An Analysis of Pre-Season Risk Factors for Low Back Injury in High-School Baseball Pitchers: A Prospective Study

Kurumi Nakase
Gunma University
Hitoshi Shitara (hshitara@gunma-u.ac.jp)
Gunma University
Tsuyoshi Tajika
Gunma University
Takuro Kuboi
Gunma University
Tsuyoshi Ichinose
Gunma University
Tsuyoshi Sasaki
Gunma University
Noritaka Hamano
Gunma University
Fumitaka Endo
Gunma University
Masataka Kamiyama
Gunma University
Ryosuke Miyamoto
Gunma University
Atsushi Yamamoto
Gunma University
Tsutomu Kobayashi
Gunma University
Kenji Takagishi
Gunma University
Hirotaka Chikuda
Gunma University

Research Article

Keywords: ROM, dominant, ABER, ABIR

Posted Date: February 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-153640/v1

Abstract

A pitching motion requires whole-body coordination; therefore, poor control of the lower extremities, pelvis and trunk may cause shoulder and elbow injuries. However, few studies have described the relationship between the shoulder joint function and low back injury in high-school baseball pitchers. In this study, 97 high-school baseball pitchers who underwent pre-season medical checkups were enrolled and their shoulder range of motion and strength were measured. The participants completed a self-recorded questionnaire regarding the presence of low back pain and were divided into injured and non-injured groups. The statistical analyses were performed to identify the independent risk factors for low back injury. Low back injury was observed in 13 participants (13.4%). In the injured group, horizontal adduction on the dominant shoulder was significantly less frequent than in the non-injured group. A logistic regression analysis showed that horizontal adduction on the dominant side was a significant independent risk factor for low back injury during the season. It is important to recognize that restriction of the shoulder function not only causes shoulder and elbow injuries but can also risk low back injury.

Introduction

We previously reported that, in high-school baseball pitchers, limitations in the internal rotation range of motion (ROM) of shoulder on the dominant side at the preseason medical check are a risk factor for the development of shoulder and elbow injuries during the season[17]. However, pitching requires whole-body coordination, and poor control of the lower extremities, pelvis and trunk may cause shoulder and elbow injuries.

The lumbar spine is reported to be essential in the kinematics of pitching, since the energy transfers from the lower to upper of the body during pitching[21]. In previous studies, the low back injury rates have ranged from 8.3–12% among professional and college baseball players[5, 11], and the prevalence of chronic low back pain ranges from 1–40% among baseball players of all experience levels[1, 4]. Furthermore, because various parts of the body are involved in pitching, low back injury can alter the neuromuscular coordination of the upper extremities and may contribute to subsequent injuries elsewhere in the kinematics[3]. However, few studies have described the relationship between the shoulder joint function and low back injury in high-school baseball pitchers, information that would be valuable for helping prevent injuries and providing effective rehabilitation programs for young athletes.

We hypothesized that shoulder and elbow joint dysfunction might affect low back injury because trunk flexion and rotation might require excessive motion to compensate and thus increase the energy transmitted from the lower extremities when the upper extremities cannot provide normal pitching power. To test this hypothesis, we investigated whether or not the shoulder and elbow condition at the pre-season medical checkup could predict low back injury during the season in high-school baseball pitchers.

Methods

The institutional review board of Gunma University Hospital (Identification number 1003) approved this study. All methods were carried out in accordance with relevant guidelines and regulations. Written informed consent was obtained from the parents of the participants.

In this prospective study, we examined 128 high school male baseball pitchers who were 15 to 17 years of age. They participated in pre-season medical checkups, which were held in January and February 2018.

Pitchers who were able to complete a daily questionnaire about the presence of low back pain, which was collected every month, were considered for inclusion. Those who have had orthopedic surgeries before or already had shoulder, elbow or low back pain at pre-season medical checkups.

Pre-season medical checkups

As previously reported[17, 18], pre-season medical checkups were performed as baseline medical examinations. To avoid confirmation bias, participants' hand dominance was not announced to examiners. The participants completed a questionnaire on their baseline characteristics, including height, their years of baseball experience, and hand dominance. The following physical parameters were assessed: (1) shoulder ROM and (2) shoulder muscle strength.

