

Daily Players' Satisfaction with Pitching Performance Could Predict Shoulder and Elbow Injuries in High-school Baseball Pitchers: A Prospective Time-to-event Study

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Abstract

The relationship between baseball pitchers' satisfaction with their own performance and the incidence of shoulder and elbow injuries is unclear. We analyzed the relationship between daily satisfaction scores before injury and incidence of shoulder/elbow injury in high-school baseball pitchers in this prospective, time-to-event study. We collected baseline data on baseball experience, height, weight, elbow and shoulder range of motion, and shoulder muscle strength. The 108 enrolled participants aged 15-17 years were divided into satisfied (88) and unsatisfied (22) groups based on the Receiver operating characteristics analysis results that revealed the cutoff value to be 4 points. The incidence of injury was 10.2% and 50.0% in the satisfied and unsatisfied groups, respectively. We observed that high-school baseball pitchers with a low satisfaction significantly increased the risk of shoulder and elbow injuries: these players had a 7.3-times greater risk of injuries and a 1.9-times earlier occurrence of injuries than pitchers who are satisfied with their performance. High-school baseball pitchers who had low satisfaction with their pitching performance had higher risk of shoulder and elbow injuries and lower time to injury than satisfied pitchers. Daily evaluation of players' self-satisfaction could predict shoulder and elbow injuries in high-school baseball pitchers.

Introduction

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 players¹ and junior high-school baseball players respectively;² 26% as elbow pain and 32% as shoulder pain during two seasons;³ 20.0% during one season in high-school baseball pitchers;⁴ and 47.9% during five seasons in professional pitchers.⁵ 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 in previous prospective studies.⁴⁻⁸ 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,⁴ a low ratio of the prone external rotation strength of the dominant to nondominant side,⁴ and supraspinatus weakness.⁶ However, knowledge regarding the in-season risk factors for shoulder and elbow injuries, including 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 pain² and that pitching more than 100 innings per year was a significant risk factor for baseball-related arm injury in young pitchers.⁹ 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 has 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.³ Moreover, no studies have been conducted to assess 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 remains unclear.

We hypothesized that self-evaluated satisfaction of pitching performance before 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 injury and the incidence of shoulder and elbow injuries in high-school baseball pitchers using time-to-event analysis.

Results

Receiver operating characteristic analysis.

The cutoff value for the average daily self-satisfaction score with pitching performance, as determined by the receiver operating characteristic (ROC) analysis, was 4 points ($P = 0.001$, area under curve [AUC] = 0.73, Fig. 1), indicating a moderate diagnostic accuracy.¹⁰

Baseline characteristics and in-season factor.

As 20 participants were excluded because of data unavailability because they forgot to fill the daily questionnaire even for 1 day except for days off or if they dropped out, a total of 108 participants were finally enrolled. The participants were then divided into satisfied (score ≥ 4) and unsatisfied (score < 4) groups with 88 and 22 pitchers, respectively (Fig. 2). Body weight and prone external rotation (PER) of the dominant side at baseline were significantly higher in the unsatisfied group than in the satisfied group. There were no other significant differences in baseline values between the two groups (Table 1).

Table 1
Baseline characteristics of the players

Baseline characteristics	Satisfied group		Unsatisfied group		P value
	(n = 88)		(n = 20)		
	Mean	SD	Mean	SD	
Baseball experience (years)	8.66	1.65	8.29	2.05	0.427
Body height (cm)	173.03	5.95	172.92	4.97	0.940
Body weight (kg)	67.99	8.11	74.30	7.71	0.002 *
Elbow flexion on the dominant side (deg)	141.20	6.55	141.15	5.11	0.972
Elbow extension on the dominant side (deg)	2.91	5.81	1.45	4.35	0.292
ABER on the dominant side (deg)	107.51	12.02	106.45	13.85	0.729
ABIR on the dominant side (deg)	38.69	9.78	38.50	10.88	0.938
HA on the dominant side (deg)	13.72	13.82	12.84	13.12	0.794
PER on dominant side (kg)	15.82	6.34	19.19	8.55	0.048 *
PER ratio	19.33	7.55	21.68	7.67	0.213
PIR on the dominant side (kg)	0.96	0.17	1.01	0.14	0.291
PIR ratio	1.00	0.17	1.00	0.23	0.973
PER/PIR ratio	0.84	0.22	0.87	0.18	0.584
In-season factor					
Practice/training duration (hours/week)	26.31	17.13	22.60	14.89	0.394
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.					
Ratio refers to the ratio of the strength of the dominant side to that of the nondominant side. * $P < 0.05$.					

