

A Preseason Checklist for Predicting Elbow Injury in Little League Baseball Players

Taiki Yukutake,^{*†} PT, MSc, Masumi Kuwata,[‡] MSc, Minoru Yamada,[§] PT, PhD, and Tomoki Aoyama,[†] MD, PhD

Investigation performed at Kyoto University, Kyoto, Japan

Background: Despite pitch count limits, the incidence of Little League elbow is increasing. A risk-evaluation tool capable of predicting which players are predisposed to throwing injury could potentially prevent injuries.

Purpose: To investigate the effectiveness of a risk factor checklist for predicting elbow injury in Little League baseball players during 1 season. The hypothesis was that a preseason risk-evaluation checklist could predict which players were predisposed to elbow injury.

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

Methods: A preseason risk-evaluation checklist was distributed to Little League baseball teams in Japan. Six months later, a follow-up questionnaire was mailed to determine injuries sustained during the season. Logistic regression analysis was performed, assigning presence or absence of elbow injury during the season as the dependent variable, and an injury risk score (IRS) was developed based on the statistically significant variables. Receiver operating characteristic (ROC) curve analysis was conducted to determine the predictive validity of the checklist and the optimal cutoff IRS.

Results: Data from 389 Little League players were analyzed. Among them, 53 players experienced an elbow injury requiring medical treatment during the season. Six checklist items associated with a medical history of throwing injury, pitch volume, and arm fatigue were found to be significant. Responses to the items could predict the players who were susceptible to injury during the season, with a two-thirds cutoff value for a 6-item checklist (area under the curve, 0.810; sensitivity, 0.717; specificity, 0.771).

Conclusion: Results from a 6-item preseason checklist can predict which Little League players are to sustain an elbow injury by the end of the season.

Clinical Relevance: The ability to predict which Little League baseball players are predisposed to elbow injury allows parents and coaches to initiate preventive measures in those players prior to and during the baseball season, which could lead to fewer elbow injuries.

Keywords: Little League elbow; prevention; checklist

Throwing injuries in young baseball players are a serious problem. Little League elbow, including epicondylitis and osteochondrosis dissecans, is one of the most severe throwing injuries, occurring in 20% to 40% of school-aged pitchers.^{11,13-15} Such an injury can prematurely end a baseball

career⁴; therefore, adults should do everything possible to protect children from these injuries.

Many studies have reported the risk factors for throwing injury. Ways to prevent such injuries, including limiting the number of pitches, have been suggested to protect players.^{3,14,15,18} As a result, USA Baseball Medical and Safety Advisory Committee guidelines were developed in 2006 to provide recommendations for limiting pitch counts similar to recommendations made in Japan in 1995.^{9,20,22} However, there are several problems with these recommendations. For one, these recommendations are meaningless without strict compliance, and a small proportion of coaches have complied with these recommendations. According to 2 recent studies, coaches in the United States answered 43% of questions regarding pitch count and rest periods correctly, whereas 28% of coaches complied with the recommendations in Japan.^{1,22} Because few coaches follow these limits regularly, despite evidence that the number of pitches strongly influences development of Little League

*Address correspondence to Taiki Yukutake, PT, MSc, Graduate School of Medicine, Human Health Sciences, Kyoto University, 53 Kawahara-cho, Shogoin, Sakyo-ku, Kyoto 606-8507 Japan (e-mail: ty0617bbp@hotmail.co.jp).

†Graduate School of Medicine, Human Health Sciences, Kyoto University, Kyoto, Japan.

‡Amici del Cuore, Tokyo, Japan.

§Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tokyo, Japan.

