Efficacy of a Prevention Program for Medial Elbow Injuries in Youth Baseball Players

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Background: Youth baseball players are at high risk for elbow injuries, which can lead to future functional disability.

Purpose: To evaluate the effectiveness of a prevention program to lower the risk of medial elbow injury in these athletes.

Study Design: Cohort study; Level of evidence, 2.

Methods: Youth baseball players, 8 to 11 years old, without a history of elbow and shoulder pain, were allocated to either the intervention (n = 136) or control (n = 169) group. The intervention consisted of 9 strengthening and 9 stretching exercises, performed during warm-up or at home, with high compliance defined as completion of the program 1 or more times per week. The following outcome variables were measured: clinical assessment of the elbow and shoulder joint, ultrasonography assessment of the elbow, and assessment of physical function (passive range of motion of the elbow, shoulder, and hip; strength of the shoulder and scapular muscles; and measurement of the thoracic kyphosis angle). The clinical and ultrasonography assessments were measured at baseline and at 3-month intervals over the 1-year follow-up. Physical function outcomes were measured at baseline and at the endpoint of the follow-up. The primary endpoint of effectiveness was the incidence of medial elbow injury. Secondary endpoints were absolute measures of physical function and change in these measures over the 1-year follow-up.

Results: The incidence rate of medial elbow injury was significantly lower in the intervention group (0.8/1000 athlete-exposures) than the control group (1.7/1000 athlete-exposures) (hazard ratio, 50.8%; 95% CI, 0.292-0.882; $P = .016$). The program improved total range of shoulder rotation (dominant side), hip internal rotation (nondominant side), shoulder internal rotation deficit (bilaterally), lower trapezius muscle strength (dominant side), and the thoracic kyphosis angle. Improvements in the following variables of physical function were predictive of a lower rate of medial elbow injury: increased total shoulder total rotation (odds ratio [OR], 0.973; 95% CI, 0.950-0.997), increased hip internal rotation of the nondominant side (OR, 0.962; 95% CI, 0.936-0.989), and decreased thoracic kyphosis angle (OR, 1.058; 95% CI, 1.015-1.103).

Conclusion: A prevention program aiming to improve physical function can prevent medial elbow injury in youth baseball players.

Keywords: youth baseball player; medial elbow injury; prevention; intervention

Youth baseball players are at high risk for elbow injuries, and 25% of pitchers aged 9 to 12 years report elbow pain while pitching.[11] Moreover, the resulting pain and/or limitation in range of motion can lead to future impairment in upper limb function and disability.[1] Therefore, prevention programs are needed regarding elbow injuries related to throwing in young baseball players.

Young players are susceptible to 2 principal types of elbow conditions associated with pitching: osteochondritis dissecans of the humeral capitellum and medial elbow injury. van Mechelen et al[31] described 4 stages of injury prevention in sport: analysis of the magnitude of the injury, clarification of the mechanism and risk factors of the injury, development of a prevention program, and evaluation of the effectiveness of the prevention program. Medial elbow injuries in youth baseball players meet the van Mechelen criteria for prevention due to their high prevalence. The incidence of elbow pain in youth players has been estimated at 1.5 per 1000 athlete-exposures (AEs), with a rate of medial elbow injury of 1.4 per 1000 AEs.[25] Specifically in high school baseball players, aged 13 to 18 years, Shanley et al[26] reported a rate of elbow pain of 1.0 per 1000 AEs, with the risk of medial elbow injury being higher in youths than in older players. Injury

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to the medial elbow results from the excessive valgus moment and stretch stress placed on this structure during the pitching motion. Sakata et al[25] recently identified an increase in thoracic kyphosis and deficits in elbow extension as factors that increased the risk of medial elbow injury with pitching. Previous prospective studies have further reported the following physical risk factors as being associated with throwing injuries of the shoulder and elbow: altered shoulder range of motion (ROM),[7,26,29] posterior shoulder tightness,[26,29] rotator cuff weakness,[29] scapular dysfunction,[17] lower extremity muscle tightness,[33] and deficits in single-leg standing balance.[33] Theoretically, improving or modifying these physical risk factors could lower the risk of medial elbow injury. However, to our knowledge, prospective studies have not been conducted to evaluate the effectiveness of an intervention program focused on improving these functional factors in lowering the incidence of medial elbow injury in youth baseball players.

The aim of our study was to evaluate the effectiveness of a prevention program that we developed to improve physical function in lowering the incidence of medial elbow injury in youth baseball players. We hypothesized that our program would be effective in reducing the incidence of medial elbow injury by 50%, compared with a control group who maintained their usual training. Additionally, we evaluated the contribution of the 1-year change in targeted physical function on the incidence of medial elbow injury in this sport population over a 1-year period. We also hypothesized that a decrease in the thoracic kyphosis angle would further lower the incidence rate of medial elbow injury. These hypotheses were based on previous studies that have reported an incidence rate of medial elbow injury twice as high among players with a thoracic kyphosis angle greater than 30° than in those with an angle 30° or less.[25]

METHODS

We conducted a nonrandomized controlled trial comparing the incidence of medial elbow injury during a 12-month follow-up period between 2 groups: an intervention group of participants who performed the prevention program and a control group of participants who continued their usual training. The present study was approved by our institutional review board, and informed consent was obtained from all participants and their guardians before enrollment. The guidelines for Transparent Reporting of Evaluations with Nonrandomized Designs[4] were applied.

