

Risk Factors for Shoulder and Elbow Injuries in Adolescent Baseball Pitchers

Samuel J. Olsen II, MD, Glenn S. Fleisig,* PhD, Shouchen Dun, MS, Jeremy Loftice, and James R. Andrews, MD

From the American Sports Medicine Institute, Birmingham, Alabama

Background: There is little evidence supporting current safety recommendations for adolescent pitchers.

Hypothesis: Pitching practices of adolescent pitchers without history of arm injury will be significantly different from those of adolescent pitchers who required shoulder or elbow surgery.

Study Design: Case control study; Level of evidence, 3.

Methods: Ninety-five adolescent pitchers who had shoulder or elbow surgery and 45 adolescent pitchers who never had a significant pitching-related injury completed a survey. Responses were compared between the 2 groups using *t* tests and χ^2 analyses. Multivariable logistic regression models were developed to identify the risk factors.

Results: The injured group pitched significantly more months per year, games per year, innings per game, pitches per game, pitches per year, and warm-up pitches before a game. These pitchers were more frequently starting pitchers, pitched in more showcases, pitched with higher velocity, and pitched more often with arm pain and fatigue. They also used anti-inflammatory drugs and ice more frequently to prevent an injury. Although the groups were age matched, the injured group was taller and heavier. There were no significant differences regarding private pitching instruction, coach's chief concern, pitcher's self-rating, exercise programs, stretching practices, relieving frequency, pitch type frequency, or age at which pitch types were first thrown.

Conclusion: Pitching practices were significantly different between the groups. The factors with the strongest associations with injury were overuse and fatigue. High pitch velocity and participation in showcases were also associated with increased risk for injury.

Clinical Relevance: New recommendations were made based on these results. Adherence to the recommendations may reduce the incidence of significant injury to adolescent pitchers.

Keywords: pitch count; curveball; velocity; showcase; surgery; prevention

Baseball pitchers are at increased risk for shoulder and elbow injuries. Over the past several years at our institution, we have noted a sharp increase in the number of high school and collegiate pitchers requiring surgery for a pitching-related injury. When comparing the time period of 1994-1999 to 2000-2004, there was a 4-fold increase in the number of elbow surgeries performed on collegiate baseball pitchers by our senior surgeon (J.R.A.) and a 6-fold increase for high school pitchers.⁹ Because of this observation, attempts have been made to identify risk factors for these injuries.

Lyman et al¹⁵ followed 298 youth baseball pitchers (9-12 years old) during 2 consecutive spring seasons. They found that the incidence of elbow pain increased with increased

age, increased weight, decreased height, lifting weights, playing outside the league, decreased satisfaction with one's pitching, pitching with arm fatigue, and number of pitches thrown per season.¹⁵ They also identified risk factors for shoulder pain, which included decreased satisfaction with one's pitching, pitching with arm fatigue, number of pitches thrown per game, and number of pitches thrown per season.¹⁵ The subsequent study by the same authors made several similar conclusions. In addition, they recommended that pitchers between ages 9 and 14 years should not throw breaking pitches because of an increased incidence of shoulder and elbow pain.¹³ However, long-term follow-up of these subjects has not yet been reported. Therefore, it is unknown whether their pain was an early indicator for significant injury.

On the basis of these studies, the USA Baseball Medical and Safety Advisory Committee made several recommendations to help young pitchers avoid injury.²¹ Included was a statement that adults should pay attention and react appropriately to arm pain in these athletes. Pitch counts should be monitored closely. Pitchers should avoid throwing

*Address correspondence to Glenn S. Fleisig, PhD, American Sports Medicine Institute, 833 St Vincent's Drive, Suite 100, Birmingham, AL 35205 (e-mail: glennf@asmi.org).

No potential conflict of interest declared.

breaking pitches in competition until puberty but should concentrate more on proper fastball pitching mechanics. The statement also discouraged pitching in showcases, returning to the mound after being removed from the game, pitching in more than 1 simultaneous season, or pitching more than 9 months out of the year.²¹ However, these recommendations were made without clinical data showing that such risk factors lead to serious injury.