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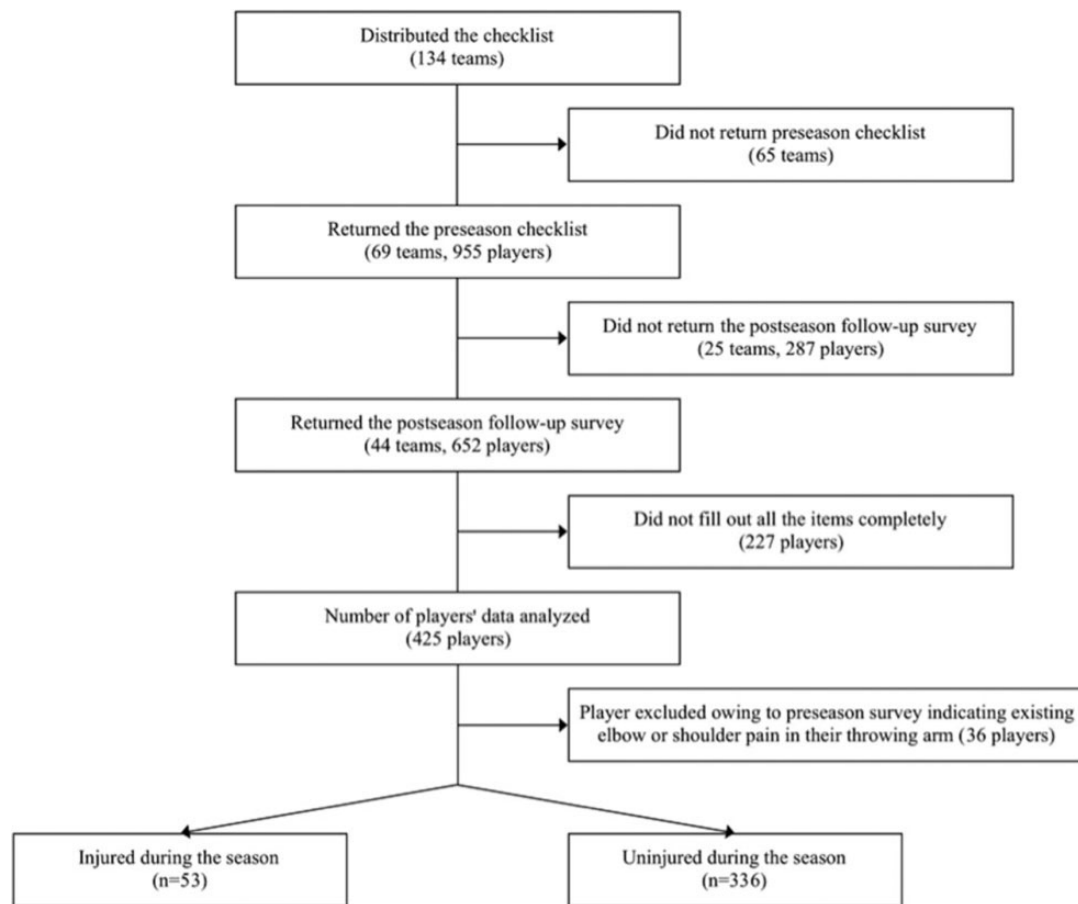


Figure 1. Flowchart showing the process of this research.

elbow, especially in Japan, another approach for prevention of elbow injury must be considered in addition to these limits.

When developing another strategy for primary prevention of youth baseball elbow injury, several things must be taken into account. First, it must be easy for coaches and parents to understand. Medical evaluation by experts, including medical doctors and physical therapists, has been reported to be an effective prevention strategy for throwing injury.⁷ However, a large number of children play baseball worldwide: 5.7 million children in eighth grade or lower in the United States, and there are nearly 15,000 elementary school baseball teams in Japan.^{2,8} With such large numbers, it is almost impossible for medical specialists to assess all of them. Therefore, coaches and parents, most of whom have no medical knowledge, inevitably have to be responsible for protecting children from injury. Second, the various factors must be evaluated comprehensively. Research has shown that the amount of force placed on a player's elbow is the principal risk factor for injury. Such force is influenced by pitching mechanics, pitch type, and pitch volume.¹⁰ Other risk factors, including arm fatigue, playing baseball outside the league, and range of motion of the shoulder joint, also have been reported.^{6,15,18} Thus, prevention cannot focus only on 1 factor, but various factors must

be considered comprehensively to successfully prevent throwing injury.

Considering this, we created a checklist for predicting which Little League baseball players are predisposed to elbow injury. To our knowledge, studies using a checklist for injury prevention have not been performed for baseball or any other sport. The aim of the current study was to investigate the effectiveness of a risk factor checklist for predicting elbow injury in Little League baseball players during 1 season.