Shoulder ROM and strength measurements

The intra-rater and inter-rater reliability of digital protractors have been established in the literature[17]. According to previously reported methods[6–10, 16–18], a certified orthopedic surgeon assessed the passive shoulder ROM of 90° abducted external and internal rotation (ABER, ABIR) and horizontal adduction (HA), and the elbow ROM of flexion and extension were measured on both the dominant and non-dominant shoulders using a digital protractor with a bubble level indicator (iGaging, Los Angeles, CA, USA). The participant was placed in the supine position on the examination table, with the shoulder abducted to 90° and elbow flexed to 90º. A small rolled towel was placed under the elbow to keep the humerus in the right position. The scapula was stabilized posteriorly against the examination table by applying pressure to the coracoid process using the thenar eminence and thumb, and the humerus was passively rotated both ABER and ABIR until an end feel was obtained and the scapula began to move. The axis of the digital protractor was placed on the olecranon process of the elbow with the stationary arm aligned vertically, and the moving arm was aligned with the forearm. The total arc was calculated for the dominant shoulder by adding the ABER and ABIR.

When the shoulder HA ROM was measured, the participant was positioned in the supine position on the examination table with the scapula stabilized by the examiner's pressure on the lateral border of the scapula with the thenar eminence. The test shoulder and elbow were positioned in 90° of both flexion and abduction. The examiner's opposite hand then held the participant's forearm, and the humerus was passively moved into HA until an end feel was obtained and the lateral border of the scapula began to move. The axis of the digital protractor was placed at the estimated center of the glenohumeral joint with

the stationary arm perpendicular to the horizontal plane, and the moving arm was aligned with the humerus. All shoulder ROM measurements were performed by two examiners with one examiner providing stabilization force to maintain the shoulder position while the other obtained the ROM measurement.

The intra-rater and inter-rater reliability of the shoulder strength measurements by hand-held dynamometers have been established in a previous study[17]. In accordance with previous studies[2, 17, 18], using a PowerTrack II Commander hand-held dynamometer (J-Tech Medical, Salt Lake City, UT, USA), a certified orthopedic surgeon measured the strength of the supraspinatus in the seated position (SS), prone external rotation (PER) and prone internal rotation (PIR) in both the dominant and non-dominant shoulders. When the SS strength was measured, the participant sat on the examination table with his back against the wall. The humerus was abducted to 90° and then horizontally adducted to 45° with the forearm neutral. The examiner placed the dynamometer 5 cm proximal to the proximal wrist extension crease, and the participant raised his arm perpendicular to the floor with maximum effort. The PER and PIR strength were measured in the prone position with the shoulder abducted to 90º and the elbow flexed to 90º. The examiner stabilized the humerus and set the arm in 0º of rotation, and then the participant rotated his arm externally and internally with maximum effort against the dynamometer. When the PIR strength was measured, the dynamometer was placed 5 cm proximal to the proximal wrist flexion crease, and when the PER strength was measured, the dynamometer was placed at the dorsal side of the forearm, opposite to the proximal wrist flexion crease.

Low back injury

In this study, “low back injury” was defined as any condition that resulted in the pitcher being considered disabled for eight days or more[17]. In the statistical analyses, other injuries caused by other mechanisms, such as being hit by a ball, colliding with other players, or suffering trauma from falls, were excluded. To avoid recall bias, participants were instructed to complete a self-recorded questionnaire everyday regarding the presence of low back pain, limitations to pitching caused by low back pain and the presence of other injuries.

Statistical analyses

Statistical analyses were performed using the SAS 9.4 software program (SAS Institute Inc., Cary, NC, USA). All tests were two-sided with a P = 0.05 significance level. Depending on the presence of low back injuries, the participants were divided into injured and non-injured groups. Categorical data were reported as the frequency (%), and group differences were evaluated using the chi-square test. Continuous data were reported as median with inter quarter range (IQR), and group differences were evaluated using the Mann-Whitney U-test. After adjusting for significant variables identified in univariate analyses, the logistic regression analysis was performed to calculate odds ratios (ORs) and 95% confidence intervals (CIs) to identify the risk factors for low back pain.

