

# Shoulder and Elbow Injuries in Elite Taiwanese High School Baseball Pitchers From 2016 to 2017

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**Background:** Numerous studies have discussed the risk factors for shoulder and elbow injuries in high school baseball players worldwide.

**Purpose:** To determine the risk factors for pitching-related shoulder and elbow injuries in Taiwanese high school pitchers.

**Study Design:** Cross-sectional study; Level of evidence, 3.

**Methods:** Included in the study were 144 pitchers from 11 top-ranked Taiwanese high school baseball teams between 2016 and 2017 high school baseball season. The participants answered a 55-item questionnaire concerning physical characteristics, pitching activities, injury history, and off-season activities. Univariate analyses were conducted separately for participants with and those without a pitching-related injury in the 12-month study period. The chi-square test or Fisher exact test was applied to categorical variables, and the *F* test or *t* test was applied to continuous variables. A stepwise multivariate logistic regression analysis was used to identify factors related to pitching-related injuries, and those results were calculated as odds ratios (ORs).

**Results:** Having a pitching-related injury was significantly related to the number of pitches per week in the past 12 months (OR, 1.01; *P* = .006), pain over the shoulder and/or elbow in the past 12 months (OR, 3.56; *P* = .008), pitching competitive baseball for more than 8 of the past 12 months (OR, 2.53; *P* = .036), throwing sliders (OR, 2.97; *P* = .026), and lack of participating in other over-the-shoulder activities (0.03-0.11 fewer odds; *P* ≤ .010).

**Conclusion:** For elite high school pitchers in Taiwan, pitching-related shoulder and elbow injuries were related to the number of pitches per week, pitching competitive baseball for more than 8 of the past 12 months, pain over the shoulder and/or elbow in the past 12 months, throwing sliders, and a lack of participation in other sports with over-the-shoulder activities.

**Keywords:** elbow; shoulder; pitching; baseball

For 2 decades, Taiwanese Little League Baseball players have competed successfully in the Little League World Series in Williamsport, Pennsylvania,<sup>5</sup> and baseball has become a national pastime in Taiwan. Because they aspire to becoming professional baseball players, more students nowadays enroll in organized training during their youth. Although the occurrence of serious arm injuries in young pitchers has leveled off because of the improvements made in preventive sports medicine and the introduction of recommendations designed to reduce pitching injuries (eg, the Pitch Smart guidelines by Major League Baseball [MLB]<sup>23,25</sup>), there are still a significant number of serious shoulder and elbow injuries among high school pitchers, who seek medical professionals for treatment.<sup>17,18</sup> In the

past 10 years, approximately 5% of young pitchers in the United States required surgery or retirement from baseball because of serious elbow or shoulder injuries.<sup>10</sup> Although the risk of injury increases with age, arm injuries among young pitchers are alarmingly common.<sup>6,18</sup> Arm injuries during youth not only delay the players' training plans and decrease game participation but also increase the risk for injury in the future.<sup>19</sup>

A number of studies have discussed the risk factors for shoulder and elbow injuries among young pitchers.<sup>1,17,22</sup> Agresta et al<sup>1</sup> conducted a systemic review and found that risk factors such as a history of elbow pain, training or pitching load, and loss of shoulder range of motion were highly related to pitching-related injuries. The American Sports Medicine Institute (ASMI) also updated its recommendation for adolescent pitchers in 2013, referring to several studies focusing on risk factors for arm injuries.<sup>3,10,13,22</sup> Based on these recommendations, specific

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risk-prone behaviors include (1) pitching competitive baseball more than 8 months per year, (2) pitching in a league without pitch or inning limits and specified rest days between games, (3) pitching on consecutive days, (4) pitching in more than 1 game per day, and (5) playing baseball exclusively (ie, no other competitive sports).<sup>3</sup>

Despite the abundant studies regarding this topic, the target group was mainly American players, while there have been no studies to our knowledge focusing mainly on Taiwanese elite high school pitchers. Because of different physical conditions, school systems, and training programs between the players in the United States and those in Taiwan, the risk factors of arm injuries may vary between the 2 groups and thus influence the recommendation for young baseball pitchers in Taiwan.

The aim of this study was to determine the risk factors for pitching-related shoulder and elbow injuries in young Taiwanese baseball pitchers. The hypothesis was that shoulder and elbow injuries in Taiwanese high school pitchers would be related to the ASMI 2013 recommendations for avoiding risk-prone behaviors.<sup>3</sup>

## METHODS

### Players

For this questionnaire-based study, we recruited 176 elite high school pitchers who participated in competitive senior high school baseball games in Taiwan during 2016-2017 high school baseball season. The pitchers were from 11 top-ranked Taiwanese high school baseball teams. Pitchers were excluded from the study for the following reasons: (1) no official high school game appearance in the past 12 months and (2) no response to the question regarding time-loss injury to the shoulder or elbow. Ultimately, 144 players (aged 13-19 years; high school grades 10-12) were included in the study. Institutional review board approval was received for this study, and all participating players and their parents signed the informed consent form.

