Relation between grip and pinch strength and pitch type in high school pitchers with and without elbow symptoms

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Abstract
Objective: Griping and pinching a ball is a fundamentally important part of the kinetic chain for throwing baseball pitches of various types. This study of high school pitchers was conducted to assess the association between grip and pinch strength, the pitch type, and the history of elbow symptoms.

Methods: We examined 133 high school baseball pitchers, all of whom had completed a self-administered questionnaire including items related to pitch type throwing ratios, the age at starting each pitch type, and throwing-related elbow joint pain sustained during the prior 3 years. We measured grip strength and the bilateral side tip, key, and palmar pinch strengths. Comparisons were made between the participants with and without an elbow symptom history to assess the grip and each pinch strength, throwing ratio of pitch type, and the age at starting to throw each pitch type.

Results: Pitchers with an elbow symptom history exhibited less difference between the grip strength on the throwing side than those with no elbow symptom history (p = 0.04). No difference was found between participants with and without an elbow symptom history in terms of pinch strength, the throwing ratios of pitch types, or the age at starting to throw pitches of each type. Positive significant association was found between pinch strength on the pitching side and the forkball and screwball throwing ratio (r = 0.27, p = 0.002).

Conclusion: Grip strength might influence high school baseball pitcher elbow conditions. The frequency of certain pitch types might develop pinch strength in high school baseball pitchers.

Keywords
baseball, elbow, grip strength, injury, pinch strength, pitcher, pitch type

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Introduction
Throwing motions are accomplished through activation of the kinetic chain in which individual body parts such as leg, pelvis, trunk, and arm are coordinated in their movements by muscle activity and body positions to generate, summate, and transfer force through the body into the arm.¹–³

Gripping and pinching a ball is a fundamental part of the kinetic chain associated with the throwing motion. The flexor digitorum superficialis (FDS) muscle, which is used to hold the ball in a pitching motion, contributes to dynamic
valgus stability at the elbow.\textsuperscript{4,5} From the perspective of anatomical and kinematic effects, grip is apparently closely related to the elbow condition, which is proximal to the joint of the hand in the throwing motion. Pitchers have thrown various pitch types from youth. Intrinsic muscles of the hand are used to control movement for the various pitch types.\textsuperscript{6} Pitch Smart guidelines recommend that players under 12 years avoid throwing pitches other than fastball and changeups. Players aged 13–18 years can begin using breaking pitches after developing consistent fastball and changeup performance.\textsuperscript{7} Earlier reports of some studies have described a relation between pitch types and the risk of throwing injury in baseball pitchers.\textsuperscript{8–17} It is apparently important to check the grip and pinch strength periodically to prevent throwing injury. Nevertheless, no report has described a study investigating the association between grip strength and pitch type and the history of elbow symptoms in high school pitchers. This study of high school baseball pitchers with and without elbow symptoms assessed relations between grip, pinch strength, and the throwing ratios of pitch types.

**Materials and methods**

From local high schools, 133 high school baseball pitchers aged 15–17 years voluntarily participated. We examined their physical condition during the winter off-season. Each participant had completed a self-administered questionnaire including items related to age, hand dominance, years of playing, throwing ratios of pitch types (fastball, slider ball, curveball, changeup ball, and other), and their history of throwing-related elbow joint pain sustained during the prior year. Elbow joint pain was defined for this study as any condition, caused directly by throwing, which results in participation loss. All participants reported their self-satisfaction scores for throwing. The score reflects their self-assessment of ball control, ball speed, and throwing condition.