To determine the sample size for this study, a prior statistical power analysis for a logistic regression analysis was performed. This analysis indicated that a total of 70 participants would be needed,

depending on a statistical power of 80% at an α level of 0.05 (assumptive incidence rate = 20%, OR ratio = 2.5)[20].

Results

A total of 128 high-school baseball pitchers participated in pre-season medical checkups. We were able to collect questionnaires from 97 pitchers and they were all included in the final analysis. Low back injury was observed in 13 participants (13.4%) during the season (Fig. 1).

In the preseason baseline assessment, there were no significant differences between non-injured and injured group in height (P = 0.25; 173.5 ± 7.2 and 170.7 ± 3.4 cm, respectively) and baseball experience (P = 0.21; 8.4 ± 1.7 and 9.2 ± 1.7 years, respectively).

The rate of HA on the dominant shoulder was significantly lower in the injured group than in the non-injured group (P = 0.013). No significant differences were observed between the injured and non-injured groups with respect to HA on the non-dominant side, ABER, ABIR, total arc, SS, PER or PIR (Table 1).

Table 1
Results of the univariate analysis

	Non-injured		**Injured**		**P value**	
	n = 84		**n = 13**			
	Median	IQR	Median	IQR		
Shoulder ROM						
Dominant side (°)						
ABER	107.9	100.9-116.1	106.3	102.0-110.5	0.388	
ABIR	37.5	28.5–45.8	41.3	35.6–44.3	0.433	
Total arc	146.0	135.6-154.8	148.4	144.7-152.5	0.691	
HA	9.9	2.5–17.5	-3.9	-7.3-13.7	0.013	*
Non-dominant side (°)						
ABER	100.5	94.4-107.1	97.5	95.0-101.5	0.113	
ABIR	48.0	42.3–53.8	45.3	38.6–48.3	0.187	
HA	22.9	12.8–29.5	21.1	16.3–23.8	0.388	
Shoulder Strength						
Dominant side (kg)						
SS	9.1	8.1–10.6	9.5	8.3–10.5	0.437	
PER	13.4	11.5–15.8	13.2	11.5–14.7	0.945	
PIR	17.0	14.9–19.2	17.9	14.5–20.4	0.865	
PER/PIR	0.81	0.69–0.92	0.75	0.67–0.95	0.937	
Non-dominant side (kg)						
SS	9.2	8.1–10.5	9.6	9.1–11.2	0.193	
PER	13.6	12.2–16.5	14.8	14.1–16.2	0.141	
PIR	17.1	14.9–19.3	16.0	13.8–19.8	0.751	

IQR, inter quarter range; ROM, range of motion; ABER and ABIR, ROM of external and internal rotation with shoulder abducted to 90°; Total arc, ABER + ABIR; HA, horizontal adduction; Difference, ROM on dominant side – ROM on the non-dominant side; SS, seated supraspinatus; PER, prone external rotation; PIR, prone internal rotation; Strength ratio, strength of the dominant side/strength of the non-dominant side; PER/PIR strength ratio, PER strength of the dominant side/PIR strength of the dominant side

* $P < 0.05$

A logistic regression analysis showed that HA on the dominant side was a significant independent risk factor for low back injury during the season (P = 0.010, OR 0.92, 95% CI 0.87–0.98).

Discussion

The most important finding of this study was that ROM deficit of HA on the dominant shoulder was an independent risk factor for baseball-related low back injury in high-school baseball pitchers. Furthermore, we showed that if HA on the dominant side were improved by 13.8°, which was the ROM difference between the injured and non-injured group, the injury risk would be reduced by 68% (calculated OR: 0.32). These findings may help prevent low back injury as well as shoulder and elbow injury.

The relationship between lower limb, trunk and upper limb injuries

In pitching kinematics, the trunk begins to rotate toward to home plate in the late cocking phase and flexes in the acceleration phase[21], while HA of the shoulder joint is observed from the acceleration through the deceleration phase[19].

