Effect of Clubbell Training on Glenohumeral Internal and External Rotation, Muscle Function, and Ball Velocity in Baseball Pitchers

Won-Ho Choi*; Jung-No Lee

Department of Physical Education, Graduate School, Dankook University, Republic of Korea

ABSTRACT

OBJECTIVES This study examined the effects of clubbell exercises in a pitcher training program on the range of motion (ROM), muscle function, and its subsequent influence on pitching velocity. Additionally, this study aimed to develop an optimal training program to prevent injury while improving pitcher performance.

METHODS Eighteen pitchers were included and equally divided into clubbell exercise and control groups. Clubbell training was conducted through 60-minute sessions twice a week for 12 weeks. Internal/external rotational (IR/ER) ROM, IR/ER muscle strength, muscle endurance, muscle power, and pitching velocity were measured before and after the intervention.

RESULTS The IR ($p = 0.051$) and total ROM (TROM; $p = 0.05$) of the throwing arm decreased in the control group but increased in the clubbell exercise group, with an observed tendency of interaction. In the non-throwing arm, the ER ROM was significantly different between the two groups ($p < 0.05$), also with an observed tendency of interaction ($p = 0.055$). IR peak torque per body weight at 60°/sec significantly increased in both groups over the exercise period ($p < 0.01$). Total work per body weight and average power of IR at 180°/sec increased in both groups over the exercise period ($p < 0.01$). The pitching velocity decreased in both groups throughout the exercise period ($p < 0.05$).

CONCLUSIONS Although 12 weeks of clubbell training had limited effects on ROM, the findings revealed that this exercise could be effective in improving pitching performance, preventing injuries, and maintaining long-term performance. Further studies are recommended for a more detailed assessment.

Introduction

Performance in baseball games is determined by physical, technical, mental, and tactical factors. These factors have varying influences depending on the game level and age of the players. Among them, physical aspects differ depending on the characteristics of the player’s role [1].

The throwing motion, which is the most common action in baseball, accounts for approximately 70% of the total physical activity and can be divided into two forms: pitching and throwing [2]. Pitching consists of various phases as follows: the wind-up phase, involving lifting one knee; stride phase, with inward rotation and abduction of the shoulder where the front foot contacts the ground as the ball is removed from the glove and the arm is opened; arm cocking phase, in which maximal external rotation occurs when the shoulder joint abducts by 90°; acceleration phase, when the ball is released at maximum external rotation; deceleration phase, with maximum internal rotation of the shoulder from ball release; and follow-through phase, with maximum internal rotation of the shoulder to

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*Correspondence: Department of Physical Education, Graduate School, Dankook University, 152, Jukjeon-ro, Suji-gu, Yongin-si, Gyeonggi-do, 16890, Republic of Korea; Tel: +82-10-6210-1307; Fax: +82-41-550-3831; E-mail: yoonchan45@naver.com

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When pitching, power is continuously transmitted from the lower extremities through the hips, torso, shoulders, and hands [5]. The pelvis and torso connect the lower and upper extremities, transmitting the momentum from the lower extremities to the upper extremities [6,7]. Steps and trunk rotation generate approximately 46.9% of pitching velocity, and the remaining 53.1% is added by the shoulder joint [8].

The rotational force of the arm increases during the arm cocking and acceleration phases. At this time, the external rotation of the shoulder and external torque of the elbow are significantly loaded [9]. Previous studies have reported that the external rotation of the shoulder reaches 170° during the cocking phase, and the external torque of the shoulder during maximal external rotation increases up to 70 Nm [4,10]. In addition, the angular velocity of the internal shoulder rotation in the acceleration phase reaches 7,250°/s, and the distraction force on the shoulder joint during ball release is approximately 1–1.5× the bodyweight [11]. Therefore, pitchers who repeat rapid throwing motions use their shoulder joints excessively, leading to structural and functional changes in the shoulder joint, which consequently causes decreased joint mobility and increased risk of injuries [12,13].

