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Physical functions, to be or not to be a risk factor for osteochondritis dissecans of the humeral capitellum?

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Background: Physical risk factors for osteochondritis dissecans (OCD) of the humeral capitellum in young baseball players have not been fully elucidated. We aimed to identify the risk factors for capitellar OCD in baseball players aged 8-14 years.

Methods: Between December 2018 and December 2019, young baseball players were recruited from 8 regional baseball leagues. Ultrasonography and physical assessments were performed preseason and at the end of the study period. Bilateral passive ranges of motion (ROM) of horizontal adduction of the shoulders, internal rotation (IR) of the hips, and the thoracic kyphosis angle were measured. 1-year follow-ups were scheduled to determine the occurrence of OCD. Players with OCD were categorized into an OCD group; those without OCD and any elbow pain for one year were categorized into a non-injured group. The players' baseline data (age, sex, position in baseball, and Rohrer's Index) were analyzed using univariate analyses. Their physical parameters were analyzed using two-way analysis of variance with repeated measures to investigate OCD-related risk factors.

Results: In total, 3651 baseball players attended the 1-year follow-up. Of these, 71 (1.9%) players had OCD of the humeral capitellum. In the OCD group, a significant association was found at baseline and at the end of the study period between a higher Rohrer index at the baseline and a smaller hip IR ROM on the nondominant side.

Conclusions: Loss of hip IR ROM on the nondominant side is a newly discovered risk factor related to physical function in the development of OCD.

The fourth Ethics Research Review Subcommittee of Japanese Society of Physical Therapy approved this study on February 22, 2020. Approval Number: R01-005.

Informed consent was obtained from all participants and their guardians prior to study enrollment.

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Osteochondritis dissecans (OCD) of the humeral capitellum is a critical and relatively rare injury in young baseball players. Nonoperative treatment of capitellar OCD involves long-term rest from throwing, surgical treatments recommended for young baseball players with advanced stage capitellar OCD.[2,20] Previous cross-sectional studies have reported the prevalence of capitellar OCD to range from 1.3% to 3.4%.[3,5,17] The incidence of capitellar OCD has been reported in a limited number of prospective cohort studies. Matsuura et al[11] showed that the incidence of capitellar OCD within a 1-year period in young baseball players was 1.8%.

In athletic overhead throwing, the elbow is subjected to valgus overload.[16] Valgus stress increases contact pressure in the radiocapitellar joint.[13] The cause of OCD of the humeral capitellum might be due to repetitive compression forces on the humeroradial joint, and this microtrauma may lead to articular cartilage changes and stress reactions to subchondral bone (humeral capitellum). However, one previous study found no association between the player position, age at starting to play baseball, and years of play, and capitellar OCD.[11] Some studies have reported that the risk factors for capitellar OCD include ischemia of the humeral capitellum[4,24] and genetic factors.[22] However, no definitive study of the risk factors associated with capitellar OCD has been published.

Two prospective studies have identified some physical risk factors for throwing elbow injury in adolescent and youth baseball players.[18,21] With respect to height and weight, Lyman et al[10] reported that much taller or heavier players were at an increased risk of elbow pain occurrence. Shanley et al[21] reported that posterior shoulder tightness conferred a greater risk for throwing injuries in adolescent baseball players. Sakata et al[18] reported that the risk of medial elbow injury increased in young players with excessive thoracic kyphosis and in those with a silent elbow extension deficit. They also reported a significant relationship between medial elbow injury and decreased hip flexibility.[18] However, no previous studies have investigated the physical functions associated with lateral elbow injury in young baseball players because of the low prevalence of capitellar OCD. Therefore, this prospective study aimed to identify the physical risk factors for capitellar OCD in young baseball players. We hypothesized that players with shoulder tightness and hip rotational ROM deficits would be at greater risk of OCD than those without.