METHODS

This prospective cohort study investigated the effectiveness of a checklist for predicting elbow injury in young baseball players. Initially, we created an original checklist for predicting Little League elbow based on previous research that explored the risk factors for this injury. This checklist was distributed to each team's representative who participated in the annual tournament in Kyoto and Fukuoka in March 2013 (preseason). A total of 134 teams in 4 cities in Japan received the checklist (Figure 1). To increase response reliability, the players' parents were instructed to work with the players to help complete the

TABLE 1
Preseason Checklist for Little League Players

	Yes	No
Condition of the elbow of the pitching arm		
1. Is the angle of the elbow in full extension different between your arms?	1	0
2. Do you have pain in the elbow of the pitching arm when it is extended?	1	0
3. Is the angle of the elbow in full flexion different between your arms?	1	0
4. Do you have pain in the elbow of the pitching arm when it is flexed?	1	0
Information about baseball playing		
5. Are you a regular player?	1	0
6. Do you often throw more than 100 pitches per week?	1	0
7. Do you have an off-season (a period when you do not throw anything for at least 1 month)?	0	1
8. Does your pitching arm often feel fatigued while playing baseball?	1	0
9. Do you practice throwing breaking pitches often?	1	0
10. Are you more often satisfied than dissatisfied with your performance?	0	1
11. Do you often play catch or throw a ball in noncompetition settings?	1	0
12. Do you often participate in resistance training?	1	0
Pitching form		
13. Is your elbow in a straight line with your shoulders (horizontal shoulder abduction) when in the cocking stage of a pitch?	0	1
14. Is your elbow at or above shoulder level (abducted $\geq 90^\circ$) in the acceleration phase of a pitch?	0	1
15. Is your front foot pointed straight on an extension of the pitcher-catcher line or angled slightly toward third base (for a right-handed pitcher)?	0	1
16. Is your front foot angled straight toward or slightly inward from the catcher?	0	1
Flexibility		
17. When prone with knees flexed at 90° , is there a difference in the internal rotation angle of your hips?	1	0
18. Is there a difference in the height of your thumbs when the dorsum of your hand is placed at maximum height against your back on the line of the spine? (Reflecting range of motion of the shoulders when internally rotated.)	1	0
19. With your knee fully flexed, is the distance between your heel and buttock 0 cm for both legs? (Reflecting flexibility of the quadriceps.)	0	1
20. When you are fully flexed at the waist, is the distance between your fingers and the floor 0 cm? (Reflecting flexibility of the hamstrings.)	0	1

checklist. After the parents had verified the responses, the players/parents mailed back the completed checklist. The purpose and methods of this study were explained to the players' parents in detail in a verbal statement, and written informed consent was obtained from the coaches and parents. This study was approved by the Institutional Review Board of Kyoto University (Approval No. E1669).

Checklist

We designed a 20-item checklist (Table 1). These items were chosen according to 2 criteria: (1) whether the factors were already reported as risk factors for throwing-related elbow injury in previous studies and (2) whether the coaches and parents could easily evaluate the factors with reliability. This checklist consisted of 4 areas of risk: condition of the elbow of the throwing arm, information about the individual player's baseball playing and practice, pitching form, and flexibility. All questions had to be easily answered by parents without medical knowledge. Therefore, pitching form and flexibility were illustrated using photos, and alternative flexibility tests rather than direct range of motion or muscle flexibility tests were used because of the large size of the participants. In addition, each question was designed with a yes/no answer. Intrarater reliability of pitching form and flexibility evaluation was tested by 10 subjects who were not medical specialists, who assessed each variable twice on separate occasions.

Pitching form was quoted from the pitching model developed by the American Sports Medicine Institute and American Baseball Foundation.^{5,14} These intrarater tests revealed kappa coefficient consistency >0.60 (range, 0.73-1.00) for all 4 pitching form and flexibility variables. These data ranges suggested that coaches and parents with no medical knowledge could answer with substantial reliability.¹² In addition to the checklist questions, basic player information was investigated, including age, height, weight, number of months playing baseball, field position (fielder, pitcher, catcher, or pitcher who concomitantly plays catcher), number of team-training days per week (<4 or ≥ 4), number of self-training days per week (≤ 6 or 7), presence or absence of pain with throwing in the shoulder or elbow in the preseason, pain in the shoulder or elbow of the throwing arm over the preceding 12 months, and elbow or shoulder injury that ever required medical treatment.

