JSES International 4 (2020) 1026–1030

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Grip strength is not related to increased medial elbow joint-space gapping induced by repetitive pitching

Hiroshi Hattori, PT, MS, CSCS [a,b], Kiyokazu Akasaka, PT, PhD [a,c,*], Takahiro Otsudo, PT, PhD [a,c], Toby Hall, PT, PhD [d]

[a] Graduate School of Medicine, Saitama Medical University, Moroyama, Saitama, Japan
[b] Department of Rehabilitation, Kawagoe Clinic, Saitama Medical University, Kawagoe, Saitama, Japan
[c] School of Physical Therapy, Saitama Medical University, Moroyama, Saitama, Japan
[d] School of Physiotherapy and Exercise Science, Curtin University, Perth, WA, Australia

ARTICLE INFO

Keywords:
Elbow
ultrasound
baseball
grip strength
medial elbow joint-space gapping
repetitive pitching

Level of evidence: Basic Science Study; Physiology

Background: Pitching induces elbow valgus stress, which can lead to an increase in medial elbow joint-space gapping when repeated. Previous basic research on the medial elbow joint shows that the contraction associated with gripping reduces medial elbow joint-space gapping. However, no studies have investigated the relationship between grip strength and increased medial elbow joint-space gapping during repetitive pitching. The purpose of this study was to investigate whether grip strength is related to medial elbow joint-space gapping during repetitive pitching. Our hypothesis was that increased grip strength would correlate with a reduction in medial elbow joint-space gapping.
Methods: A total of 25 high school baseball players participated in this study. Each subject pitched 100 times. The medial elbow joint-space gapping and grip strength were measured before and after pitching. Correlation analysis was used to identify the relationship between medial elbow joint-space gapping and grip strength.
Results: Medial elbow joint-space gapping (mm) increased by 25.5% ± 8.0% after 100 pitches (gapping before, 5.0 ± 0.9; gapping after, 6.2 ± 1.1; $P < .001$). Grip strength (kg) after 100 pitches decreased by 2.8% ± 7.4% to that before pitching (before, 40.4 ± 5.5; after 39.2 ± 5.6; $P < .05$). There was no significant correlation between the change rate of medial elbow joint gapping and grip strength at any time (grip strength: before pitching, $P = .74$; after pitching, $P = .40$; change rate from before to after pitching, $P = .24$).
Conclusions: Grip strength is not related to increased medial elbow joint-space gapping induced by repetitive pitching. This indicates that physical ability expressed by grip strength is not associated with preventing increases in medial elbow joint-space gapping during repetitive pitching. Further studies are required to investigate the stabilization mechanism of the medial elbow joint during pitching.

The throwing motion induces 64 N m valgus stress across the elbow joint and a tensile stress in the medial elbow joint shortly before the arm reaches maximum external rotation during this motion.[10] The main stabilizer preventing elbow valgus stress as well as tensile stress on other tissues such as the ulnar nerve is the anterior bundle of the ulnar collateral ligament (UCL).[18] The number of UCL reconstructions in 15- to 19-year-old amateur and adolescent baseball players has shown a rapid increase in recent years, and it is important to protect their elbows.[17] In a previous study that investigated the immediate change of the medial elbow joint during repetitive pitching in high school baseball players, it was shown that more than 60 pitches lead to an increase in medial elbow joint-space gapping, which places an immediate burden on the medial elbow joint structures.[13] Baseball pitchers have a risk of medial elbow injury and instability due to this repetitive elbow valgus stress.

Dynamic stabilization of the medial elbow joint is provided by the forearm flexor-pronator muscles (FPMs).[3,21] Previous studies have reported that gripping contributes to a reduction in the medial elbow joint-space gapping,[14,22] and it is suggested that the forearm muscles involved in gripping contribute to protecting the medial elbow joint during repetitive pitching. In addition, DiGiovine et al[7] reported that the FPMs showed high levels of muscle activation during the cocking phase of pitching, which occur at extreme elbow valgus stress. The activity of the FPMs was believed to be important

This study followed the Declaration of Helsinki and was approved by the Ethics Committee at the Saitama Medical University, Saitama, Japan (M-66).