Participants

A minimum sample size of 304 participants was determined to be necessary to detect a 50% reduction in the incidence of medial elbow injury, over a 1-year period, at a power of 80% (2-tailed α of .05), based on a predicted annual incidence of medial elbow injury of 25%. With an expected dropout rate of 10%, and considering that 30% of participants would likely have a history of elbow or shoulder pain, our accrual target was 483 participants. To meet this accrual target, we recruited 33 youth baseball teams from 2 independent regional leagues in Yokohama City, Japan, between December 2013 and November 2014. Players who could not fully participate on the team during the 1-year follow-up period and those with an injury or illness that limited their participation were excluded.

Participants completed a detailed questionnaire to provide relevant personal information (age, sex, height, and weight), baseball position played (pitcher or other), the typical number of throws performed per day, the hours of baseball played per day, and previous elbow and/or shoulder pain related to throwing.

Teams were purposefully allocated to the intervention or control group based on their regional location. Participants in the intervention group were instructed to perform our throwing injury prevention program during the warm-up period (or at home) at least once per week. Participants in the control group continued their usual training over the study period. All participants underwent clinical assessment, ultrasonography, and measurement of physical function (ROM, strength, and posture), before the start of the baseball season and at the endpoint of the 1-year follow-up. In addition, clinical and ultrasound assessments were conducted at 3-month intervals over the follow-up to record the occurrence of a new injury. Each examination was performed by the same examiner, who was blinded to group assignment.

Intervention

Our intervention program, named Yokohama Baseball-9 (YKB-9), included 9 stretching and 9 strengthening exercises designed to improve parameters of physical function identified as risk factors for throwing injuries in previous studies.[7,12,17,25,26,29,33] The individual components of the stretching program are described in Figure 1. Stretching exercises were designed to improve ROM of the elbow (stretching exercises 1 and 2), shoulder (stretching exercises 3-5), and hip (stretching exercises 8 and 9) and to improve posture (stretching exercises 6 and 7) (all shown in Figure 1). All stretches were held for 10 seconds. The individual components of the strengthening program are described in Figure 2. Strength exercises focused on the rotator cuff (strength exercises 1-3), scapular function (strength exercises 4 and 5), posture (strength exercises 6 and 7), and lower extremity balance (strength exercises 1, 8, and 9) (all shown in Figure 2). Twenty repetitions of the strength exercises for the rotator cuff were performed, and 10 repetitions were performed for the remaining exercises. The total prevention program could be completed in about 20 minutes, and participants were asked to complete the YKB-9 at least once a week, either during the warm-up period or at home. The program was demonstrated to participants in the intervention group, and their coaches, by a physical therapist at 3 time points: baseline and 1 and 3 months after program initiation. Players and coaches also received a leaflet describing the program items to increase compliance.

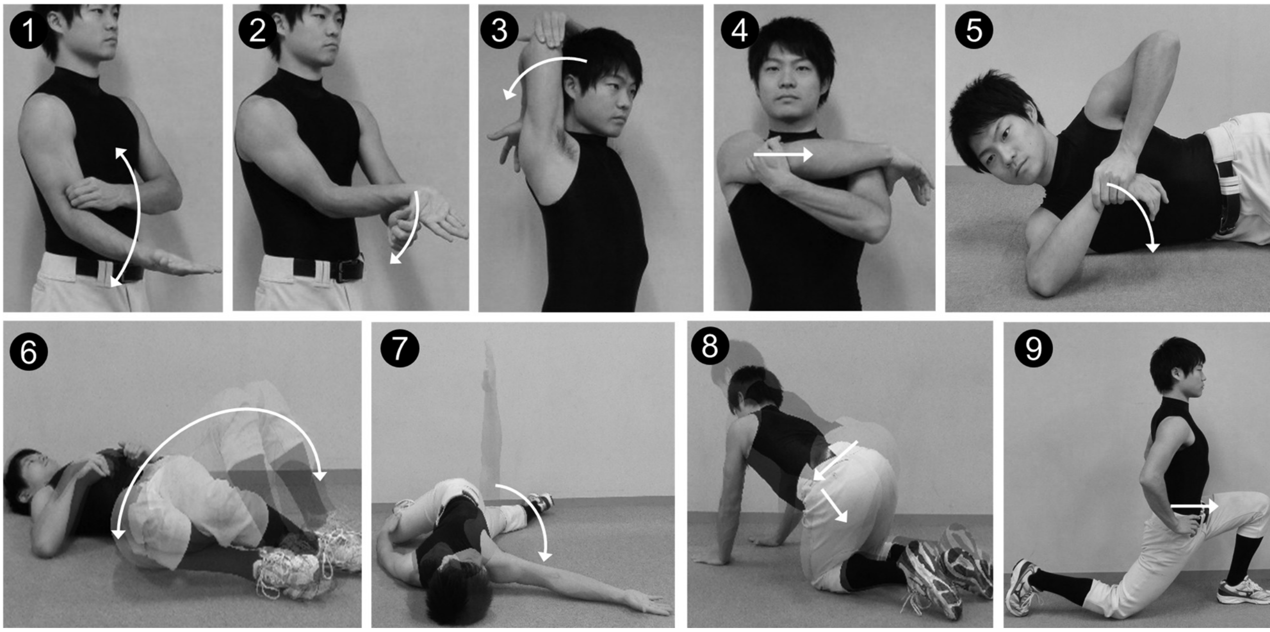

Figure 1. Nine stretching exercises in the Yokohama Baseball-9 protocol. (1) Brachial muscle massage: grip distal brachial muscles and extend the elbow continuously (dominant side, 10 times). (2) Pronator muscle stretch: with the palm facing upward, hold the thumb and pull down while supinating the forearm and extending the wrist (dominant side, 10 s). (3) Triceps muscle stretch: raise the arm above the head, bend the elbow, and pull the elbow backward (dominant side, 10 s). (4) Cross arm stretch: bring the arm across the chest and pull the elbow inward (dominant side, 10 s). (5) Sleeper stretch: put the elbow in front of the chest and push the forearm down toward the floor (dominant side, 10 s). (6) Mobilization of the lower thorax: hold the anterior edge of the lower ribs and rotate the pelvis actively (both sides, 10 times). (7) Trunk rotation stretch: rotate the trunk with horizontal abduction of the shoulder (both sides, 10 s). (8) Posterior hip stretch: start on all fours and slide the pelvis toward lateral and posterior side (nondominant side, 10 s). (9) Hip flexor stretch: step forward and move the pelvis forward (dominant side, 10 s).

