

# Effects of a six-week weighted-implement throwing program on baseball pitching velocity, kinematics, arm stress, and arm range of motion

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## Background.

Weighted-baseball training programs are frequently used at the high school, collegiate, and professional levels of baseball. The purpose of this study was to compare a six-week training period using weighted implements, manual therapy, weightlifting, and other modalities on how they may affect arm stress, arm range of motion, pitching velocity, and kinematics.

## Hypothesis.

There is a gain in pitching velocity with concomitant increases in arm angular velocities, joint kinetics, and arm range of motion, particularly in shoulder external rotation.

## Methods.

Seventeen collegiate and professional baseball pitchers training at Driveline Baseball were tested with an eight-camera motion-capture system, range-of-motion measurements, and radar- and pitch-tracking equipment before and after a six-week training period. Each participant received their own individualized training program as standard protocol, with significant overlap in training methods for all athletes. Twenty-eight biomechanical parameters were computed for each bullpen trial, four arm range-of-motion measurements were taken, and pitching velocities were recorded before and after the training period. Pre- and post-training period data were compared using post-hoc paired *t*-tests.

## Results.

There was a statistically insignificant change in pitching velocity across the seventeen subjects. Among the biomechanical parameters computed, four were significantly different after the training period: internal rotational velocity was higher, shoulder abduction was lower at ball release, the shoulder was less externally rotated at ball release and shoulder adduction torque was higher. Among the arm laxity range of motion measurements, four were significantly different after the training period: the shoulder internal rotation range of motion and total range of motion for both the dominant and non-dominant arm. When the group was divided into those who gained pitching velocity and those who did not, the group that gained pitching velocity showed no significant increase in shoulder external rotation, or elbow valgus stress.

# **Conclusions.**

Following the training period, athletes did not show an increase in metrics such as joint kinetics or arm laxity most commonly linked to injury, even when the groups were divided into those who gained pitching velocity and those who did not. The group showed a statistically insignificant gain in pitching velocity. These findings run counter to the theory that weighted baseball training primarily develops pitching velocity via increased shoulder external rotation and joint kinetics on the arm. Further testing and follow-up is required to see if velocity gains would be developed over time as a result of positive developments in kinematics and range of motion as demonstrated in the study.

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# Introduction

Studies on underweight and overweight baseballs have shown a positive training effect on the throwing velocity of regulation-weight baseballs (DeRenne et al., 2005; DeRenne et al., 1990; Egstrom et al., 1960; DeRenne, 1985). Additionally, studies have also shown no effects of throwing underweight and overweight implements on pitching control or injury risk (DeRenne et al., 2005; DeRenne et al., 1994).

A recent biomechanical study shows that pitching slightly underweight and overweight baseballs can produce variations in kinematics without increased arm kinetics and that maximum-effort crow-hop throwing with the same implements can increase shoulder internal rotation angular velocity and elbow varus torque (Fleisig et al., 2017; Fleisig et al., 2016), while a study under current review (Reinold, M. 2017) indicates weighted-baseball throwing can increase shoulder external rotation in a six-week training period on high school athletes.

There is also published research on heavier-weighted plyometric throws as used in training and rehab programs (Wilk, Meister & Andrews, 2002). Further research has found eight weeks of plyometric training can improve shoulder internal rotation power and throwing distance (Fortun, Davies & Kernozck, 1998). A different study using plyos and “The Ballistic Six” found a significant improvement in throwing velocity (Carter et al., 2007). While there is also research suggesting that throwing weighted plyos from 2–8 lb. may improve proprioception (Swanik et al., 2002).

Major League Baseball teams have increasingly adopted the use of weighted-implement training and have seen a large uptick in drafted players with prior experience using weighted baseballs as amateurs. No conclusive evidence exists that truly explains the mechanism of the velocity gains, but claims that weighted-ball training can increase “arm strength” may be false (Cressey, E. 2013).

Increases in throwing shoulder external rotation and loss of throwing shoulder internal rotation are potentially deleterious (Wilk et al., 2011), but no weighted-implement training program in existing research combines a throwing program with other training modalities to potentially reduce negative adaptive effects on the arm. There is evidence that certain mobility programs can reduce the negative adaptive effects of throwing (Laudner et al., 2008), and it is theorized that heavy resistance training and manual therapy can potentially aid in this regard as well.

Driveline Baseball’s summer training periods show documented increases of 2.7 MPH in 2016 and 3.26 MPH in 2017 pitching velocity (Driveline Baseball, 2016 and 2017), so there is anecdotal case study support for the programs’ effectiveness.

The purpose of this study was to see what the positive training effects on throwing weighted implements would be and to see if the negative effects of throwing shown in other studies could be replicated or if the secondary exercises included in the training program could

effectively combat these adaptations. It was hypothesized that the standard effects would be shown—increased external rotation, increased ball velocity, and increased elbow varus torque.

## Methods

### *Participants and Informed Consent*

Healthy and asymptomatic college and professional pitchers were recruited from the Driveline Baseball 2017 training group via opt-in forms. Before each pitcher was scheduled for their initial test, investigators asked the pitchers about their current injury status. Pitchers were excluded if they had current symptoms of arm or shoulder pain or fatigue, or any other pain or discomfort that would prohibit completion of the testing period. Additionally, a prerequisite to train in the Driveline Baseball spring-summer group required medical clearance and trainer sign-off before throwing pitches off a mound. Pitchers were not excluded based on previous history of injuries that did not currently manifest themselves.

Pitchers were scheduled to come into the Driveline Baseball Research Facility (Kent, WA) for one visit. Upon arrival, participants were provided a verbal explanation of the study and asked to read and sign an Informed Consent document before beginning. The investigator verbally confirmed the major bullet points of the Informed Consent document in addition to obtaining a witnessed, legal signature from the pitcher, only proceeding if the pitcher submitted both a valid signature *and* verbally confirmed acceptance of all the risks contained within the Informed Consent document.

The study was approved by Hummingbird IRB, who granted ethical approval to carry out the study at the author's facilities (Hummingbird IRB #: 2017-29, Protocol WB-DLR-115).