Logistic regression analysis.

Based on the results of the univariate analyses ($P < 0.05$), we selected body weight and PER strength in the dominant shoulder for the logistic regression analysis, which showed that there was no significant independent risk factor for shoulder and elbow injuries (Table 2).

Table 2
Results of the logistic regression analysis

Explanatory variable	Odds ratio	95% CI	P value
Body weight	1.027	0.965–1.093	0.401
PER on the dominant side	1.059	0.991–1.132	0.092
CI, confidence interval; PER, muscle strength of prone external rotation			

Time-to-event analysis.

The incidence of injury was 10.2% in the satisfied group and 50.0% in the unsatisfied group. The median time to injury was 55.0 days in the satisfied group and 29.5 days in the unsatisfied group (Fig. 3), representing a 1.9-times earlier incidence of injury among pitchers who were not satisfied with their performance. Kaplan–Meier analysis revealed a hazard ratio (HR) of 7.299 for the unsatisfied group compared with that in the satisfied group (Table 3). The log-rank test revealed that the incidence of injury was significantly lower in the satisfied group than in the unsatisfied group ($P < 0.001$).

Table 3
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)
Abbreviations: CI, confidence interval; HR, hazard ratio.			

Post-hoc power analysis.

The post-hoc power analysis revealed that the power of the present study was 0.990, confirming that the sample size was sufficient to test the aim of our 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 the present study was that high-school baseball pitchers with a mean pre-injury self-satisfaction score of 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 on 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).³ 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 ($r = 0.27$),¹¹ as well as baseball experience,¹² but significantly negatively correlated with ulnar collateral ligament thicknesses on the dominant side ($r = -0.20$).¹² Although a direct comparison between our study and the previous prospective study³ is difficult because the risk was represented as HR in our results and as odds ratios in the previous study,³ we believe that the accuracy and consistency of self-evaluation might be higher in the present study than in the previous study because our participants aged 15–17 years were older and more physically and mentally mature than subjects 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 check-ups 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.^{13,14} Balaguer et al. reported that performance and self-satisfaction with performance improved when handball players trained in a strongly task-oriented motivational environment.¹⁵ Furthermore, a recent study investigating the role of the coach reported that the coach should encourage young players to evaluate their performance through self-evaluation.¹⁶ 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 elbow injury.³ In this study, body weight in the unsatisfied group was significantly heavier than that in the satisfied group. Although this result seems to be similar to that of the previous study,³ 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.⁴ However, this was not observed in the present study; PER on the dominant side was significantly greater in the unsatisfied group. As 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 main result that high-school baseball pitchers with a mean pre-injury self-satisfaction score of pitching performance of < 4 points are at a significantly increased risk of shoulder and elbow injuries.

Limitations.

This study has some limitations that should be acknowledged. 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; further studies are needed 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, 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, one limitation was that our study did not clarify the relationship between injury severity and self-satisfaction with pitching performance. Finally, in-season risk factors such as the number of pitches and innings, which are related to shoulder and elbow injuries, were not collected in this study. These factors may have affected the results, although the training and practice duration was 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 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 own 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 check the whole body for any decrease in function.

Methods

Participants.