Petty et al¹⁸ surveyed 27 high school baseball players who had ulnar collateral ligament reconstruction to determine the prevalence of proposed risk factors. They noted that self-reported pitch speed greater than 80 mph (72%), throwing 10 or more months per year (69%), using curveballs before age 14 years (67%), and seasonal overuse (defined as routinely violating the USA Baseball recommendations for maximum pitch count and minimum rest; 62%) were common in this group. Although this small study provided an informative description of young pitchers who required surgery, it did not compare those pitchers with a healthy control group to determine risk factors. The current study attempts to make that comparison.

The purpose of this study was to identify risk factors that could predispose an adolescent pitcher to a significant shoulder or elbow injury. We hypothesized that there are significant differences in pitching practices between the healthiest adolescent pitchers (ie, pitchers with no history of problematic shoulder or elbow pain) and the most seriously injured adolescent pitchers (ie, pitchers who have required either shoulder or elbow surgery for a pitching-related injury).

METHODS

The research protocol received approval by the institutional review board. This was a case control study with a retrospective cohort. A survey was formulated containing questions about injury history, playing history, and potential risk factors (see Appendix, available in the online version of this article at <http://ajsm.sagepub.com/cgi/content/full/34/6/905/DC1>). The survey was provided to adolescent pitchers (14-20 years old) who sustained a serious pitching-related injury. For this study, an injury was defined as an elbow or shoulder injury in the dominant arm that resulted in surgery. The survey was also provided to active high school and college pitchers to isolate healthy, age-matched controls.

Participants

The injured group was composed of 95 adolescent male baseball pitchers who had either shoulder or elbow surgery performed by the senior author (J.R.A.) between September 2003 and September 2004 (Table 1). We used the time period of 1 year before our survey to limit the recall bias. The injured group was divided into 2 subgroups: shoulder injury and elbow injury. All subjects in the injured group were contacted by telephone and gave permission to be used in the study after oral informed consent. If the pitcher was younger than 18 years, informed consent was obtained from a parent. All questionnaires were completed by telephone conversation with the primary author. Patients were excluded from the study if the injury

TABLE 1
Primary Surgical Procedure Performed
on Injury Group Pitchers

Group	n
Elbow injury subgroup	66
Ulnar collateral ligament reconstruction	53
Loose body removal	4
Osteophyte excision	4
Ulnar nerve transposition	3
Open reduction and internal fixation	1
medial epicondyle fracture	
Radial head plica excision	1
Shoulder injury subgroup	29
Labral repair	21
Capsulorrhaphy	3
Rotator cuff debridement	2
Bennett lesion excision	1
Debridement of glenoid osteochondritis	1
dissecans lesion	
Subacromial decompression	1

that resulted in surgery was owing to something other than pitching. Of the 155 possible pitchers identified, 110 were successfully contacted. Two were excluded because they did not consider themselves pitchers. One pitcher did not want to participate. The 12 oldest were excluded to age match the injured group and the control group.

The control group included male baseball pitchers at the high school and college level. We distributed the survey to the athletic trainers at 8 high schools and 11 colleges in Alabama. The pitchers completed the questionnaire with assistance from their athletic trainers after reading and signing the consent form. If the pitcher was younger than 18 years, a parent or guardian also signed the consent form. Others were enlisted from a contact list of pitchers who participated in one of our previous studies.¹³ These questionnaires were completed by telephone conversation with the primary author. Generally, the participants had no trouble giving specific answers to the survey questions.

Pitchers were excluded from the control group if they had a history of any of the following: (1) shoulder or elbow pain lasting more than 2 weeks, (2) shoulder or elbow pain that caused them not to play in a game or practice, or (3) recurrent shoulder or elbow pain. These stringent criteria were thought to exclude the majority of pitchers having even a minor shoulder or elbow injury from pitching. This is consistent with the definition of minor and major injuries as put forth by Gugenheim et al.¹⁰ They defined a minor injury as one that does not exclude the player from 1 or more games. A major injury was defined as one that does exclude the player from 1 or more competitions.¹⁰ Subjects who did not consider themselves pitchers were also excluded. Nearly 300 pitchers were contacted; only 45 pitchers fit the criteria.