Twenty-one baseball pitchers with high school and college pitching experience met these criteria and agreed to participate. Four were excluded bringing the final number to seventeen.

[TABLE 1]

[TABLE 2]

### *Testing Procedure and Measurements*

During the testing period, range of motion measurements were taken using a goniometer to measure shoulder internal and external rotation in both the dominant and non-dominant arms. The same investigator was used for each individual in the initial and final tests; previous research has shown high intra-reliability in goniometer measurements (Boone et al., 1978). Each pitcher was measured on the same day as the biomechanical screening.

Measurements were taken with each athlete lying in the lateral decubitus position. Testing was done in this position due to the fact that when lying supine, the humeral head is more likely to

glide forward in the socket, causing irritation in the anterior shoulder and leading to more inaccurate measurements as the athlete can compensate for a lack of range of motion by rolling his shoulder forward or backward. In the lateral decubitus plane, the humeral head is in a more advantageous position to externally and internally rotate without humeral head glide (Reinold et al., 2004).

[ Figure 1 ]

The investigator performing this part of the study was specifically trained in measuring range of motion of the shoulder using standard tools. Once the athlete was in the appropriate position, the investigator passively moved the arm until tension was reached and the measurement was taken. The intraclass correlation coefficient (ICC) of a trained clinician performing total range of motion tests of the shoulder have shown to be very reliable (Wilk et al., 2009).

The pitchers were allowed to throw as many pitches as they liked until they signalled to investigators that they were ready to pitch. Pitchers were fitted with reflective markers in preparation for three-dimensional motion capture portion of the pre-test and post-test for later kinematic and kinetic analyses. Forty-eight reflective markers were attached bilaterally on the third distal phalanx, lateral and medial malleolus, calcaneus, tibia, lateral and medial femoral epicondyle, femur, anterior and posterior iliac spine, iliac crest, inferior angle of scapula, acromial joint, midpoint of the humerus, lateral and medial humeral epicondyle, midpoint of the ulna, radial styloid, ulnar styloid, distal end of index metacarpal, parietal bone, and frontal bone, as well as on the C7 and T10 vertebrae, the sternal end of the clavicle, and the xiphoid process.

Pitchers then threw between 3-8 maximum effort throws, with approximately 30-60 seconds of rest between pitches. Fatigue was assumed to be negligible with such a low pitch count. Throws were made using a 5-oz. (142g) regulation baseball off the mound to a strike zone target (Oates Specialties, LLC, Huntsville, TX) located above home plate, which was 60' 6" (18.4 m) away. Testing concluded when the investigators were satisfied they had at least three clean takes for analysis. Sample photographs and high-speed videos (Sanstreak Corp., San Jose, CA) of the setup and pitches in motion are shown in Supplemental Photos and Videos 1-3.

For each trial, ball velocity was measured by a Doppler radar gun (Applied Concepts; Stalker Radar, Richardson, Texas). Additionally, for all trials, the three-dimensional motions of the reflective markers were tracked with an 8-camera automated motion-capture system, sampling at 240 Hz (Prime 13 System, Natural Motion / Optitrack, Corvallis, Oregon), shown in research to be comparable to more commonly-used high-end motion-capture systems (Thewlis et al., 2013). A total of 8 cameras were placed symmetrically around the capture volume, approximately 8 feet from the center of the pitching mound, at roughly 8 feet high. One camera

was lowered on the throwing-arm side to avoid collisions, and an additional camera was lowered to aid in marker tracking.

In total, 28 kinematic and kinetic values (11 position, 6 velocity, and 11 kinetic) were calculated using our personal code based on Fleisig methods (Fleisig et al., 2017) in Visual3D (C-Motion Inc., Germantown MD). Marker position data was filtered using a 20-Hz Butterworth low-pass filter. The mean values for all variables were calculated for each participant based upon their 3 best throws (Escamilla et al., 1998).

Five position values were found at both foot contact (FC) and ball release (BR): elbow flexion, shoulder horizontal abduction, shoulder abduction, shoulder external rotation, and wrist extension, as well as maximum dynamic shoulder external rotation. Measurements were all taken as their local joint angles.

The six velocity parameters include pelvis angular velocity at FC and BR, and the maximum values of pelvis angular velocity, upper torso angular velocity, elbow extension velocity, shoulder internal rotation velocity. Pelvis and upper torso angular velocities were measured by their rotations in the global reference frame. Elbow, shoulder, and wrist velocities were calculated as the rate of change in the joint angle.

Maximum values for elbow and shoulder kinetics were calculated. Values were reported as either a force or a torque applied onto the joint, applied by the proximal segment onto the distal segment at the joint. Six forces were calculated, including medial, anterior, and compression forces on the elbow, and superior, anterior, and compression forces on the elbow. Five torques were also computed: elbow flexion torque, elbow varus torque, shoulder horizontal adduction torque, shoulder adduction torque, and shoulder internal rotation torque.

### *Training Methods*

In between the two tests, pitchers were exposed to a six-week training program, slightly individualized for each person based on their strengths and weaknesses.

Each pitcher began his warm-up by using foam rollers and lacrosse balls for self-myofascial release (SMR) of various lower body and throwing arm muscles. Another option was rolling out the forearm with Arm Aid Extreme devices (The Armaid Company, Inc., Blue Hill, ME). Athletes were allowed to roll out for a period of time they determined necessary and were able to use SMR on other body parts if necessary. The standard SMR exercises can be found in the supplemental materials pages 1-7 of HTKC1.

Following SMR, athletes completed a set of exercises using Jaeger Band surgical tubing. Pitchers performed a forward fly to overhead reach, reverse fly to overhead reach, bicep curl with supination, tricep extension with pronation, internal and external rotations with elbow at shoulder height. Further details on the exercises can be found on pages 8-12 of the supplemental materials of HTKC1



Although Jaeger bands use a wrist cuff, surgical-tubing exercises with a handle have been shown to result in low to moderate EMG activation of the rotator cuff and surrounding musculature (Myers et al., 2005). A thesis has also stated surgical tubing exercises can improve velocity and shoulder internal and external strength (Baheti, 2000).