The pitchers were gathered from each high school associated with a baseball club of a competitive level in Gunma prefecture; in total, 128 pitchers participated in an annual free preseason medical check-up, which was held as a social contribution to prevent injury by our department. At the preseason medical check-up, we recruited all participating male high-school baseball pitchers aged 15–17 years (mean: 16.7 years) for the present study and obtained written informed consent from their parents prior to participation. According to the criteria used in previous studies,^{4,17} we included pitchers who participated in baseball practice as active pitchers without shoulder or elbow issues detected in the medical check-up. The exclusion criteria were previous major injuries (such as 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 at the preseason medical check-up was conducted as previously reported^{4,17} and used to divide the study population into two groups based on self-evaluated satisfaction with pitching performance during the season. The cutoff for the division of the groups was determined by an ROC curve analysis with Youden's index. We collected data on baseball experience, height, weight, elbow and shoulder ROM, and shoulder muscle strength. When evaluating these items, the examiners were blinded to information regarding the dominant arm.

Elbow and shoulder range of motion. The intra-rater validity and reliability of ROM measurements obtained using a digital protractor have been previously reported.^{4,17} 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 intra-rater validity and reliability of hand-held dynamometers have been previously established.^{4,5,17} In the present study, a certified orthopedic surgeon assessed the prone external and internal rotation strength (PER and PIR, respectively) of both shoulders using a PowerTrack II Commander hand-held dynamometer (J-Tech Medical, Salt Lake City, UT, USA). The dominant-to-nondominant ratios of 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" was defined as any condition that resulted in the pitcher being unable to pitch/unable to use the arm for ≥ 8 days,^{4,17,18} whereas from the clinician's viewpoint, after identifying what type of injuries occurred is important, we prioritized the players' viewpoint in this study. To investigate when injuries occurred, participants were asked to complete a self-recorded questionnaire

every day regarding the presence of shoulder and/or elbow pain, limitations to pitching caused by shoulder or elbow pain, and the presence of other injuries. To collect the data of external load, participants were asked to complete a questionnaire every day on how long a day they trained and practiced baseball. 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 also asked to complete a questionnaire every day during the season for 150 days and to assign their pitching performance a numerical score between 0 (worst) and 10 (best). To reduce potential recall bias, we encouraged participants to complete the questionnaire by calling them daily and asking them to return completed questionnaires every month.

Statistical analysis.

We used SAS v9.4 (SAS Institute Inc., Cary, NC, USA) for all statistical analyses. All tests were two-sided with a significance level of $P < 0.05$. Differences between groups at baseline were compared using the Mann–Whitney U test. When a significant difference was found in the factors between the groups at baseline, logistic regression analysis was performed to identify whether the factors were significant risk factors for shoulder and elbow injury. A ROC curve analysis with Youden’s index was used to determine the cutoff value for average self-evaluated satisfaction scores before injury, and participants were divided into two groups using this cutoff value. A Kaplan–Meier analysis was used to generate time-to-event curves, and 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 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 with an HR of 2.7,⁴ an accrual interval of 150 days, a follow-up interval of 150 days, and a median time to failure in the group, with the smallest time to failure of 50 days in the Kaplan–Meier analysis.¹⁹ Finally, we performed a post-hoc power analysis to verify the statistical power of this study.

Declarations

Data Availability.

The data supporting the findings of this study are available on request from the corresponding author H.S. The data are not publicly available because they contain information that could compromise the privacy of research participants.

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Authors' contributions

H.S., T.T., A.Y., K.T., and H.C. conceived and designed the experiments. H.S., T.T., T. Kuboi, T.I., T.S., N.H., F.E., A.Y., T. Kobayashi, and K.T. recruited the participants. H.S., T.T., T. Kuboi, T.I., T.S., N.H., F.E., M.K., R.M., K.N., A.Y., and T. Kobayashi. performed the experiments. H.S. and N.H. analyzed the data. H.S. wrote the paper. All authors reviewed and approved the final version of the paper.

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Competing Interests

The authors have no competing interests to declare.

