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JSES International

journal homepage: www.jsesinternational.org

Players' satisfaction with daily pitching performance could predict shoulder and elbow injuries in high-school baseball pitchers: a prospective time-to-event study

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ARTICLE INFO

Keywords:

Baseball
Shoulder
Elbow
Injury prevention
Risk factor
Self-satisfaction

Level of evidence: Level I; Prospective Cohort Design; Prognosis Study

Hypothesis and Background: The relationship between baseball pitchers' satisfaction with their performance and the incidence of shoulder and elbow injuries is unclear. We hypothesized that self-evaluated satisfaction with pitching performance before an injury and incidence of shoulder and elbow injuries are related.

Methods: Baseline data on baseball experience, height, weight, elbow and shoulder range of motion, and shoulder muscle strength of high-school baseball pitchers were collected. During the season, all participants completed a self-recorded questionnaire regarding satisfaction scores, presence of shoulder and/or elbow pain, and pitching limitations due to shoulder and/or elbow pain experienced daily to determine when injuries occurred and record the satisfaction scores. The optimal satisfaction score cutoff value was determined through receiver operating characteristic curve analysis; participants were categorized into satisfied and unsatisfied groups. Statistical tests were performed to evaluate the differences between the groups, obtain the time-to-event curves, and calculate the hazard ratios for the incidence of injury.

Results: Overall, 108 participants aged 15–17 years were enrolled and divided into satisfied (88) and unsatisfied (20) groups. The injury incidence rate was 10.2% and 50.0% in the satisfied and unsatisfied groups, respectively. High-school baseball pitchers with low satisfaction had a significantly increased risk of shoulder and elbow injuries; these players had a 7.3-times greater risk of injuries and 1.9-times earlier occurrence of injuries than pitchers who were satisfied with their performance.

Conclusion: Daily evaluation of players' self-satisfaction could predict shoulder and elbow injuries in high-school baseball pitchers.

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Baseball players often experience shoulder and elbow injuries and pain. The incidence of shoulder and elbow injuries has been reported as follows: 17.4% and 28.0% during the previous 1 year in elementary school baseball players¹⁶ and junior high-school baseball players, respectively,¹⁵ 26% as elbow pain and 32% as shoulder

pain during 2 seasons,⁶ 20.0% during one season in high-school baseball pitchers,¹⁰ and 47.9% during 5 seasons in professional pitchers.² In previous prospective studies, preseason risk factors for the occurrence of shoulder and elbow injuries include deficits in the range of motion (ROM) of the dominant shoulder (glenohumeral internal and external rotation), total shoulder rotation, and abduction and prone external rotation strength (PER).^{2,3,10,17,19} In high-school baseball pitchers, the preseason risk factors for shoulder and elbow injuries have been identified as deficits in the glenohumeral internal rotation ROM on the dominant side,¹⁰ a low ratio of the PER of the dominant to the nondominant side,¹⁰ and supraspinatus weakness.¹⁷ However, knowledge regarding the in-season risk factors for shoulder and elbow injuries, including

The Institutional Review Board of Gunma University Hospital (Identification No. 1003) approved this study. Informed consent for participation and publication was obtained from the parents of the participants.

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<https://doi.org/10.1016/j.jseint.2021.09.011>

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the number of pitches, number of innings, and external load (training and competition hours), remains limited. A retrospective study involving junior high-school baseball players demonstrated that players who performed 70 or more full-power pitches per day and 300 or more full-power pitches per week were at a significantly higher risk of elbow pain¹⁵ and that pitching more than 100 innings per year was a significant risk factor for baseball-related arm injury in young pitchers.⁴ Pitchers may not be able to control the above-mentioned factors because the length of practice and number of pitches are usually determined by the coach. However, self-evaluation could provide a means of identifying players at a higher risk of injury, as it includes evaluation of psychological factors, such as anxiety, confidence, and frustration that might affect pain perception. Furthermore, this self-evaluation approach should not be affected by other people, such as coaches.

To the best of our knowledge, only one prospective study investigated players' satisfaction and sports performance and found low self-evaluated satisfaction with pitching performance using a 5-point Likert scale (1 = poor; 5 = excellent) during the season to be a risk factor for shoulder and elbow pain in young baseball players aged 8–12 years.⁶ Moreover, no studies have assessed this among high-school baseball players. Because of limited evidence, the timing of these injuries and the level of self-evaluated satisfaction with pitching performance just before the onset of injury remain unclear.