### Study Questionnaire

The questionnaire used in this study was developed and modified based on an existing instrument that evaluates

risk factors for shoulder and elbow injuries in adolescent pitchers.<sup>17,22</sup> Included were 55 items about pitching activities (eg, pitching volume, types of pitches thrown, pitching styles, and highest pitching velocity), preventive/protective activities, pitching-related shoulder and/or elbow injuries, treatments received, shoulder or elbow pain in the past 12 months, and participation in activities other than baseball. The corresponding authors (C.C. and W.C.) conducted the questionnaire in person, in either English or Taiwanese. The English-language version is available as Supplemental Material.

### Study Variables

Our outcome of interest was self-reported pitching-related injury, which was defined as a shoulder and/or elbow injury in the past 12 months that led to an inability to participate in pitching for at least 1 practice or game. We included both pitching and nonpitching variables. Pitching variables included number of pitches per week, types of pitches thrown in the past 12 months, current fastball speed, and history of shoulder and/or elbow injury. Nonpitching variables included weight training and participation in other over-the-shoulder sports (eg, swimming) or contact sports (eg, rugby or basketball) in either an official or unofficial capacity, where official participation meant the players were part of the school team and had regular training. These variables were selected mainly based on the recommendations by the ASMI<sup>3</sup> and MLB (Pitch Smart)<sup>23</sup> for activities that should be avoided because of their putative causal connection with shoulder and/or elbow problems.

### Statistical Analysis

All data were analyzed using SPSS Version 25.0 (IBM Corp). Univariate analyses were conducted separately for participants who had a pitching-related injury in the past 12 months and those who did not. The chi-square test or Fisher exact test was applied for categorical variables, and the *F* test or *t* test was applied for continuous variables. Only the parameters consistently associated with pitching-related injuries were considered for further multivariate logistic regression analysis. A stepwise multivariate logistic regression analysis was used to identify factors that were related to pitching-related injuries, with results

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Ethical approval for this study was obtained from Chang Gung Medical Foundation (reference No. 202101106B0A3).

TABLE 1  
Demographic Data of High School Baseball Pitchers With and Without Pitching-Related Injury (N = 144)<sup>a</sup>

	Pitching-Related Injury, n = 76 <sup>b</sup>	No Pitching-Related Injury, n = 68	P
Physiological age, y	16.4 ± 1.1	16.3 ± 1.2	.817
Body height, cm	174.9 ± 5.9	174.9 ± 12.7	.995
Body weight, kg	69.8 ± 10.3	70.8 ± 9.5	.557
Body mass index, kg/m <sup>2</sup>	22.8 ± 3.0	24.2 ± 12.7	.382
Pitching experience in organized baseball, y <sup>c</sup>	5.1 ± 2.3	5.0 ± 2.2	.858

<sup>a</sup>Data are presented as mean ± SD.

<sup>b</sup>Defined as a self-reported shoulder and/or elbow injury in the past 12 months that led to an inability to participate in pitching for at least 1 practice or game.

<sup>c</sup>n = 137 players (76 with pitching-related injury, 68 with no pitching-related injury).

TABLE 2  
Pitch Counts, Types, and Velocity<sup>a</sup>

	n	Pitching-Related Injury	No Pitching-Related Injury	P
No. of pitches per week <sup>b</sup>	144	95.4 ± 71.1 (76)	71.2 ± 47.8 (68)	<b>.017</b>
No. of months of organized pitching <sup>b</sup>	126	7.0 ± 4.5 (66)	7.8 ± 4.5 (60)	.301
Experience throwing curve balls, y	132	2.9 ± 1.7 (70)	2.9 ± 1.7 (62)	.797
Experience throwing sliders or sinkers, y	127	2.9 ± 1.7 (68)	3.0 ± 1.8 (59)	.767
Current highest fastball velocity, km/h	121	129.4 ± 9.4 (62)	126.5 ± 9.6 (59)	.101

<sup>a</sup>Data are presented as mean ± SD (No. of participants). Bolded P value indicates a statistically significant difference between groups (P < .05).

<sup>b</sup>Within the past 12 months.

reported as odds ratios (ORs) and 95% CIs. For all analyses, P values <.05 were considered to represent statistical significance.

## RESULTS

Of the 144 participants, 76 (52.8%) had experienced a pitching-related injury in the past 12 months and 68 (47.2%) had no pitching-related injury. Demographic data and pitching experience in organized baseball were not significantly different between the groups (Table 1).