Follow-up Survey

Six months after distributing the preseason checklist, a follow-up questionnaire to determine injuries sustained during the season was distributed to players who had returned the preseason questionnaire. For this study, injury was defined as an elbow injury in the dominant arm sustained during the baseball season that required any medical treatment at least once. After the players' parents had verified the responses, the completed follow-up survey was returned.

Statistical Analysis

We excluded players who had ongoing throwing pain in the elbow or shoulder at the start of the season documented on the preseason questionnaire. We divided the players into 2 groups: those with occurrence of elbow injury during the season and those without injury. We statistically analyzed the differences between these 2 groups using the unpaired *t* test for interval items (age, height, weight, and number of months playing baseball) and the chi-square test for ordinal items.

Next, logistic regression analysis, performed in a stepwise manner, was carried out to examine whether the potential determinants were independently associated with occurrence of elbow injury during the season. In this analysis, presence or absence of elbow injury during the season was used as the dependent variable, and all items with a *P* value < .1 in univariate analyses were employed as independent variables.

Finally, we developed an “injury risk score” (IRS) based on the logistic regression analysis, distributing 1 point for significant variables to each individual. We then used receiver operating characteristic (ROC) curve analysis to examine the predictive validity of the checklist and the optimal cutoff IRS based on the Youden index,²¹ assigning occurrence of elbow injury as a state variable. Area under the curve (AUC), sensitivity, and specificity of the IRS were calculated based on the ROC curve. The cutoff value for the IRS was determined based on optimal sensitivity and specificity. A *P* value < .05 was considered to be statistically significant for all analyses.

RESULTS

The 20-item preseason checklist was completed and returned by 69 teams representing 955 players (mean age, 10.0 ± 1.0 years). Of those, 25 teams failed to return the postseason follow-up survey, leaving us with pre- and postseason data from 44 teams, representing 652 players (mean age, 10.0 ± 1.0 years). After eliminating all players with incomplete surveys, data from 425 players remained. After eliminating 36 more players whose preseason surveys indicated existing elbow or shoulder pain in their throwing arm, data from 389 players remained (mean age, 10.1 ± 0.9 years) (Figure 1).

By the end of the season, 53 of 389 players had experienced an elbow injury, resulting in an injury rate of 13.6%. Basic information of these players is shown in Table 2. Results of the unpaired *t* test showed that age, height, weight, and length of time playing baseball were significantly different between the 2 groups, whereas results of the chi-square test showed that pain in the elbow or shoulder while throwing within the past 12 months (*n* = 37, 69.8%), throwing-related elbow or shoulder injury ever requiring medical treatment (*n* = 22, 41.5%), status of pitcher (*n* = 31, 58.5%), team training ≥4 days per week (*n* = 23, 43.4%), self-training 7 days per week (*n* = 10, 18.9%), and checklist items 5 (starting lineup member; *n* = 52, 98.1%), 6 (frequently throwing >100 pitches per

TABLE 2
Comparison of Players With and Without Elbow Injury Sustained During the Season^a