We hypothesized that self-evaluated satisfaction of pitching performance before an injury is related to the incidence of shoulder and elbow injuries. Therefore, the daily self-evaluated score could be used as a predictor of injury. To test this hypothesis, we prospectively investigated the relationship between daily self-evaluated satisfaction scores before an injury and the incidence of shoulder and elbow injuries in high-school baseball pitchers using time-to-event analysis.

Materials and methods

Participants

The pitchers were enrolled from each high school associated with a baseball club (competitive level) in Gunma prefecture; in total, 128 pitchers participated in an annual free preseason medical checkup, which was held as a social contribution to prevent injury by our department. At the preseason medical checkup, all participating male high-school baseball pitchers aged 15–17 years (mean: 16.7 years) were recruited for this study, and written informed consent was obtained from their parents before participation. As per the criteria used in previous studies,^{10,11} we included pitchers who participated in baseball practice and considered them as active pitchers after confirming that they had no shoulder or elbow issues after undergoing a medical checkup. The exclusion criteria were previous major injuries (such as a fracture) or surgery of the dominant arm and limitations in pitching due to shoulder or elbow problems, such as discomfort or pain during pitching.

This study was approved by the institutional review board of Gunma University Hospital (approval number: 1003). All procedures were performed in accordance with the relevant regulations and guidelines.

Baseline assessment

Baseline assessment (preseason medical checkup) was performed as previously reported.^{10,11} Data on baseball experience, height, weight, elbow and shoulder ROM, and shoulder muscle strength were collected. When evaluating these items, the examiners were blinded to information regarding the dominant arm.

Elbow and shoulder ROM

The intrarater validity and reliability of ROM measurements obtained using a digital protractor have been previously reported.^{10,11} In the present study, a certified orthopedic surgeon measured the bilateral ROM for elbow flexion and extension, shoulder 90°-abducted external and internal rotation, and shoulder horizontal adduction using a digital protractor (iGaging, Los Angeles, CA, USA).

Shoulder strength

The intrarater validity and reliability of handheld dynamometers have been previously established.^{2,10,11} In the present study, a certified orthopedic surgeon assessed the PER and prone internal rotation strength (PIR) of both shoulders using a PowerTrack II Commander handheld dynamometer (J-Tech Medical, Salt Lake City, UT, USA). The dominant-to-nondominant ratios of the PER and PIR and the ratio of PER to PIR on the dominant side were calculated for each participant.

Injury tracking and in-season data collection

Injury tracking was started on April 1, 2018, for a period of 150 days. From the players' viewpoint, "shoulder or elbow injury" is defined as any condition, mainly pain in the shoulder and/or elbow, resulting in the pitcher being unable to pitch/unable to use the arm for ≥ 8 days,^{8,10,11} whereas from the clinician's viewpoint, identifying the type of injuries that occurred is important. However, we focused on the players' viewpoint in this study. A self-recorded questionnaire (Fig. 1) to investigate when injuries occurred was completed by participants every day regarding the presence of shoulder and/or elbow pain, limitations to pitching caused by shoulder or elbow pain, and presence of other injuries. To collect external load data, participants were asked to complete a questionnaire every day on the duration of baseball training and practice per day. For analysis, the average training and practice duration per week was calculated.

Self-evaluated satisfaction with pitching performance was assessed before the onset of injury. Participants were asked to complete a questionnaire evaluating satisfaction with pitching performance every day during the season for 150 days and assign their pitching performance a numerical score between 0 (worst) and 10 (best). To reduce potential recall bias, participants were encouraged to complete the questionnaire by calling them daily and asking them to return completed questionnaires every month by fax.