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Figures

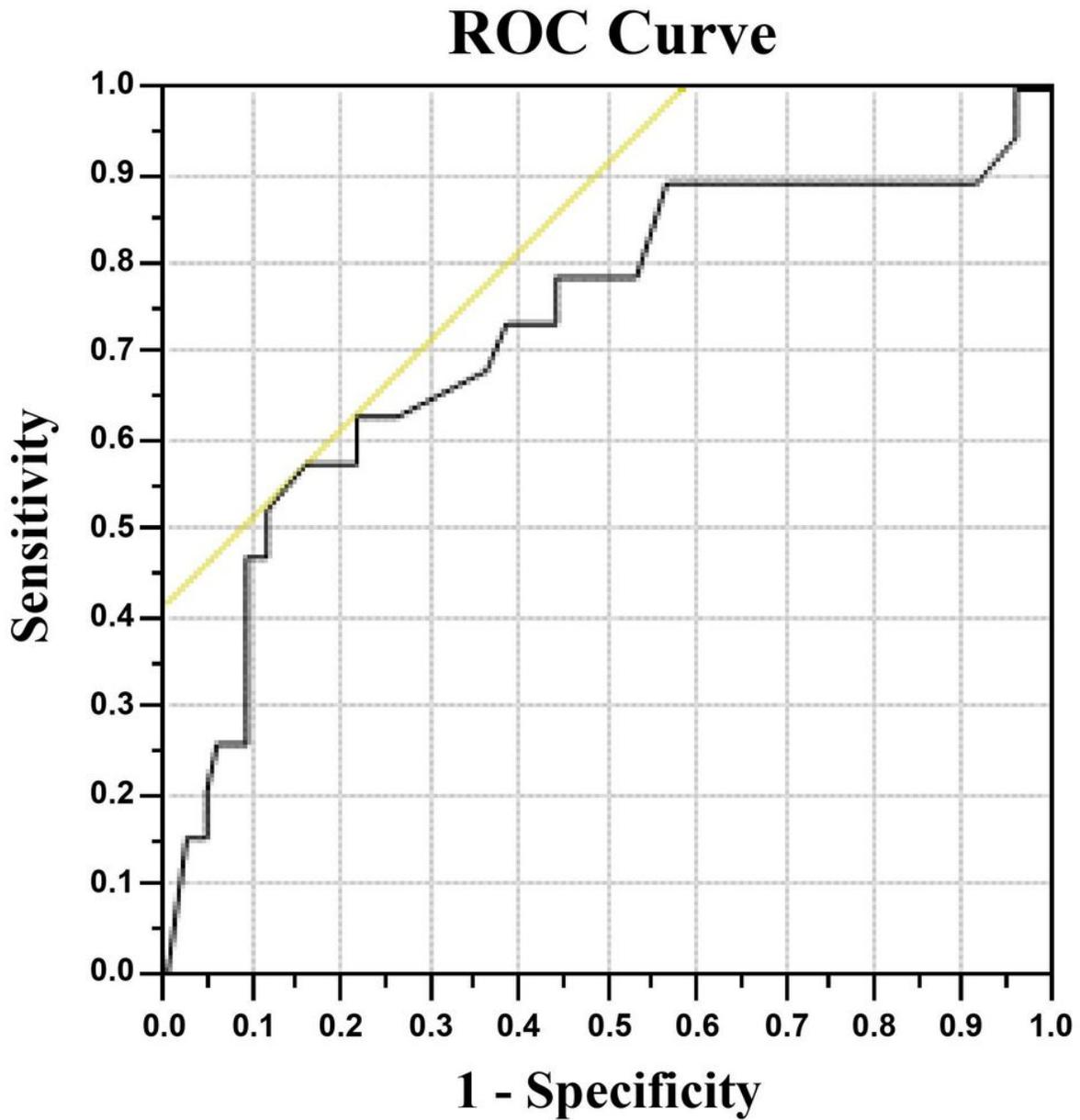


Figure 1

Receiver operating characteristics (ROC) curve The ROC analysis shows that the cutoff value of the average daily self-satisfaction score with pitching performance is 4 points ($P = 0.001$, area under curve [AUC] = 0.73)