Variables

Variables were chosen based on literature review and currently proposed risk factors. For discussion purposes, the variables were grouped into the following 3 categories: nonmodifiable

factors, preventive measures, and competition habits. In addition to the variables shown in the appendix online, the "number of pitches thrown per year" was estimated for each subject by multiplying his average number of pitches per game by the total number of games pitched per year. Therefore, the figures for this variable were not based on actual pitch counts. To estimate pitching age relative to puberty, the age that the pitcher started shaving facial hair was subtracted from the age he began throwing each pitch type.

Statistical Analysis

Data for the injured group and the control group were statistically analyzed using SPSS 10.0.5 (SPSS Inc, Chicago, Ill). Univariate analyses were performed using the χ^2 test for categorical variables and the 2-tailed Student *t* test for continuous variables. The level of statistical significance was set at $P < .01$ to minimize the risk of type I error with the large number of variable comparisons. The association of pitching type with throwing injuries was tested using multivariate analysis of variance. These procedures were then repeated to compare the shoulder subgroup and the elbow subgroup to the control group.

A multivariable logistic regression model was developed to identify variables independently associated with the injured group. Variables considered for the model were selected based on the results of univariate analyses ($P < .1$). Models were developed with forward stepwise (conditional) regression. Variables were retained in the model if the Wald test had a *P* value less than .05. Each continuous variable identified by the multivariable logistic regression model was then divided into a high group and a low group, and odds ratios were determined.

RESULTS

Comparison of Injured Group to Control Group

The injured and control groups were similar in age and number of years pitching, but the injured pitchers were taller and heavier. The injured group pitched significantly more months during the year, games per year, innings per game, pitches per game, pitches per year, and warm-up pitches before a game. These pitchers were more frequently starting pitchers and pitched in more showcases. Baseball showcases are events created to give baseball players opportunities to "showcase" their talent. At a showcase, participants may have aspects of their talents quantified (radar gun speeds of their pitches, time needed to run around the bases, etc), performance statistics may be measured (batting average during the showcase, etc), and they may perform in front of scouts from schools or professional organizations. The injured group also pitched with higher velocity and more often with arm pain and fatigue. They also used anti-inflammatory drugs and ice more frequently to prevent an injury (Table 2).

Subgroup Analyses

The variables with significant differences from the control group were the same for the elbow injury subgroup as for

the injured group (Table 2). The elbow injury subgroup tended to throw more warm-up pitches and pitch despite arm pain more often than did the control group, but these differences were not statistically significant.

The number of subjects in the shoulder injury subgroup was relatively small; therefore, not all the variables remained significantly different (Table 2). Compared with the control group, the shoulder subgroup pitched significantly more months of the year, innings per game, pitches per game, pitches per year, and warm-up pitches before a game. These pitchers were more frequently used as starting pitchers and pitched in more showcases. They pitched with higher velocity and despite fatigue. They also used anti-inflammatory drugs more frequently to prevent an injury.

Multivariable Analysis

Four variables were identified as the most significant risk factors by the multivariable logistic regression model with a goodness of fit of 0.755 (Table 3). Odds ratios show the degree of increased risk compared with the referent group. The model revealed that injury risk increased 5-fold for pitching more than 8 months per year and nearly 4-fold for pitching more than 80 pitches per game. Pitching with a fastball speed of more than 85 mph increased injury risk 2.58 times. Pitching often despite arm fatigue increased the risk for injury 36 times.

DISCUSSION

Risk Factors

There is a paucity of scientific data regarding high school and collegiate baseball pitchers. Consequently, there is little evidence to support current safety recommendations for this age group. A few key articles have contributed to the evidence regarding pitching-related risk factors. Lyman et al^{13,15} conducted 2 studies with youth baseball pitchers (9-14 years old) and found multiple risk factors for shoulder and elbow pain. Petty et al¹⁸ described common characteristics of high school pitchers that required ulnar collateral ligament reconstruction, but they did not have a control group for comparison. The current study compared adolescent pitchers without significant injury and age-matched pitchers with injuries significant enough to require surgery. It is important to realize that the current study was designed to identify risk factors associated with injured pitchers but was not designed to prove cause and effect.

Nonmodifiable Factors. The pitching practices were significantly different for several variables, but there were also several factors that were not significantly different between groups. Of note, the groups were age matched. Other studies have shown that increased age is a risk for arm pain in pitchers.^{12,13,15} Because there was no age difference, we are able to focus on risk factors specifically for high school and collegiate pitchers. Similarly, there was no difference in number of years pitching.