Registration of Injury Incidence, Exposure, and Compliance

Every 3 months, researchers visited the teams to complete the clinical and ultrasonography assessments. The following clinical information was recorded by the physical therapist (J.S.) at each time point of assessment for the elbow: medial elbow pain with flexion, extension, and valgus stress (performed with the elbow in 30° of flexion and a moving valgus stress test[19]). For the shoulder, the following information was recorded: tenderness on palpation of the proximal humeral epiphysis, pain with resistance applied to shoulder internal (IR) and external (ER) rotation with the shoulder in 0° of elevation, Hawkins test, full/empty-can test, and pain on resisted ER with the shoulder in 90° of abduction. The medial aspect of the elbow was evaluated by 3D/4D ultrasonography (Voluson I; GE Healthcare) performed by a medical doctor (A.A.) with more than 10 years of experience in diagnosing throwing elbow injuries using ultrasonography. The morphological features of the medial epicondyle were assessed to detect irregularity in the inferior edge of the medial epicondyle (along its short axis) and partial or complete bone fragmentation (along its long axis). A positive case was defined as morphological changes only of the throwing arm.[25]

Participants were provided with diaries for daily recording of episodes of elbow and/or shoulder pain. The criteria for clinically meaningful pain were as follows: duration more than 2 weeks, inability to practice or play in a game due to the pain, or pain recurrence.[22] A medial elbow injury was defined as medial elbow pain during throwing associated with abnormal findings on the ultrasonography or clinical assessment. Similarly, a throwing shoulder injury was defined by pain during throwing with abnormal findings on the clinical assessment. The endpoint of analysis was the proportion of players in the control and intervention groups who experienced a first episode of medial elbow injury or shoulder injury during the 1-year follow-up period. Athlete-exposure (AE) was defined as 1 athlete participating in 1 practice or game where the player is at risk of sustaining an injury to the elbow or shoulder. Participants recorded their number of practices or games in their diary, and these events were used to calculate the incidence of elbow and shoulder pain and injury. Participants also recorded in their diary the number of times they completed the YKB-9 per week, and this information was used to calculate compliance. For analysis, compliance was classified as follows, based on the study by Walden et al[32]: high compliance, defined by completion of the program at least once per week, on