Following band work, pitchers performed a series of exercises with an Oates Specialties shoulder tube. The tube is designed as oscillation work to warm up the rotator cuff. Pitchers performed shoulder flexion in front, shoulder abduction to the side, external/internal rotations, pronation/supination twirls, and stride-length forward shoulder rotations. More detail on these exercises can be found on pages 13-16 of the supplemental materials of HTKC1.

The pitchers then performed a series of four exercises with 10-lb. wrist weights. The goals of the exercises are to warm up the muscles of the forearm and work the back of the shoulder eccentrically. The exercises were Pronated Swings (with two-arms), Two-Arm Throws, modified Cuban Press, and Pivot-Pickoff Throws. Further details of the exercises can be found on pages 17-24 in the supplemental materials of HTKC1.

Athletes then moved to a specific series of throws using plyometric PlyoBalls (soft sand-filled weighted balls ranging from 100-2000 grams, sold out of Driveline Baseball, Kent WA). There are five exercises performed; each exercise is unique within the constraints of the body's position to focus on different mechanical elements. Pitchers performed Reverse Throws, Pivot Pickoffs, Roll-in Throws, Rockers, and Walking Windups.

The ball weights, sets, and reps were all standard across the participants, depending on the training day. Pitchers completed the above warm-up six days a week with the volume and intensity of PlyoCare throws varying on the day. The throwing schedules and explanations on how to perform the exercises are listed on pages 25-36 in the supplemental materials of HTKC1.

On certain days pitchers were scheduled to long-toss. This occurred either off-site at a local park or inside while throwing into a net. Research on long-toss has largely focused on throws at max distance while throwing hard on-a-line, with one study finding max distance throws resulted in more torque than in pitching (Fleisig et al., 2011). Another study found that max distance, hard on-a-line throws resulted in similar loads to pitching (Slenker et al., 2014).

Long-toss as described in the programming did not solely consist of max distance, hard on-a-line throws. Most consisted of high-arc (extension) throws to a tolerable distance for the day, otherwise described as catch-play to a distance that is tolerable. Certain training days did consist of hard on-a-line (compression) throws, which are marked in the supplemental materials. It is important to note these distinctions since a recent study showed that many coaches, ATCs, and players define long-toss differently (Stone et al., 2017).

Each pitcher completed a post-throwing exercise circuit after each day of throwing workouts. The circuit consisted of standing rebounders; the pitchers threw a 4- and 2-lb. PlyoCare ball at a trampoline on the ground and were told to stick the catch of the ball.

Following rebounders were reverse scap pull-aparts, anterior band pull-aparts, and the no money drill. After band exercises, pitchers performed waiter walks. The pitchers held a kettlebell with their humerus at shoulder height and forearm facing vertically while walking. The kettlebell is gripped by the handle with the weight facing the ceiling. More details of the post throwing circuit can be found in the supplemental materials of HTKC2.

After the exercise circuit, each pitcher was able to use the Marc Pro EMS device. The Marc Pro has been shown to improve muscle performance, recovery, and reduce DOMS caused by exercise (Westcott et al., 2011, Westcott et al., 2013). It has been hypothesized that these results come from and increase in blood flow (DiNubile et al., 2011).

In conjunction with the throwing program athletes were also involved in a strength and conditioning program. This program included lifting weights, medicine ball throws, and mobility work. This program was individualized to each athlete depending on a separate physical and athletic screening.

Pitchers also saw a physical therapist during the training period. Trainers are also certified in FAKTR, cupping, and other manual therapy techniques. Athletes were able to receive treatment on an as-needed basis.

Each pitcher in this study had five- to six-throwing days scheduled a week. The throwing days were classified as high-intent days, hybrid days (medium intent days), and recovery days (low intent days), with the intensity and volume of throws changing per day.

To be included in the final study, pitchers had to have participated in at least 90% of the training days laid out for them, or they were dropped from the study.

Data from the training periods—including schedules, workloads, lifting programs, and intermediate progress—can be found in the supplemental data as spreadsheets for all pitchers involved in the study.

All statistical analyses were performed using R (RStudio Team, Boston, MA). After cleaning and preprocessing each individual athlete's data (the initial and post biomechanical parameters, the range of motion measurements, the range of motion strength numbers, and velocity data), means and standard deviations were calculated for each single metric, and then the differences were computed, along with the subsequent t metric and p-value. A paired t-test was used due to a relatively small sample size and unknown true population variances. To calculate the t metric, the mean differences between observations were divided by the standard error of these differences, which was calculated by the standard deviation of differences divided by the square root of the sample size, n. An n-1 degree of freedom was used, along with an alpha level of 0.05, leaving the pure probabilistic chance of any metric being highlighted as a false positive as 5% or less.

## Results

Pre- and post-range of motion tests are shown in Table 3. Four arm-laxity measurements were significantly different after the training period: internal rotation range of motion and total range of motion were higher for both dominant and non-dominant arms.

Perhaps notably, shoulder external-rotation range of motion was not significantly increased after the training period. Of the entire sample size, passive external rotation saw a gain of 1 degrees in the dominant arm, which was not significant.

[ TABLE 3 ]

Splitting the groups post hoc into the pitchers that gained velocity and those who did not may yield interesting results. For instance when those who gained throwing velocity were split into their own group, we might have expected to see the group that gained velocity (n=9) to have statistically significant increases in post-training passive shoulder external-rotation range of motion, but the gain was 2.8 degrees, which was not statistically significant.

Range-of-motion changes of the increase and decrease velocity groups can be found in tables 4 and 5 below.

[ TABLE 4 ]

[ TABLE 5 ]

Mean kinematic values of the pre and post-test are shown in Table 6. At front-foot contact, there were no significant differences. During arm cocking, maximum internal rotation velocity was higher. At ball release shoulder abduction was lower and external rotation decreased. Meaning the arm was more fully internally rotated towards the target at the moment of ball separation in the delivery.

[ TABLE 6 ]

For the increase velocity group, no values were statistically significantly different at front foot contact. Maximum internal rotation velocity and maximum elbow extension velocity were significantly higher in the arm cocking phase. External rotation was significantly lower at ball release.