Injured pitchers were 4 cm taller and 5 kg heavier. This finding may relate to the ability of these pitchers to throw harder. Parents and coaches simply need to watch taller

TABLE 2
 Comparisons Between the Control Group Pitchers and Pitchers in the Injured Group,
 Elbow Injury Subgroup, and Shoulder Injury Subgroup

Variable	Control (n = 45)	Injured (n = 95)	P	Elbow Injury (n = 66)	P	Shoulder Injury (n = 29)	P
	M ± SD	M ± SD		M ± SD		M ± SD	
Nonmodifiable factor							
Age, y	18.3 ± 1.5	18.6 ± 1.6	.396	18.6 ± 1.5	.274	18.4 ± 1.7	.896
Height, cm	181.3 ± 5.4	185.0 ± 6.6	.006	185.5 ± 6.6	<.01	183.8 ± 6.6	.144
Weight, kg	80.6 ± 10.1	86.0 ± 11.0	.008	86.5 ± 10.5	<.01	84.7 ± 12.1	.126
No. of years pitching	9.0 ± 2.4	9.2 ± 2.6	.702	9.2 ± 2.8	.687	9.2 ± 2.3	.833
Age began throwing, y							
Fastball	8.7 ± 2.5	9.4 ± 2.3	.119	9.4 ± 2.6	.136	9.2 ± 1.7	.311
Change-up	11.7 ± 2.7	12.3 ± 2.4	.229	12.5 ± 2.5	.145	11.9 ± 2.4	.773
Breaking ball	12.9 ± 1.4	13.2 ± 2.2	.412	13.3 ± 2.3	.234	12.8 ± 2.1	.872
No. of years before shaving began throwing							
Fastball	5.1 ± 4.3	5.5 ± 2.6	.45	5.6 ± 2.9	.492	5.5 ± 1.9	.647
Change-up	2.0 ± 4.3	2.6 ± 2.7	.361	2.5 ± 2.8	.494	2.8 ± 2.4	.403
Breaking ball	1.2 ± 2.7	1.7 ± 2.6	.244	1.7 ± 2.8	.339	1.8 ± 2.0	.265
Pitcher self-rating, %			.041		.102		.070
Fair	13.3	2.1		3.0		0.0	
Good	66.7	68.4		69.7		65.5	
Excellent	20.0	29.5		27.3		34.5	
Coach's chief concern, %			.156		.064		.763
Game	11.4	24.2		27.3		17.2	
Season	38.6	27.4		22.7		37.9	
Career	50.0	48.4		50.0		44.9	
Preventive measures							
Received private pitching instruction, %	53.3	55.8	.785	51.5	.851	65.5	.300
Involved in exercise program, %	91.9	97.9	.064	97.0	.180	100.0	.099
Exercise involved free weights, %	88.6	87.4	.832	86.4	.726	89.7	.892
Exercise involved tubing for rotator cuff, %	88.9	82.1	.303	83.3	.413	79.3	.258
Exercise involved aerobic activity, %	84.4	95.8	.020	93.9	.100	100.0	.026
Exercise designed for pitchers, %	70.3	58.1	.197	53.1	.091	69.0	.909
Stretch before pitching, %	100.0	96.8	.228	95.5	.147	100.0	1.000
Stretch after pitching, %	64.4	52.6	.188	53.0	.232	51.7	.277
No. of warm-up pitches	28.1 ± 11.9	34.1 ± 11.7	<.01	32.4 ± 11.7	.063	38.1 ± 10.8	<.001
Regularly use nonsteroidal anti-inflammatory drug to prevent injury, %	22.2	54.7	<.001	50.0	<.01	65.5	<.001
Regularly use ice to prevent injury, %	40.0	76.8	<.001	80.3	<.001	69.0	.015
Regularly use topicals to prevent injury, %	20.0	28.4	.287	22.7	.732	41.4	.046
Competition habits							
Months per year of competitive pitching	5.5 ± 2.3	7.9 ± 2.5	<.001	7.8 ± 2.4	<.001	8.1 ± 2.8	<.001
No. of pitching appearances per year	18.6 ± 13.0	28.8 ± 14.7	<.001	30.1 ± 15.6	<.001	26.0 ± 12.3	.017
No. of innings per appearance	4.3 ± 1.7	5.6 ± 1.4	<.001	5.4 ± 1.4	<.001	6.1 ± 1.1	<.001
No. of pitches per appearance	66.2 ± 25.3	87.8 ± 21.8	<.001	85.2 ± 23.8	<.001	93.6 ± 15.2	<.001
No. of pitches per year	1268.9 ± 1039.7	2562.7 ± 1505.7	<.001	2608.4 ± 1587.3	<.001	2458.6 ± 1321.3	<.001
Out of 10 pitches, how many were:			.495		.656		.391
Fastballs	6.0 ± 1.0	6.2 ± 1.1		6.2 ± 1.2		6.3 ± 0.8	
Change-ups	1.6 ± 0.9	1.4 ± 0.8		1.4 ± 0.8		1.4 ± 0.8	
Breaking balls	2.4 ± 0.9	2.3 ± 1.1		2.4 ± 1.1		2.3 ± 1.2	
How often a starting pitcher, %			<.001		<.01		<.001
Never	11.1	1.1		1.5		0.0	
Infrequently	35.6	11.6		15.2		3.4	
Regularly	75.6	87.3		83.3		96.6	
Regularly stay in game at another position after being relieved, %	75.6	73.7	.814	71.2	.619	79.3	.716