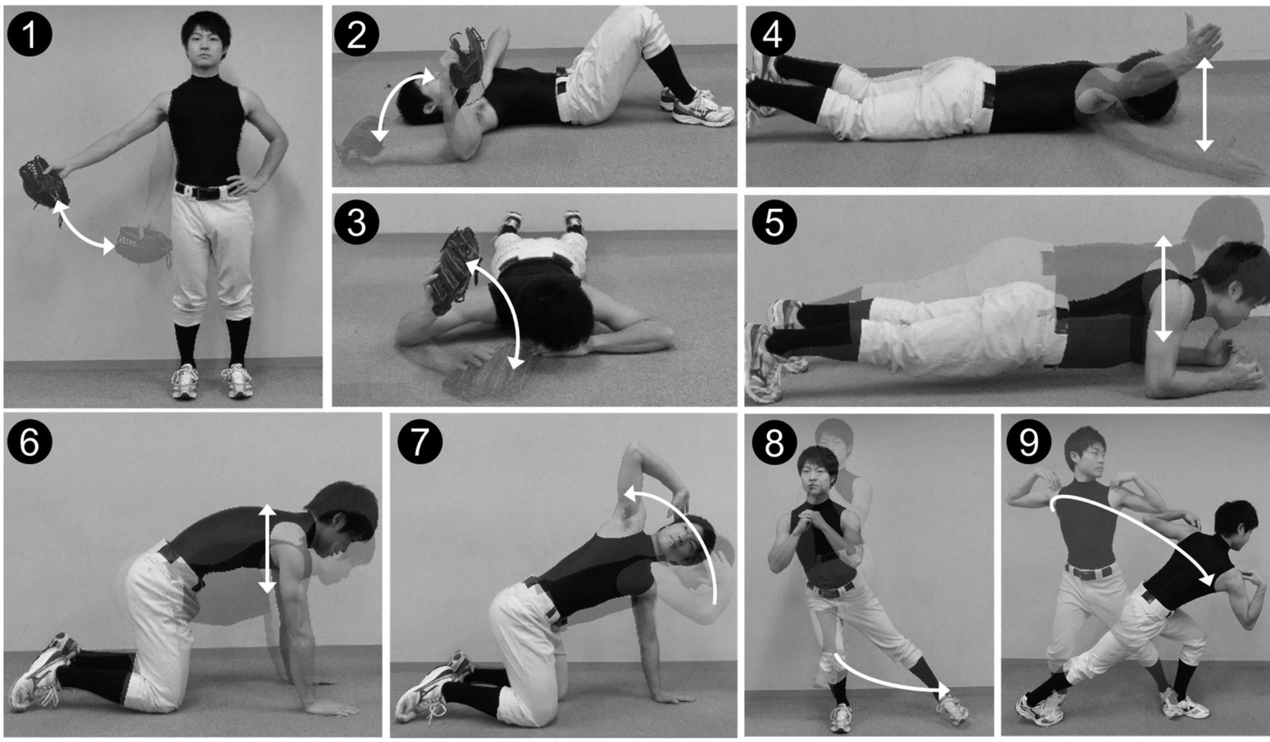

Figure 2. Nine strength exercises in the Yokohama Baseball-9 protocol. (1) Supraspinatus exercise: using a baseball glove, grip the glove and abduct the shoulder 60° (dominant side, 20 times). (2) Subscapularis exercise: grip the glove and rotate the shoulder (dominant side, 20 times). (3) Teres minor exercise: place the glove above the head and lift it from the floor (dominant side, 20 times). (4) Trapezius exercise: use the same position as in strength exercise 3, extend the elbow, and then lift the arm from the floor (dominant side, 10 times). (5) Push-up plus on elbow: assume the plank position, lift both knees from floor, and then push up and down using scapula (10 times). (6) Upper back rounding exercise: assume the all-fours position, extend the spine with scapular retraction, and roll the spine with scapular protraction (10 times). (7) Trunk rotation exercise: use the same position as in strength exercise 6, put the hand on the head, and then rotate the trunk with scapular retraction (both sides, 10 times). (8) Lateral slide exercise: assume a single-leg stance on the dominant leg and reach laterally with the nonweightbearing (nondominant) leg (10 times). (9) Elbow to knee exercise: step forward, with hands on shoulders, and rotate the pelvis to touch the elbow to knee (nondominant side, 10 times).

average; and low compliance, defined by completion of the program less than once per week, on average.

Physical Function Measurements

The following physical function variables were evaluated by a physical therapist (J.S.): passive ROM of elbow extension; shoulder ROM in ER and IR with the shoulder in 90° of abduction; total shoulder rotation (ER + IR); ROM of shoulder horizontal adduction (HA), measured with a digital inclinometer (DWL-80Pro; Digi-Pas Inc, Cambridge Ventura) as per the methods of Laudner et al[8]; and IR of the hip at 90° of flexion, measured with a standard goniometer. All measures were obtained bilaterally, with deficits in ROM defined as a difference between the nondominant and dominant limb. Strength of the dominant limb was measured by a physical therapist (E.N.) using hand-held dynamometry (MicroFET; Hoggan Health Industries Inc) for shoulder IR and ER and for selected scapular muscles (lower trapezius muscle and serratus anterior). Hand-held dynamometry provides a valid and reliable measure to detect muscle weakness of the shoulder complex.[14,28,30] Measurements were repeated twice, and the average of the 2 measurements, normalized to body weight, was used for analysis.

For the evaluation of posture, participants assumed a relaxed standing position, and a physical therapist (J.S.) measured the thoracic kyphosis angle using an inclinometer (Bubble Inclinometer; Baseline Inc) placed over the spinous processes of the first and second thoracic vertebrae and another placed over the spinous processes of the twelfth thoracic and first lumbar vertebrae. These measurements were taken once. The thoracic kyphosis angle was calculated as the sum of these angles.[20] The intra- and intertester reliability of this measurement has been established (intraclass correlation [single], 0.95; 95% CI, 0.91-0.97).[9,10]

To evaluate the change in physical function, measurements were performed before the intervention and at the 1-year follow-up, and the difference in measurement from these 2 time points was calculated.

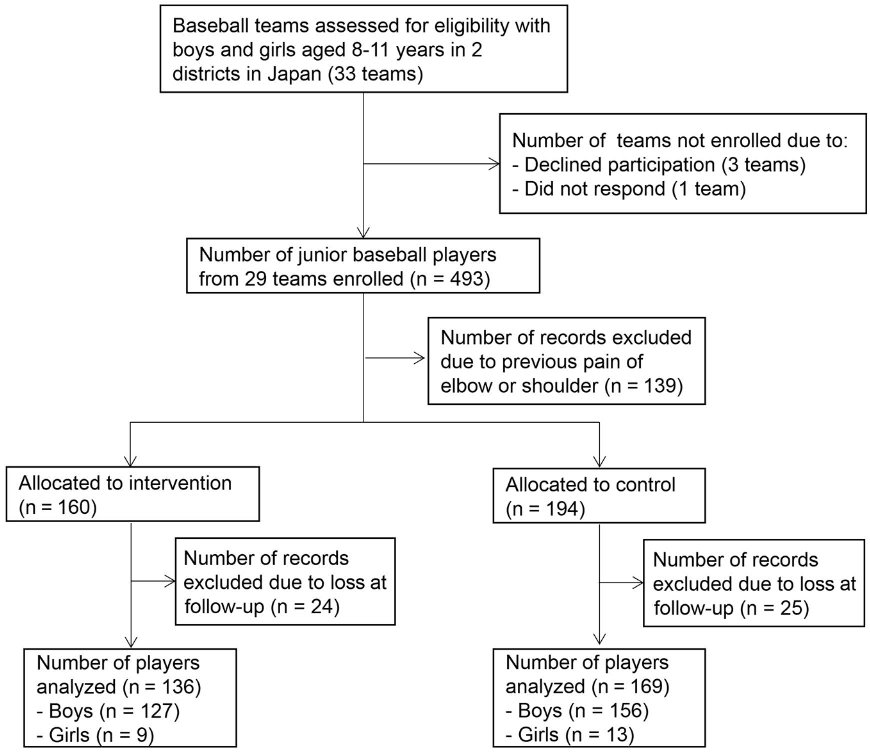

Figure 3. Study flow diagram.