* Corresponding author: Kiyokazu Akasaka, PT, PhD, Saitama Medical University, 981 Kawakado, Moroyama, Saitama 350-0495, Japan.
E-mail address: akasaka-smc@umin.ac.jp (K. Akasaka).

https://doi.org/10.1016/j.jseint.2020.07.007

in maintaining tension across the medial elbow joint structures and resisting elbow valgus stress during the pitching motion. Anecdotally, many baseball pitchers believe that increasing grip strength, including contraction of the FPMs, can help to prevent medial elbow injuries and improve performance.

To our knowledge, there are no reports that have investigated whether the forearm muscles involved in gripping can prevent increasing medial elbow joint-space gapping during repetitive pitching. Therefore, the purpose of this study was to investigate whether physical ability expressed in grip strength is correlated with increased medial elbow joint-space gapping during repetitive pitching. Our hypothesis was that increased grip strength as physical ability would correlate with a reduction in medial elbow joint-space gapping. This study has the potential to inform on training for baseball pitchers in order to prevent medial elbow injury.

Materials and methods

Participants

Twenty-five healthy high school baseball players participated in this study (mean ± standard deviation: age, 16.6 ± 0.7 years; height, 172.6 ± 6.3 cm; weight, 66.1 ± 7.1 kg; years of baseball experience, 8.8 ± 1.9 years). Participants were excluded if they had (1) pain during pitching; (2) a history of shoulder, elbow, or hand surgery; (3) pitched in 24 hours before measurement; or (4) poor pitching ability, such as not being able to throw the ball in the strike zone. Their abilities were such that they could make it to the quarterfinals in a tournament in which 152 high schools in Saitama participated. In addition, all participants had the overhead throwing motion. There were 24 right-hand- and 1 left-hand-dominant participants. All participants agreed to sign an informed consent declaration.

Setup and protocol

The setup and pitching procedure have been reported in a previous study.[15] Each participant freely performed a warm-up exercise as a routine program including running, static or dynamic stretching, and warm-up throwing, until fastball pitching at maximum effort was possible before measurement (approximately 15 minutes). The participants pitched 100 fastballs in total from the set position toward the simulated strike zone (Fig. 1). The throwing motion was overhead in all participants. The pitching protocol consisted of 5 sets (5-minute interval) of 20 fastball pitches (15-second interval) at maximum effort. The official baseball (MIZUNO Co., Ltd., Tokyo, Japan; weight, 141.7-148.8 g) was used during the pitching protocol. In order to eliminate any failed pitching, we calculated the average ball velocity for the first 20 pitches and did not include those less than 70% of this value. As a result, there were no pitches that were less than this 70% value.

Figure 1 Pitching task. The participants pitched 100 fastballs in total from the set position toward the simulated strike zone. The throwing distance was 18.44 m. The pitching protocol consisted of 5 sets (5-minute interval) of 20 fastball pitches (15-second interval) at maximum effort.

Measurements

The ulnohumeral joint space with gravity stress was measured ultrasonically (Aloka Co., Ltd., Tokyo, Japan) before and after pitching. Grip strength was also measured before and after pitching. In addition, the ball velocity was measured using a speed gun (SR3600; Sports Radar Co., Ltd., Florida, USA) placed 1.5 m behind the home plate at all pitches.