Previous studies have investigated the association of deficits in the trunk and lower extremities with shoulder and elbow pain and injury in adolescent baseball players. In those studies, deficiencies in the hip ROM and the existence of low back pain were independent risk factors for shoulder and elbow injuries. Sekiguchi et al. investigated 1582 young baseball players 6–15 years of age using a questionnaire with regard to their shoulder, elbow, low back and knee pain. The results showed that the presence of low back and knee pain was significantly associated with the prevalence of shoulder and/or elbow pain both in pitchers and non-pitchers[14]. They also demonstrated that restriction of hip rotation in the stride leg was associated with shoulder and elbow pain in young baseball players 9–12 years of age. A total of 177 participants were included in their analysis, and 9% developed shoulder and elbow pain during a 3-day-tournament. They also showed significant restriction of the hip internal rotation of the stride leg, which had been measured just before the tournament[15].

Saito et al. similarly showed that 27% of 122 baseball players 6–14 years of age had elbow pain at their pre-season medical checkups. Hip flexion and internal rotation when the hip and knee joint of the study side were flexed to 90° with the contralateral hip and knee joint fully extended were significantly restricted in the injured group compared to the non-injured group[12].

These studies both indicated that efficient throwing mechanics depend on a player's ability to perform a sequence of body movements, which progresses from the lower extremities, hip and trunk to the arm. Thus, inappropriate timing in the body motion sequence leads to an increased risk of throwing-arm injury. However, these previous studies were either cross-sectional or case-control studies, so whether the hip ROM limitations occurred before or after shoulder and/or elbow pain has been unclear. In addition, the participants in those studies were younger than those in our own.

Shoulder ROM and injuries

In terms of prospective studies and results concerning the association between restriction in the shoulder ROM and subsequent injuries, Shanley et al. investigated143 high-school baseball players, and 18 shoulder and elbow injuries were observed during the season. Furthermore, the HA on the dominant side was significantly lower in the injured players' dominant shoulder than in the uninjured players' dominant shoulder[16].

To our knowledge, this is the first prospective study to report the risk of low back injury based on shoulder ROM data measured in pre-season medical checkups before the development of low back injury among high-school baseball pitchers. This study showed that the injured group had a significantly lower HA in the dominant shoulder than the uninjured group. Based on the present and previous findings, it is plausible that a decreased HA on the dominant may lead to insufficient trunk rotation, and a lack of HA may cause the pitcher to be unable to transfer energy from the legs to the arm efficiently, leading to excessive use of the trunk and thus causing low back injury. Further research is necessary to determine whether or not players with poor HA of the shoulder ROM actually use their low back muscles more than others when pitching.

In our univariate analysis, the elbow extension on the non-dominant side was significantly lower in the injured group than in the uninjured group. Although a previous prospective study showed that those who had an elbow extension deficit of ≥ 5° were likely to have elbow injury among junior baseball players 6–12 years of age[13], no previous study has investigated the relationship between the pre-season elbow ROM and low back injury. Further studies are needed to confirm the present findings.

Limitations

Several limitations associated with this study should be acknowledged. First, we did not consider other external load factors, such as batting, total number of pitches or number of innings pitched, which might have affected the lower back condition. Second, we did not evaluate the pitching form, such as overarm or underhanded, which might have had different effects on the pitching kinematic chain. Third, we did not evaluate the trunk condition in detail at the pre-season medical checkup. However, we believe that we did not enroll participants who had severe low back conditions because we conducted a screening test by asking if participants had low back problems that affected their pitching performance. Finally, the sample size was small because the incidence of low back injury is low among high-school baseball pitchers. However, the number of participants matched the condition that the prior power analysis required (total 70 participants). Further studies are needed to resolve the above issues.

Conclusion

In summary, we performed a prospective analysis using the data from pre-season medical checkups for high-school baseball pitchers to elucidate the relationship between the shoulder joint function and low back injury. A ROM deficit of HA on the dominant shoulder was a significant independent risk factor for

baseball-related low back injury in high-school baseball pitchers. Furthermore, we found that if HA on the dominant side were improved by 13.8°, which was the ROM difference between the injured and non-injured group, the injury risk would be reduced by 68%. These findings may help prevent low back injury as well as shoulder and elbow injury.

Declarations

Acknowledgments

We would like to thank the personnel, players, coaches, and staff of the Gunma High School Baseball Federation for their assistance and cooperation in this study. Also, we would like to thank Kureha Special Laboratory Co., Ltd. for assistance with statistical analysis.