Materials and methods

This multicenter, prospective, cohort study across 8 regions covered a baseball season (December 2018 to December 2019). Ethical approval was obtained from the appropriate institutional review board. We recruited young baseball players (age, 8-14 years) who played for baseball leagues from each region, and informed consents were obtained from all participants and their guardians prior to the study enrollment. Exclusion criteria comprised players (i) who were injured at the initial examination, (ii) unable to undergo the physical assessments, and (iii) with a diagnosis of OCD at the initial examination.

Baseline data including age, sex, and the position in baseball (a pitcher or other) were collated for analysis. Players' height and weight were measured. Normal body mass index (BMI) values in children and adolescents vary as they gain in height and weight[15]; therefore, Rohrer's Index (weight (kg)/height (m)^3 $\times$ 10) was used to evaluate the players' physique.

All examinations (ie, ultrasonographic and physical examinations) were conducted prior to the start of the baseball season. The ultrasonographic examinations were performed by orthopedic surgeons and sonographers. The number of examiners ranged from 2 to 10 in each region, and all examiners had more than ten years of experience in examining throwing elbow injuries using an ultrasound device. Both sides of the humeral capitellum were assessed using short- and long-axis ultrasound approaches. The ultrasonographic examinations were performed, as previously described.[3,5,12,17] The probe was placed on the anterolateral aspect of the elbow in extension and on the posterolateral aspect of the elbow in flexion. An irregularity (Fig. 1, *A* and *a*), a break in the continuity of the echo line (Fig. 1, *B* and *b*), or a double line of subchondral bone of the capitellum (Fig. 1, *C* and *c*) was determined to be an abnormal finding. A positive finding was declared when the aforementioned abnormalities were observed on the throwing side.

Physical therapists were blinded to the ultrasonographic findings, and the number of examiners varied from 10 to 25 in each region. Training sessions were conducted before physical assessments were undertaken to ensure consistency across the different sites. All examiners underwent a process of familiarization with each physical assessment to confirm that the same values would appear for the same participant at least 10 times.

Bilateral passive ROM in internal rotation (IR) of the hips at 90° flexion was measured using a universal goniometer with the participant in a supine position. The hip IR intraclass correlation coefficient (ICC) was excellent (0.965), and the standard error of the mean (SEM) hip IR measurement was 2.2°.[1] Shoulder horizontal adduction (HA) was measured using a digital inclinometer (DWL-80Pro, Digi-Pas Inc., Cambridge, UK) with each participant lying in a supine position, and the scapula stabilized. Shoulder HA ROM deficits (nondominant − dominant) were calculated. The ICCs were high concerning the intra- (0.93; SEM, 1.64°) and inter-tester (0.91; SEM, 1.71°) measurements.[7] The thoracic kyphosis angle was measured with players in a relaxed standing position using a manual inclinometer (Bubble Inclinometer, Baseline Inc., NY, USA). The thoracic kyphosis angle was calculated as the summation of the angle of the manual inclinometer placed over the spinous processes of the first and second thoracic vertebrae (T1 and T2), and the angle of the inclinometer placed over the spinous processes of T12 and the first lumbar vertebrae.[9] The intra-tester reliability of this test has previously been established (ICC 0.95; SEM, 1°).[8] All measurements were performed once.

One year after the initial examination, the participants underwent ultrasonography of the elbow and physical assessment using the same methods, as previously described. They also reported of any elbow and/or shoulder pain since the initial examination. The occurrence of capitellar OCD was declared when the aforementioned morphological abnormalities were not present at the initial examination, but present at the last examination on the throwing side. Players with OCD were categorized into an OCD group, and those without OCD and elbow and/or shoulder pain over a 1-year period were categorized into a non-injured group. Players without OCD but with elbow and/or shoulder pain were excluded.