Statistical Analysis

Differences in baseline characteristics between the intervention and control groups were evaluated by univariate analysis for continuous variables (age, total number of practices and games, body mass index, practice days per week, and playing hours per day). For normally distributed continuous data (ascertained by the Kolmogorov-Smirnov test), an unpaired *t* test was used for between-group comparisons, and the Mann-Whitney *U* test was used for nonnormally distributed data. In an intention-to-treat analysis, we used the log rank test to evaluate the influence of position played, pitch count, and the intervention program on the incidence of medial elbow and shoulder injury. For variables with a *P* value less than .05 on the log rank test, a Cox regression analysis was used to estimate the hazard rate ratio (and its 95% CI) between the intervention and control groups. The effect of the intervention program on the 1-year change in physical function measures was evaluated by use of a 2 × 2 analysis of variance (ANOVA) with repeated measures (2 groups, intervention and control; and 2 time points), before and after the intervention. The homogeneity of variances was analyzed with Levene's test. For variables with equal variance, the data were adequately transformed before the ANOVA was conducted. The hypothesis of interest was the Intervention × Time interaction, and main effects were evaluated for significant interactions by use of a Bonferroni correction for alpha. In the absence of significant interactions, only main effects were analyzed. When main effects of the intervention were identified, post hoc multiple comparisons were used, with Bonferroni adjustment, to determine the direction of the effect.

The 1-year changes in measured physical function variables identified as being significantly influenced by the intervention were entered into a multivariable logistic regression to identify the effective variables of the prevention program. Only variables with $P < .05$ were retained in each model. Models were developed by use of a forward stepwise (conditional) regression, with the odds ratio (ORs) and the profile likelihood 95% CIs from the final model reported. All data were analyzed with PASW Statistics 18 (IBM Japan).

RESULTS

Thirty-three eligible clubs were approached for recruitment, and 493 players from 29 teams agreed to participate. Of these, 139 players had previous elbow or shoulder pain and 49 players dropped out, with 305 players completing the follow-up. Of these 305 players, 136 were allocated to the intervention group and 169 players to the control group (Figure 3), with no between-group differences at baseline (Table 1 and see Figure 5).

Over the 1-year follow-up, 22 players (16.2%) in the intervention group reported elbow pain and 15 (11.0%) reported a shoulder injury of the pitching arm. Among the 22 players with elbow pain, 4 players also reported

TABLE 1
Univariate Analysis for Baseline Characteristics

Variable	Intervention Group Mean	Intervention Group SD	Control Group Mean	Control Group SD	P Value
Age, years	9.7	1.0	9.5	1.0	.110
Total years played	2.3	1.3	2.4	1.3	.467
Body mass index, kg/m^2	16.9	2.1	16.9	2.0	.354
Practice days per week	3.7	2.0	3.4	2.1	.102
Playing hours per day	3.1	0.8	3.2	0.9	.314

a shoulder injury. A medial elbow injury was identified in 17 of the 22 players who reported elbow pain (12.5% of the intervention group). When a medial elbow injury occurred, the morphological condition of the medial epicondyle of these players was as follows: 2 normal, 7 irregular, 4 partial fragment, 3 complete fragment, and 1 combined irregular and partial fragment. In comparison, in the control group, 47 players (27.8%) reported elbow pain and 22 (13.0%) reported a shoulder injury of the pitching arm, with 6 players reporting both elbow pain and a shoulder injury. Among the 47 players who reported elbow pain, a medial elbow injury was identified in 43 (25.4% of the control group). Of 43 players with a medial elbow injury, the conditions of the medial epicondyle were as follows: normal, 2 cases; irregular, 15 cases; partial fragment, 13 cases; complete fragment, 8 cases; irregular and partial fragment, 4 cases; and combined irregular and complete fragment, 1 case.

The overall incidence of elbow pain was 1.1 per 1000 AEs in the intervention group and 1.9 per 1000 AEs in the control group, with an incidence of medial elbow injury of 0.8 per 1000 AEs and 1.7 per 1000 AEs, respectively. The overall incidence of a throwing shoulder injury was 0.7 per 1000 AEs in the intervention group and 0.9 per 1000 AEs in the control group.

On the log rank test, the pitcher position and the intervention were significantly associated with a medial elbow injury ($P < .05$), and pitch count was not identified as a contributing factor ($P = .247$). The Cox regression analysis, based on the intention to treat, showed a statistically significant 49.2% reduction in the incidence of medial elbow injury in the intervention group compared with the control group (hazard rate ratio, 50.8%; 95% CI, 0.292-0.882; $P = .016$; Figure 4), this risk being independent of pitcher position (95% CI, 0.331-1.054; $P = .075$). No variables were associated with a pitching shoulder injury: intervention, $P = .353$; pitcher position, $P = .077$; and pitching count, $P = .349$.

With regard to compliance with the prevention program, 78 players (57.4%) in the intervention group were compliant, performing the program 1.3 times per week on average (high-compliance subgroup). The remaining 58 players in the intervention group (42.6%) had low compliance, performing the program 0.3 times per week on average (low-compliance subgroup). The incidence of medial elbow injury was 0.5 per 1000 AEs in the high-compliance subgroup compared with 1.2 per 1000 AEs in the low-compliance subgroup.

