes was that excessive pitching leads to pain, and that pain eventually leads to serious injury. Note that proving a clear association between amount of pitching and serious arm injury was beyond the scope of the Lyman et al work.

The first investigation between pitching and serious arm injury compared 45 adolescent pitchers with no history of arm injury and 95 adolescent pitchers undergoing elbow or shoulder surgery.¹⁴ In that retrospective study, each pitcher was asked about his history of pitching and arm pain. The injured group reported pitching more months per year, games per year, and pitches per game. The injured group had also pitched more often when fatigued.

To further reduce the risk of overuse, Little League Baseball added rules in 2009 prohibiting a participant from playing pitcher and catcher in the same game. The theory was that the high number of throws that a catcher makes to the pitcher or to infielders could compound the harm to an arm already fatigued by pitching. Hang et al⁸ demonstrated comparatively high rates of elbow soreness in youth pitchers and catchers. However, there are no known data on risk of injury from the combination of pitching and catching.

The relationship between pitch types (particularly curveballs) and injuries in young baseball pitchers is less clear and more controversial. Sports medicine experts have been warning since the 1970s that throwing curveballs at a young age can lead to elbow injury.^{1,2,17} The theory is that more stress is exerted about the elbow when throwing a curveball than when throwing a fastball and that the skeletally immature elbow of a youth pitcher cannot withstand the higher stress. A 1996 survey by USA Baseball supported this longstanding belief, showing that experts recommend that the curveball be learned at 14 ± 2 years old.^{1,15} Lyman et al¹¹ did find associations between breaking pitches and arm pain; however, it was (unexpectedly) the slider that correlated with increased risk of elbow pain and the curveball that correlated with

increased risk of shoulder pain. Three biomechanical studies subsequently investigated whether a curveball is more stressful to the elbow than a fastball. A study of college pitchers showed no difference in elbow varus torque between the curveball and fastball.⁴ The other 2 studies showed less elbow varus torque in the curveball than in the fastball in high school pitchers and youth pitchers.^{3,13} All 3 biomechanical studies showed the least varus torque in the changeup. In the retrospective study by Olsen et al,¹⁴ pitchers were asked questions about when and how often they had thrown curveballs. There was no difference in the percentage of breaking pitches thrown during their most recent season (approximately 25% of pitches thrown) nor in the age they began throwing breaking pitches (approximately 13 years old).

Thus, the true risk of serious injuries to youth baseball pitchers is unknown, and the risk factors leading to these injuries are unproven. The purpose of the current study was to determine the cumulative incidence of serious injuries resulting from pitching in youth and adolescent baseball. For this study, an injury was defined as elbow surgery, shoulder surgery, or retirement from baseball due to throwing injury. In addition, the associations between potential risk factors and injuries were studied. It was hypothesized that

1. a pitcher with a high volume of pitching had an increased risk of injury;
2. a pitcher who threw curveballs at a young age had an increased risk of injury; and
3. a pitcher who also played catcher had an increased risk of injury.

METHODS

This study was approved by the Institutional Review Board of HealthSouth Medical Center (Birmingham, Alabama). In this study, the 481 participants from a previous study¹¹ were followed over the course of 10 years (1999-2008). All were healthy, active youth baseball pitchers (aged 9 to 14 years) at the time that the study was initiated. Although we know of no rule prohibiting girls from playing in the participating leagues, all participants were boys, who were contacted by telephone each fall and invited to participate in an annual survey.

The participant was asked whether he played baseball during the past 12 months and what positions he played. If he had pitched, he was asked how many innings he had pitched and for what teams during the past fall, winter, spring, and summer. Whereas the number of pitches thrown would have been preferred instead of the number of innings pitched, most young pitchers and their families did not typically keep track of their annual pitch counts. Players were also asked what types of pitches they threw in competition (fastball, curveball, etc) and whether they participated in any showcases.