(Continued)

TABLE 2
(Continued)

Variable	Control (n = 45)	Injured (n = 95)	P	Elbow Injury (n = 66)	P	Shoulder Injury (n = 29)	P
	M ± SD or %	M ± SD		M ± SD		M ± SD	
How often returned to mound in same game after being relieved, %			.645		.602		.415
Never	71.9	66.3		68.2		62.1	
Infrequently	28.1	31.6		28.8		37.9	
Regularly	0.0	2.1		3.0		0.0	
How often a relief pitcher, %			.084		.396		.011
Never	2.2	4.2		3.0		6.9	
Infrequently	42.2	60		54.5		72.4	
Regularly	55.6	35.8		42.5		20.7	
How often start at another position before relieving, %			.016		.046		.070
Never	15.6	24.5		23.1		27.6	
Infrequently	37.7	16.0		16.9		13.8	
Regularly	46.7	59.5		60.0		58.6	
How often pitch with arm fatigue, %			<.001		<.001		<.001
Never	22.2	5.3		4.5		6.9	
Infrequently	66.7	43.2		48.5		31.0	
Regularly	11.1	51.5		47.0		62.1	
Continue pitching despite arm pain, %	42.2	67.4	<.01	65.2	.014	72.4	.011
Fastball speed, mph	82.7 ± 5.1	88.3 ± 6.2	<.001	88.1 ± 6.6	<.001	88.6 ± 5.3	<.001
No. of career showcases participated	1.0 ± 1.8	3.9 ± 5.4	<.01	3.8 ± 5.1	<.01	4.2 ± 6.3	<.01

TABLE 3
Multivariable Analysis of Factors Associated With Injury^a

Variable	Odds Ratio	95% Confidence Interval
Months per year of competitive pitching		
≤8	Referent	
>8	5.05	1.39-18.32
No. of pitches per appearance		
≤80	Referent	
>80	3.83	1.36-10.77
Fastball speed, mph		
≤85	Referent	
>85	2.58	0.94-7.02
How often pitch with arm fatigued		
Never	Referent	
Infrequently	4.04	0.97-16.74
Regularly	36.18	5.92-221.22

^aGoodness-of-fit (Hosmer and Lemeshow test) = 0.755.

and heavier pitchers closely for signs of injury. Lyman et al¹⁵ found that there was an increased incidence of elbow pain in pitchers (9-12 years old) with increased weight but decreased height. It is difficult to correlate this finding with the current study given the differences in age and maturity.

Although previous research has shown a higher risk of arm pain in young pitchers (9-14 years old) who throw breaking pitches,¹³ the current study failed to show a correlation between age at which a breaking ball was first thrown and risk for surgery. The injured and control groups both started throwing a fastball at 9 years of age, a change-up at 12 years, and a breaking ball at 13 years. Furthermore, the number of years each pitch was thrown before puberty was similar for the 2 groups. In the study by Lyman et al,¹³ more than half of the participants were throwing breaking pitches before age 13 years. This may account for the differences in results. The accuracy of our results is uncertain for these variables because of the limitations of data collection and recall. A true difference may exist, but more research is needed to address this topic prospectively.