[ TABLE 7 ]

No values were different for the velocity decrease group at front foot contact, arm cocking, or ball release.

[ TABLE 8 ]

Maximum shoulder adduction torque was the only parameter to significantly increase during the arm cocking phase. No values significantly changed in the deceleration phase.

[ TABLE 9 ]

For the velocity increase group, no value was significantly change in the arm cocking phase. Maximum shoulder superior force was the only variable significantly higher in the deceleration phase.

[ TABLE 10 ]

Maximum shoulder adduction torque was the only value significantly higher in the velocity decrease group at arm cocking. Elbow anterior force, elbow compressive force, elbow flexion torque, and shoulder compressive force were all significantly lower in the arm deceleration phase.

[ TABLE 11 ]

# **Discussion**

The hypothesis that a baseball training program that features weighted implements would significantly increase shoulder external-rotation range of motion was not supported by the current study—not in the entire subject pool nor in taking just those who gained velocity—despite this phenomenon being posited as a way to enhance ball velocity (Matsuo et al., 2001).

It has generally been hypothesized in research that weighted balls work along the speed-strength spectrum. One study found significant differences in maximal internal rotation (IR) and elbow extension (EE) velocity when throwing different ball weights (Tillaar & Ettema, 2011). With a second study finding 67% of ball velocity at release could be accounted for by internal rotation and elbow extension (van den Tillaar & Ettema, 2004). Of the entire sample there was a significant change in IR velocity, but not EE velocity.

Broken up into increase- and decrease-velocity groups, we see that the velocity-increase group saw statistically significant increases in both internal-rotation velocity and elbow-extension, whereas the velocity-decrease group saw no significant change in either metric.

There was no significant change in elbow valgus torque, and the values reported in this study are similar to previous studies (Feltner & Dapena, 1986; Fleisig et al., 2015)

No metrics were significantly different at front foot contact in any group.

A previous study found shoulder abduction angle at stride foot contact to be one of four variables that could explain 97% of variance in valgus stress through a regression analysis (Werner et al., 2002). In this study, comparing pre- and post-analysis found no significant decrease in shoulder abduction angle at stride foot contact but a significant change of abduction angle at ball release.

It has been suggested previously that the most optimal abduction angle at release is close to 90 degrees but may vary slightly depending on the individual. (Fortenbaugh, Fleisig & Andrews,

2009; Matsuo et al., 2002) The pitchers in this study saw a significant change in shoulder abduction angle at release, moving closer to 90 degrees.

Notably, no group had significant changes in elbow valgus torque or shoulder internal rotation torque. The increase velocity group had a significant increase in shoulder superior force, while the decrease velocity group had a significant increase in shoulder adduction torque, and significant decreases in elbow anterior force, elbow compressive force, elbow flexion torque, and shoulder compressive force.

The amount of external rotation was not significantly different at front foot contact, but was significantly decreased at ball release, which may be a novel finding. This change was present and significant in the combined and velocity increase group.

Maximum shoulder adduction torque was significantly higher in the post-training group. Research has found that shoulder adduction torque was one of two variables related to elbow valgus torque, along with maximum internal rotation torque (Sabick et al., 2004). The study stated that maximum shoulder adduction torque and maximum internal rotation torque were negatively correlated with elbow valgus torque, so as those two values increased, elbow valgus torque tended to decrease.

Interestingly, shoulder adduction torque only significantly increased in the group that lost velocity. The group that increased velocity had an increase in shoulder adduction torque, but it was not found to be significant.

Maximum torso angular velocity and maximum pelvis angular velocity were not significantly different in the pre- and post-group analysis. Split into increase and decrease velocity groups, there were no significant changes in torso angular velocity or pelvis angular velocity.

Previous research has shown mixed results on the relationship between pelvis- and torso- angular velocity and throwing velocity, though none compared pre- and post-training periods (Matsuo et al., 2001; Young, 2014; Dowling, 2016; Stodden et al., 2001). Theoretically, increasing the rotational forces of the pelvis and torso allows energy to be transferred from the trunk to the throwing arm and then to the ball, which should result in higher velocities.

These studies would also suggest that peak torso and pelvis velocities play a role in increasing velocity, but the timing of these forces is also vitally important. While the timing was not examined in this study, further studies should examine the possible changes of constraint training and weighted balls of the timing of hip and torso rotation. More research should also be attempted at pre- and post-group analysis to look at hip and torso velocities.

The degree of elbow flexion at ball release did not significantly change, even though a previous study found significant differences in the angle of the elbow at ball release, depending on ball weight (van den Tillaar & Ettema, 2004).

It has also been postulated that training with weighted balls causes gains in external rotation, both passive and dynamic. Dynamic max shoulder ER has been associated with ball velocity (Matsuo et al., 2001; Werner et al., 2008), but research looking within pitcher variation found no significant association between maximum external rotation and ball velocity (Stodden et al., 2005). The theory holds that weighted-ball use may result in velocity gains from excess glenohumeral external rotation, which may be linked to increased elbow valgus load (Aguinaldo & Chambers, 2009; Sabick et al., 2004).

Although previous research on high-school pitchers did not find a significant correlation between passive external rotation and pitch velocity (Keller, 2015), other research did see a significant moderate correlation between passive external rotation and the degree of external rotation seen in a throw (Miyashita et al., 2008).

It should be noted that the biomechanical measurement of external rotation cannot be attributed only to changes of the glenohumeral joint. There can be changes in thoracic extension or scapula position that can affect measurements.

The subjects in this study did see a passive range-of-motion increase of 1.7 degrees in the dominant arm, but the findings were statistically insignificant. The non-dominant arm saw a lesser, but still statistically insignificant, finding of 0.1 degrees.

Having broken up velocity into increase and decrease groups, we can see the increase group had an increase in external rotation of 2.8 degrees while the decrease velocity group saw an increase of 0.6 degrees. Interestingly, there were wide swings in the non-dominant arm external rotation. The velocity-increase group saw an increase in non-dominant external rotation of 7.8 degrees while the velocity decrease group saw a decrease of 8.6 degrees. This may bring into question what part of the changes in the dominant arm can be attributed to throwing and what parts can be attributed to non-throwing work, such as mobility or strength work, as it seems the change in non-dominant ROM came from mobility or strength work.