In the measurement of medial elbow joint-space gapping, ultrasound images of the medial elbow joint were taken according to the methods used in previous studies[15] and the standards set forth by the American Institute of Ultrasound in Medicine.[2] Ultrasound imaging of the medial aspect of the throwing elbow was performed with the use of a 5-18 MHz linear array transducer. Participants were placed supine on the bed with the shoulder in 90° abduction, 0° horizontal abduction, with the elbow in 90° flexion, and the forearm in neutral position. A towel roll and a digital inclinometer were used to maintain the humerus in the horizontal plane. Gravity stress was applied to the forearm by placing the upper limb distal to the elbow joint out of the bed, to strain the medial aspect of the elbow, and to assess medial elbow joint-space gapping (Fig. 2, *A*).[11,12,15,19,23] Gravity stress used in this study has been reported as being useful in the assessment of medial elbow joint-space gapping and is similar to measurements taken when using the commonly used Telos device.[11] No participant experienced elbow pain during the examination. The ultrasound transducer was placed in a standardized position on the medial elbow aspect such that the ultrasound image included the top of the medial epicondyle of the humerus, the trochlea of the humerus, the sublime tubercle of the ulna, and the UCL.[15] The degree of medial elbow joint-space gapping was assessed by measuring the ulnohumeral joint space between the distal-medial corner of the trochlea of the humerus and the proximal edge of the medial tubercular portion of the sublime tubercle of the ulna (Fig. 2, *B*). The distance of the 2 points (the distal-medial corner of the trochlea of the humerus and the proximal edge of the medial tubercular portion of the sublime tubercle of the ulna) on the image was measured by using the ultrasound distance measurement method (minimum unit 0.1 mm). The mean of 3 trials was calculated. Furthermore, the change rate in medial elbow joint-space gapping, before and after pitching, was calculated and used for data analysis.

The grip strength of the throwing arm was measured using a grip strength tester (GRIP-D T.K.K.5401; Takei Scientific Instruments Co., Ltd., Niigata, Japan) before pitching and after 100 pitches. Participants stood upright, with their arms by their side, and they were asked to reach maximum gripping for 3 seconds (Fig. 3). The mean of 3 trials was used for data analysis. Furthermore, the change rate in grip strength before and after pitching was calculated and used for data analysis.

Statistical analysis

All data were analyzed with SPSS Statistics version 25.0 (IBM Co., Japan). Paired *t*-tests were used to compare medial elbow joint-space gapping and grip strength between before and after pitching. Correlation analysis was used to examine the relationship between the change rate in medial elbow joint-space gapping and grip strength: (1) the change rate in gapping vs. grip strength before pitching, (2) the change rate in gapping vs. grip strength after pitching, (3) the change rate in gapping vs. the change rate in grip strength. In addition, as a characteristic of participants, correlation

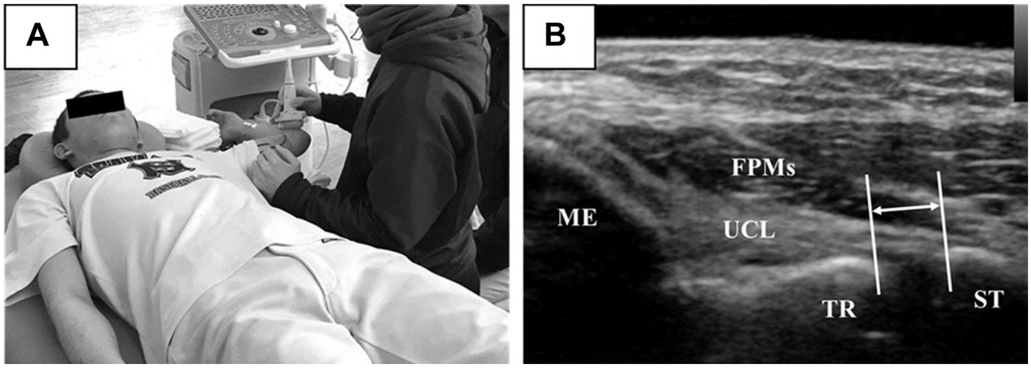

Figure 2 The measurement of medial elbow joint-space gapping. (**A**) Gravity stress was applied to the forearm by placing the upper limb distal to the elbow joint out of the bed. Ultrasound imaging of the medial aspect of the throwing elbow was performed with the use of a 5-18 MHz linear array transducer. (**B**) The degree of medial elbow joint-space gapping was assessed by measuring the distance between the trochlea of the humerus and the sublime tubercle of the ulna. *ME*, medial epicondyle; *FPMs*, forearm flexor-pronator muscles; *UCL*, ulnar collateral ligament; *TR*, trochlea; *ST*, sublime tubercle.

analysis was also used to identify the relationship between the change rate in medial elbow joint-space gapping and the mean ball velocity. Significant differences were set at a level of .05.