The annual survey included medical questions. The participant was asked whether he experienced any pain from pitching or other throwing, where the pain was located, and whether he received any medical treatment.

Furthermore, he was asked whether the pain or injury had led to any missed practice, missed games, or surgery. He was also asked whether he planned on playing organized baseball in the future or he was retired. When a player declared that he was retired, he was asked if the reason was injury, failure to make the team, lost interest, or another reason. If a player did not play baseball for 2 consecutive years and indicated that he was retired, he was removed from the follow-up list and called no more.

The number of injuries was determined by identifying all players who had elbow surgery, had shoulder surgery, or had retired owing to throwing injury during the 10-year study. Retirement or surgery resulting from other activities (eg, collisions, weightlifting, batting, fielding, and nonthrowing sports) were not considered an injury in the current study.

The players were then divided into 3 groups: injured, successful, and short-term pitchers. Injured pitchers were those who had elbow surgery, shoulder surgery, or retired owing to injury. The other participants were divided into the remaining 2 groups based on how many years they pitched in the study; successful pitchers were those who pitched at least 4 years during the study, whereas short-term pitchers were those who pitched 3 or fewer years. Data for the 3 groups were compared with analyses of variance. Differences were considered significant when $P < .05$.

Fisher exact test was used to compare the risk of injury between players who pitched 4 or more years during the study and those who pitched less than 4 years. Fisher exact test was then used to investigate the risk of injury for each of the 3 proposed risk factors—high volume of pitching, throwing curveballs at a young age, and concomitantly playing catcher. To test the risk of injury from high volume, injury rates were compared between pitchers who pitched more than a particular number of innings in at least 1 calendar year and those who did not. Specifically, Fisher exact tests were run using cutoff points of 70, 80, 90, 100, 110, 120, and 130 innings. The cutoff point was used from the Fisher exact test that produced the lowest P value. Similarly, the Fisher exact test with the lowest P value was identified for throwing curveballs before age 10, 11, 12, 13, 14, and 15 years. Participants who played catcher for at least 3 years during the study were considered to be catchers. Because of the potential that pitchers who simply pitched more years were more likely to experience the proposed risk factors, the data were stratified and reanalyzed to examine this potential exposure bias. Specifically, Fisher exact tests were performed separately for those who pitched at least 4 years in the study and for those who pitched less than 4 years in the study. Results for each Fisher exact test were considered significant if $P < .05$.

RESULTS

During the 10-year span, 3 participants had elbow surgery and 7 had shoulder surgery. In addition, there were 14 who had no surgery but retired because of a throwing injury. The average age at time of injury was 17.6 years, with

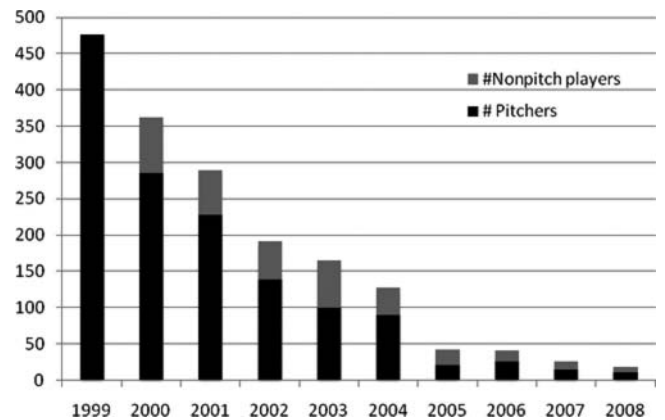


Figure 1. Participants still pitching and playing other positions during the 10-year study.

a range from 11.9 to 20.9 years. Thus, the cumulative incidence of injury was 5.0% (25 of 481). Only 2.2% (11 of 481) were still pitching by the 10th year of the study (Figure 1). Thirty-five could not be reached at some point during the study the year after being an active participant; thus, the lost-to-follow-up rate was 0.8% per year.

