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## Four-year trend in shoulder and elbow injuries in competitive-level high school baseball pitchers: a repeated cross-sectional survey

Tsuyoshi Sasaki, MD, PhD, Hitoshi Shitara, MD, PhD\*, Tsuyoshi Tajika, MD, PhD, Takuro Kuboi, MD, Tsuyoshi Ichinose, MD, PhD, Daisuke Shimoyama, MD, Noritaka Hamano, MD, PhD, Masataka Kamiyama, MD, Ryosuke Miyamoto, MD, Kurumi Nakase, MD, Atsushi Yamamoto, MD, PhD, Tsutomu Kobayashi, MD, PhD, Kenji Takagishi, MD, PhD, Hirotaka Chikuda, MD, PhD

Department of Orthopaedic Surgery, Gunma University Graduate School of Medicine, Maebashi, Gunma, Japan

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**Background:** Shoulder and elbow injuries are the main cause of throwing disability among high school baseball pitchers. However, longitudinal studies on shoulder and elbow injuries among competitive-level high school baseball pitchers have been insufficient. This study aimed to investigate shoulder and elbow injuries in competitive-level high school baseball pitchers over a four-year period and elucidate the effects of implementing medical checkups on the incidence of shoulder and elbow injuries.

**Methods:** Five hundred fifty-two high school baseball pitchers, who received preseason medical checkups from February 2012 to February 2015, were enrolled in this study. Shoulder and elbow injuries occurring during the season after medical checkups were prospectively evaluated by a postseason medical questionnaire. Pitchers who were not able to pitch for >7 days owing to shoulder or elbow pain were defined as having shoulder and elbow injuries during the season. The incidence rates of shoulder and elbow injuries during the seasons were calculated and compared over the 4-year period.

**Results:** Ninety-six percent of medical checkup participants were included in the study. The mean questionnaire collection rate of the prospective study was 71.6% (range: 67.7–78.9%). The incidence of shoulder and elbow injuries significantly decreased from 20.0% in 2012 to 7.7% in 2015 ( $P = .013$ ).

**Conclusion:** The four-year trend in the incidence of shoulder and elbow injuries in competitive-level high school baseball pitchers was evaluated. The incidence of shoulder and elbow injuries during the season significantly decreased with a linear downward trend during the survey period after the implementation of medical checkups.

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Shoulder and elbow injuries are the main cause of pitching-related disorders among high school baseball pitchers.<sup>1</sup> Thus, the prevention or early detection of these injuries is important. There have been some reports on medical checkups to investigate the incidence of shoulder and elbow injuries among high school baseball pitchers and for the identification of risk factors for the injuries.<sup>5,8,9,12</sup> In those reports, the risk factors for shoulder and elbow injuries were identified by prospectively investigating the association between physical examination findings and

subsequent shoulder and elbow injuries. In addition, a previous study showed that instructional intervention for risk factors identified in another previous study could be effective for preventing shoulder and elbow injuries.<sup>10</sup> However, most previous reports were cross-sectional studies that assessed the incidence of shoulder and elbow injuries in a single year<sup>8,9</sup> or cross-sectional studies that summarized and analyzed the results of multiple years.<sup>5,12</sup> Regarding trends in the occurrence of shoulder and elbow injuries in high school baseball players, several studies have reported the incidence of shoulder and elbow disorders over time.<sup>7,11</sup> Toritsuka et al<sup>11</sup> studied the incidence of shoulder and elbow injuries in high school baseball pitchers in the national tournament over the past 23 years and reported a decrease in the incidence of shoulder and elbow injuries. However, while their study evaluated shoulder and elbow injuries in high school baseball pitchers over a more-than-20-year period, the general

The Institutional Review Board of Gunma University Hospital (Identification number 1003) approved this study.

\* Corresponding author: Hitoshi Shitara, MD, PhD, Department of Orthopaedic Surgery, Gunma University Graduate School of Medicine, 3-39-22, Showamachi, Maebashi, Gunma 371-8511, Japan.

E-mail address: [hshitara@gunma-u.ac.jp](mailto:hshitara@gunma-u.ac.jp) (H. Shitara).