An unpaired *t*-test was used to compare age and Rohrer's index values between the 2 groups. A chi-square test was used to evaluate categorical variables (sex and position in baseball) to investigate the risk factors for OCD. Two-way analysis of variance with

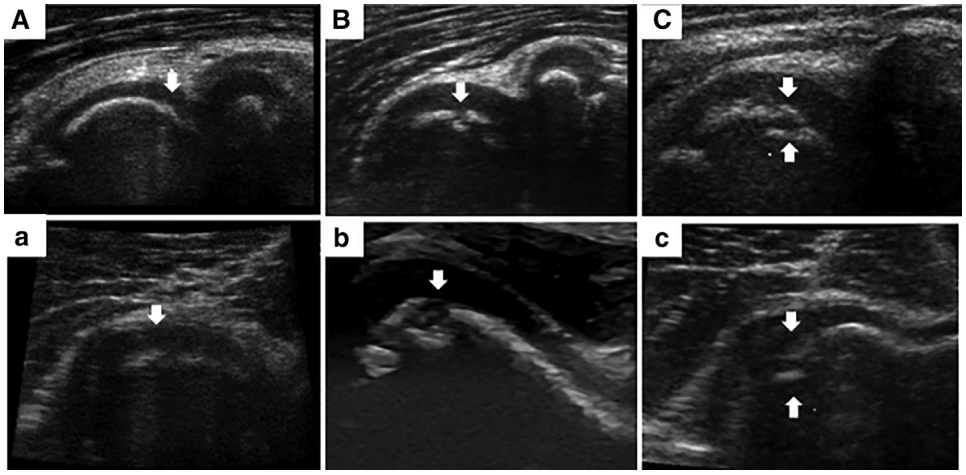

Figure 1 Ultrasonographic images of the humeral capitellum. Irregularity (*arrow*) is seen on the capitellum (**A**: anterior long-axis view and **a**: anterior short-axis view). A break in the continuity (*arrow*) is seen on the capitellum (**B**: anterior long-axis view and **b**: posterior short-axis view). Double floor line (*arrows*) is observed on the capitellum (**C**: anterior long-axis view and **c**: anterior short-axis view).

repeated measures (two groups, non-injured and OCD, and two time points, baseline and end of study period) were also performed to determine the physical risk factors for OCD. When no significant interaction effect was observed on the two-way analysis of variance, only single main effects were analyzed. Single main effects were evaluated for significant differences between the groups using a Bonferroni correction for alpha. All data were analyzed using PASW Statistics 18 (IBM Japan, Tokyo, Japan) software. Statistical significance was set at a P value < .05.

Results

At the time of the initial examination, 3978 players had agreed to participate in this study. Of these, 81 players presented with capitellar OCD at the initial examination and 246 players dropped out of the study. In total, 3651 players completed the follow-up during one season period (Fig. 2).

A total of 1859 (50.9%) players reported having had elbow and/or shoulder pain in the throwing arm during the 1-year follow-up period without the occurrence of OCD. Seventy-one (1.9%) players had been diagnosed with capitellar OCD. Of these, 44 reported elbow pain. The incidence of OCD did not differ between male (2.0%) and female (0%) participants ($P = .055$), and between pitchers (1.0%) and those in other positions (2.0%) ($P = .087$). The average ages of the players in the two groups did not differ significantly (non-injured group, 10.5 ± 1.1 years; OCD group, 10.5 ± 0.8 years, $P = .715$). The incidence of OCD remained almost the same (range, approximately from 1% to 3%) throughout each age group, except for a slight decrease at age 14 years at the initial examination (Fig. 3). Univariate analysis showed that the OCD group was significantly associated with a higher Rohrer index (non-injured group, 123.7.5 ± 16.2; OCD group, 131.7 ± 19.7, $P = .001$).