The elbow range of motion (ROM) was measured using the method applied in an earlier study. We established the intra-rater validity and reliability of measurements of elbow ROM.\textsuperscript{18} We measured the bilateral grip strength using a digital dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan). A pinch gauge (MG-4320NC pinch gauge; B&L [SantaAna, CA, USA]) was used to measure the tip, key, and palmar pinch strengths on both dominant and nondominant sides. Grip testing was performed using a standardized position recommended by the American Society of Hand Therapists. Subjects were seated with the shoulder in abduction and neutral rotation, elbow flexed at 90°, forearm in a neutral position, wrist between 0° and 30° of extension, and 0° and 15° of ulnar deviation. Pinch testing was performed with the shoulder, elbow, forearm, and wrist in a neutral position. We conducted pinch tests of three kinds: a tip pinch is the thumb tip to the index fingertip, a key pinch is the thumb pad to the lateral aspect of middle phalanx of index finger, and a palmar pinch is the thumb pad to pads of the index and middle fingers. For each grip and pinch test, three measurements were performed to assess the dominant and nondominant sides. All tests were conducted by a single orthopedic surgeon. Height was measured using a digital height meter (A&D Corp., Tokyo, Japan). The body composition was measured using a multi-frequency segmental body composition analyzer (MC780U; Tanita Corp., Tokyo, Japan).

**Statistical analysis**

Differences between dominant and nondominant elbow ROM and grip strength, and pinch strengths of three types were compared using a paired-sample $t$-test or Wilcoxon rank-sum test. Participants were stratified according to their respective histories of elbow pain or lack thereof. Responses indicated that 60 pitchers had a history of elbow pain and 74 pitchers had no history of elbow pain. Between the two groups, we compared the differences between grip strength and the three respective pinch strengths and the throwing ratio of pitch type, as well as the age they started throwing each pitch type. Spearman rank correlation was applied to elucidate the association between muscle strength and throwing ratios of pitch types. The ages at starting to throw each pitch type were compared using Scheffe’s multiple comparison test for all participants. Data are presented as means and standard deviations. A $p$ value of less than 0.05 was inferred as statistically significant. All participants and their parents gave informed consent to participation in this study, which was approved by the institutional review board.

**Results**

Physical findings related to the dominant and nondominant sides in all participants are presented in Table 1. For all participants, the dominant side exhibited significantly smaller ROM of elbow extension and flexion than the

| Table 1. Physical findings related with dominant and nondominant side in all participants.\textsuperscript{a} |
|-----------------------------------------|----------|----------|----------|
| Elbow ROM (°)                          |          |          |          |
| Extension                               | 2.3 ± 5.8| 7.0 ± 4.7| <0.001   |
| Flexion                                 | 144.5 ± 5.0| 147.4 ± 4.0| <0.001   |
| Muscle strength (kg)                    |          |          |          |
| Grip                                    | 37.8 ± 5.7| 37.7 ± 6.1| 0.78     |
| Tip pinch                               | 6.7 ± 1.3 | 6.5 ± 1.3 | 0.04     |
| Key pinch                               | 9.3 ± 1.4 | 9.6 ± 1.5 | 0.04     |
| Palmar pinch                            | 8.2 ± 1.6 | 8.1 ± 1.6 | 0.04     |

SD: standard deviation.

\textsuperscript{a}Values are means ± SDs. Statistical significance: $p < 0.05$. 


The dominant-side tip pinch and palmar pinch strengths were greater than those of the nondominant side. For all participants, the nondominant side exhibited significantly greater key pinch strength than the dominant side.

Results of comparison between the No elbow pain group and the Elbow pain group are presented in Table 2. Pitchers who had reported an elbow symptom history exhibited less difference between the grip strength on the throwing side than those with no elbow symptom history ($p = 0.04$). No difference was found between pitchers with an elbow symptom history on the throwing side in terms of tip pinch, key pinch, or palmar pinch strength. For all participants, the age at starting to throw a fastball was younger than those of all other pitch types (Table 3, Figure 1). No difference was found between pitchers with an elbow symptom history and those with no elbow symptom history on the throwing side in terms of the throwing ratio of any pitch type and the age started throwing all pitch types (Table 4). For all