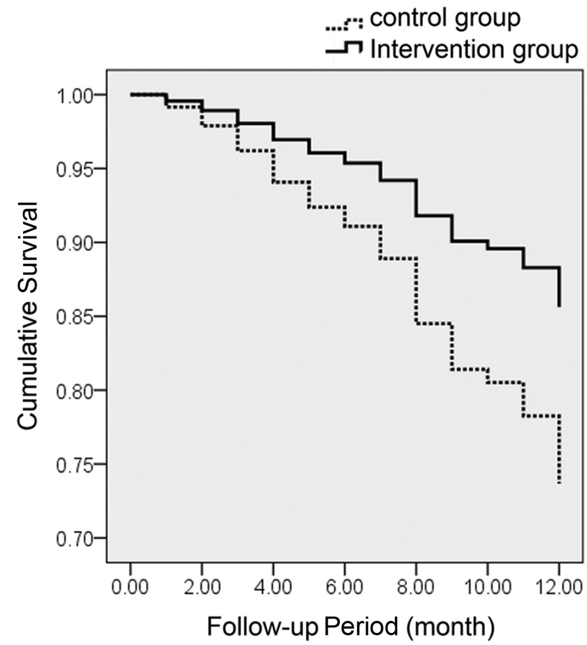

Figure 4. Survival curve for players without medial elbow injury in the intervention and control groups. The rate of medial elbow injury in the intervention group was decreased 49.2% compared with the control group.

A significant interaction between the intervention and the 1-year change in the following physical function variables was identified by repeated-measures ANOVA (Figure 5): total rotational ROM of the dominant shoulder ($F = 16.076$, $P < .001$); IR ROM of the nondominant hip ($F = 4.987$, $P < .05$); strength of the lower trapezius muscle of the dominant side ($F = 5.390$, $P < .05$); and thoracic kyphosis angle ($F = 11.378$, $P < .01$). The following simple main effects of the intervention at the endpoint of follow-up were identified: total rotation ROM of the dominant shoulder ($P < .001$), IR ROM of the nondominant hip ($P < .01$), lower trapezius muscle strength of the dominant side ($P < .01$), and thoracic kyphosis angle ($P < .001$). Accordingly, at the endpoint of follow-up, total rotation ROM of the dominant shoulder ($P < .001$) and IR ROM of the nondominant hip ($P < .01$) were significantly lower in the control than the intervention group, with a larger increase in the thoracic kyphosis angle ($P < .001$) over the 1-year follow-up for the control than the intervention group. A significant increase in the strength of the lower trapezius muscle on the dominant side was identified in the intervention group ($P < .01$).

No significant interaction effect was identified for the following variables (Figure 6): deficit in elbow extension ($F = 1.584$, $P = .209$), deficit in shoulder IR ROM ($F = 3.007$, $P = .084$), deficit in shoulder HA ROM ($F = 2.508$, $P = .114$), hip IR ROM on the dominant side ($F = 1.574$, $P = .211$), shoulder ER strength on the dominant side ($F = 1.508$, $P = .221$), shoulder IR strength on the dominant side ($F = 3.339$, $P = .066$), and serratus anterior strength on the dominant side ($F = 0.076$, $P = .783$). The simple

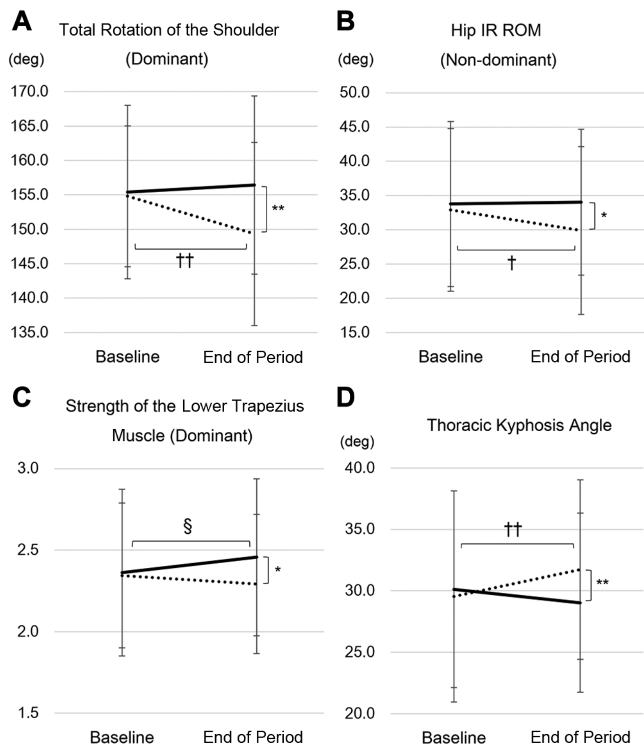

Figure 5. One-year change in measured variables of physical function with a significant interaction effect. Thick lines show the group mean values at baseline and at the endpoint for the intervention group, and dotted lines show the mean values for the control group. *Significant simple main effect of intervention at the endpoint of follow-up, $P < .01$. **Significant simple main effect of intervention at the endpoint of follow-up, $P < .001$. †Significant simple main effect of time in the control group, $P < .01$. ††Significant simple main effect of time in the control group, $P < .001$. §Significant simple main effect of time in intervention group, $P < .05$.

main effect of the intervention was not significant for the deficit in elbow extension ($P = .415$), shoulder HA ROM ($P = .936$), hip IR ROM on the dominant side ($P = .519$), shoulder ER strength on the dominant side ($P = .910$), shoulder IR strength on the dominant side ($P = .297$), and serratus anterior muscle strength on the dominant side ($P = .685$). A unique simple main effect of the intervention on the deficit of shoulder IR ROM was identified ($P < .001$). Multiple post hoc comparisons identified a significant between-groups difference in the deficit in shoulder IR ROM at the endpoint of follow-up ($P < .01$). The main effect of time was significant for the deficit in elbow extension ($P < .001$) and shoulder IR ROM ($P < .01$) and for shoulder ER and IR strength on the dominant side ($P < .001$).