Authors' contribution

All authors contributed to the conception or design of the study. TI and HS participated in the design of the study. KN drafted the manuscript. HS performed the statistical analysis and helped to draft the manuscript. TT, T.Kuboi, TI, TS, NH, FE, MK, RM, AY, and T.Kobayashi participated in medical checkups and collected the data. KT conceived of the study and participated in coordination. HC participated in coordination and helped to draft the manuscript. All authors reviewed and approved the final version of the manuscript.

Competing Interests

The authors have no competing interests to declare.

References

1. Bono, C. M. Low-back pain in athletes. *J Bone Joint Surg Am.***86**, 382–396 (2004).
2. Byram, I. R. *et al.* Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. *Am J Sports Med.***38**, 1375–1382 (2010).
3. Chaudhari, A. M., McKenzie, C. S., Pan, X. & Oñate, J. A. Lumbopelvic control and days missed because of injury in professional baseball pitchers. *Am J Sports Med.***42**, 2734–2740 (2014).
4. d'Hemecourt, P. A., Gerbino, P. G. & Micheli, L. J. Back injuries in the young athlete. *Clin Sports Med.***19**, 663–679 (2000).
5. Dick, R. *et al.* Descriptive epidemiology of collegiate men's baseball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train.***42**, 183–193 (2007).
6. Donatelli, R. *et al.* Assessment of shoulder strength in professional baseball pitchers. *J Orthop Sports Phys Ther.***30**, 544–551 (2000).

7. Laudner, K. G., Stanek, J. M. & Meister, K. Assessing posterior shoulder contracture: the reliability and validity of measuring glenohumeral joint horizontal adduction. *J Athl Train.* **41**, 375–380 (2006).
8. Lintner, D., Mayol, M., Uzodinma, O., Jones, R. & Labossiere, D. Glenohumeral internal rotation deficits in professional pitchers enrolled in an internal rotation stretching program. *Am J Sports Med.* **35**, 617–621 (2007).
9. Myers, J. B., Laudner, K. G., Pasquale, M. R., Bradley, J. P. & Lephart, S. M. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Med.* **34**, 385–391 (2006).
10. Myers, J. B. *et al.* Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes. *Am J Sports Med.* **35**, 1922–1930 (2007).
11. Posner, M., Cameron, K. L., Wolf, J. M., Belmont, P. J. & Owens, B. D. Epidemiology of Major League Baseball injuries. *Am J Sports Med.* **39**, 1676–1680 (2011).
12. Saito, M. *et al.* Relationship Between Tightness of the Hip Joint and Elbow Pain in Adolescent Baseball Players. *Orthop J Sports Med.* **2**, 2325967114532424 (2014).
13. Sakata, J., Nakamura, E., Suzukawa, M., Akaike, A. & Shimizu, K. Physical Risk Factors for a Medial Elbow Injury in Junior Baseball Players: A Prospective Cohort Study of 353 Players. *Am J Sports Med.* **45**, 135–143 (2017).
14. Sekiguchi, T. *et al.* Youth baseball players with elbow and shoulder pain have both low back and knee pain: a cross-sectional study. *Knee Surg Sports Traumatol Arthrosc.* **26**, 1927–1935 (2018).
15. Sekiguchi, T. *et al.* Restriction in the hip internal rotation of the stride leg is associated with elbow and shoulder pain in elite young baseball players. *J Shoulder Elbow Surg.* **29**, 139–145 (2020).
16. Shanley, E. *et al.* Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *Am J Sports Med.* **39**, 1997–2006 (2011).
17. Shitara, H. *et al.* Prospective multifactorial analysis of preseason risk factors for shoulder and elbow injuries in high school baseball pitchers. *Knee Surg Sports Traumatol Arthrosc.* **25**, 3303–3310 (2017).
18. Shitara, H. *et al.* Shoulder Stretching Intervention Reduces the Incidence of Shoulder and Elbow Injuries in High School Baseball Players: a Time-to-Event Analysis. *Sci Rep.* **7**, 45304 (2017).
19. Wicke, J., Keeley, D. W. & Oliver, G. D. Comparison of pitching kinematics between youth and adult baseball pitchers: a meta-analytic approach. *Sports Biomech.* **12**, 315–323 (2013).
20. Wilk, K. E. *et al.* Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med.* **39**, 329–335 (2011).
21. Young, J. L., Herring, S. A., Press, J. M. & Casazza, B. A. The influence of the spine on the shoulder in the throwing athlete. *J Back Musculoskelet Rehabil.* **7**, 5–17 (1996).