Statistical analyses

SAS v9.4 (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses. All tests were 2-sided with a significance level of $P < .05$. Differences between groups at baseline were compared using the Mann–Whitney U test. When a significant difference was found in the factors between the 2 groups at baseline, logistic regression analysis was performed to identify whether the factors were significant risk factors for shoulder and elbow injuries. A receiver operating characteristic (ROC) curve analysis with Youden's index was used to determine the cutoff value for the average self-evaluated satisfaction score before injury, and participants were divided into 2 groups using this cutoff value. A Kaplan–Meier analysis was used to generate time-to-event curves, and hazard ratios (HRs) for the incidence of injury were calculated using Cox proportional hazards models. The incidence of injury was compared between groups using a log-rank test. The sample size

April	School:			Name:			
	1	2	3	4	5	6	7
Presence of pain	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow
Presence of other injuries	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)
Limitations to pitching caused by shoulder/elbow pain	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes
Practice/training duration (hours)							
Satisfaction of pitching performance (0-10)							
	8	9	10	11	12	13	14
Presence of pain	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow
Presence of other injuries	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)
Limitations to pitching caused by shoulder/elbow pain	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes
Practice/training duration (hours)							
Satisfaction of pitching performance (0-10)							
	15	16	17	18	19	20	21
Presence of pain	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow
Presence of other injuries	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)
Limitations to pitching caused by shoulder/elbow pain	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes
Practice/training duration (hours)							
Satisfaction of pitching performance (0-10)							
	22	23	24	25	26	27	28
Presence of pain	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow	No / shoulder / elbow
Presence of other injuries	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)	No / Yes (where:)
Limitations to pitching caused by shoulder/elbow pain	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes	No / Yes
Practice/training duration (hours)							
Satisfaction of pitching performance (0-10)							
	29	30					
Presence of pain	No / shoulder / elbow	No / shoulder / elbow					
Presence of other injuries	No / Yes (where:)	No / Yes (where:)					
Limitations to pitching caused by shoulder/elbow pain	No / Yes	No / Yes					
Practice/training duration (hours)							
Satisfaction of pitching performance (0-10)							

Figure 1 Self-recorded questionnaire. This figure shows the example of a self-recorded questionnaire in April.

was determined by performing a priori statistical power analysis, which indicated that 39 participants would provide a statistical power of 80% at an α level of 0.05, an HR of 2.7,¹⁰ an accrual interval of 150 days, a follow-up interval of 150 days, and a median time to failure in the group, with the shortest time to failure of 50 days in the Kaplan–Meier analysis.⁹ Finally, a post hoc power analysis was performed to verify the statistical power of this study.

Results

ROC analysis

The cutoff value for the average daily self-satisfaction score with pitching performance before injury, as determined by the ROC

analysis, was 4 points ($P = .001$, the area under the curve = 0.73, Fig. 2) with a moderate diagnostic accuracy.¹²

Baseline characteristics and in-season factors

Participants were excluded ($n = 20$) because of data unavailability even if they forgot to fill the daily questionnaire for 1 day except for days off or if they dropped out, and a total of 108 participants were finally enrolled. Participants were then divided into the satisfied (score ≥ 4) and unsatisfied (score < 4) groups with 88 and 20 pitchers, respectively (Fig. 3). Body weight and PER of the dominant side at baseline were significantly higher in the unsatisfied group than those in the satisfied group. No other significant differences in baseline values were found between the 2 groups (Table 1).

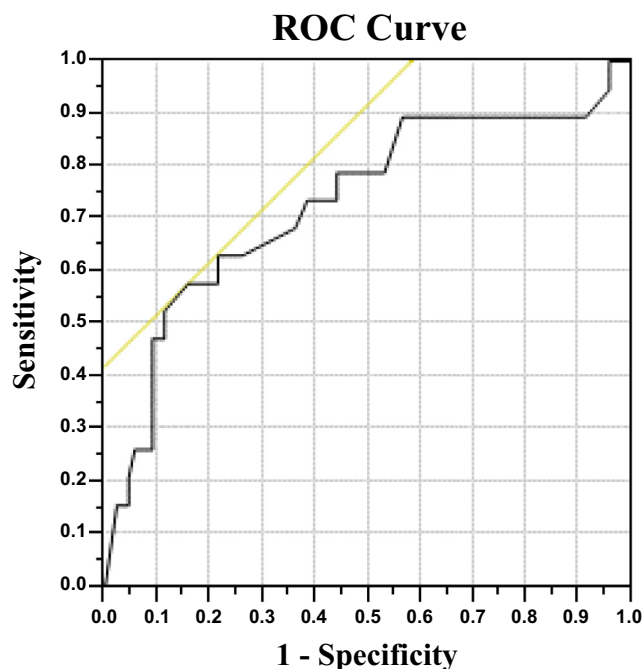


Figure 2 Receiver operating characteristic (ROC) curve. The ROC analysis shows that the cutoff value of the average daily self-satisfaction score with pitching performance is 4 points ($P = .001$, the area under the curve [AUC] = 0.73).