On multivariate logistic regression analysis, the following 3 variables were identified as being important for the prevention of medial elbow injury: 1-year change in total rotation of the shoulder on the nondominant side (OR = 0.973; 95% CI, 0.950-0.997), hip IR ROM on the nondominant side (OR = 0.962; 95% CI, 0.936-0.989), and the thoracic kyphosis angle (OR = 1.058; 95% CI, 1.015-1.103).

DISCUSSION

We undertook this study to evaluate the effectiveness of a prevention program consisting of 9 stretching and 9 strengthening exercises in lowering the incidence of medial elbow injury among youth baseball players. The main results of the study were as follows. First, the YKB-9 resulted in significantly fewer players sustaining a medial elbow injury in the intervention group than in the control group. Second, the YKB-9 improved physical risk factors associated with medial elbow injury, namely shoulder total rotation ROM, hip IR ROM, and the thoracic kyphosis angle. On the basis of these findings, we propose that it may be possible to prevent medial elbow injury by improving or modifying physical risk factors.

Prevention of Throwing Injuries

Pitching-related injuries of the upper limb are common in youth baseball players, with an incidence rate of elbow pain of 20.4% to 30.5%.[7,12,13,25] Of note, the injury rate of our control group was comparable with these previously reported elbow injury rates (25.4%). Considering the high rate of medial elbow injury in youth baseball players,[12] it is important to develop prevention programs to reduce the risk for these injuries. Several factors have been associated with an increased risk of medial elbow injury, including an asymptomatic elbow extension deficit, limitation in shoulder ROM, increased posterior shoulder tightness, rotator cuff weakness, scapular dysfunction, lower extremity muscle tightness, deficits in single-leg standing balance, and poor posture.[5,7,17,25,26] Therefore, we developed our prevention program to improve physical variables that can increase the risk of medial elbow injury, and we provide evidence of the effectiveness of this approach, with a 49.2% decrease in the incidence of medial elbow injury. To our knowledge, we are the first to have adopted this approach for the prevention of elbow injuries in youth baseball players. Moreover, although several studies have suggested that limiting the number of pitches is important to reduce the risk of injuries,[6,12] we have demonstrated that pitch count was not predictive of medial elbow injury after our prevention program improved the physical risk factors underlying this throwing injury. These results suggest that decreasing the mechanical stress on the elbow by improving physical function could prevent medial elbow injury despite increasing the pitch count.

Effectiveness of the Intervention in Improving Physical Function Variables

The YKB-9 yielded significant improvements in the total rotation ROM of the shoulder on the dominant side, the deficit in shoulder IR ROM, the deficit of hip IR ROM on the nondominant side, and strength of the lower trapezius muscle on the dominant side, and the program decreased the thoracic kyphosis angle. Of these factors, improvement in total shoulder rotation ROM, hip IR ROM, and the