There were no significant interaction effects among the following variables (Fig. 4): shoulder HA ROM of the throwing side ($F = 0.056$, $P = .813$), deficit in shoulder HA ROM ($F = 0.483$, $P = .487$), hip IR ROM on the dominant side ($F = 0.387$, $P = .534$), hip IR ROM on the nondominant side ($F = 0.0001$, $P = .984$), and thoracic kyphosis angle ($F = .593$, $P = .492$). The simple main effects in the OCD and non-injured groups at baseline were identified as significantly different, hip IR ROM on the nondominant side (non-injured group, 37.5 ± 12.7; OCD group, 34.1 ± 12.1; $P = .05$). The difference in hip IR ROM at baseline was 3.4° (95% confidence interval [CI] 0.005-6.946). IR ROM on the nondominant hip at the end of the study period was also found to be significant for simple main effects in the OCD and non-injured groups (non-injured group, 35.0 ± 12.4; OCD group, 31.5 ± 11.5; $P = .041$). The difference in hip IR ROM at the end of study was 3.5° (95% confidence interval 0.136-6.889).

Discussion

This study aimed to identify the physical risk factors for capitellar OCD in young baseball players. This is the first prospective cohort study to investigate the physical risk factors for OCD of the humeral capitellum. Matsuura et al[11] reported an incidence rate of 1.8% concerning capitellar OCD within one year in preadolescent baseball players, and players aged 10-11 years had a significantly greater risk of developing OCD than those aged 6-9 years. In this study, the incidence of OCD was similar (1.9%). In addition, our results showed that the occurrence of OCD was similar in participants aged 8-13 years, with a peak age at 10-11 years. Otoshi et al[17] found that the prevalence of capitellar OCD remained the same for all ages in players in the later years of elementary school. Our results were consistent with these findings, and capitellar OCD onset appears to occur more commonly in players in the later years of elementary school, between the ages of 9 and 12 years, who have immature elbows.

The Rohrer index has been used to assess obesity in children. In this study, OCD was associated with a higher Rohrer index. The Rohrer index of the OCD group was 131.7 ± 19.7, which did not reflect obesity in this age group. Komiya et al[6] reported that, as children grow, their Rohrer index decreases. Therefore, it may be that the higher Rohrer index in the OCD group was affected by their growth phase. One risk factor for OCD might be immaturity in development. Takahara et al[23] showed that separation of the immature epiphyseal cartilage is an early event in OCD. Our study suggests that OCD begins at an age at which the epiphyseal cartilages are immature.

As in previous studies concerning the risk of medial elbow injury,[18] we found that a reduced hip IR ROM on the nondominant side was a risk factor for capitellar OCD. A preventive intervention study also found that an improvement in IR ROM on the nondominant side after intervention was related to a reduced incidence of medial elbow injury.[19] A difference in hip IR of only 3.4° between the injured and non-injured groups at baseline has been associated with an increased risk of OCD, and hip flexibility