	With Injury (<i>n</i> = 53)	Without Injury (<i>n</i> = 336)	<i>P</i> Value
Age, y, mean ± SD	10.4 ± 0.7	10.0 ± 1.0	<.01 ^b
Height, cm, mean ± SD	141.5 ± 7.1	138.5 ± 7.6	<.01 ^b
Weight, kg, mean ± SD	35.2 ± 7.6	32.6 ± 6.2	<.01 ^b
Previous baseball experience, mo, mean ± SD	33.9 ± 16.0	28.0 ± 15.4	.01 ^c
Has experienced shoulder or elbow pain while throwing in the preceding 12 months	37 (69.8)	108 (32.1)	<.01 ^b
Has ever experienced an elbow or shoulder injury requiring medical attention	22 (41.5)	38 (11.3)	<.01 ^b
Fielding position			
Pitcher	31 (58.5)	111 (33.0)	<.01 ^b
Catcher	12 (22.6)	86 (25.6)	.74
Fielder	49 (92.5)	316 (94.0)	.55
Pitcher who concomitantly plays catcher	6 (11.3)	42 (12.5)	>.99
Team training ≥4 days per week	23 (43.4)	78 (23.2)	<.01 ^b
Self-training 7 days per week	10 (18.9)	23 (6.8)	.01 ^c
Checklist item			
No. 1	4 (7.5)	16 (4.8)	.33
No. 2	1 (1.9)	4 (1.2)	.52
No. 3	2 (3.8)	6 (1.8)	.30
No. 4	0 (0.0)	3 (0.9)	>.99
No. 5	52 (98.1)	266 (79.2)	<.01 ^b
No. 6	13 (24.5)	37 (11.0)	.01 ^c
No. 7	51 (96.2)	322 (95.8)	>.99
No. 8	23 (43.4)	52 (15.5)	<.01 ^b
No. 9	1 (1.9)	8 (2.4)	>.99
No. 10	26 (49.1)	158 (47.0)	.88
No. 11	26 (49.1)	167 (49.7)	>.99
No. 12	7 (13.2)	52 (15.5)	.84
No. 13	17 (32.1)	133 (39.6)	.36
No. 14	11 (20.8)	47 (14.0)	.21
No. 15	10 (18.9)	66 (19.6)	>.99
No. 16	8 (15.1)	43 (12.8)	.66
No. 17	7 (13.2)	43 (12.8)	>.99
No. 18	19 (35.8)	100 (29.8)	.42
No. 19	5 (9.4)	32 (9.5)	>.99
No. 20	18 (34.0)	129 (38.4)	.65

^aValues are reported as *n* (%) unless otherwise indicated.

^b*P* < .01.

^c*P* < .05.

week; *n* = 13, 24.5%), and 8 (frequently feeling fatigue in the throwing arm during the season; *n* = 23, 43.4%) were significantly different between players with and without elbow injury (Table 2).

Logistic regression analysis revealed that pain in the elbow or shoulder while throwing within the past 12 months

TABLE 3

Factors Associated With Occurrence of Elbow Injury During the Season According to Stepwise Logistic Regression Analysis

	Odds Ratio	95% CI	P Value
Has experienced shoulder or elbow pain while throwing in the preceding 12 months	2.64	1.31-5.34	.007
Has ever experienced an elbow or shoulder injury requiring medical attention	4.10	1.96-8.54	<.001
Team training ≥4 days per week	2.58	1.30-5.12	.007
Self-training 7 days per week	3.15	1.23-8.09	.017
Checklist item No. 5	10.29	1.26-84.0	.030
Checklist item No. 8	3.01	1.48-6.11	.002

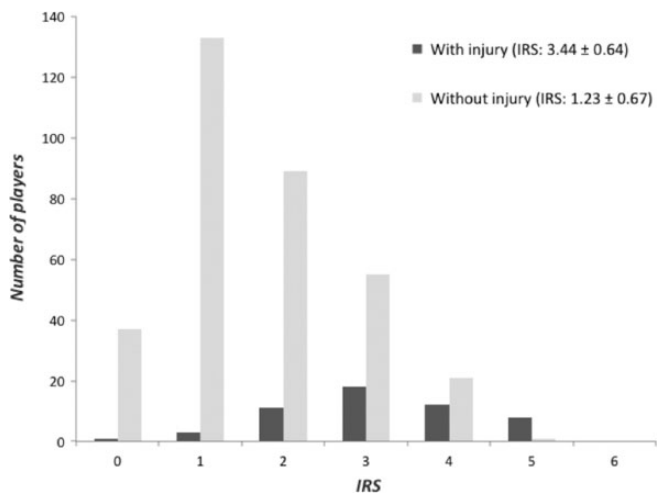


Figure 2. Injury risk score for players with and without elbow injury during the season. IRS, injury risk score.