Most participants felt that they were good or excellent pitchers. To pitch at the high school or college level, they were probably correct in that assessment. Lyman et al¹⁵ found decreased self-satisfaction to be a risk factor for pain in pitchers aged 9 to 12 years. These dissatisfied pitchers may not have made it to the level of those in our study. About half of all participants perceived their coaches to be more concerned about winning the game or having a successful season than about the pitcher's long-term success. This unfortunate finding is consistent with the findings reported by Petty et al.¹⁸

Preventive Measures. The injured group threw more warm-up pitches before an appearance. On average, they recalled throwing 34 warm-up pitches, compared with 26 in the control group. This statistical difference may not be

clinically significant. Several articles recommend an adequate warm-up before an appearance.^{3,4,6,17,18,22} These pitchers may have been experiencing discomfort, which could have led them to throw more warm-ups to “loosen up.” It is difficult to determine the pitcher’s reasons for a more extensive warm-up, but there may be an upper limit to the optimal number of warm-up pitches.

The injured group also used more anti-inflammatory drugs and ice to prevent an injury. This may relate to the assumption that they were pitching through pain or discomfort.

The fact that more than half of the pitchers in this study had received private pitching instruction was encouraging. We cannot conclude whether improper pitching biomechanics is a risk factor for injury based on this finding. Many studies recommend proper mechanics,^{1,2,4-8,11-13,19,21,22} but it is difficult to document “proper technique” without quantified motion analysis because of the complexity of the throwing process.¹⁶

The vast majority of both groups used stretching, as well as an exercise program that involved free weights, tubing for rotator cuff strength, and aerobic activity. More than half of both groups believed the exercise program was designed specifically for pitchers. The research showing that lifting weights predisposed a pitcher to arm pain was done in pitchers between the ages of 9 and 14 years.¹⁵ This finding may be related to their musculoskeletal maturity, which would not be as major a factor with the current study’s participants. Several articles recommended good general physical conditioning,^{3,4-7,17,19,21,22} but this was based on opinion and intuition. Again, it is difficult to document “good physical condition.”

Competition Habits. Pitchers who had surgery averaged 8 months of competitive pitching per year, compared with 5.5 months in the control group. Through multivariable analysis (Table 3), we found that pitchers who competed more than 8 months per year were at about 5 times increased risk for injury requiring surgery. The current recommendation is to discourage year-round pitching and to have at least 3 months of active rest per year.^{4,7,18,21} Here, active rest is defined as rest from throwing but not from other sports or activities. On the basis of the data from the current study, pitchers may need more than 3 months of active rest.

The injured pitchers pitched on average 6 innings per appearance, compared with 4 innings in the control group. They also pitched approximately 88 pitches per game, compared with 66 pitches per game in the control group. Pitchers who throw more than 80 pitches per game are at nearly 4 times increased risk of injury requiring surgery compared with those pitchers who throw fewer than 80 pitches per game. The current USA Baseball recommendation for a 14-year-old pitcher is to throw fewer than 75 pitches per game and fewer than 3000 pitches per year.²¹ These recommendations may be too liberal.

The injured pitchers threw harder and were more likely to be regular starters. The mean self-reported fastball speed was 88 mph, compared with about 83 mph in the control group. These pitchers should also be watched closely for injury. Through multivariable analysis, we found that pitchers who report velocities greater than 85 mph are at

2.6 times increased risk of injury requiring surgery. This could relate to overuse; pitchers who can throw harder may pitch more often in games. The establishment of the radar gun in scholastic baseball may have contributed to a harmful emphasis on pitch velocity.

It has also been recommended that young pitchers avoid participating in showcases.^{20,22} Although some showcases are organized as safe and effective programs, other showcases put unneeded physical and mental stress on an athlete to throw harder than they should so that they can impress scouts. Furthermore, showcases often occur during the off-season, when participants are not physically prepared to give full effort or leave the athletes with inadequate time to recover between seasons.²¹ The injured group pitched in roughly 4 career showcases, compared with only 1 career showcase in the control group. Pitchers who participate in these events need to be monitored closely for signs of injury.