Logistic regression analysis

Based on the results of the univariate analyses ($P < .05$), body weight and PER of the dominant shoulder were selected for the logistic regression analysis, which showed that there was no significant independent risk factor for shoulder and elbow injuries (Table II).

Time-to-event analysis

The rate of incidence of injury was 10.2% ($n = 9$; shoulder, 7 and elbow, 2) and 50.0% ($n = 10$; shoulder, 6 and elbow, 4) in the satisfied and unsatisfied groups, respectively. The median time to injury was 55.0 and 29.5 days in the satisfied and unsatisfied groups, respectively (Fig. 4), representing a 1.9-times earlier incidence of injury among pitchers who were not satisfied with their performance. Kaplan-Meier analysis revealed an HR of 7.299 for the unsatisfied group when compared with the satisfied group (Table III). The log-rank test revealed that the incidence of injury was significantly lower in the satisfied group than that in the unsatisfied group ($P < .001$).

Post hoc power analysis

The post hoc power analysis revealed that the power of this study was 0.990, confirming that the sample size was sufficient to test the aim of the study.

Discussion

This study tested the hypothesis that low pitchers' satisfaction with their performance would be predictive of shoulder and elbow injuries. The main finding of this study was that high-school baseball pitchers with a mean preinjury self-satisfaction score for pitching performance of <4 points are at a significantly increased

risk of shoulder and elbow injuries. Furthermore, these pitchers are at a 7.3-fold higher risk of injury occurring 1.9 times earlier than pitchers who are satisfied with their performance. Baseline differences in body weight and PER of the dominant shoulder between the satisfied and unsatisfied groups were not related to the risk for occurrence of shoulder and elbow injuries. To the best of our knowledge, this is the first prospective study to provide evidence related to both the increase in risk and the time at which injuries might occur.

Self-satisfaction and sports performance

Lyman et al reported that decreased self-satisfaction—categorized as excellent, good, average, fair, or poor—is a risk factor for elbow and shoulder pain during the season in baseball players aged 8–12 years (odds ratio = 0.83 and 0.75, respectively).⁶ Self-satisfaction with pitching performance has been shown to be significantly positively correlated with flexor carpi ulnaris muscle strength on the pitching side among high-school pitchers ($r = 0.27$),¹³ as well as baseball experience,¹⁴ but significantly negatively correlated with ulnar collateral ligament thicknesses on the dominant side ($r = -0.20$).¹⁴ Although a direct comparison between our study and the previous prospective study⁶ is difficult because the risk was represented as the HR in our results and as odds ratios in the previous study,⁶ we believe that the accuracy and consistency of self-evaluation might be higher in the present study than those in the previous study because our participants aged 15–17 years were older and more physically and mentally mature than participants aged 8–12 years, which is advantageous in terms of self-evaluation. Therefore, assessing self-satisfaction with pitching performance may enable the prediction of pitching-related shoulder and elbow injuries in high-school baseball pitchers and provide a method that is more useful than physical checkups because athletes are not required to visit a clinic.

Previous studies have shown that training in a competitive environment reduces athletes' satisfaction with their performance.^{7,18} Balaguer et al reported that performance and self-satisfaction with performance improved when handball players trained in a strongly task-oriented motivational environment.¹ Furthermore, a recent study investigated the role of the coach and reported that the coach should encourage young players to evaluate their performance through self-evaluation.⁵ Our study did not evaluate the motivational environment; therefore, further studies are required to confirm the utility of assessing self-satisfaction in different training environments.

Baseline differences

Lyman et al reported that increased body weight is a risk factor for an elbow injury.⁶ In the present study, regarding body weight, the weight of participants in the unsatisfied group was significantly higher than that of participants in the satisfied group. Although this result seems to be similar to that of the previous study,⁶ logistic regression analysis showed that body weight was not a significant risk factor for shoulder and elbow injuries in this study.

A low PER ratio has been demonstrated to be a risk factor for shoulder and elbow injuries among high-school baseball pitchers.¹⁰ However, this was not observed in the present study; PER on the dominant side was significantly greater in the unsatisfied group. As the logistic regression analysis showed that PER on the dominant side was not a significant risk factor for shoulder and elbow injuries, we do not believe that the increased risk of injury in the unsatisfied group was related to the higher PER in this study.