### Table 2. Physical characteristics of participants with and without elbow pain.

|                      | No elbow pain ($n = 74$) | Elbow pain ($n = 60$) | p Value |
|----------------------|--------------------------|-----------------------|---------|
| Age (years)          | 16.5 ± 0.6               | 16.4 ± 0.7            | 0.12    |
| Height (cm)          | 172.3 ± 5.7              | 173.1 ± 5.8           | 0.44    |
| Weight (kg)          | 65.8 ± 7.9               | 65.4 ± 6.7            | 0.72    |
| BMI (kg/m$^2$)       | 22.2 ± 2.8               | 21.8 ± 1.9            | 0.99    |
| Experience (years)   | 7.9 ± 2.1                | 8.4 ± 1.9             | 0.19    |
| Elbow ROM            |                          |                       |         |
| Dominant elbow (°)   |                          |                       |         |
| Extension            | 3.9 ± 5.7                | 0.4 ± 5.4             | <0.001  |
| Flexion              | 145.0 ± 4.1              | 143.8 ± 6.0           | 0.17    |
| Nondominant elbow (°) |                         |                       |         |
| Extension            | 7.2 ± 5.1                | 6.9 ± 4.2             | 0.64    |
| Flexion              | 147.1 ± 4.1              | 143.3 ± 4.2           | 0.29    |
| Throwing side (n)    |                          |                       |         |
| Right                | 55                       | 47                    | 0.69    |
| Left                 | 19                       | 13                    |         |
| Pitching performance score | 57.5 ± 17.5            | 54.2 ± 20.0           | 0.31    |
| Dominant muscle strength (kg) |               |                       |         |
| Grip                 | 38.7 ± 5.7               | 36.7 ± 6.3            | 0.04    |
| Tip pinch            | 6.7 ± 1.3                | 6.6 ± 1.3             | 0.91    |
| Key pinch            | 9.4 ± 1.3                | 9.3 ± 1.5             | 0.68    |
| Palmar pinch         | 8.4 ± 2.7                | 8.1 ± 2.5             | 0.29    |
| Nondominant muscle strength (kg) |               |                       |         |
| Grip                 | 38.2 ± 5.9               | 37.1 ± 6.3            | 0.32    |
| Tip pinch            | 6.6 ± 1.2                | 6.3 ± 1.4             | 0.27    |
| Key pinch            | 9.7 ± 1.4                | 9.5 ± 1.5             | 0.52    |
| Palmar pinch         | 8.2 ± 1.6                | 7.8 ± 1.5             | 0.13    |

SD: standard deviation.

Values are means ± SDs. Statistical significance: $p < 0.05$.

### Table 3. Correlation between grip and each pinch strength and throwing ratios of each type on the dominant side.

| Grip (kg) | Tip pinch (kg) | Key pinch (kg) | Palmar pinch (kg) | Fastball (%) | Curveball (%) | Slider (%) | Changeup (%) | Other (%) |
|-----------|----------------|----------------|-------------------|--------------|---------------|-----------|--------------|----------|
| Grip (kg) | 1.00           |                |                   |              |               |           |              |          |
| Tip pinch (kg) | 0.38a         | 1.00           |                   |              |               |           |              |          |
| Key pinch (kg) | 0.43a         | 0.39a          | 1.00              |              |               |           |              |          |
| Palmar pinch (kg) | 0.39a     | 0.58a          | 0.47a             | 1.00        |               |           |              |          |
| Fastball (%) | −0.009       | −0.13          | −0.13             | −0.19b      | 1.00          |           |              |          |
| Curveball (%) | 0.004        | 0.03           | 0.13              | −0.01       | −0.32a        | 1.00      |              |          |
| Slider (%) | 0.003         | 0.10           | −0.02             | 0.01        | −0.56a        | −0.25a    | 1.00        |          |
| Changeup (%) | 0.15         | 0.08           | 0.03              | 0.11        | −0.13         | −0.11     | −0.08       | 1.00     |
| Other (%) | 0.09          | 0.11           | 0.18b             | 0.26b       | −0.23a        | −0.19b    | 0.01        | −0.09    | 1.00 |

aStatistical significance: $p < 0.01$.

bStatistical significance: $p < 0.05$.
participants, a positive significant correlation was found between pinch strength on the throwing side and the throwing ratio of other pitch type (forkball, screwball) (key pinch, $r = 0.18$, $p = 0.04$; palmar pinch, $r = 0.27$, $p = 0.003$).