Although the finding of increased external rotation in the dominant arm was not statistically significant, it should still be considered an interesting finding since it has been suggested that humans have adapted to having more external rotation in order to better store elastic energy and increase power (Roach et al., 2013).

It has been hypothesized that training with weighted baseballs would result in negative anatomical effects, such as increased external rotation on top of other effects similar to pitching. The findings of this study are interesting because the range-of-motion findings are dissimilar to that hypothesis and to most short- and long-term range-of-motion studies.

Many of the pitchers in the study performed training days, which were either bullpens or training with weighted balls, designed to replicate high-intent pitching. The acute effects of range-of-motion on weighted balls have not been studied, but there has been research on

acute changes of pitching and bullpens. It has been hypothesized that range-of-motion changes that occur in the short-term may be exacerbated over the long-term. But the research conclusions of both short- and long-term ROM changes vary.

Two studies looking at the acute effects of pitching on range of motion found a loss of internal rotation that was sustained for 24 or 72 hours (Reinold et al., 2008; Kibler, Sciascia & Moore, 2012).

Counter to the above studies, Freehill et al. (2014) found a single start resulted in no significant change in IR but rather a significant increase in passive external rotation after pitching in a game.

Another study on minor league pitching starts found both a significant decrease in internal rotation, significant gain in external rotation, and significant gain in total arm range of motion (Case et al., 2015). Twenty-four hours after pitching, IR returned to pre-game baseline while ER was still significantly greater.

Long-term studies examining range of motion have also found conflicting results in internal rotation and external rotation when compared to this study. Freehill et al. (2011) found an increase in external rotation and internal rotation that was not statistically significant. This study has a similar sample size (21 pitchers, over 29 individual seasons) compared to the 17 pitchers in our study. Freehill et al. (2011) lasted over the course of a baseball season, four months long, compared to the six weeks that our study lasted. These pitchers also performed a capsule-stretching program during the season. Stretching programs have been seen to have positive effects on pitchers, such as reducing the chance of loss of internal rotation (Lintner et al., 2007).

A different study found that preseason and postseason measurements resulted in significantly more ER, significantly less IR, and significantly less total range of motion (Freehill et al., 2014).

A study on baseball and softball athletes found no change in internal rotation over the course of a season but did find increased external rotation and total range of motion (Dwelly et al., 2009).

These long-term studies align with the acute studies, to the extent in that the most common adaptations to throwing are a loss of internal rotation and a gain of external rotation, though the degree of change varies.

It is unknown exactly why these long-term studies differ, but it could likely be attributed to something in the training program outside of throwing. It should be noted that none of these long-term studies found a significant increase in internal rotation in the throwing arm.

This would suggest that range of motion is a fluid measurement. Further research should attempt to examine if there is an acceptable range of internal and external measurements.

It has been hypothesized that the loss of internal rotation may be caused by the eccentric muscle contraction that occurs in the posterior shoulder during the follow-through of pitching (Proske & Morgan, 2001). It is possible that no decreases were seen in dominant arm internal range of motion because of the daily soft-tissue work that each pitcher completed. Although the exact causes of self-myofascial release are unknown, research has suggested SMR has positive short-term effects on range of motion without negatively affecting muscle performance (Cheatham et al., 2015).

As mentioned previously, the pitchers had access to instrument-assisted soft-tissue mobilization (IASTM) on an as-needed basis. Previous research on baseball players found that some acute ROM losses could be attributed to muscular/rotator-cuff stiffness, and IASTM plus stretching displayed greater gains in internal rotation than in self-stretching alone (Bailey et al., 2015). The gains in that study were attributed to decreased rotator-cuff stiffness and humeral retrotorsion, but not joint translation.

More specifically, one study comparing IASTM and self-stretching saw a greater increase in internal rotation and total range of motion when compared with self-stretching alone; gains similar to those found in this study (Bailey et al., 2017). This would suggest that soft-tissue work such as IASTM played a role in the increase in internal rotation and total range of motion that was seen in this study.

Proske & Morgan (2001) also hypothesized that because injuries can occur from eccentric exercise, a way to combat injury risk would be to perform an eccentric-exercise program to strengthen and, therefore, protect the muscles. Eccentric training in this program occurs while using wrist weights, j-band external and internal rotations, rebounders, and upward tosses. But wrist-weight exercises, and the other exercises, have not been studied in the literature for their effects on strength or range-of-motion effects.

Pitchers also performed daily exercises in the warm-up and throwing program that are designed to work the posterior shoulder concentrically: specifically, Jaeger band exercises and reverse throws with PlyoCare balls. The effects that long-term concentric exercise has on posterior shoulder strength and range of motion have also not been studied.

A previous study found that performing a series of short-duration stretching/calisthenics drills (titled the Two-Out drill) resulted in short-term deficits in range of motion caused by pitching to be restored to their pre-pitching levels (Rafael et al., 2017). The post-throwing exercise circuit used in this study did not contain the same exercises; the exercises in this study were strength-based, not stretching/calisthenic based. However, it does show evidence that possible deficits created by throwing may be brought back to baseline by stretching or exercise. Further studies should examine the effect that the post-throwing exercise circuit and the use of concentric and isometric exercise on the shoulder used in this study have on range of motion.

It is unlikely that the use of the Marc Pro EMS device had an effect on range of motion. Since it has been seen that pitchers see reduced blood flow in their throwing arms, the Marc Pro is



used to encourage blood flow, but that increase in blood flow may not result in changes in range of motion (Laudner et al., 2014). A study comparing different recovery techniques found that EMS resulted in a lower rating of perceived exertion and blood-lactate concentration, but no change in range-of-motion testing (Warren, Szymanski & Landers, 2015). It's unknown whether the different EMS devices used in the Warren et al. (2015) would result in similar results.