Results

As a characteristic of the participants, the mean maximal ball velocity was 30.1 ± 2.3 m/s (67.8 ± 5.3 mph). There was no significant correlation between the change rate in medial elbow joint-space gapping and the mean ball velocity ($P = .96$).

Descriptive statistics for medial elbow joint-space gapping and grip strength is shown in Table I. Medial elbow joint-space gapping after 100 pitches increased significantly compared with that before pitching (mean ± standard deviation [mm]: before pitching, 5.0 ± 0.9; after pitching, 6.2 ± 1.1; $P < .001$). The change rate in medial elbow joint-space gapping before and after pitching was 125.5% ± 8.0%. The grip strength after 100 pitches decreased significantly compared with that before pitching (mean ± standard deviation [kg]: before pitching, 40.4 ± 5.5; after pitching, 39.2 ± 5.6; $P < .05$). The change rate in grip strength before and after pitching was 97.2% ± 7.4%.

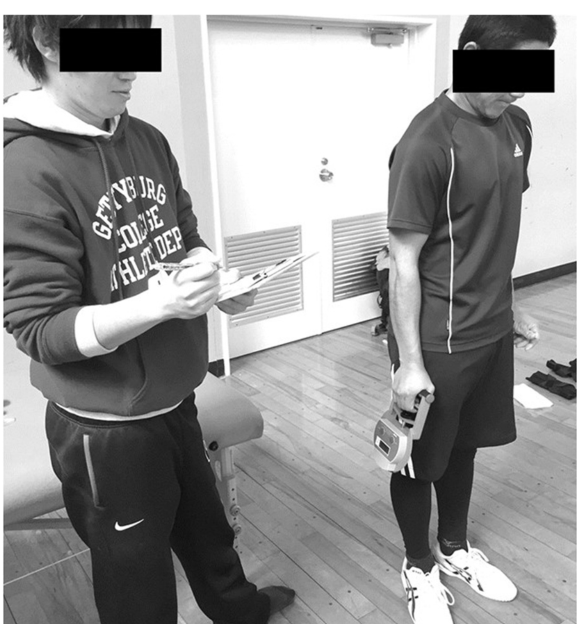

Figure 3 The measurement of the grip strength of the throwing arm was measured using a grip strength tester. Participants stood upright, with their arms resting by their side, attempting maximum gripping for 3 seconds.

The correlation between the rate of change in medial elbow joint-space gapping and grip strength at all time points is shown in Fig. 4. There was no significant correlation between the rate of change in medial elbow joint-space gapping and grip strength at each time point: (1) the rate of change on gapping vs. grip strength before pitching, $P = .74$; (2) the rate of change in gapping vs. grip strength after pitching, $P = .40$; (3) the rate of change in gapping vs. the rate of change on grip strength, $P = .24$.

Discussion

It is reported that 10% of professional baseball players have had UCL reconstruction surgery at least once, while the rate increases to 25% in major league pitchers.[5] This would indicate that medial elbow injuries are common among baseball players. For the purpose of preventing medial elbow injuries, various studies have been widely reported, including those investigating the impact of pitching count, fatigue, range of motion, pitching mechanics, and pitching type among others.[1,4,8,9,20,24,25] However, the number of UCL reconstructions in amateur and adolescent baseball players has shown a rapid increase in recent years.[16,17] As reported by Hodgins et al,[16] the number of UCL reconstruction surgical procedures increased by 193% in New York State between 2002 and 2011. Mahure et al[17] suggested to expect further increases in the number of UCL reconstruction procedures in the future. As can be understood from these reports, further prevention of medial elbow injury in baseball players is strongly required at present.

In this study, we investigated whether physical ability expressed in grip strength is correlated with medial elbow joint-space gapping induced by repetitive pitching. As a result, no significant correlation was found between grip strength and an increased rate of medial elbow joint-space gapping after 100 pitches. This would indicate that physical ability expressed in grip strength does not play a significant role in the prevention of medial elbow joint stress caused by repetitive pitching.