Pitching despite arm fatigue was found to be a major risk factor.^{5,13-15} Nearly 52% of the injured group regularly pitched despite arm fatigue, compared with 11% of the control group. Approximately 67% of the injured group pitched despite arm pain, compared with 42% of the controls. Through multivariable analysis, we found that a pitcher who regularly pitches despite arm fatigue is at 36 times increased risk of injury. In our clinical experience, history is quite valuable for diagnosing an injury. We suggest that parents and coaches also recognize the value of direct communication with young athletes and listen to players who indicate fatigue or pain.

There was no difference in the frequency of relief pitching between the groups. Roughly half of all participants regularly started at another position before relieving. Nearly three fourths of all participants usually stayed in the game at another position after being relieved. It has also been recommended that pitchers do not return to the mound in the same game after being relieved.²¹ Based on our information, more than two thirds of all participants have never done this.

Previous studies of youth pitchers demonstrated relationships between breaking pitches and arm pain,¹³ but a study of collegiate pitchers found no increase in elbow or shoulder kinetics with breaking pitches.⁹ In the current study, pitch type frequency was not statistically different between groups. Out of every 10 pitches, both groups threw about 6 fastballs, 1.5 change-ups, and 2.5 breaking pitches. Thus, it is still unproven whether throwing breaking pitches at younger ages increases the risk of serious injury. Future studies comparing matched groups of pitchers with similar pitching volumes and other characteristics but different pitch types would be difficult but could provide more definitive information about the risk of breaking pitches.

Limitations of the Study

This case control study brings new information to the data available regarding adolescent pitchers. Multiple risk factors were identified, but there are several limitations to the study. One major limitation is that our figures are based on the participants’ recall of pitching practices approximately 1 year prior to the study. Healthy pitchers may

TABLE 4
Authors' Safety Recommendations for Adolescent
Baseball Pitchers

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1. Avoid pitching with arm fatigue.
 2. Avoid pitching with arm pain.
 3. Avoid pitching too much. Further research is needed on this topic, but reasonable limits are as follows:
 - a. Avoid pitching more than 80 pitches per game.
 - b. Avoid pitching competitively more than 8 months per year.
 - c. Avoid pitching more than 2500 pitches in competition per year.
 4. Monitor pitchers with the following characteristics closely for injury:
 - a. Pitchers who regularly use anti-inflammatory drugs or ice to "prevent" an injury
 - b. Regularly starting pitchers
 - c. Pitchers who throw with velocity >85 mph
 - d. Taller and heavier pitchers
 - e. Pitchers who warm up excessively
 - f. Pitchers who participate in showcases
-

remember pitching practices differently than do injured pitchers. There were also a few control group pitchers who completed the survey on paper without the benefit of the telephone interview. We believe that the survey was self-explanatory, so it is unlikely that this affected the results significantly. The number of pitches per year was an extrapolated figure, and this should be kept in mind when interpreting the results for that variable. Inaccurate reporting by the participant may be a factor for variables such as "age began throwing breaking ball," "pitches per game," and "coach's chief concern" for several possible reasons, including fear of retribution. Growing facial hair is a practical but imperfect indicator for the onset of puberty. We also recognize that the reported fastball speeds are likely inflated, but pitchers evaluated for medical problems are just as likely to inflate their velocities. The survey was formulated without previous validation. There were several associations made between variables and injuries, but cause and effect cannot be established with this study.

Recommendations for Prevention

Pitching practices between the 2 groups were found to be significantly different for several variables. The overriding risk for injury is overuse. Although individual pitchers have different vulnerabilities to injury due to genetics, pitching mechanics, and many other factors, it is impossible to accurately individualize safety guidelines to each adolescent pitcher. New safety recommendations were made by the authors because of the lack of guidelines for this age group (Table 4). These recommendations were influenced in part by the results of this study, as well as the authors' opinions. We recognize the limitations of using a survey to formulate recommendations. In general, we attempted to make recommendations that were not so liberal that injury rates are

unaffected, yet not so conservative that they unreasonably limit safe play. These recommendations should not be generalized to other age groups because risk factors may vary with level of competition. Future studies should be directed at addressing these recommendations with a prospective cohort.