A significant increase in internal rotation of the dominant arm may be seen as a positive since it has been suggested that losses of internal rotation in the throwing arm may lead to a higher risk of injury (Wilk et al., 2011; Myers et al., 2006; Dines et al., 2009). A study on pitchers in Japan did find a relationship between more IR range of motion in their dominant arms and injury (Sueyoshi et al., 2017). Sueyoshi et al. included a wider range of athletes (Little League to college age) than in this study, and younger athletes have been seen to have greater IR ROM than older athletes, which may have affected the results (Astolfi et al., 2015). The injured group in Sueyoshi et al. also pitched in more games and more innings than the no-injury group.

The pitchers in both the pre and post measurements of this study would not qualify for either measurement of GIRD, even though the difference between non-dominant and dominant arms increased (Burkhart, Morgan & Kibler, 2003). This increase in the difference between internal rotation of the non-dominant and dominant arms was driven by larger increases in internal rotation range of motion in the non-dominant arm than in the dominant arm.

The concept of total range of motion (TROM) has also been introduced to examine whether differences between arms may lead to injuries (Wilk, Meister & Andrews, 2002). In this study, TROM saw significant increases in both the dominant and the non-dominant arm. Both arms saw larger gains in internal rotation compared to external rotation.

Furthermore, neither the pre- or post-ROM measurements qualify for either external rotation deficit (external rotation at least 5 degrees more in the dominant arm when compared to the non-dominant arm) or TROM deficit (when TROM of the non-dominant arm is at least 5 degrees more than that the dominant arm). Pitchers with insufficient external rotation (<5 greater external rotation in throwing shoulder than non-dominant shoulder) have been seen to be more likely to have a shoulder injury (Wilk et al., 2015). Pitchers with deficits equal to or greater than 5 degrees in total rotation in their throwing shoulders compared to their non-dominant arms have been viewed as at higher risk of injuries (Wilk et al., 2014).

One thing unknown about these prospective studies is if the problem of deficits, by comparing the dominant to non-dominant arm, holds under longer term tracking and possible changes in the non-dominant arm. For example, a pitcher may qualify for a deficit while having no change of ROM in the dominant arm but see a significant change in the non-dominant arm. Even though both dominant and non-dominant TROM gained in this study, the non-dominant arm had a greater range of motion than the dominant arm post training.

When examining bilateral differences in range of motion over time, researchers should take note of whether the changes are coming from the dominant or non-dominant arm. Many of the changes in range of motion are focused on comparing from throwing and the dominant arm, but significant changes in range of motion in the non-dominant arm, seen in this study, show that there can be large changes that don't come from throwing.

Humeral retroversion was not measured in this study, although it has been said that this could partially explain the range-of-motion differences between the dominant and non-dominant arm (Chant et al., 2007). There is also research suggesting that humeral torsion adaptations occur pre-high school, suggesting that changes in this study came from soft tissue adaptations (Oyama, Hibberd & Myers, 2013). Further research examining range-of-motion changes and weighted-ball training should attempt to measure humeral retroversion, as well as range of motion.

This study is one of the first papers to be considered for publication regarding a training period, and as such, there is little data to compare it to. The throwing velocity of this group is very competitive with studies comparing similar subject pools, with the average initial pitching velocity of the seventeen pitchers being  $35.1 \pm 1.8$  m/s (78.6 mph); Fleisig et al. (2017) had a group of similar amateur pitchers ( $n=25$ ) with an average pitching velocity of  $34.2 \pm 2.0$  m/s (76.5 mph). Fleisig et al.'s study of underweight and overweight baseball throwing showed variations in arm kinetics, variations in angular velocities, and relatively small changes in body positions; these could be considered reasonable training modalities for pitchers (Fleisig et al., 2017).

This study would also suggest that pitching mechanics can be changed over a six-week training period. A previous study by Fleisig et al. (2017b) found that pitchers can change their mechanics based off a biomechanical observation over periods of time ranging from 2-48 months. In this study, the initial screenings were not given to players with specific direction to change mechanics; the screening was purposefully observatory.

This paper included fourteen right-handed and three left-handed pitchers. Further research should examine the differences of weighted-ball training between right- and left-handed pitchers, as previous research has suggested differences in range of motion, humeral retroversion, and biomechanics depending on the dominant throwing arm (Solomito, Ferreira & Nissen, 2017; Werner et al., 2010; Takenaga et al., 2017). It is therefore possible that pitchers should have different throwing, mobility, and strength programs depending on which arm is dominant.

## *Conclusion*

This study contradicts the original hypothesis. There were few changes comparing the pre- and post- groups, most notably there was no significant increase in elbow valgus or shoulder internal rotation torque and no significant increase in external rotation of the dominant arm.

The velocity increase group had statistically significant increases in internal rotation and elbow extension angular velocities.

This study contradicts the premise that weighted-implement training leads to rapid gains in shoulder external range of motion (Reinold, M. 2017). Literature on the topic of restoring shoulder internal rotation range of motion is supported (Laudner et al., 2008), but further research is required into individual modalities that may be contributing to these physical adaptations.

### *Limitations*

The pitchers in this study were asked to throw as hard as comfortable on their testing days. That, combined with the unfamiliarity of wearing biomechanical markers, resulted in lower velocities than what would be seen in a game or training environment.

Range-of-motion measurements were taken during the training period, so there could be unknown effects from measurements taken at different times. Range-of-motion measurements were also taken in a way that differs from other papers. Since the same subject measured every range-of-motion test, the results are reliable to each other but may not be directly comparable to other papers.

Lastly, this study involved a small sample size of seventeen pitchers and references smaller groups of velocity increase and velocity decrease groups.

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# Figure 1

## Range of motion testing

*\*Note: Auto Gamma Correction was used for the image. This only affects the reviewing manuscript. See original source image if needed for review.*



# **Table 1**(on next page)

## Athlete Data

General measurement data on the athletes in this study like weight/height etc.

1

17 Pitchers	Height (CM)	Weight Pre (KG)	Weight Post (KG)
Age: 19.9	184.82 ± 5.04 cm	88.61 ± 6.27 KG	88.98 ± 6.24 KG

2

3

# **Table 2**(on next page)

Athlete Data - post study

1

17 Pitchers	Height (CM)	Weight Post (KG)
Age: 19.9	184.82 ± 5.04 cm	88.98 ± 6.24 KG

2

3

4

# **Table 3**(on next page)

ROM Data Pre/Post

Shoulder range of motion data pre/post training period.