To prevent these damages, pitchers must have flexible shoulder joints, muscle strength, and shoulder stabilization to withstand the substantial load on the shoulder [14,15]. Proper range of motion (ROM) and shoulder joint strength reduce injuries and improve the pitching motion during the season [16,17]. Pitching velocity increases with greater maximum external rotation of the shoulder in the early stage of the acceleration phase [18,19]. Moreover, increased strength in the shoulder, lower extremity muscles, trunk flexors, and greater joint flexibility are related to improved pitching ability [8].

In baseball, pitchers play an essential role in determining the game’s outcome, and pitching velocity is an important attribute that can lead to victory or defeat [20]. Therefore, various training methods have been suggested to increase pitching velocity. Resistance training is known to develop the total body endurance, shoulder strength, and lower body strength required to improve pitching performance [21].

Similar to a baseball bat, a clubbell positions the center of gravity outside the hand [22], and uses inertia according to the movement of the center of gravity during dynamic exercise to improve the shoulder ROM [23]. Moreover, clubbell use contracts the muscles around the shoulder simultaneously, thereby stabilizing the shoulder joint. Additionally, the energy generated from the lower extremities during clubbell exercise is transferred through the trunk to the upper extremities and activates the core muscles [24]. Among javelin throwers, the clubbell exercise group showed greater improvement in terms of the javelin throwing record and physical ability test as compared to the control group [25]. Another study reported that the clubbell exercise group improved; although there was no statistical difference in the effect on the shoulder joint, the range of motion of the shoulder joint was slightly improved [26]. The study suggested that clubbell training could be used as a training program for physical activities or sports that use the shoulder and arm extensively. Moreover, An et al. [27] reported that the performance improvement of the clubbell training group in terms of accuracy and distance was higher in the grenade-throwing performance evaluation. Therefore, training programs using a clubbell would help improve pitchers’ performance by increasing the ROM and strength of the shoulder joint and by activating the pitcher’s core muscles. However, there is a lack of evidence on the efficacy of clubbell exercise for increasing pitching velocity.

Thus, this study analyzed the effects of introducing clubbell training to existing resistance exercise regimes on ROM, muscle strength, endurance, and power and assessed the resulting changes in pitching velocity. In addition, this study was conducted to develop an optimal training program to improve pitching performance and decrease injury.

Methods

Participants

Eighteen first- to fourth-year university baseball pitchers in the C and D areas who were official members of the Korean Baseball Organization (KBO) and were previously diagnosed with and treated for shoulder and elbow joint injuries were included in this study. Before inclusion, the study’s aims, scope, and assessment methods were fully explained to the participants, as were precautions to be undertaken during
the study period. The groups were classified into a clubbell training group (CTG) and a group continuing the existing training (CON). Voluntary informed consent was obtained from all participants.

**Body composition**

The participants’ heights were measured using a BSM370 automatic height measuring instrument (InBody, Biospace Inc., Seoul, Korea). Their weights and BMIs were measured using an InBody770 analyzer (InBody, Biospace Inc., Seoul, Korea). Bodyweight was measured in kilograms. The participants were prohibited from consuming alcohol or exercising for 12 hours and fasted for 8 hours before measurements. Physical characteristics of participants were shown in Table 1.

**Shoulder joint range of motion**

A goniometer (Goniometer, Hamar, USA) was used jointly by one evaluator and one assistant to measure the shoulder joint ROM. ROM was measured as internal rotation (IR), external rotation (ER), and total ROM (TROM; IR + ER). First, with the participant in the supine position, the shoulder joint was abducted 90° and pronated horizontally at 10°. Then, the elbow was bent at 90° for measurement. To stabilize the scapula, the assistant placed their thumb on the participant’s coracoid process and held the scapula with their other hand to prevent compensatory action of the participant. Three measurements were taken, and the average was used for analysis [28].

**Shoulder joint muscle function**

Biodex System Pro4 (Biodex Medical System, USA), an isokinetic muscle strength assessment device, was used to measure muscle strength, power, and endurance during extension and flexion of the shoulder joint. These results were used to assess maximum muscle strength, maximum muscle strength per body weight, muscle power, and muscle endurance. Muscle strength and power were measured five times at an angular velocity of 60°/sec, while muscle endurance was measured 25 times at an angular velocity of 180°/sec. Before measurement, participants were asked to perform light walking and stretching for ten minutes, and education on external and internal rotation methods was provided. A sample test was also performed to ensure that participants were fully aware of the assessment method [11].