Concerning pitch counts, types, and velocity, there was a significant difference between the injured and noninjured pitchers in number of pitches thrown per week in the past 12 months (95.4 ± 71.1 vs 71.2 ± 47.8, respectively; P = .017, independent-samples t test) (Table 2).

Regarding the other categorical variables, the chi-square test and Fisher exact test were administered to estimate candidate variables for next-step multivariate logistic regression. Variables of pitching activities were first arranged in our model. In the stepwise multivariate logistic regression, the model showed that having a pitching-related injury was significantly related to the number of pitches per week in the past 12 months (1 more pitch per week led to a 1.01 [95% CI, 1.00-1.02] greater odds of the injury; P = .006), pain over the shoulder and/or elbow in the past 12 months (OR, 3.56; 95% CI, 1.39-9.13; P = .008), pitching competitive baseball for more than 8 of the past 12 months (OR, 2.53; 95% CI, 1.06-6.01; P = .036), and throwing sliders (OR, 2.97; 95% CI, 1.14-7.75; P = .026)

(Table 3). There was a trend for pitching with higher velocity (ie, fastball speed) to be associated with increased risk of pitching-related injuries, although the relationship was not statistically significant (P = .197).

Regarding nonpitching variables, participating in other over-the-shoulder sports, both unofficially (OR, 0.03; 95% CI, 0.04-0.21; P < .001) and officially (OR, 0.11; 95% CI, 0.22-0.60; P = .010), was associated with lower odds of having a pitching-related injury (Table 4).

## DISCUSSION

The study results indicated that among 144 elite high school pitchers in Taiwan, 76 (52.8%) pitchers reported experiences of pitching-related injuries to the shoulder and/or elbow in the past year. Shoulder and elbow injuries in Taiwanese high school pitchers were associated with the number of pitches per week (1 more pitch per week led to a 1.01 [95% CI, 1.00-1.02] times greater odds of injury; P = .006), pitching competitively for more than 8 of the past 12 months (OR, 2.53; P = .036), shoulder and/or elbow pain over the past 12 months (OR, 3.56; P = .008), throwing sliders (OR, 2.97; P = .026), and not participating in other over-the-shoulder activities (0.03 fewer odds for unofficial participation [P < .001] and 0.11 fewer odds for official participation [P = .010]).

Our finding that pitching competitively for more than 8 of the past 12 months was associated with pitching-related injury is consistent with previous biomechanical studies<sup>4</sup> stating that high pitching volume with inadequate recovery

TABLE 3  
Odds Ratios for Pitching-Related Injury by Pitching Variables<sup>a</sup>

	OR (95% CI)	P
Pitches per week	1.01 (1.00-1.02)	<b>.006</b>
Current fastball speed	1.03 (0.98-1.09)	.197
Pain over shoulder and/or elbow in past 12 mo, yes vs no	3.56 (1.39-9.13)	<b>.008</b>
Pitching competitive baseball for >8 mo in past 12 mo, yes vs no	2.53 (1.06-6.01)	<b>.036</b>
Pitching multiple games per day, yes vs no	2.04 (0.41-10.19)	.386
Pitching back-to-back days, yes vs no	1.03 (0.37-2.88)	.960
Pitching in a league without pitch counts or limits, yes vs no	1.44 (0.59-3.47)	.424
Throwing changeups, yes vs no	1.88 (0.76-4.60)	.170
Throwing curveballs, yes vs no	1.57 (0.52-4.75)	.421
Throwing sliders, yes vs no	2.97 (1.14-7.75)	<b>.026</b>
Throwing sinkers, yes vs no	0.66 (0.23-1.92)	.449

<sup>a</sup>Bolded *P* values indicate statistical significance ( $P < .05$ ). OR, odds ratio.

TABLE 4  
Odds Ratios for Pitching-Related Injury by Nonpitching Variables<sup>a</sup>

	OR (95% CI)	P
Weight training, no vs yes	0.74 (0.17-3.26)	.785
Other over-the-shoulder sports (eg, swimming)		
Never	Referent	
Unofficial participation	0.03 (0.04-0.21)	<b>&lt;.001</b>
Official participation	0.11 (0.22-0.60)	<b>.010</b>
Contact sports (eg, rugby, basketball)		
Never	Referent	
Unofficial participation	0.48 (0.13-1.80)	.28
Official participation	2.08 (0.14-30.71)	.59

<sup>a</sup>Bolded *P* values indicate statistical significance ( $P < .05$ ). OR, odds ratio.

time to heal or undergo the natural reparative process leads to increased risk of arm injuries.<sup>11,17,22</sup> These findings add to the current literature on overuse as an important factor in the development of potential upper extremity injuries and have important implications for injury prevention programs in youth pitchers.<sup>10,26</sup>

Studies are divided as to whether certain pitch types can lead to injuries in younger players.<sup>7,12,14,15,17</sup> Throwing curveballs has been mentioned as a risk factor for pitching-related injuries in several studies<sup>7,14</sup>; however, we did not find this to be the case in the current study (OR, 1.57; 95% CI, 0.52-4.75;  $P = .421$ ). Throwing sliders, however, accounted for a 2.97 times higher risk for pitching-related injuries in our study, which corresponds with the study of Lyman et al,<sup>17</sup> which demonstrated that sliders were associated with an 86% increased risk of elbow pain in a group of youth pitchers.