One consideration in this result is the influence of the medial elbow joint stabilization mechanism at the time that the forearm muscles are activated when gripping. In a previous study that investigated the tissue elasticity of the UCL and FPMs at rest and during contraction associated with gripping,[14] it was reported that the ratios of tissue elasticity in the UCL and FPMs (UCL/FPMs) at rest

Table I
Comparison of medial elbow joint-space gapping and grip strength before and after 100 pitches, and rate of change of these (N = 25)

	Before pitching	After 100 pitches	Change rate (before-after) (%)	*P* value (before vs. after)
Medial elbow joint-space gapping (mm)	5.0 ± 0.9	6.2 ± 1.1	125.5 ± 8.0	<.001*
Grip strength (kg)	40.4 ± 5.5	39.2 ± 5.6	97.2 ± 7.4	.037*

Data are expressed as mean ± standard deviation.
* Significant difference between before pitching and after 100 pitches by the paired *t*-test ($P < .05$).

and during gripping were almost identical and suggested that the ratio of the UCL and FPMs against elbow joint valgus stress may not change between rest and gripping evoked muscle contraction. This indicates that the FPMs during contraction may not contribute to any reduction in tensile stress generated in the UCL during elbow valgus loading. It was inferred that repetitive elbow valgus stress due to repetitive pitching causes tensile stress in the medial elbow tissues including the UCL even during muscle contraction, resulting in cyclic creep (an increase of strain due to the increase in the number of constant repetitive stress), which is one of the visco-elastic properties of ligaments and tendons.[6] As a result, medial elbow joint-space gapping may have been caused by repetitive pitching regardless of the degree in grip strength. Although many baseball pitchers have incorporated the training of grip strength including contraction of the FPMs into their training programs, the results of this study are considered important in considering training programs for the prevention of elbow injury in baseball players.

This study only investigated medial elbow joint-space gapping and its relationship to grip strength, yet other factors may also influence gapping. They may include (1) the timing of maximal elbow valgus stress and forearm muscles activity, and (2) the angle of elbow flexion and forearm pronation-supination at maximal elbow valgus stress and during forearm muscle activity. In the future, investigating these factors at the same time will further clarify the stabilization mechanism of the medial elbow joint during pitching, which may lead to a better understanding of the factors associated with increased medial elbow joint-space gapping among baseball players.

This study has a number of limitations. First, subjects were baseball players with a narrow age range of 16.6 ± 0.7 years. Future studies should investigate a wider age range. Second, we observed the medial elbow joint-space gapping changes up to a maximum of 100 pitches. This was based on an ethical consideration with the potential for harm to the participants if more pitches were undertaken. Changes to the medial elbow joint-space gapping with a pitch count greater than 100 are unknown. Third, the ball velocity of the baseball players who participated in this study was slow. Olsen et al[20] reported that the risk of injury increases when throwing at speeds greater than 85 mph. It is unknown and requires further study to understand whether grip strength will prevent an increase in the medial elbow joint-space gapping in pitchers who pitch at greater speed. Fourth, as a result of checking an adequate sample size by prior power analyses (G*Power 3.1.9.4; http://www.gpower.hhu.de/: effect size = 0.5; $\alpha = 0.05$; $1 - \beta = 0.8$) for achieving statistical significance with 80% power ($1 - \beta$), 29 participants were required for this study. The number of participants we could have collected in this study was 25, which was slightly insufficient as the number of participants required for this study. Finally, this study focused on the medial elbow joint-space gapping, and it is not yet clear whether the degree of grip strength contributes to the prevention of medial elbow injury. In the future, it is necessary to clarify this using a longitudinal study design.