**Discussion**

One distinguishing characteristic of our results is that high school baseball pitchers with an elbow symptom history exhibited significantly less difference between the grip strength on the throwing side than those with no elbow symptom history. These findings implicate grip strength as a physical characteristic related to elbow health conditions in high school baseball pitchers. Earlier studies investigated the relation between certain specific physical fitness characteristics and pitched ball kinetic energy in youth baseball pitchers. Grip strength was reported as a significant predictor of physical performance of pitching with high achievement. In anatomical respects, the grip is apparently an important function for elbow joint stability. Earlier studies demonstrated that the active constraints of the flexor–pronator muscles contribute to dynamic valgus stability at the elbow. The FDS muscle, which is used for grasping a ball, was a greater muscular dynamic stabilizer than the pronator teres and flexor carpi ulnaris.

Our result suggests the need for a strategy of muscle training to prevent elbow injury related to throwing. We assessed the pinch strengths of three types in high school baseball pitchers with and without elbow symptoms. No significant difference was found between the two groups in terms of pinch strength. Few reports to date have described hand pinch strength in baseball pitchers with and without elbow symptoms. The proximal joint condition might influence distal musculoskeletal condition in view of kinetic chain. In the final stage of the throwing motion, the strong internal force generated by kinetic chain is transmitted to the hands of pitchers. Pitchers hold the ball with an adequate amount of finger force to prevent ball slippage and to throw and to control various breaking balls. It is apparently important for baseball pitchers to assess the intrinsic hand muscle strength to improve pitching performance. Wang et al. evaluated the dominant finger ROM used during the acceleration phase for fastball, slider,

**Table 4.** Throwing ratios of pitch types and the age at starting to throw pitch types of participants with and without elbow pain.

|                     | No elbow pain (n = 74) | Elbow pain (n = 60) | p   | Value |
|---------------------|------------------------|---------------------|-----|-------|
| Throwing ratio of pitch type (%) |                        |                     |     |       |
| Fastball            | 57.1 ± 15.4            | 60.3 ± 14.8         | 0.24|       |
| Curveball           | 18.0 ± 10.1            | 15.2 ± 12.2         | 0.16|       |
| Slider              | 17.2 ± 13.4            | 18.1 ± 14.1         | 0.69|       |
| Changeup            | 3.5 ± 5.9              | 3.6 ± 5.6           | 0.95|       |
| Other               | 4.2 ± 8.0              | 2.8 ± 4.9           | 0.26|       |
| Age at starting to throw each pitch type (years) |                     |                     |     |       |
| Fastball            | 11.3 ± 2.6             | 10.7 ± 7.4          | 0.31|       |
| Curveball           | 13.6 ± 1.4             | 13.3 ± 0.9          | 0.31|       |
| Slider              | 14.4 ± 1.3             | 13.9 ± 1.3          | 0.09|       |
| Changeup            | 15.5 ± 1.0             | 15.3 ± 1.2          | 0.65|       |
| Other               | 15.2 ± 1.2             | 15.5 ± 1.3          | 0.22|       |

SD: standard deviation.

*Values are means ± SDs. Statistical significance: $p < 0.05$. 

Figure 1. Comparison of the start age of throwing among pitch types. * $p < .01$, ** $p < .01$, *** $p < .01$ and **** $p < .01$: Significantly different from the age started throwing fastballs.
and curveball pitches by 11 high school and college baseball pitchers.\textsuperscript{24} The study found that finger motion and grip types affect the relative position between the fingers and the ball. Specific finger positions were produced corresponding to the respective pitch types. The present study assessed the correlation between pinch strength and the throwing ratio of the pitch type. A positive correlation was found between pinch strength on the throwing side and the throwing ratio of other pitch types (forkball and screwball; key pinch, $r = 0.18, p = 0.04$; palmar pinch, $r = 0.27, p = 0.003$). This finding might be useful for pitchers throwing forkballs and screwballs in clinical training to improve pitching skill.