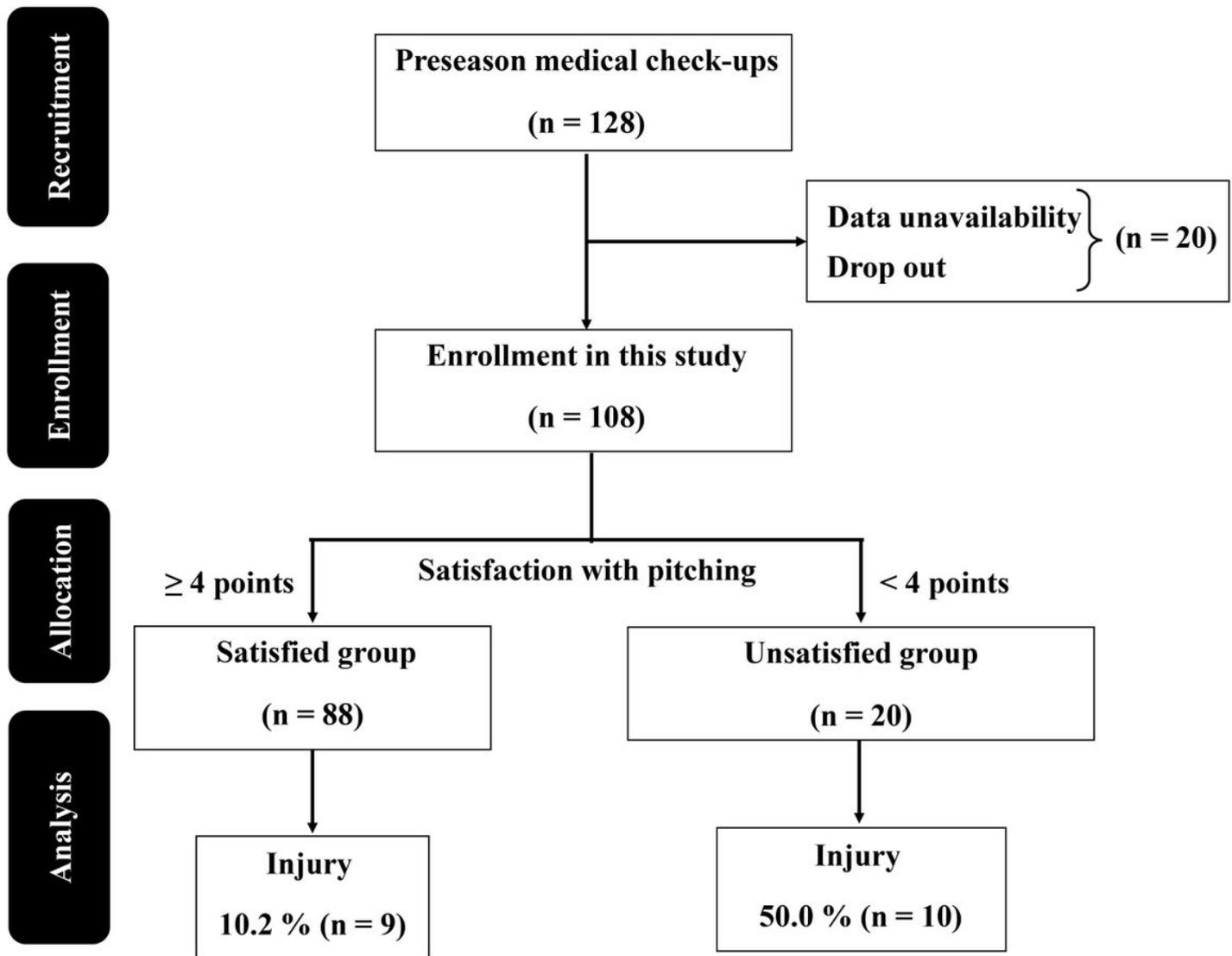


Figure 2

Flow diagram showing the study recruitment process.