Conclusion

We investigated whether physical ability expressed in grip strength is correlated with an increase in medial elbow joint-space gapping during repetitive pitching. However, no significant correlation was found between the increasing rate of medial elbow joint-space gapping produced after 100 pitches and grip strength. This indicates that physical ability expressed in grip strength is not associated with preventing increases in medial elbow joint-space gapping during repetitive pitching.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

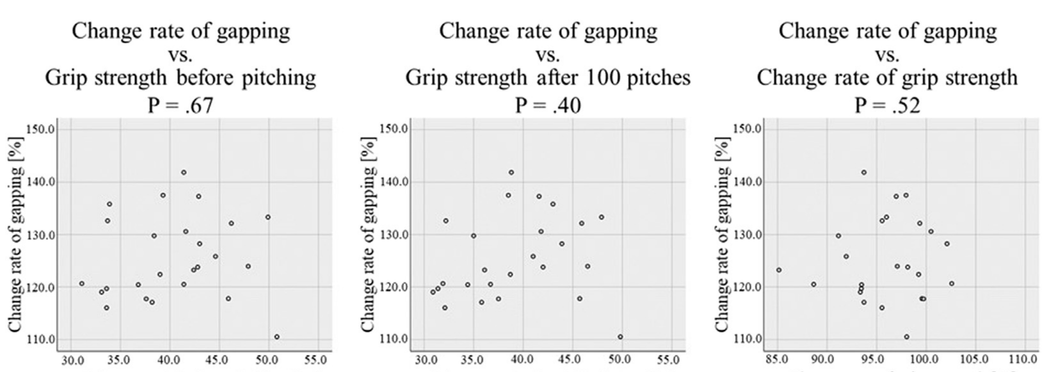

Figure 4 The correlation between rate of change in medial elbow joint-space gapping and grip strength at all time points. There was no significant correlation between the rate of change in medial elbow joint-space gapping and grip strength at any time point: (1) the rate of change in gapping vs. grip strength before pitching, $P = .74$; (2) the rate of change in gapping vs. grip strength after pitching, $P = .40$; (3) the rate of change in gapping vs. the rate of change in grip strength, $P = .24$.