(odds ratio [OR], 2.64; 95% CI, 1.31-5.34; $P = .007$), throwing-related elbow or shoulder injury ever requiring medical treatment (OR, 4.10; 95% CI, 1.96-8.54; $P < .001$), team training ≥ 4 days per week (OR, 2.58; 95% CI, 1.30-5.12; $P = .007$), self-training 7 days per week (OR, 3.15; 95% CI, 1.23-8.09; $P = .017$), checklist item 5 (OR, 10.29; 95% CI, 1.26-84.0; $P = .030$), and checklist item 8 (OR, 3.01; 95% CI, 1.48-6.11; $P = .002$) were independently associated with occurrence of elbow injury during the season (Table 3).

Using the 6 variables that were significant in the logistic regression analysis, we calculated the IRS going up to 6 points. In the injured player group, the mean IRS was 3.44 ± 0.64 , whereas that in the noninjured player group was 1.27 ± 0.67 ($P < .01$) (Figure 2). The ROC curve had a relatively high AUC for the IRS (0.810), and we determined that a two-thirds cutoff point had a sensitivity of 0.717 and a specificity of 0.771 (Figure 3). Among players with an IRS of 3 to 6 ($n = 115$), 38 players had been injured during the season (injury rate, 33.0%). Among players with an IRS of 0 to 2 ($n = 274$), 15 players (injury rate, 5.5%) had been injured (Figure 2).

DISCUSSION

We developed a preseason checklist to predict predisposition to elbow injury in Little League baseball players. As

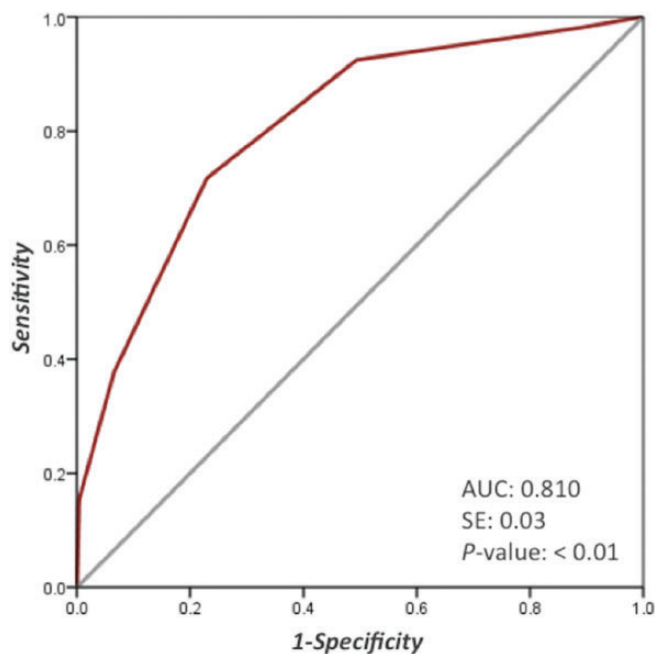


Figure 3. Receiver operating characteristic (ROC) curve analysis for injury risk score (IRS). ROC analysis was conducted to determine the predictive validity of the checklist and the optimal cutoff IRS, assigning occurrence of elbow injury as a state variable. We were able to predict the players who were injured during the season with a two-thirds cutoff value for a 6-item checklist (area under the curve [AUC], 0.810; sensitivity, 0.717; specificity, 0.771).

a result, we could predict the players who would be injured during the season with a two-thirds cutoff value for a 6-item checklist. The final version of the checklist (Table 4) has some desirable features, such as being easy to answer for coaches and parents, and comprehensively considering the risk factors. Therefore, we believe this checklist will be helpful for primary prevention of Little League elbow in the future. To our knowledge, this is the first longitudinal study aimed to develop an injury-predicting checklist for Little League baseball players.