Therefore, in this study, baseline differences in body weight and PER on the dominant side may not have significantly affected the

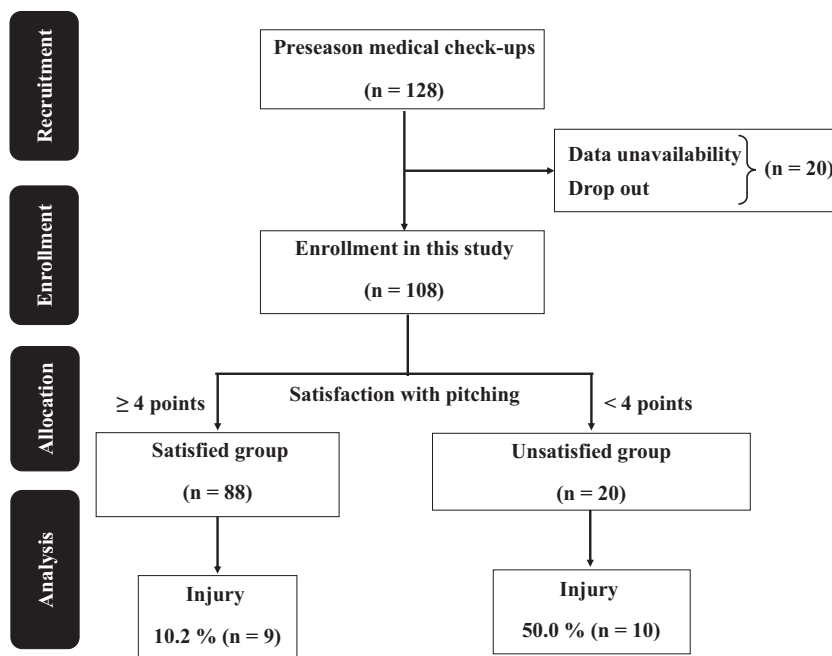


Figure 3 Flow diagram showing the study recruitment process.

Table I
Baseline characteristics of the players.

Baseline characteristics	Satisfied group (n = 88)		Unsatisfied group (n = 20)		P value
	Mean	SD	Mean	SD	
Baseball experience (yrs)	8.66	1.65	8.29	2.05	.427
Body height (cm)	173.03	5.95	172.92	4.97	.940
Body weight (kg)	67.99	8.11	74.30	7.71	.002*
Elbow flexion on the dominant side (deg)	141.20	6.55	141.15	5.11	.972
Elbow extension on the dominant side (deg)	2.91	5.81	1.45	4.35	.292
ABER on the dominant side (deg)	107.51	12.02	106.45	13.85	.729
ABIR on the dominant side (deg)	38.69	9.78	38.50	10.88	.938
HA on the dominant side (deg)	13.72	13.82	12.84	13.12	.794
PER on the dominant side (kg)	15.82	6.34	19.19	8.55	.048*
PER ratio	19.33	7.55	21.68	7.67	.213
PIR on the dominant side (kg)	0.96	0.17	1.01	0.14	.291
PIR ratio	1.00	0.17	1.00	0.23	.973
PER/PIR ratio	0.84	0.22	0.87	0.18	.584
In-season factor					
Practice/training duration (hours/week)	26.31	17.13	22.60	14.89	.394

ABER, range of motion of 90°-abducted external rotation in the shoulder; ABIR, range of motion of 90°-abducted internal rotation in the shoulder; HA, range of motion of horizontal adduction in the shoulder; PER, muscle strength of prone external rotation; PIR, muscle strength of prone internal rotation; SD, standard deviation.

Ratio refers to the ratio of the strength of the dominant side to that of the nondominant side.

*P < .05.

Table II
Results of the logistic regression analysis.

Explanatory variable	Odds ratio	95% CI	P value
Body weight	1.027	0.965-1.093	.401
PER on the dominant side	1.059	0.991-1.132	.092

CI, confidence interval; PER, muscle strength of prone external rotation.

main result that high-school baseball pitchers with a mean pre-injury self-satisfaction score for pitching performance of <4 points are at a significantly increased risk of shoulder and elbow injuries.