There are several other recommendations with which the authors agree but that were not directly supported by this study. Pitchers should avoid throwing breaking pitches at least until 13 years of age. Proper pitching mechanics should be encouraged. Parents and coaches should obviously keep the long-term health of the pitcher in mind. We also encourage a good stretching and general physical conditioning program. Warming up is important, but other aerobic activities should be considered rather than pitching alone to avoid excessive warm-ups. Our hope is that pitchers, parents, coaches, leagues, and organizations will use these recommendations to prevent avoidable injuries.

ACKNOWLEDGMENT

Special thanks to Tracy Ray, MD, for his guidance in completing this study. The authors also thank Stephen Lyman, PhD, for his advice on statistical approach and David Kingsley for his assistance in data collection and processing. This study was funded in part by financial support from Smith & Nephew.

REFERENCES

1. Albright JA, Jokl P, Shaw R, Albright JP. Clinical study of baseball pitchers: correlation of injury to the throwing arm with method of delivery. *Am J Sports Med.* 1978;6:15-21.
2. American Academy of Pediatrics Committee on Sports Medicine and Fitness. Risk of injury from baseball and softball in children. *Pediatrics.* 2001;107:782-784.
3. Axe MJ. Recommendations for protecting youth baseball pitchers. *Sports Med Arthrosc Rev.* 2001;9:147-153.
4. Buettner CM, Leaver-Dunn D. Prevention and treatment of elbow injuries in adolescent pitchers. *Athl Ther Today.* 2000;5:19-24.
5. Ciccantelli P. Avoiding elbow pain: tips for young pitchers. *Phys Sportsmed.* 1994;22:65-66.
6. Congeni JA. Treating—and preventing—little league elbow. *Phys Sportsmed.* 1994;22:54-64.
7. Congeni JA, Walter KD. Don't let little league shoulder or elbow sideline your patient permanently. *Contemp Pediatr.* 2004;21:69-92.
8. Fleisig GS, Andrews JR, Dillman C, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med.* 1995;23:233-239.
9. Fleisig GS, Kingsley DS, Loftice JW, et al. Kinetic comparison among the fastball, curveball, change-up, and slider in collegiate baseball pitchers. *Am J Sports Med.* 2006;34:423-430.
10. Gugenheim JJ, Stanley R, Woods GW, Tullos HS. Little league survey: the Houston study. *Am J Sports Med.* 1976;4:189-200.
11. Ireland ML, Andrews JR. Shoulder and elbow injuries in the young athlete. *Clin Sports Med.* 1988;7:473-494.
12. Lyman S, Fleisig GS. Baseball. In: Caine DJ, Maffulli N, eds. *Epidemiology of Pediatric Sports Injuries.* Basel, Switzerland: Karger. In press.
13. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *Am J Sports Med.* 2002;30:463-468.
14. Lyman S, Fleisig GS, Osinski ED, et al. Incidence and determinants of arm injury in youth baseball pitchers: a pilot study. *Med Sci Sports Exerc.* 1998;30(suppl):4.

15. Lyman S, Fleisig GS, Waterbor JW, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. *Med Sci Sports Exerc.* 2001;33:1803-1810.
16. Nicholls R, Fleisig GS, Elliott B, Lyman S, Osinski E. Accuracy of qualitative analysis for assessment of skilled baseball pitching technique. *Sports Biomech.* 2003;2:213-226.
17. Pappas AM, Zawacki RM. Baseball: too much on a young pitcher's shoulders? *Phys Sportsmed.* 1991;19:107-117.
18. Petty DH, Andrews JR, Fleisig GS, Cain EL. Ulnar collateral ligament reconstruction in high school baseball players: clinical results and injury risk factors. *Am J Sports Med.* 2004;32:1158-1164.
19. Rizio L, Uribe JW. Overuse injuries of the upper extremity in baseball. *Clin Sports Med.* 2001;20:453-468.
20. Torg JS, Pollack H, Sweterlitsch P. The effect of competitive pitching on the shoulders and elbows of preadolescent baseball players. *Pediatrics.* 1972;49:267-272.
21. USA Baseball Medical and Safety Advisory Committee. Position statement on youth baseball injuries. Available at: www.usabaseball.com/med_position_statement.html. Accessed November 7, 2004.
22. Whiteside JA, Andrews JR, Fleisig GS. Elbow injuries in young baseball players. *Phys Sportsmed.* 1999;27:87-92, 102.