**Measurement of pitching velocity**

Pitching velocity was measured when the players felt prepared after sufficient individual pitching on the mound and long tosses. The pitching distance was 18.44 m, equivalent to the distance from the pitcher’s mound to home plate. The speed gun (Bushnell velocity speed gun, USA), used to measure the pitching velocity, was installed behind the catcher. Each participant was asked to pitch ten times at maximum effort and rest for at least ten seconds between each pitch. The maximum value out of the ten pitches was defined as the pitching velocity.

**Exercise training**

The pitchers performed their regular strength training. Additional clubbell training was conducted through 60-minute sessions twice a week for 12 weeks. Each session include 10 minutes warm-up, 40 minutes clubbell training, and 10 minutes cool-down. The clubbell program details are shown in Table 2.

**Statistical analysis**

Statistical analysis was performed using SPSS (version

| Table 1. The characteristic of subjects |
|-----------------------------------------|
| Group | N | Age (years) | Height (cm) | Weight (kg) | BMI (kg/m²) | Career (years) |
|-------|---|-------------|-------------|-------------|-------------|----------------|
| CON   | 9 | 20.92 ± 1.75| 176.00 ± 4.16| 77.13 ± 7.82| 24.84 ± 1.60| 10.92 ± 1.75  |
| CTG   | 9 | 20.78 ± 1.39| 181.33 ± 3.54| 82.71 ± 7.96| 25.17 ± 2.51| 10.78 ± 1.39  |

Data are expressed as mean±SD. CTG, clubbell training group; CON, control group.
| Exercise composition | Exercise type |
|----------------------|--------------|
| **1–4 weeks** (Left and right with 10~15 lbs, 10 reps, 3 sets) | |
| Front arm cast | Torso twist |
| Side shoulder cast | Front circle |
| Forward two-handed Order lunge | Two-handed Side swing |
| **5–8 weeks** (left and right with 10~15 lbs, 15 reps, 3 sets) | |
| Arm cast (front) | Side shoulder cast |
| Front circle | Front Pendulum |
| Side Pendulum | Mill cast |
| Two-handed technical SWIPE | Two-handed side swing |
| Straddle-stance lift up | |
| **9–12 weeks** (left and right with 10–20 lbs, 15 reps, 3 sets) | |
| Technical SWIPE (Lt./Rt.) | Lunge torso twist (Lt./Rt.) |
| Technical MILL (Lt./Rt.) | |
| Hammer swing | Two-handed Shield cast |
25.0), and the statistical significance level was set to α = 0.05. Descriptive analysis was used to determine the mean and standard deviation of the variables. An independent t-test was performed to determine the differences between the CTG and CON groups before clubbell training. In addition, two-way repeated measures ANOVA (group; time) was performed to compare the changes after the training between the two groups (CTG and CON), and time (pre- and post-training measures) the within-participants factor. An analysis of covariance was performed on the values as covariates before training when there were differences in values between the two groups. When there were differences in values before training between the two groups, an analysis of covariance was performed on the values as covariates before training.

Results

Changes in the range of motion

Table 3 shows the changes in the pitchers’ ROMs following clubbell exercise. IR ROM ($p = 0.051$) and TROM ($p = 0.05$) of the throwing arm decreased in the control group but increased in the clubbell exercise group, tendency of interaction effect was observed ($p < 0.05$). At baseline, the ER ROM ($p < 0.01$) and TROM ($p < 0.05$) of the non-throwing arm were different between the groups. In the non-throwing arm, ER ROM observed significant difference between group ($p < 0.05$) and TROM observed tendency of interaction effect ($p = 0.055$).