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trends in the incidence of shoulder and elbow injuries in competitive-level high school baseball pitchers have yet to be examined, as they only analyzed injuries in top-level pitchers who participated in national tournaments. Saper et al<sup>7</sup> examined trends in the incidence of shoulder and elbow injury among competitive-level high school baseball players, including positional players and pitchers, and reported no change in the incidence of shoulder and elbow injuries over a 10-year period from 2005 to 2015. Their report was based on a large database of schools with affiliated athletic trainers from the National Athletic Trainers Association and compared the shoulder and elbow injuries of pitchers and position players. However, their study was limited by the fact that there were no diagnostic criteria for the shoulder and elbow injuries because the reported incidence of the injuries was solely based on the judgment of the reporting athletic trainers. Therefore, the reported injuries lacked unified definitions; thus, the incidence of injuries may be inaccurate. Thus, the trends in the incidence of shoulder and elbow injuries among competitive-level high school baseball pitchers are still unclear. Shoulder and elbow injuries in adolescent baseball players are not just a problem for top players.<sup>6</sup> To guide and develop measures for preventing shoulder and elbow injuries in high school baseball pitchers, the incidence and trends in shoulder and elbow injuries in competitive-level high school baseball pitchers must be determined and the uncertainties regarding shoulder and elbow injury statistics should be clarified. We hypothesized that shoulder and elbow injuries in competitive-level high school baseball pitchers would be reduced after the implementation of medical checkups.

The purpose of this study was to investigate the trend in the incidence of shoulder and elbow injuries in competitive-level high school baseball pitchers and to elucidate the effects of implementing medical checkups on the incidence of shoulder and elbow injuries.

## Materials and methods

This study received approval from our institutional review board. After a sufficient explanation, written informed consent was obtained from all participants' parents.

### Subjects

High school baseball pitchers, who received preseason checkups from 2012 to 2015 were enrolled in this study. Medical checkups were conducted every February before the season began. Two pitchers from all high schools who are members of the High School Baseball Federation in our prefecture were selected each year. The characteristics of the players, including their age, height, weight, baseball experience, and pitching side, were recorded.

### Inclusion criteria

Pitchers who agreed to participate in the study and who responded to a questionnaire about shoulder and elbow injuries at the preseason checkup and those with injuries that occurred during the season were included.

### Exclusion criteria

Pitchers who did not consent to participate in the study, those who were being treated for any injuries unrelated to pitching-related disorders at the time of medical checkups, or had any trauma unrelated to pitching during the subsequent seasons were excluded.

## Injury prevention guidance

All players were given physical examinations and general conditioning instructions to prevent injury. Physical examinations included measurements of the shoulder passive range of motion and muscular strength as routine examinations. Shoulder range of motion measurements were performed in three positions: abducted 90 degrees external and internal rotation in a supine position and horizontal adduction, in accordance with previously described methods.<sup>8</sup> Muscular strength measurements were performed in two positions; abducted 90 degrees external and internal rotation in a prone position, as previously described.<sup>9</sup> Players with decreased range of motion in abducted internal rotation or weakened external rotational strength, which are reported to be risk factors for shoulder and elbow injuries,<sup>9</sup> were given instructions to improve them. General conditioning instructions included stretching exercises for the upper extremity, lower extremity, and trunk by a physical therapist. Both players and their coaches were given instructions regarding physical conditioning and the prevention of overuse. The same injury prevention instructions were repeated annually.

## Definition of shoulder and elbow injuries

Based on previous studies,<sup>8,10</sup> we defined shoulder and elbow injuries as the inability to pitch for more than seven days owing to shoulder or elbow pain.

### Shoulder and elbow injuries that occurred during the subsequent season

Pitchers were asked to be interviewed in relation to shoulder and elbow injuries that occurred during the subsequent season by completing a questionnaire at the end of the baseball season after the medical checkups. We analyzed the data obtained from the questionnaire for the four years from 2012 to 2015.

### Statistical analysis

Demographic data for each year (age, height, weight, baseball history, and pitching side) were compared by one-way analysis of variance for continuous variables and a chi-squared test for categorical variables to test the differences in background factors among the groups each year.

We calculated the incidence of shoulder and elbow injuries for each year. First, the incidence of shoulder and elbow injuries in the first and last years of the study was compared by a chi-squared test. Next, the trend in the incidence of shoulder and elbow injuries over the four-year study period was examined using the Cochran-Armitage trend test.<sup>2,3</sup> We also evaluated whether or not the change in the incidence showed a linear trend.

### Post hoc power analysis

The statistical power for the comparison of the incidence of injuries during seasons was performed by a post hoc power analysis of the incidence of the injuries between the first year and the most recent year. The power analysis was performed using G\*power 3.1.9.2.<sup>4</sup> Other statistical analyses were conducted using R, version 3.5 (2018, The R Foundation for Statistical Computing). *P* values of <.05 were considered to indicate statistical significance.