Kaplan–Meier time-to-injury curve

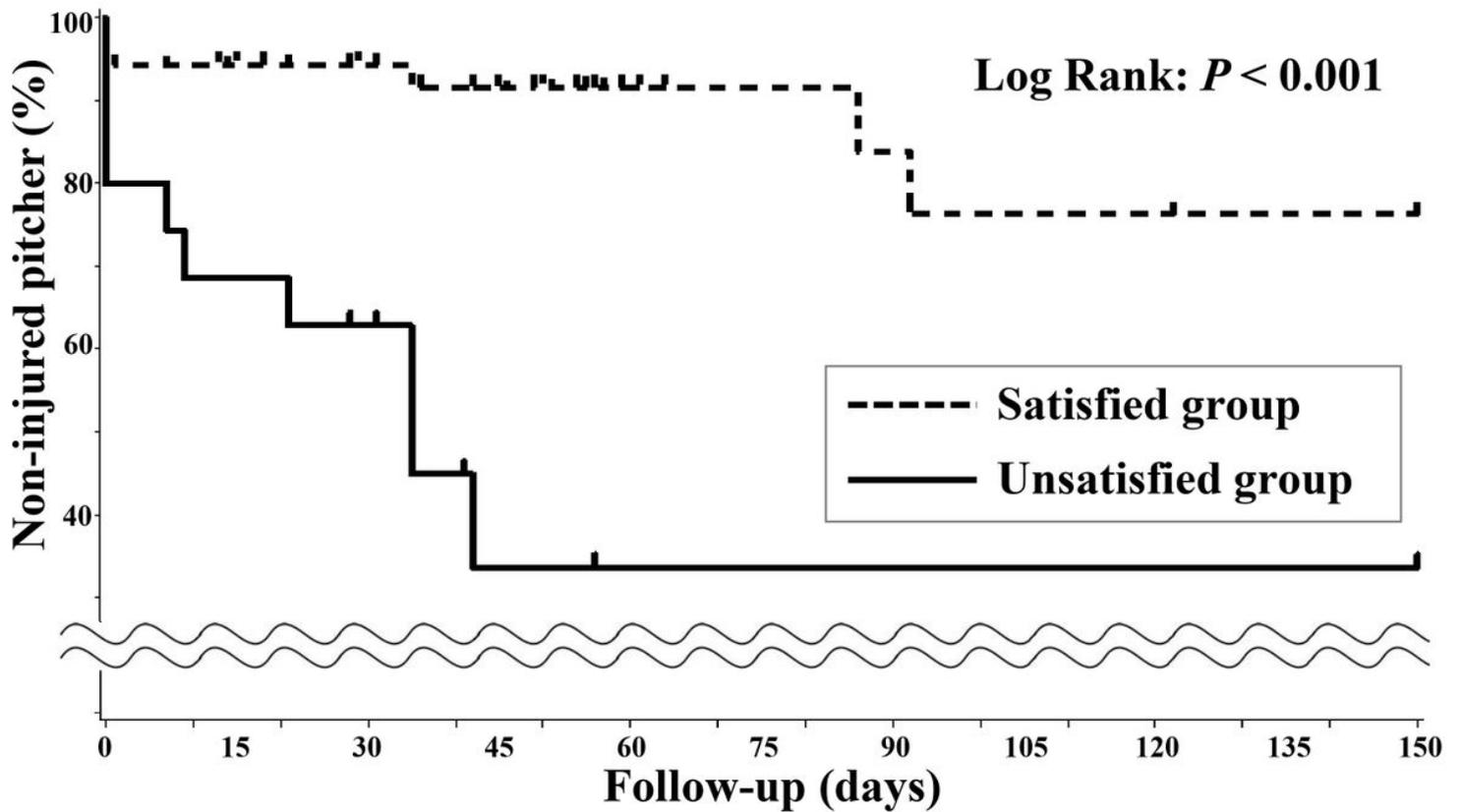


Figure 3

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 in the unsatisfied group.