Changes in the function of shoulder muscle

Table 4 shows the changes in the pitchers’ muscle function following clubbell exercise. IR peak torque per body weight at 60°/sec increased in both groups, significant changes over the exercise period ($p < 0.01$) was observed. ER peak torque per body weight was decreased in both groups, showing a tendency for changes over the exercise period ($p = 0.056$). Total work per body weight and average power of IR at 180°/}

| Table 3. The changes of range of motion after clubbell training |
|-----------------------------------------------|
| Throwing Arm | Pre | Post | $\Delta$ | F    | Sig |
|---------------|-----|-----|-------|------|-----|
| IR (°)        | CON | 62.78 ± 17.70 | 58.44 ± 16.60 | -4.33 ± 8.08 | G x T | 4.305 | .051 |
|               | CTG | 58.92 ± 53.77 | 53.77 ± 23.50 | 4.85 ± 11.40# | T    | .013 | .909 |
|               |     | 1.251 | .277 | | G    |     |     |
| ER (°)        | CON | 100.00 ± 12.25 | 97.00 ± 12.79 | -3.00 ± 10.30 | G x T | 1.407 | .249 |
|               | CTG | 87.69 ± 14.86 | 89.38 ± 11.62 | 1.69 ± 8.25  | T    | .109 | .744 |
|               |     | 3.552 | .074 | | G    |     |     |
| TROM (°)      | CON | 162.78 ± 23.99 | 155.44 ± 20.67 | -7.33 ± 12.87 | G x T | 4.342 | .050 |
|               | CTG | 146.62 ± 25.94 | 143.15 ± 28.98 | 6.54 ± 16.80# | T    | 1.212 | .285 |
|               |     | 1.726 | .205 | | G    |     |     |
| Non-throwing Arm | Pre | Post | $\Delta$ | F    | Sig |
|-----------------|-----|-----|-------|------|-----|
| IR (°)          | CON | 73.89 ± 20.88 | 70.56 ± 15.29 | -3.33 ± 11.46 | G x T | 3.900 | .062 |
|                 | CTG | 67.69 ± 12.18 | 77.31 ± 15.76 | 9.62 ± 17.13  | T    | .918 | .349 |
|                 |     | .002 | .964 | | G    |     |     |
| ER (°)          | CON | 91.67 ± 5.00 | 91.78 ± 8.23 | 0.11 ± 6.57   | G x T | 1.038 | .321 |
|                 | CTG | 78.85 ± 14.17## | 83.08 ± 11.82 | 4.23 ± 10.58# | T    | 3.808 | .066 |
|                 |     | .530 | .476 | | G    |     |     |
| TROM (°)        | CON | 165.56 ± 18.62 | 162.33 ± 14.39 | -3.22 ± 15.42 | G x T | 1.035 | .322 |
|                 | CTG | 146.57 ± 23.04# | 160.39 ± 23.23 | 13.85 ± 21.52# | T    | 7.682 | .012 |
|                 |     | 1.035 | .322 | | G    |     |     |

Data are expressed as mean±SD. CTG, clubbell training group; CON, control group; IR, internal rotation; ER, external rotation; TROM, total range of motion (IR+ER); $\Delta$, % of change between pre and post; #, the difference changes value between CTG and CON.
sec increased in both groups over the exercise period \( p < 0.01 \). There was no difference in shoulder muscle function before and after the clubbell exercises for all variables between the two groups \( p > 0.05 \).

**Changes in pitching velocity**

Table 5 shows the changes in ball velocity of the pitchers after clubbell exercise. The pitching velocity decreased in both groups, showing significant changes over exercise period \( p < 0.05 \).

Discussion

Changes in the ROM and strength of the shoulder can affect injury risk in pitchers by altering the biomechanics of the upper extremities [14]. The IR of the pitching arm decreases while ER increases [28,29]. These alterations to the ROM are the consequences of soft tissue (posterior shoulder tightness and anterior capsular laxity) [30,31] and osseous (humeral head retroversion) adaptations [32,33] due to repetitive stress. The loss of glenohumeral IR by posterior...
shoulder tightness and the increase in ER motion by anterior capsular laxity are related to injuries of the throwing shoulder and elbow [28,29,34,35].

In this study, after including clubbell exercises in the training program of pitchers for 12 weeks, the IR ROM and TROM significantly increased in the clubbell exercise group and significantly decreased in the control group. These findings reveal that clubbell exercises may prevent ROM loss for pitchers during the season. The effects of clubbell exercise are thought to be mediated by typical swing, cast, circle, mill cast, pendulum, and swipe motions (shoulder flexion, extension, pronation/abduction, and internal rotation/external rotation) of the shoulders [36]. Furthermore, clubbell use stretches the shoulder muscles, and controlling the various forces of the clubbell may help increase shoulder stability [24,37].