Table 1 compares injured, successful, and short-term pitchers. As stated, more than 5% of the participants were categorized as injured pitchers, whereas 65% (313 of 481) were short-term pitchers and the remaining 30% (143 of 481) were successful pitchers. There was a significant difference in years pitched among the 3 groups, which was not surprising considering that years pitched was used to define the successful and short-term groups. There were no differences among the groups in age at the beginning of the study, in number of years playing catcher during the study, or in age began using curveballs. About half the short-term and injured pitchers used curveballs, whereas almost all the successful pitchers (140 of 143) used curveballs.

Table 2 shows the results from the Fisher exact tests for the complete sample. The risk for pitchers who pitched at least 4 years and those who pitched fewer years was close to the 5% cumulative incidence. Pitchers who pitched more than 100 innings in at least 1 year were 3.5 times more likely to be injured during the study ($P = .049$, 95% confidence interval = 1.16 to 10.44). Pitchers who threw curveballs before age 13 years had a slight increase in risk of injury, but this increase was not statistically significant ($P = .41$). There was a trend for pitchers who also played catcher to have an increased risk of throwing injury, but this trend was not statistically significant ($P = .09$).

Results for subgroups based on number of years pitched are shown in the Appendix (available in the online version of this article at <http://ajs.sagepub.com/supplemental/>). Of the 327 players who pitched less than 4 years, only 3 ever pitched more than 100 innings in a year; thus, there were insufficient data to analyze this factor. The relationship between injury and curveballs at a young age was not significant. There appeared to be an increased risk of injury for the pitchers who also played catcher, but there were not

TABLE 1
Comparison of Injured, Successful, and Short-term Pitchers

	Injured ^a	Successful ^b	Short-Term ^c	All
n	25	143	313	481
Age, y, in 1999	12.2 ± 1.5	11.7 ± 1.7	12.1 ± 1.7	12.0 ± 1.7
Years pitched in study ^d	3.8 ± 2.6	5.1 ± 1.2	1.8 ± 0.8	2.9 ± 1.9
Years played catcher in study	0.9 ± 2.0	0.8 ± 1.3	0.4 ± 0.9	0.6 ± 1.1
Threw curveballs at any point in study, ^d % (n)	64 (16)	98 (140)	43 (134)	60 (290)
Age began using curveballs, y	13.4 ± 1.6	13.5 ± 1.6	14.0 ± 1.8	13.7 ± 1.7
Maximum innings pitched in 1 year ^d	48.9 ± 38.8	71.0 ± 42.1	25.1 ± 22.4	40.0 ± 36.9

^aSurgery or retired because of injury.

^bPitched 4 to 10 years, no injury.

^cPitched 1 to 3 years, no injury.

^d $P < .05$ (among injured, successful, and short-term pitchers).

TABLE 2
Risk Factors for Injury

Risk Factor	Pitchers With an Injury, % (n)		Odds Ratio (95% Confidence Interval)	P^a
	With Risk Factor	Without Risk Factor		
Pitched at least 4 years in study	6 (10 of 154)	4 (14 of 327)	1.6 (0.69 to 3.51)	.37
Pitched more than 100 innings in 1 year	14 (4 of 29)	4 (20 of 452)	3.5 (1.16 to 10.44)	.049
Threw curveballs before 13 years old	7 (7 of 103)	4 (8 of 187)	1.6 (0.60 to 4.47)	.41
Played catcher at least 3 years in study	11 (4 of 35)	4 (20 of 446)	2.7 (0.93 to 8.19)	.088

^aFrom Fisher exact test.

enough participants to demonstrate statistical significance. Among those who pitched at least 4 years, players who pitched more than 100 innings in a year seemed more likely to be injured, and this trend was almost significant. No injury trend was evident for pitchers who threw a curveball at a young age or for those who also played catcher.