Whether throwing sliders is associated with a greater risk of injury is a controversial issue. Despite the traditional recommendation against throwing curveballs or sliders at an early age,<sup>3</sup> a study of professional pitchers found that doing so does not place greater stress on the shoulder

and elbow than throwing fastballs.<sup>8</sup> A study of adult baseball pitchers suggested that the throwing pattern of the individual pitcher or inherent force difference of the throw, rather than the type of throw, is associated with greater valgus forces on the medial side of the elbow, which may lead to increased risk of arm injuries.<sup>2,16</sup> It is possible that the observed pitching-related injuries associated with sliders is the mark of a more experienced pitcher who throws more forcefully and perhaps throws more pitches.<sup>11,22</sup>

According to the MLB Pitch Smart guidelines, youth pitchers could start using breaking pitches, including sliders and curveballs, once they have developed a consistent fastball and changeup,<sup>23</sup> which may mean that certain pitch types are not harmful to youth pitchers as long as the players are experienced enough in pitching techniques. Further studies need to employ more specific assessment tools geared toward young pitchers to better identify the role of pitch types in the risk of shoulder and elbow injuries.

A history of pain in the involved arm is also an important risk factor for pitching-related injuries.<sup>19</sup> In our study, a history of pain over the shoulder and/or elbow in the past 12 months had a 3.56 higher risk of pitching-related injury. According to the index study, a history of shoulder or elbow pain was one of the strongest risk factors for current pain and potentially upcoming pitching-related injuries. Also, a history of elbow pain was associated with a higher incidence of shoulder pain.<sup>20</sup> Our study also highlighted the strong association of a history of pain with current pitching-related injuries, emphasizing the importance of pitchers' reporting their arm and shoulder pain immediately to avoid more serious injury occurrence.

Pitch velocity as a risk factor for pitching-related injuries was also discussed in several studies.<sup>14,16</sup> In our study, there was a trend for pitchers with a higher pitch velocity to have a higher odds of injury than those with a lower pitch velocity, but this was not statistically significant. According to Kurokawa et al,<sup>16</sup> as the pitch velocity increases, there is a morphological change that increases the valgus stress in the medial epicondyle,<sup>9,21</sup> which may be the possible pathophysiology for high-velocity pitchers prone to injury.

Last, according to the ASMI recommendations, playing baseball exclusively without other sports participation was associated with a higher likelihood of youth pitchers being injured and was therefore not recommended.<sup>3</sup> In our study, we separated other sports into 2 categories: over-the-shoulder and contact sports. The latter showed no significant difference. When it comes to participation in over-the-shoulder activities, pitchers either officially or nonofficially playing other over-the-shoulder activities revealed lower ORs for pitching-related injuries than those exclusively playing baseball. For those playing solely baseball, specific muscles may be exerted repeatedly. This may weaken other parts of young players' bodies, resulting in imbalanced growth and thus leading to injuries.<sup>24</sup> Further investigation of the short-term and long-term health consequences of such intense training and specialization compared with playing various sports is needed.

### Limitations

This study has some limitations. First, the study relied on the self-report of the participants for the data. Consequently, some of the data collected on pitching activities and behaviors (eg, average pitches per week in the past 12 months) may lack precision and could also be subject to recall bias. Second, because of the cross-sectional nature of this study, it is difficult to conclude what is the relationship between the risk factors and the arm problems. Finally, elbow or shoulder injuries assessed in this study were not diagnosed by a medical professional but estimated by subjective notion and, in some cases, were of limited severity and duration. It is possible that the risk factors for more severe conditions that come to the attention of health care professionals are different from those found in the present investigation. However, by the time a high school pitcher experiences pain so severe that he has to skip a pitch appearance or practice, it is likely that he has experienced a slow crescendo of pain for several weeks or even months.

### CONCLUSION

As for elite high school pitchers in Taiwan, pitching-related shoulder and elbow injuries were related to the number of pitches per week, pitching competitive baseball for more than 8 of the past 12 months, pain over the shoulder and/or elbow in the past 12 months, throwing sliders, and a lack of participation in other over-the-shoulder sports activities. As more baseball training concepts are exchanged between countries and leagues, our results in Taiwan may provide a good reference for high school baseball programs worldwide.

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