The IRS of this checklist is composed of 6 items. As demonstrated in many previous studies,^{3,14,15,18} volume of playing baseball was a significant risk factor in our study. Playing baseball outside of league competition also has been reported to be a risk factor,^{15,18} which might be close

TABLE 4
Final Version of Checklist

	Yes	No
1. Have you experienced shoulder or elbow pain while throwing in the preceding 12 months?	1	0
2. Have you ever experienced a shoulder or elbow injury requiring medical treatment?	1	0
3. Do you participate in team training ≥ 4 days per week?	1	0
4. Do you participate in self-training 7 days per week?	1	0
5. Are you in the starting lineup?	1	0
6. Does your pitching arm often feel fatigued while playing baseball?	1	0

to our finding: A similar measure, number of self-training days per week = 7, was found to be significant in our study. The more frequently baseball is played, the larger the amount of force a player's elbow receives. Players who spend a significant amount of time training outside the league competition should be monitored closely for signs of injury. Arm fatigue in the preseason also was found to be a significant risk factor. We cannot confirm whether this fatigue would continue during the season, but fatigue on a daily basis could affect the onset of injury. As shown in several studies,^{15,18} coaches and parents may be able to use such fatigue as an easily observed predictor of elbow injury. In addition, a medical history of throwing injury was shown to be a significant factor. Some studies excluded players who had preexisting throwing injury or did not consider the history of injury^{6,18}; therefore, the causal relationship between past medical history and new onset of injury remains unknown. Medical history may be misleading in players who continue to use their throwing arm despite known abnormalities on imaging studies or ongoing clinical symptoms.^{7,16} These players often have worse outcomes¹⁹ for several reasons: An injury that is not completely treated may become more severe with activity; an injury may have changed the player's pitching mechanics, making the player more susceptible to injury; and players who have experienced an injury in the past are more likely to sustain a new injury. Consequently, players with signs or symptoms of a previous or ongoing injury should be followed more closely for evidence of a new or worsening injury than players without a preexisting injury. In this study, one of the most important risk factors, pitching mechanics, was not shown to be significant. However, this may be because the checklist was designed to be easily answered by parents, and proper pitching motion analysis is quite complicated¹⁷; thus, only 4 of 24 items in the pitching model developed by the American Sports Medicine Institute and American Baseball Foundation were selected for evaluation. Incorporating pitching mechanics into our checklist will be considered in a future study.

Researchers have identified risk factors for Little League elbow, including age, height, weight, range of motion of the shoulder joint, pitch count, fatigue, pitching biomechanics, and pitch type.^{3,6,14,15,18} Based on this information, several primary prevention strategies have been considered. Limiting pitch count is regarded as the most effective way to prevent throwing injury.^{2,11} While we agree that this is true, these limits are meaningless without strict compliance.^{1,22}

One cause of poor compliance is that pitch count limits are monitored by coaches rather than parents, and coaches may have less interest in protecting players from injury than parents. We believe that parents have the potential to prevent children from being injured, and our checklist, which we have shown can predict predisposition to injury, was designed to be easy for parents to use. The most important clinical implication of this study is that parents can evaluate and follow their child's condition and determine whether the child is at risk of developing Little League elbow. When parents are aware that their child is at risk for elbow injury, they can monitor pitch count limits themselves and encourage coaches to apply the limits more strictly. Closer monitoring by parents may lead to earlier detection and prevention of Little League elbow. Players with an IRS of ≥ 3 on this checklist had only a 33% chance of injury; therefore, it might be exaggerated to suggest that use of this checklist only is effective for prevention of injury. However, this is a step in the right direction, and the checklist would be more valuable in combination with other preventive measures. We expect that use of our checklist in combination with pitch count limits or other preventive measures in collaboration between coaches and parents will be helpful for primary prevention of Little League elbow.

Our study has several limitations. First, selection bias might have influenced the results. Participants were lost to dropout, preexisting injury, and omissions on the follow-up survey. Second, pitching mechanics were not fully investigated in the study. Until the checklist is more comprehensive in its coverage of pitching mechanics, its usefulness for predicting risk of elbow injury may be limited. Finally, because the study was confined to Japanese children, the generalizability of this study to other populations or geographic areas is unknown. Further research is required to ensure the external validation of our checklist.

CONCLUSION

Our study showed that responses on a 6-item checklist of risk factors for elbow injury can predict which Little League baseball players are predisposed to elbow injury. The ability to predict which Little League baseball players are predisposed to elbow injury allows parents and coaches to initiate preventive measures in those players prior to and during the season, which could lead to fewer elbow injuries.

The 6-item checklist should be applied to all Little League baseball players in the preseason to determine their predisposition to elbow injury.

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