Limitations

This study has some limitations. First, we were unable to clarify the mechanism underlying the relationship between a low

satisfaction score and the incidence of shoulder and elbow injuries. However, self-evaluation of pitching performance represents a useful tool for the early detection of shoulder and elbow injuries. Future studies are warranted to elucidate the mechanism underlying the relationship between a low satisfaction score and the incidence of shoulder and elbow injuries. Second, we did not assess the motivational environment, which might affect self-satisfaction; thus, further studies are required to evaluate the influence of this factor. Third, we did not collect detailed data regarding the injuries. Although clinicians should pay attention to where and how severe injuries occurred, the inability to pitch for the baseball players is a major problem even if persistent elbow/shoulder pain is attributed to only inflammation without any detectable anatomical failure. Although we favored the players' viewpoint in this study, our study did not clarify the relationship between injury severity and self-satisfaction with pitching performance. Fourth, we did not

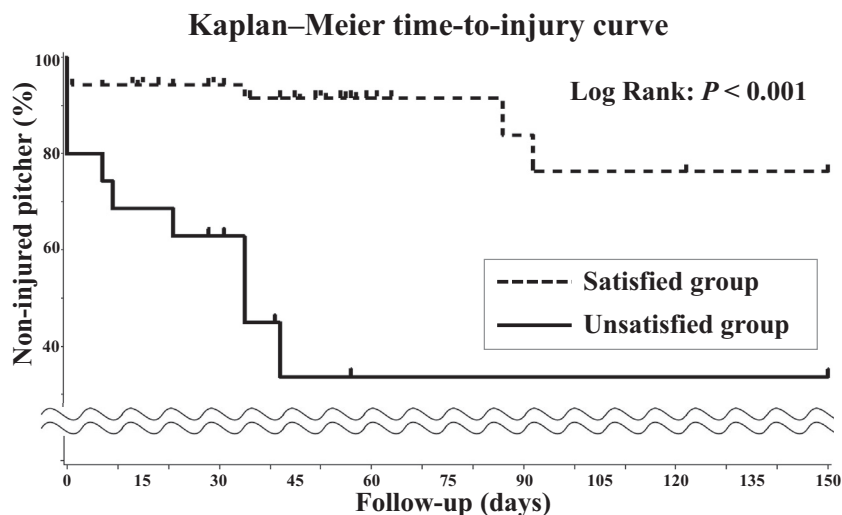


Figure 4 Kaplan–Meier time-to-injury curves. The median times to injury were 55.0 and 29.5 days in the satisfied and unsatisfied groups, respectively. The incidence of injury was found to be significantly lower in the satisfied group than that in the unsatisfied group.

Table III
Results of the Cox proportional hazards model analysis.

Group	Total	Injury occurrence	
		Number (%)	HR (95% CI)
Satisfied group	88	9 (10.2)	0.137 (0.055–0.344)
Unsatisfied group	20	10 (50.0)	7.299 (2.907–18.182)

CI, confidence interval; HR, hazard ratio.

analyze the relationship between the players’ satisfaction and shoulder and elbow-related complaints, including pain intensity, before they missed 8 days of pitching. However, the pain intensity in the shoulder and elbow should affect self-evaluated players’ satisfaction. Finally, in-season risk factors, such as the number of pitches and innings, which are related to shoulder and elbow injuries, were not evaluated in this study. These factors may have affected the results, although the training and practice durations were not different between the groups in this study.

Conclusion

In high-school baseball pitchers, low satisfaction with pitching performance increases the risk of shoulder and elbow injuries and is associated with an earlier occurrence of injury. To the best of our knowledge, this is the first prospective study to evaluate the increase in risk as well as the timing of injury. Evaluation of players’ satisfaction with their pitching may be a useful tool for predicting shoulder and elbow injuries. When pitchers report low satisfaction with pitching performance, clinicians should attribute the score not only to bad conditioning but also to an increased risk of shoulder and elbow injuries and should examine the whole body for any decrease in function.

Disclaimers:

Funding: Hitoshi Shitara received a research grant for the research and publication of this article from Gunma Foundation for Medicine and Health Science.

Conflicts of interest: All authors, their immediate families, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

Acknowledgments

The authors thank the personnel, players, coaches, and staff of the Gunma Prefecture High School Baseball Federation for their assistance and cooperation in this study. They also thank Kureha Special Laboratory Co., Ltd., and Japan Institute of Statistical Technology for assistance with the statistical analysis. Funding from Gunma Foundation for Medicine and Health Science is gratefully acknowledged. Finally, they would like to thank Editage (www.editage.com) for English language editing.

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