## Results

The target population included 552 pitchers who attended our medical checkups from 2012 to 2015. Twenty pitchers who met the

**Table 1**  
Player characteristics at the medical checkups.

Yr (number of participants)	2012 (N = 133)	2013 (N = 131)	2014 (N = 133)	2015 (N = 135)	P value
Age; mean ± SD (yr)	16.47 ± 0.62	16.47 ± 0.62	16.48 ± 0.59	16.46 ± 0.66	.813
Height; mean ± SD (cm)	172.5 ± 5.1	172.6 ± 5.1	172.8 ± 5.7	172.7 ± 5.7	.981
Body weight; mean ± SD (kg)	66.6 ± 7.4	67.3 ± 6.9	65.7 ± 8.3	65.8 ± 7.7	.265
Baseball experience; mean ± SD (yr)	8.5 ± 1.7	8.0 ± 2.1	8.4 ± 1.8	8.1 ± 2.0	.211
Pitching side (no. [%])					.352
Right	105 (78.9)	93 (71.0)	106 (79.7)	103 (76.3)	
Left	28 (21.1)	38 (29.0)	27 (20.3)	32 (23.7)	

SD, standard deviation.

Demographic data for each year (age, height, weight, baseball experience, and pitching side) were compared by a one-way analysis of variance for continuous variables and a chi-squared test for categorical variables to test the differences in background factors among the groups (grouped as per the year). The background factors of the groups did not differ to a statistically significant extent.

exclusion criteria were excluded from the study. In total, 532 (96.4%) pitchers who attended medical checkups were included as candidates in this study. The average number of pitchers in each year's medical checkups was 133 (range: 131-135). All pitchers were men. The average age was 16.5 (standard deviation [SD]: 0.6) (range: 15-17) years. The average height was 172.6 (SD: 5.4) (range: 155.5-188.3) cm, and the average body weight was 66.4 (SD: 7.6) (range: 40.1-102.0) kg. The average number of years of baseball experience was 8.2 (SD: 1.9) (range: 1-13) years. Regarding the pitching side, 76.4% of pitchers were right-handed and 23.6% were left-handed. There were no significant differences in background factors among the groups (Table 1).

The questionnaire collection rate for surveys on shoulder and elbow injuries that occurred during the season was 71.6% (range: 67.7-78.9). There were no significant differences in the yearly questionnaire response rate ( $P = .33$ ). The incidence of shoulder and elbow injuries during the 2012 season was 20.0%; this significantly decreased to 7.7% in 2015 ( $P = .013$ ) (Fig. 1). A Cochran-Armitage trend test revealed a significant linear downward trend in the incidence of shoulder and elbow injuries in each season during the study period ( $P = .007$ ) (Fig. 2).

*Post hoc power analysis*

The post hoc analysis showed that the statistical power for comparison of the incidence of shoulder and elbow injuries during the seasons of the study period was 0.97 between the first year and the most recent year of evaluation.

**Discussion**

The most important finding identified in this survey was that, as we hypothesized, in-season shoulder and elbow injuries decreased significantly after the implementation of medical checkups in each year of the study period. Although it has been reported that shoulder and elbow injuries were reduced by screening and intervention for risk factors in a single year,<sup>10</sup> there have been no previous reports on whether repetitive multiyear interventions can sustainably reduce these injuries in competitive-level high school baseball pitchers. In this study, we performed repeated multiyear medical checkups, including intervention for risk factors and guidance to prevent overuse.

This is the first report to show that repeated multiyear medical checkups can contribute to a sustained reduction in shoulder and elbow injuries in competitive-level high school baseball pitchers.

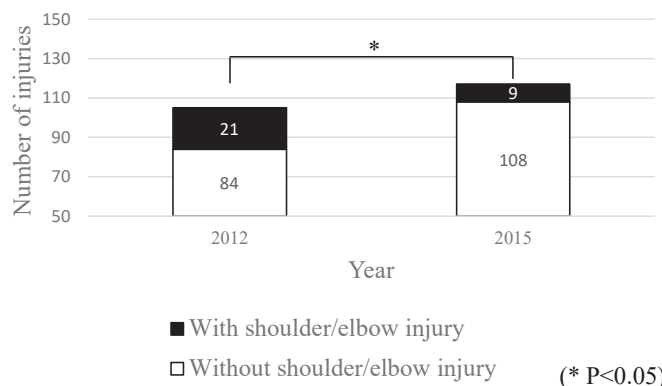
*Trend of shoulder and elbow injuries in high school baseball pitchers*

With regard to the trend in the frequency of shoulder and elbow injuries in high school baseball pitchers, the results of examinations