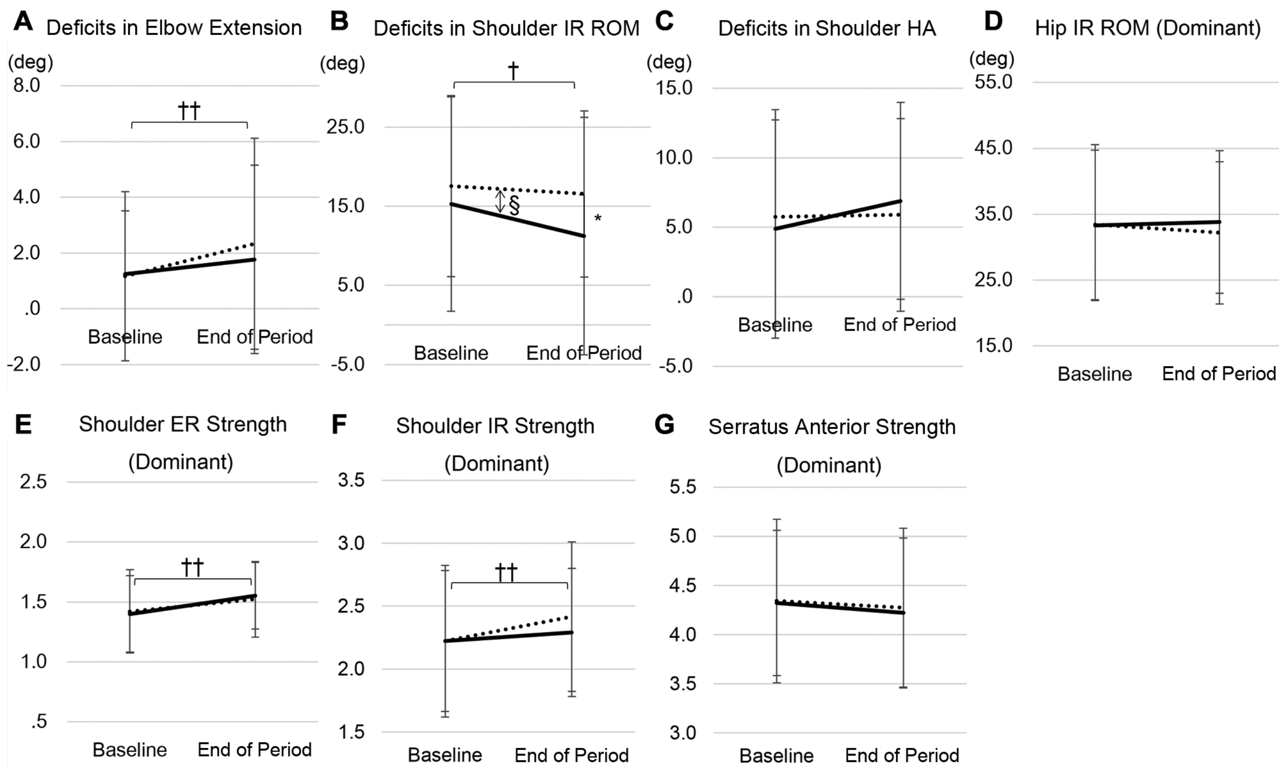

Figure 6. One-year change in measured variables of physical function with no significant interaction effect. Thick lines show the group mean values at baseline and at the endpoint for the intervention group, and dotted lines show the mean values for the control group. †Significant main effect of time, $P < .01$. ††Significant main effect of time, $P < .001$. §Significant main effect of the intervention, $P < .01$. *Significant difference of intervention at the endpoint, $P < .01$.

thoracic kyphosis angle were predictive of a reduced incidence of medial elbow injury.

During pitching, a varus torque at the elbow of 27 N·m, at most, is generated in youth baseball players.[18] Anz et al[2] demonstrated that injury to the medial elbow was associated with the magnitude of elbow varus torque generated at the point of maximum shoulder rotation. Therefore, the late cocking phase of the pitching motion is the critical point for the risk of medial elbow injury. Miyashita et al[16] reported that the ratio of the maximum ER angle at the shoulder during pitching to the available range of ER ROM at the shoulder was related to the incidence of medial elbow injury. Therefore, maintaining (or increasing) the range of total shoulder rotation could reduce the amount of valgus stress on the elbow during pitching.

Miyashita et al[15] also reported that movement at the glenohumeral joint, combined with scapular and thoracic movements, contributes significantly to the maximum ER of the shoulder complex. A decrease of the kyphosis angle may increase the contribution of thoracic movement and decrease the magnitude of stress exerted on the elbow at the point of maximum shoulder rotation during throwing. Sakata et al[25] reported a relationship between medial elbow injury and the thoracic kyphosis angle, where a 2-fold increase in injury incidence was associated with a thoracic kyphosis angle of 30° or greater. In the intervention group of the current study, the thoracic kyphosis angle did not change over the 1-year follow-up. By comparison, the kyphosis angle increased over the 1-year follow-up period among players in the control group. The predictive contribution of the thoracic kyphosis angle to the incidence of medial elbow injury was confirmed on multivariate logistic regression analysis. Therefore, improving posture may be a necessary component to prevent medial elbow injuries in youth baseball players.

By comparison, the research on the relationship between hip ROM and throwing injuries is limited.[24,25] Our prospective study previously revealed a significant association between medial elbow injury and decreased hip IR ROM of the nondominant side.[21,25] Insufficient IR ROM of the hip can alter pitching mechanics, reducing the transfer of energy from the lower extremities to the pitching arm. Further studies are needed to clarify the relationships between IR ROM of the hip, pitching mechanics, and medial elbow injuries.

Compliance

Among players in the high-compliance group, the incidence of medial elbow injury was 0.5 per 1000 AEs, which was one-third of the rate for the control group. Compliance with the YKB-9 is essential to obtain the prevention effects. Differences in compliance among players may be associated with various factors, including understanding of the importance of the exercises by both players and their coaches. Future study is needed to investigate the optimal frequency for the prevention program.

The rate of high compliance (more than once per week) for our program was not high (57.4%) compared with the compliance rates reported in previous studies of lower limb injury prevention.[21,27] Compliance may be influenced by players' age, as the age of our study group was lower than that in previous studies. In addition, the length of the program (18 items and 20 minutes for completion) may lower compliance.

Certainly, not all items in our program improved the measured variables of physical function. For example, strength was increased only for the trapezius muscle (Figure 2, strength exercise 4; Figure 5C); the strengthening exercises for the rotator cuff and scapular muscles had no effect (Figure 2, strength exercises 1, 2, 3, and 5). Therefore, the training load of the strengthening components of our program should be reconsidered.

A player's motivation for persisting with the YKB-9 during the 1-year follow-up period may have influenced compliance. Moreover, we did not consider performance-related factors, including a player's motivation to pitch faster or with increased control. Describing the positive effect of the program on performance would likely be important to increase compliance in healthy youth baseball players and their coaches. Further research is needed to investigate the association between pitching performance and physical function and the effect of a prevention program on these factors.

Limitations

The limitations of our study should be acknowledged in the interpretation of our results. Foremost, participants were not randomized to the intervention and control groups. Rather, we used purposeful allocation by region. However, as the regions were independent of each other, no information about the prevention program was available to the control group. Furthermore, we could not blind the players to their group assignment during injury surveillance. Further studies designed for randomization and participant blinding are needed to reduce researcher bias. As well, we did not consider other potential risk factors for medial elbow injury, and the mechanics of the pitching motion were not evaluated although these are known to contribute to elbow pain.[3,11,23] With regard to the prevention program, we evaluated the volume of exercises performed but did not monitor the quality of the routine performed by individual players. To standardize the intervention, the players should be encouraged to be focused and conscious of the quality of their movements and position when performing the exercise components. Finally, we excluded players with previous elbow or shoulder pain in order to exclude the effect of past treatment on measured physical function. Therefore, the effect of our program for secondary prevention is unknown.

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