Figure 3

Shoulder External and Internal Passive Ranges of Motion Measured Before and After Six Weeks of Training

	Pre-Test (n = 17)	Post-Test (n = 17)	P Value for Pre and Post-Test Comparison
Dominant arm internal ROM (°)	53 ± 13	60 ± 15	0.006*
Dominant arm external ROM (°)	122 ± 21	123 ± 10	0.637
Dominant arm total ROM (°)	174 ± 21	184 ± 16	0.031*
Non-dominant arm internal ROM (°)	66 ± 13	79 ± 11	< 0.001*
Non-dominant arm external ROM (°)	107 ± 17	107 ± 14	0.990
Non-dominant arm total ROM (°)	173 ± 17	185 ± 15	0.013*

\* indicates that value was found to be statistically significant

**Table 4**(on next page)

Shoulder ROM, Velocity Increase Group

Shoulder range of motion data for those who gained velocity

Figure 4

Shoulder External and Internal Passive Ranges of Motion Measured Before and After Six Weeks of Training: Velocity Increase Group

	Pre-Test (n = 9)	Post-Test (n = 9)	<i>P</i> Value for Pre and Post-Test Comparison
Dominant arm internal ROM (°)	55 ± 14	64 ± 17	0.056
Dominant arm external ROM (°)	119 ± 25	122 ± 11	0.648
Dominant arm total ROM (°)	174 ± 23	186 ± 19	0.124
Non-dominant arm internal ROM (°)	64 ± 11	77 ± 10	0.005*
Non-dominant arm external ROM (°)	106 ± 8	113 ± 12	0.031*
Non-dominant arm total ROM (°)	169 ± 11	191 ± 15	0.002*

\* indicates that value was found to be statistically significant

**Table 5**(on next page)

Shoulder ROM, Velocity Decrease Group

Shoulder range of motion data for those who lost velocity in the training period.

Figure 5

Shoulder External and Internal Passive Ranges of Motion Measured Before and After Six Weeks of Training: Velocity Decrease Group

	Pre-Test (n = 8)	Post-Test (n = 8)	<i>P</i> Value for Pre and Post-Test Comparison
Dominant arm internal ROM (°)	50 ± 13	57 ± 13	0.062
Dominant arm external ROM (°)	125 ± 17	125 ± 10	0.895
Dominant arm total ROM (°)	175 ± 19	182 ± 13	0.133
Non-dominant arm internal ROM (°)	68 ± 16	80 ± 12	0.049*
Non-dominant arm external ROM (°)	108 ± 25	99 ± 14	0.360
Non-dominant arm total ROM (°)	176 ± 23	180 ± 13	0.636

\* indicates that value was found to be statistically significant

**Table 6**(on next page)

Kinematic Data on All Athletes

Kinematic / biomechanical data on all athletes in the study.

Figure 6

Joint Positions and Velocities Before and After Six Weeks of Training

	Pre-Test (n = 17)	Post-Test (n = 17)	P Value for Pre and Post-Test Comparison
<i>Front foot contact</i>			
Elbow flexion (°)	91 ± 28	93 ± 20	0.651
Shoulder horizontal abduction (°)	44 ± 14	46 ± 18	0.407
Shoulder abduction (°)	83 ± 12	86 ± 13	0.163
External rotation (°)	33 ± 23	30 ± 23	0.444
Wrist extension (°)	20 ± 19	18 ± 19	0.221
Pelvis angular velocity (°/s)	92 ± 10	93 ± 9	0.475
<i>Arm cocking/ acceleration phase</i>			
Maximum pelvis angular velocity (°/s)	733 ± 104	721 ± 145	0.586
Maximum torso angular velocity (°/s)	966 ± 96	998 ± 103	0.129
Maximum internal rotation velocity (°/s)	4527 ± 470	4759 ± 542	0.013*
Maximum elbow extension velocity (°/s)	2230 ± 227	2270 ± 328	0.499
Maximum External Rotation (°)	168 ± 10	167 ± 9	0.654

*Ball release*

Elbow flexion (°)	16 ± 6	17 ± 6	0.526
Shoulder horizontal abduction (°)	0 ± 7	1 ± 7	0.320
Shoulder abduction (°)	96 ± 8	93 ± 5	0.041*
External rotation (°)	95 ± 15	86 ± 18	0.009*
Wrist extension (°)	2 ± 7	3 ± 5	0.728
Pelvis angular velocity (°/s)	107 ± 7	107 ± 9	0.564

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\* indicates that value was found to be statistically significant



**Table 7** (on next page)

Kinematic Data, Velocity Increase Grou

Kinematic / biomechanical data on athletes who gained velocity in the study.

Figure 7

Joint Positions and Velocities Before and After Six Weeks of Training: Velocity Increase Group

	Pre-Test (n = 9)	Post-Test (n = 9)	P Value for Pre and Post-Test Comparison
<i>Front foot contact</i>			
Elbow flexion (°)	77 ± 30	88 ± 21	0.166
Shoulder horizontal abduction (°)	46 ± 18	51 ± 17	0.204
Shoulder abduction (°)	81 ± 8	85 ± 12	0.147
External rotation (°)	26 ± 27	21 ± 19	0.469
Wrist extension (°)	25 ± 21	23 ± 20	0.463
Pelvis angular velocity (°/s)	90 ± 12	95 ± 11	0.076
<i>Arm cocking/ acceleration phase</i>			
Maximum pelvis angular velocity (°/s)	717 ± 110	722 ± 147	0.862
Maximum torso angular velocity (°/s)	976 ± 116	1024 ± 87	0.101
Maximum internal rotation velocity (°/s)	4429 ± 453	4813 ± 481	0.009*
Maximum elbow extension velocity (°/s)	2166 ± 260	2348 ± 327	0.010*
Maximum external rotation (°)	166 ± 11	167 ± 11	0.445

*Ball release*

Elbow flexion (°)	16 ± 6	16 ± 5	0.892
Shoulder horizontal abduction (°)	-1 ± 8	3 ± 9	0.108
Shoulder abduction (°)	94 ± 7	91 ± 5	0.188
External rotation (°)	97 ± 16	87 ± 22	0.011*
Wrist extension (°)	3 ± 8	5 ± 6	0.626
Pelvis angular velocity (°/s)	106 ± 8	106 ± 11	0.871

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\* indicates that value was found to be statistically significant

**Table 8**(on next page)

Kinematic Data, Velocity Decrease Grou

Kinematic / biomechanical data on the athletes that lost velocity in the study.