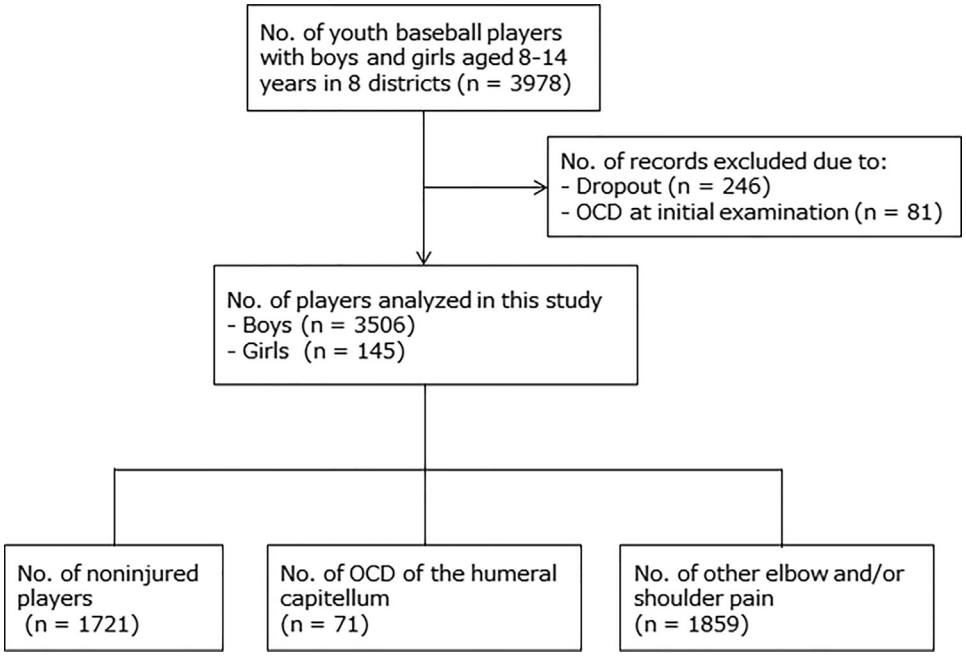

Figure 2 A Flow diagram of exclusion criteria and the outcomes. *OCD*, osteochondritis dissecans.

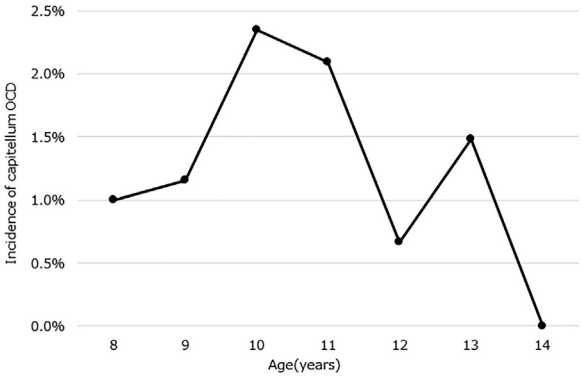

Figure 3 The incidence of capitellar OCD according to age. The incidence of capitellar OCD remained at almost the same level at all ages, with a peak at ten years old at the initial examination.

has been shown to be modifiable using a prevention program.[19] However, Bullock reported that the minimum clinically important difference in the hip IR in the youth baseball players was 5.1°.[1] While our results were statistically significant, they were not clinically significant. Milewski et al[14] evaluated the biomechanics of the lower extremities during the pitching cycle in adolescent pitchers. They found that the hip IR angle was 7° ± 11° at foot contact and 15° ± 13° at ball release. Hip IR is considered to be important at ball release; however, our results indicated that the hip IR angle at ball release was within the passive hip IR ROM in the OCD group. Further studies are needed to clarify the relationship between hip flexibility and pitching biomechanics.

In contrast, the thoracic kyphosis angle was not found to be associated with capitellar OCD. The thoracic kyphosis angle has been reported to be associated with medial elbow injuries in young players; an excessive kyphosis angle may decrease the scapular contribution to the maximum shoulder external rotation during throwing, resulting in an increased stress on the elbow joint.[18] This might suggest dissimilarity with the mechanism of medial elbow injury and OCD of the humeral capitellum. As noted, there was no association found between shoulder HA ROM and OCD. One study reported that adolescents (aged 13-18 years) with HA ROM deficits were at a greater risk of arm injury than younger individuals aged 8-12 years.[21] These results suggest that shoulder tightness may not be a risk factor for throwing injuries in young baseball players.

This study had some limitations. First, reporting of elbow and/or shoulder pain was based on questionnaires completed only at initial and final examinations. For young players, it may have been difficult to recall elbow or shoulder injuries over the course of one year. Second, we did not analyze other potential risk factors such as total years played, the number of throws, and pitching mechanics. Third, OCD was defined using ultrasonography only and not radiography, whereas previous studies have used both these examination methods.[5,11,12] Finally, all tests were performed by multiple examiners at 8 different regions. The same examiners participated throughout the study; however, players' preseason measurements and their final measurements were taken by different examiners. Although we sought to ensure data consistency, it is possible that not all examiners performed ultrasonography of the elbow and physical assessments to the same quality level.