Our study investigated the relation between elbow injury and the pitch type throwing ratio and the age at starting to throw each pitch type. No significant relation was found between elbow injury and the throwing ratio of pitch type in this study. Earlier studies have evaluated the risk of elbow injury from throwing a specific pitch type.\textsuperscript{8–17} Lyman et al. used a retrospective study to assess the association between pitch type and shoulder and elbow pain in 476 young baseball players aged 9–14 years. They reported that the curveball was associated with a 52\% increased risk of shoulder pain. The slider was associated with an 86\% increased risk of elbow pain.\textsuperscript{9} However, Lyman et al. reported no significant association between pitching a curveball and shoulder or elbow pain in a prospective cohort study of 298 youth pitchers followed up for 2 seasons.\textsuperscript{8} Earlier biomechanical studies found decreased torques and forces at the shoulder and elbow in youth pitchers throwing a curveball compared with a fastball.\textsuperscript{25} Furthermore, a 10-year prospective study conducted by Fleisig et al. found no relation between throwing a curveball before 13 years of age and arm injury in the 481 youth pitchers.\textsuperscript{15} The relation between the risk factor of throwing elbow injury and pitch type has remained controversial. Our study found no association between the age at which a pitcher began throwing a breaking ball and elbow injury, as in earlier reports.\textsuperscript{9,11–14} In growth period, the degree of physical maturity of the individual youth baseball pitchers rather than chronological age might be the indication of the start time of the breaking ball. Additional study to elucidate the relation between the degree of physical maturity at the time of starting the breaking ball and onset of elbow pain or injury should be undertaken for the individual youth baseball pitchers.

Several limitations of this study must be explained. First, our study was done with a cross-sectional design, which might not provide definitive information to infer cause-and-effect relations. A prospective longitudinal study should be conducted to investigate the relation with grip strength and elbow injury in high school baseball pitchers. Second, we defined the elbow symptoms of participants as a condition caused directly by throwing and which caused participation loss during the prior year. Furthermore, we did not confine the elbow symptom as only medial elbow pain and did not assess the elbow symptom severity. Third, we did not analyze several risk factors of elbow injury that have been described in earlier reports of the relevant literature. Results of earlier studies suggest possible risk factors including pitching mechanics, pitches per game or day, innings pitched per season, games per year, and pitch velocity.\textsuperscript{26–28} To study the elbow injury risk factors that have not been evaluated, a prospective study must be conducted.

Fourth, we did not investigate the relationships between grip and pinch strength and the pitch type, and the history of elbow symptoms in baseball pitchers of other ages. The prior article described that pitching-related injury involving the shoulder and elbow becomes evident in high school and college.\textsuperscript{29} For this reason, we checked up the associations between the throwing elbow condition and physical condition and the pitch type of throwing in high school baseball pitchers. However, the pitching-related injury might begin at the youth level. Further studies are needed to elucidate these relationships to prevent the pitching-related injury in the younger baseball pitchers.

**Conclusion**

Pitchers with an elbow symptom history showed less difference between the grip strength on the throwing side than those with no elbow symptom history. Grip strength might influence the elbow condition of high school baseball pitchers. Pinch strength was correlated with the throwing ratios of forkballs and screwballs. The frequency of throwing forkballs and screwballs might engender the development of pinch strength in high school baseball pitchers. No difference was found between participants with and without an elbow symptom history in the throwing ratios of pitch type and the age at which they started throwing each pitch type. A prospective cohort study should be conducted to elucidate the relation between the pitch type and the throwing injury in high school baseball pitchers.

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