References

1. Aguinaldo AL, Chambers H. Correlation of throwing mechanics with elbow valgus load in adult baseball pitchers. Am J Sports Med 2009;37:2043–8. https://doi.org/10.1177/0363546509336721.
2. American Institute of Ultrasound in Medicine. AIUM practice parameter for the performance of a musculoskeletal ultrasound examination. http://www.aium.org/resources/guidelines/musculoskeletal.pdf; 2017. Accessed June 3, 2019.
3. Buchanan TS, Delp SL, Solbeck JA. Muscular resistance to varus and valgus loads at the elbow. J Biomech Eng 1998;120:634–9.
4. Chalmers PN, Sgroi T, Riff AJ, Lesniak M, Sayegh ET, Verma NN, et al. Correlates with history of injury in youth and adolescent pitchers. Arthroscopy 2015;31: 1349–57. https://doi.org/10.1016/j.arthro.2015.03.017.
5. Conte SA, Fleisig GS, Dines JS, Wilk KE, Aune KT, Patterson-Flynn N, et al. Prevalence of ulnar collateral ligament surgery in professional baseball players. Am J Sports Med 2015;43:1764–9. https://doi.org/10.1177/0363546515580792.
6. De Zee M, Bojsen-Moller F, Voigt M. Dynamic viscoelastic behavior of lower extremity tendons during simulated running. J Appl Physiol 2000;89:1352–9.
7. DiGiovine NM, Jobe FW, Pink M, Perry J. A dynamic viscoelastic behavior of lower extremity tendons during simulated running n electromyographic analysis of the upper extremity in pitching. J Shoulder Elbow Surg 1992;1: 15–25.
8. Erickson BJ, Harris JD, Tetreault M, Bush-Joseph C, Cohen M, Romeo AA. Is Tommy John surgery performed more frequently in major league baseball pitchers from warm weather areas? Orthop J Sports Med 2014;2: 2325967114553916. https://doi.org/10.1177/2325967114553916.
9. Escamilla RF, Fleisig GS, Groeschner D, Akizuki K. Biomechanical comparisons among fastball, slider, curveball, and changeup pitch types and between balls and strikes in professional baseball pitchers. Am J Sports Med 2017;45: 3358–67. https://doi.org/10.1177/0363546517730052.
10. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med 1995;23:233–9.
11. Harada M, Takahara M, Maruyama M, Nemoto T, Koseki K, Kato Y. Assessment of medial elbow laxity by gravity stress radiography: comparison of valgus stress radiography with gravity and a Telos stress device. J Shoulder Elbow Surg 2014;23:561–6. https://doi.org/10.1016/j.jse.2014.01.002.
12. Harada M, Takahara M, Sasaki J, Mura N, Ito T, Ogino T. Using sonography for the early detection of elbow injuries among young baseball players. AJR Am J Roentgenol 2006;187:1436–41. https://doi.org/10.2214/AJR.05.1086.
13. Hattori H, Akasaka K, Ostudo T, Hall T, Amemiya K, Mori Y. The effect of repetitive baseball pitching on medial elbow joint space gapping associated with 2 elbow valgus stressors in high school baseball players. J Shoulder Elbow Surg 2018;27:592–8. https://doi.org/10.1016/j.jse.2017.10.031.
14. Hattori H, Akasaka K, Otsudo T, Hall T, Amemiya K, Mori Y, et al. Changes in medial elbow elasticity and joint space gapping during maximal gripping: reliability and validity in evaluation of the medial elbow joint using ultrasound elastography. J Shoulder Elbow Surg 2020;29:e245–51. https://doi.org/10.1016/j.jse.2019.11.005.
15. Hattori H, Akasaka K, Ostudo T, Takei K, Yamamoto M. The effects of elbow bracing on medial elbow joint space gapping associated with repetitive throwing in high school baseball players. Orthop J Spots Med 2017;5: 2325967117702361. https://doi.org/10.1177/2325967117702361.
16. Hodgins JL, Vitale M, Arons RR, Ahmad CS. Epidemiology of medial ulnar collateral ligament reconstruction: a 10-year study in New York State. Am J Sports Med 2016;44:729–34. https://doi.org/10.1177/0363546515622407.
17. Mahure SA, Mollon B, Shamah SD, Kwon YW, Rokito AS. Disproportionate trends in ulnar collateral ligament reconstruction: projections through 2025 and a literature review. J Shoulder Elbow Surg 2016;25:1005–12. https://doi.org/10.1016/j.jse.2016.02.036.
18. Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 1983;11:315–9.
19. Nagamoto H, Yamamoto N, Kurokawa D, Takahashi H, Muraki T, Tanaka M, et al. Evaluation of the thickness of the medial ulnar collateral ligament in junior high school baseball players. J Med Ultrason 2015;42:395–400. https://doi.org/10.1007/s10396-014-0605-1.
20. Olsen SJ II, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. Am J Sports Med 2006;34: 905–12. https://doi.org/10.1177/0363546505284188.
21. Otoshi K, Kikuchi S, Shishido H, Konno S. Ultrasonographic assessment of the flexor pronator muscles as a dynamic stabilizer of the elbow against valgus force. Fukushima J Med Sci 2014;60:123–8. https://doi.org/10.5387/fms.2014-7.
22. Pexa BS, Ryan ED, Myers JB. Medial elbow joint space increases with valgus stress and decreases when cued to perform a maximal grip contraction. Am J Sports Med 2018;46:1114–9. https://doi.org/10.1177/0363546518755149.
23. Sasaki J, Takahara M, Ogino T, Kashiwa H, Ishigaki D, Kanauchi Y. Ultrasonographic assessment of the ulnar collateral ligament and medial elbow laxity in college baseball players. J Bone Joint Surg Am 2002;84:525–31. https://doi.org/10.2106/00004623-200204000-00003.
24. Shanley E, Kissenberth MJ, Thigpen CA, Bailey LB, Hawkins RJ, Michener LA, et al. Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers. J Shoulder Elbow Surg 2015;24: 1005–13. https://doi.org/10.1016/j.jse.2015.03.012.
25. Wilk KE, Macrina LC, Fleisig GS, Aune KT, Porterfield RA, Harker P, et al. Deficits in glenohumeral passive range of motion increase risk of elbow injury in professional baseball pitchers: a prospective study. Am J Sports Med 2014;42: 2075–81. https://doi.org/10.1177/0363546514538391.