Conclusions

Although some risk factors for medial elbow injury in young and adolescent baseball throwers have been reported, including joint ROM, muscle flexibility, and muscle strength, no previous studies have examined the physical risk factors for lateral elbow injury in young baseball players. We found that reduced hip IR on the nondominant side correlated with OCD of the humeral capitellum. Increasing hip flexibility might be a key factor in preventing capitellar OCD.

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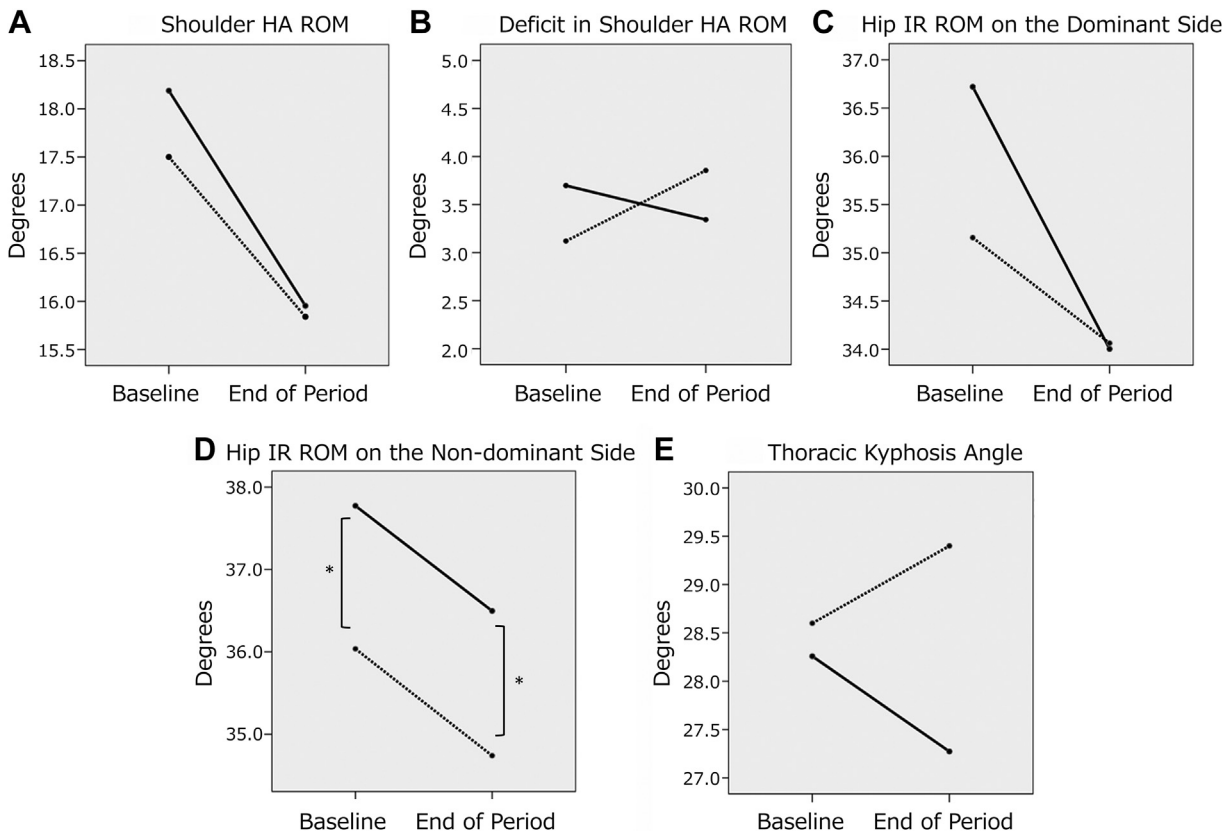

Figure 4 The annual change in variables of physical function. Thick lines show the group's mean values for the non-injured group at baseline and at the study endpoint. Dotted lines show the mean values for the OCD group. *Significant simple main effect at each of baseline and endpoint of follow-up ($P < .05$) *HA*, horizontal adduction; *IR*, internal rotation; *ROM*, range of motion; *OCD*, osteochondritis dissecans.

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