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 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).

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

	With Injury (n = 53)	Without Injury (n = 336)	*P* 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

[a]Values are reported as n (%) unless otherwise indicated.
[b]$P < .01$.
[c]$P < .05$.

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

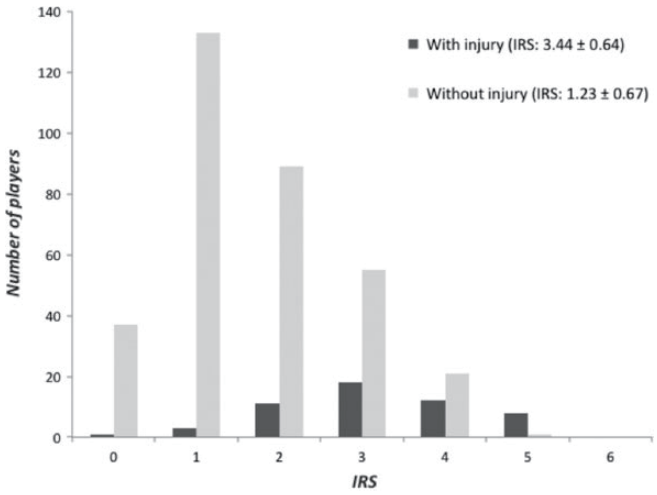

Figure 2. Injury risk score for players with and without elbow injury during the season. IRS, injury risk score.

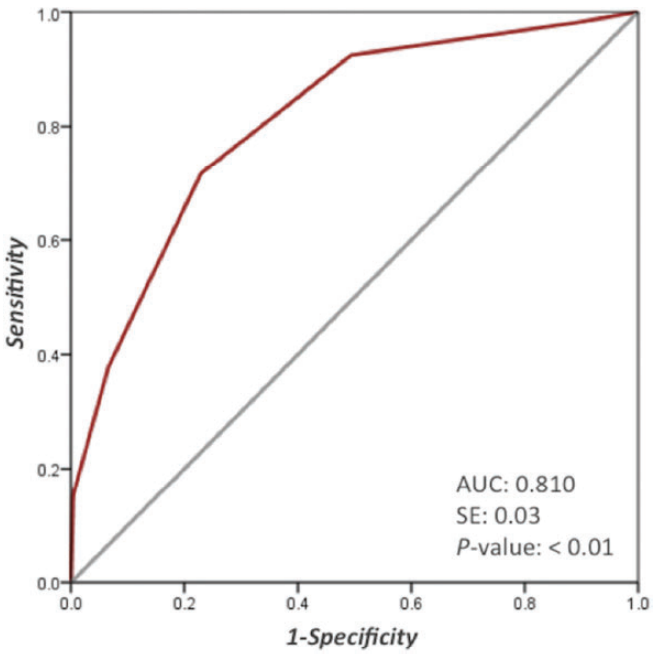

Figure 3. Receiver operating characteristic (ROC) curve analysis for injury risk score (IRS). ROC analysis was conducted to determine the predictive validity of the checklist and the optimal cutoff IRS, assigning occurrence of elbow injury as a state variable. We were able to predict the players who 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).

(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 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 outcomes[19] 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 complicated[17]; 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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REFERENCES

1. Fazarale JJ, Magnussen RA, Pedroza AD, et al. Knowledge of and compliance with pitch count recommendations: a survey of youth baseball coaches. *Sports Health*. 2012;4:202-204.
2. Fleisig GS, Andrews JR. Prevention of elbow injuries in youth baseball pitchers. *Sports Health*. 2012;4:419-424.
3. Fleisig GS, Andrews JR, Cutter GR, et al. Risk of serious injury for young baseball pitchers: a 10-year prospective study. *Am J Sports Med*. 2011;39:253-257.
4. Fleisig GS, Weber A, Hassell N, Andrews JR. Prevention of elbow injuries in youth baseball pitchers. *Curr Sports Med Rep*. 2009;8:250-254.
5. Fortenbaugh D, Fleisig GS, Andrews JR. Baseball pitching biomechanics in relation to injury risk and performance. *Sports Health*. 2009;1:314-320.
6. Harada M, Takahara M, Mura N, Sasaki J, Ito T, Ogino T. Risk factors for elbow injuries among young baseball players. *J Shoulder Elbow Surg*. 2010;19:502-507.
7. Harada M, Takahara M, Sasaki J, Mura N, Ito T, Ogino T. Using sonography for the early detection of elbow injuries among young baseball players. *AJR Am J Roentgenol*. 2006;187:1436-1441.
8. Japan Rubber Baseball Association. Number of teams in the Japan Rubber Baseball Association [in Japanese]. http://jsbb.or.jp/outline/teams. Accessed December 1, 2013.
9. Japanese Society of Clinical Sports Medicine. Recommendations for the prevention of youth baseball injuries [in Japanese]. http://www.rinspo.jp/pdf/proposal_03-1.pdf. Accessed January 7, 2015.
10. Klingele KE, Kocher MS. Little League elbow: valgus overload injury in the paediatric athlete. *Sports Med*. 2002;32:1005-1015.
11. Kerut EK, Kerut DG, Fleisig GS, Andrews JR. Prevention of arm injury in youth baseball pitchers. *J La State Med Soc*. 2008;160:95-98.
12. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159-174.
13. Lyman S, Fleisig GS. Baseball injuries. *Med Sport Sci*. 2005;49:9-30.
14. 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.
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. Matsuura T, Suzue N, Kashiwaguchi S, Arisawa K, Yasui N. Elbow injuries in youth baseball players without prior elbow pain: a 1-year prospective study. *Orthop J Sport Med*. 2013;1:1-4.
17. 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.
18. Olsen SJ 2nd, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med*. 2006;34:905-912.
19. Takahara M, Ogino T, Takagi M, Tsuchida H, Orui H, Nambu T. Natural progression of osteochondritis dissecans of the humeral capitellum: initial observations. *Radiology*. 2000;216:207-212.
20. USA Baseball. Youth baseball pitching injuries. http://web.usabaseball.com/news/article.jsp?ymd=20090813&content_id=6409508. Accessed December 1, 2013.
21. Youden WJ. Index for rating diagnostic tests. *Cancer*. 1950;3:32-35.
22. Yukutake T, Yamada M, Aoyama T. A survey examining the correlation between Japanese Little League baseball coaches' knowledge of and compliance with pitch count recommendations and player elbow pain. *Sports Health*. 2013;5:239-243.