DISCUSSION

Although elbow and shoulder surgery for young baseball pitchers has been reported,¹⁴⁻¹⁶ the risk of such injuries has not been studied. The current study showed a cumulative incidence of 5% during a 10-year period for boys who start pitching at the youth level. Five percent seems high to the 1 of 20 youth pitchers (and parents) who end up with a serious injury—such as the 2 boys in the current study who had surgery before their 13th birthday. Yet 5% is a low number for finding statistically significant risks with the sample size available.

Previous studies have correlated risk factors with increased arm pain but not directly with injury.^{7,8,10-12} The assumption was that increased pain in a young pitcher's arm is a predictor of serious injury in later years. The current study was the first to investigate the direct link between risk factors in youth baseball and pitching injuries. It was hypothesized that high pitch volume, starting curveballs early, and concomitantly playing catcher are factors that increase the risk of injury. Those who pitched

more than 100 innings in a year did indeed have an increased risk of injury. Specifically, the players who pitched more than 100 innings in at least 1 calendar year had about 3.5 times as much chance of serious injury as those who pitched less. The age at the time of pitching more than 100 innings varied greatly, from 11.6 to 22.7 years (mean, 16.1 years). The study was unable to determine whether pitchers who started throwing curveballs before age 13 years have a higher chance of injury. There may be a slight increased risk associated with starting curveballs at a young age, but the current study had far too few participants to determine such an association. Playing catcher appeared to double or triple a pitcher's risk of injury, but this trend was not significant with the number of injured players in the current study. The risk of injury from playing catcher, infield, or outfield without pitching was beyond the scope of the current study. To study injury risks for nonpitchers, a prospective study of entire teams of youth players would be needed.

Only 2.2% of the participants were still pitching by the end of the study. Given that only 5% suffered a serious injury, the majority who stopped pitching had other reasons, such as losing interest in baseball or insufficient talent to progress to higher levels.

One limitation of the current study was sample size—particularly, number of injured players. More participants would have helped in determining whether the injury trends were significant for throwing curveballs at a young age and for playing catcher. Another limitation was that all

players were from one geographic region (Alabama). It is unknown whether the association between the risk factors and injury are different in other parts of the United States or other countries. Another limitation was that other potential risk factors were not studied, such as pitching mechanics, physical conditioning, and playing other sports.

This study was limited to serious arm injuries (surgery or retirement due to injury). This narrow definition of injury was employed for 2 reasons. First, the medical professionals and baseball participants are more concerned with reducing serious injuries than lesser injuries (eg, pain and soreness). Second, retrospective recall of minor injuries at the end of each year might not produce accurate and complete data.

A couple of other potential limitations include dropouts and recall bias. As stated above, anyone who did not play for 2 consecutive years and indicated that he did not intend to play in the future was dropped off the call list for subsequent years. This was necessary from a practical perspective; these individuals were often annoyed or non-cooperative when they were called year after year, even after indicating that they no longer played. In addition, a small number of players were lost to follow-up (approximately 0.8% per year). It is possible that some of the lost or retired boys returned to baseball during the study and were perhaps even injured, but the number of such injuries, if any, was probably small. There may have also been some recall bias when the boys were asked about their activities during the past 12 months. Although it is doubtful that anyone forgot that he had surgery, played catcher, or threw curveballs during the past 12 months, it is likely that some did not accurately recall the exact number of innings pitched or whether they had arm pain.

CONCLUSION

A youth baseball pitcher has a 5% risk of serious arm injury within 10 years. Pitching more than 100 innings in a calendar year increases the risk of injury. Playing catcher in addition to pitching may increase the risk of injury as well. The current study was unable to determine whether starting curveballs before age 13 years increases the risk of injury. On the basis of these findings and review of the literature, we recommend that pitchers in high school and younger pitch no more than 100 innings in competition in any calendar year. Young pitchers who have not developed should be limited to even less, and no pitcher should continue to pitch when fatigued. A baseball player may play multiple positions, but we discourage an individual from playing both pitcher and catcher.

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