Figures

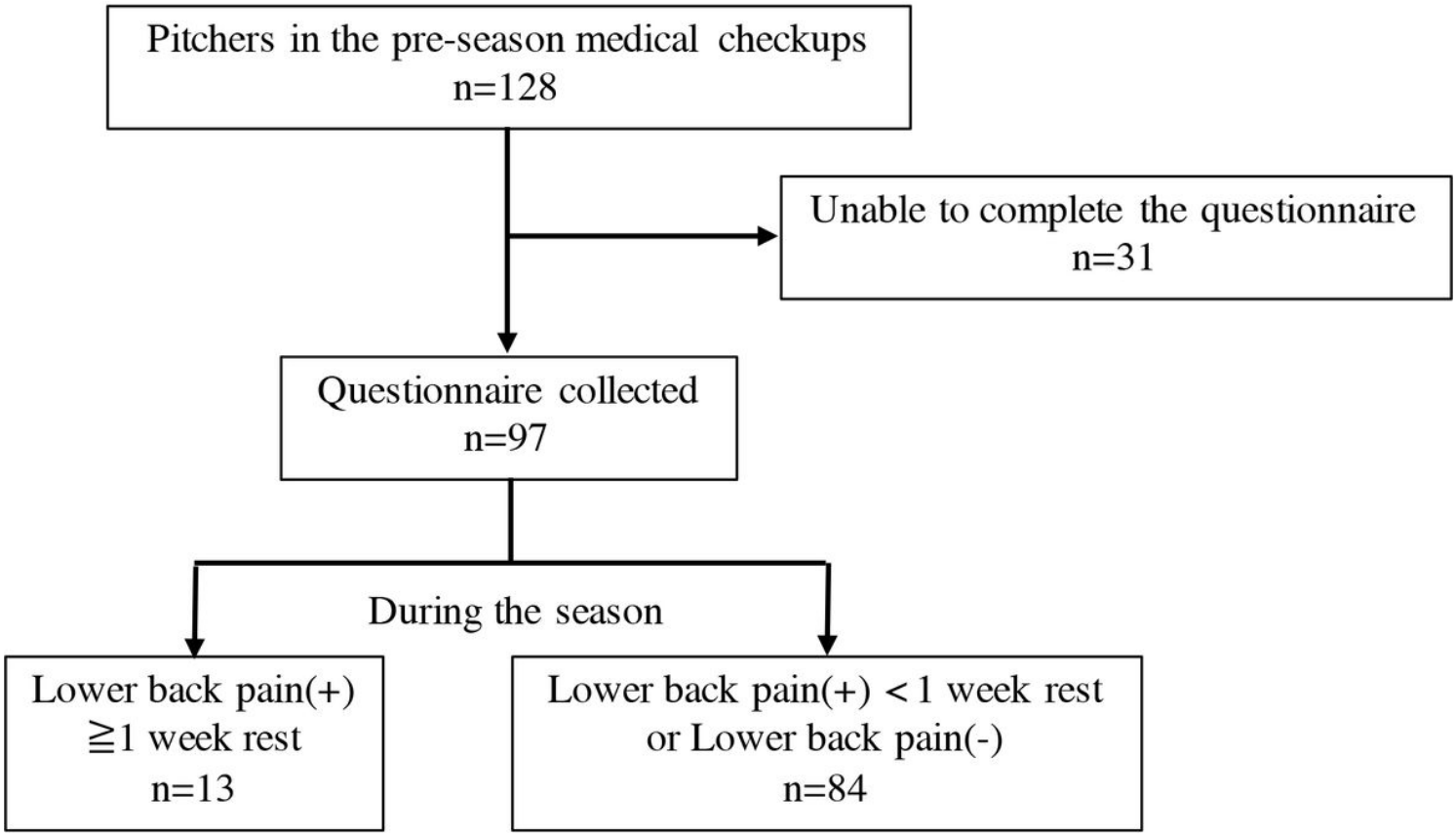

Figure 1

A flow chart to identify the pitchers included in this study