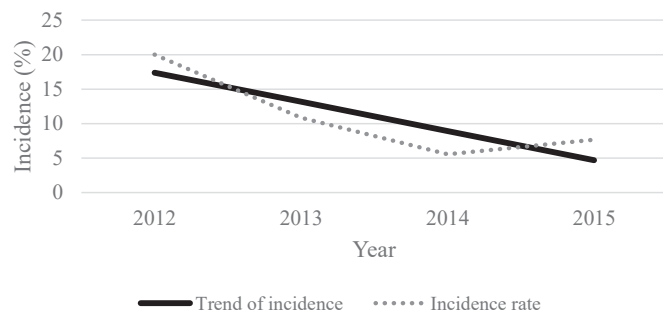
of players in Japan's National High School Baseball Invitational Tournament and National High School Baseball Championship were previously reported.<sup>11</sup> In that report, from 1994 to 2016, symptomatic disability decreased in both the shoulder and elbow at the National High School Baseball Invitational Tournament examinations and elbow disability decreased at the National High School Baseball Championship examinations, and the decreasing trend in symptomatic elbow injuries was considered to be because of the growing recognition of the importance of conditioning by preventing overuse.

However, the aforementioned report was a survey of pitchers that was based solely on the cross-sectional results of medical examinations that were performed immediately before the tournament and did not include the injury rate for the entire season. In addition, the survey was limited to top-level pitchers who were registered with the National High School Baseball Invitational Tournament or National High School Baseball Championship, and pitchers who were not on the roster were not evaluated. Owing to this selection bias, there was inadequate consideration regarding trends in the incidence of shoulder and elbow injuries among general competitive-level high school baseball pitchers.

In this study, pitchers from all high schools belonging to the high school baseball federation in our prefecture were surveyed to assess the presence or absence of injuries both immediately before the tournament and during the entire season. In this respect, the results of this study can complement the information that was missing from the previous report.



**Figure 1** Comparison of the number of shoulder and elbow injuries between the 2012 and 2015 seasons. The distribution of the number of cases with and without shoulder and elbow injuries was compared by a chi-squared test. The number of shoulder and elbow injuries that during the 2015 season was significantly decreased in comparison with the 2012 season ( $P = .013$ ).



**Figure 2** Trend in the incidence of shoulder and elbow injuries during the four seasons. The trend in the incidence from 2012 to 2015 was analyzed using the Cochran-Armitage trend test. Shoulder and elbow injuries showed a linear downward trend ( $P = .007$ ).

### *Trend in the incidence of shoulder and elbow injuries among competitive-level high school baseball players*

In a large database study of competitive-level high school baseball players, it was reported that the incidence of shoulder and elbow injuries did not decrease over the 10-year study period.<sup>7</sup> However, the aforementioned report, the presence of shoulder and elbow injuries was based on reports made by athletic trainers, and lacked diagnostic criteria for shoulder and elbow injuries. Because the presence of the injuries was solely based on the judgment of the reporting athletic trainers, the reported injuries lacked unified definitions; thus, the incidence of injuries may be inaccurate. In our report, we used the same diagnostic criteria for shoulder and elbow injuries as in previous reports.<sup>8,10</sup> Therefore, if the injuries were consistently defined within this and other reports, then a standardized evaluation of the incidence of injuries could be performed. This was the strength of our study.

The present study was associated with some limitations. First, the physical characteristics that have been identified as risk factors for shoulder and elbow injuries, as well as compliance with practice time and pitch count limits, were not been examined to determine how they fared over the four-year study period. Thus, it is unclear whether the medical checkups contributed to a decrease in shoulder and elbow injuries by improving the physical characteristics and compliance. Second, because the participants included a mixture of pitchers of different skill levels and because we were not able to collect detailed information on the actual amount of practice or game play for each player, we were not able to compare whether there were differences in the actual amount or quality of practice or whether these differences affected the incidence of shoulder and elbow injuries. However, it is unlikely that there was a significant difference in excessiveness in practice or game play because all of the participants were playing at a competitive level, not a recreational level. Third, the survey collection rate for the prospective study was 71.6%. Approximately one-quarter of the questionnaires was not collected or analyzed, which could have led to selection bias. Fourth, this study has only limited data from a limited number of participants in our prefecture, as a result, it is not possible to discuss overall trends or make any definitive conclusions. However, despite the aforementioned limitations, this study might contribute to understanding the incidence and trends in shoulder and elbow injuries in competitive-level high school baseball pitchers and to clarifying the uncertainty regarding the statistics of shoulder and elbow injuries.

## Conclusion

The trend in the incidence of shoulder and elbow injuries in competitive-level high school baseball pitchers during a four-year period was evaluated. The incidence of shoulder and elbow injuries during the season significantly decreased with a linear downward trend during the survey period after the implementation of medical checkups.

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