Yamamoto et al. [38] showed that repeated throwing motions did not aggravate humeral retroversion. High throwing volumes in 13- to 16-year-old athletes during the development stage increased humeral retroversion; however, adult athletes did not show any additional bony changes. In fact, it was suggested that the changes in adult pitchers were likely due to soft tissue alterations. [38]. Reinold et al. [31] showed that the IR ROM and TROM changes of professional pitchers lasted for 24 hours. They measured ROM before, immediately, and 24 hours after 50–60-pitch bullpen sessions. These changes in ROM were caused by acute musculoskeletal adaptations. It was noted that the contraction of extensor muscles during the follow-through phase increased passive muscle tension and induced loss of joint ROM [39]. In addition, high eccentric muscle activity was observed in ER-related muscles of the shoulder during the pitching motion involving 6,000–7,000º of internal rotation [40,41,42]. This repetitive eccentric contraction induced loss of ROM in the upper and lower extremities [43,44,45]. In contrast, Lintner et al. [30] showed that IR ROM was maintained or increased compared to in the control group following a minimum of a 3-year pitcher stretching program. Therefore, the increases in IR ROM and TROM in the clubbell exercise group may result from soft tissue adaptations to the clubbell exercises.

Pitchers experience an approximately 7% increase in IR force and a 1% decrease in ER force during the season [11]. In our study, IR peak torque per body weight at 60º/sec, total work per body weight, and average power of IR at 180º/sec were all increased in both groups. However, ER peak torque per body weight at 60º/sec significantly decreased in both groups, consistent with the findings of previous studies. The differential changes in the strength of the two muscle groups are caused by different muscle functions during the pitching motion [14]. Hinton [46] revealed that during the acceleration phase, the adductor muscles are activated for contraction. During pitching, the adductor muscle activity was similar to that during a plyometric style of training. Those explosive contractile muscle contractions were observed in the acceleration phase after maximum external rotation. Muscle power significantly increased after a similar type of plyometric strength training [47].

In contrast, the deceleration phase of the pitching motion leads to the eccentric activity of the externally rotated muscles [48,49]. Substantial eccentric loads cause tearing of the connective tissues in the muscle fibers, leading to chronic muscle damage and weakness [46]. Therefore, the differences in muscle contractions during pitching motions were suggested as a potential cause of muscle-specific adaptations in the pitchers’ strength [50]. However, in the current study, there was no difference in muscle strength, endurance, or power between the groups using 10- and 15-kg clubbells. These findings reveal that changes in the muscle function of the shoulder are caused by repetitive pitching motion during the season.

We also observed a decreased pitching velocity in both groups, unlike in our previous study on the effects of clubbell exercise infielders. These results showed a 3%–4% reduction in the joint surface of all motions after the 8-month season [11]. The alterations were thought to be related to fatigue of the rotator cuff, which is crucial for balance and stabilization of the GH joint [51]. In baseball, large and small injuries occur a lot during the season, and it is reported that shoulder injuries account for 17% of them [52]. Athletes experience repetitive micro-traumas during continuous training and play. Specifically for pitchers, posterior shoulder tightness and anterior capsular laxity during the season impair functional movement, leading to decreasing, impairing movement
performance and skill efficiency [53,54]. Specifically, the strength of IR and ER at 0° and 90° was measured using a grip dynamometer in 23 pitchers, and the IR and ER force was decreased by 20% in the 90° abduction state [55]. In this study, peak torque of IR and ER was carried out at 90° abduction, and the pitchers underwent training in the second half of the season (September to November). Therefore, the overall pitching velocity decreased possibly because of fatigue.

Conclusions

In this study, clubbell exercise in pitchers during the season maintained or increased the ROM; however, it did not improve the muscle strength or performance of the pitchers. Meanwhile, ROM of the shoulder joint is the primary cause of shoulder injury in pitchers leading to a decline in performance. Therefore, although 12 weeks of clubbell exercises had limited effects on ROM and performance, this study showed that training of this nature could be effective in improving and maintaining shoulder ROM throughout the season, possibly reducing injury incidence and improving season-long performance.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Ethical Statement

These were approved by the institutional review board of D University (IRB File No 2021-05-037).

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