Figure 8

Joint Positions and Velocities Before and After Six Weeks of Training: Velocity Decrease Group

	Pre-Test (n = 8)	Post-Test (n = 8)	P Value for Pre and Post-Test Comparison
<i>Front foot contact</i>			
Elbow flexion (°)	106 ± 18	98 ± 20	0.067
Shoulder horizontal abduction (°)	41 ± 9	41 ± 17	0.991
Shoulder abduction (°)	85 ± 15	87 ± 14	0.561
External rotation (°)	41 ± 14	39 ± 24	0.779
Wrist extension (°)	15 ± 17	12 ± 18	0.343
Pelvis angular velocity (°/s)	94 ± 9	92 ± 6	0.461
<i>Arm cocking/ acceleration phase</i>			
Maximum pelvis angular velocity (°/s)	751 ± 100	720 ± 152	0.409
Maximum torso angular velocity (°/s)	955 ± 74	968 ± 117	0.685
Maximum internal rotation velocity (°/s)	4638 ± 493	4699 ± 633	0.550
Maximum elbow extension velocity (°/s)	2302 ± 173	2181 ± 327	0.129
Maximum external rotation (°)	170 ± 8	168 ± 7	0.155

*Ball release*

Elbow flexion (°)	16 ± 6	17 ± 7	0.325
Shoulder horizontal abduction (°)	0 ± 6	-1 ± 6	0.298
Shoulder abduction (°)	98 ± 8	94 ± 5	0.151
External rotation (°)	92 ± 14	85 ± 14	0.221
Wrist extension (°)	2 ± 7	1 ± 4	0.876
Pelvis angular velocity (°/s)	109 ± 5	107 ± 8	0.315

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\* indicates that value was found to be statistically significant

# **Table 9**(on next page)

Kinetic Data, All Athletes

Kinetic / force data on all athletes in the study.

Figure 9  
Shoulder and Elbow Forces and Torques Before and After Six Weeks of Training

	Pre-Test (n = 17)	Post-Test (n = 17)	P Values for Pre and Post-Test Comparison
<i>Arm cocking/ acceleration phase</i>			
Maximum elbow medial force (N)	340 ± 60	350 ± 76	0.366
Maximum elbow varus torque (N·m)	98 ± 16	99 ± 18	0.942
Maximum shoulder anterior force (N)	322 ± 196	299 ± 146	0.345
Maximum shoulder horizontal adduction torque (N·m)	126 ± 39	123 ± 20	0.773
Maximum shoulder internal rotation torque (N·m)	98 ± 16	98 ± 18	0.925
Maximum shoulder adduction torque (N·m)	103 ± 39	138 ± 53	0.012*
<i>Arm deceleration phase</i>			
Maximum elbow anterior force (N)	192 ± 120	159 ± 53	0.239
Maximum elbow compressive force (N)	998 ± 161	969 ± 167	0.394
Maximum elbow flexion torque (N·m)	28 ± 32	21 ± 15	0.424
Maximum shoulder superior force (N)	213 ± 67	235 ± 80	0.175
Maximum shoulder compressive force (N)	1235 ± 245	1161 ± 218	0.072

\* indicates that value was found to be statistically significant



**Table 10**(on next page)

Kinetic Data, Velocity Increase Grou

Kinetic / force data on the athletes that gained velocity in the study.

Figure 10

Shoulder and Elbow Forces and Torques Before and After Six Weeks of Training: Velocity Increase Group

	Pre-Test (n = 9)	Post-Test (n = 9)	P Values for Pre and Post-Test Comparison
<i>Arm cocking/ acceleration phase</i>			
Maximum elbow medial force (N)	348 ± 57	380 ± 66	0.063
Maximum elbow varus torque (N·m)	102 ± 15	106 ± 13	0.359
Maximum shoulder anterior force (N)	304 ± 196	296 ± 174	0.746
Maximum shoulder horizontal adduction torque (N·m)	134 ± 43	129 ± 23	0.701
Maximum shoulder internal rotation torque (N·m)	100 ± 15	105 ± 15	0.200
Maximum shoulder adduction torque (N·m)	122 ± 35	155 ± 52	0.145
<i>Arm deceleration phase</i>			
Maximum elbow anterior force (N)	201 ± 159	166 ± 51	0.517
Maximum elbow compressive force (N)	1019 ± 157	1048 ± 172	0.567
Maximum elbow flexion torque (N·m)	25 ± 42	22 ± 18	0.848
Maximum shoulder superior force (N)	236 ± 45	278 ± 81	0.034*

Maximum shoulder compressive force (N)	1248 ± 216	1249 ± 213	0.974
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\* indicates that value was found to be statistically significant

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**Table 11**(on next page)

Kinetic Data, Velocity Decrease Group

Kinetic / force data on the athletes that lost velocity in the study.

Figure 11

Shoulder and Elbow Forces and Torques Before and After Six Weeks of Training: Velocity Decrease Group

	Pre-Test (n = 8)	Post-Test (n = 8)	P Values for Pre and Post-Test Comparison
<i>Arm cocking/ acceleration phase</i>			
Maximum elbow medial force (N)	331 ± 65	317 ± 75	0.332
Maximum elbow varus torque (N·m)	95 ± 17	90 ± 18	0.191
Maximum shoulder anterior force (N)	342 ± 209	302 ± 118	0.390
Maximum shoulder horizontal adduction torque (N·m)	116 ± 35	116 ± 15	0.997
Maximum shoulder internal rotation torque (N·m)	96 ± 17	90 ± 18	0.087
Maximum shoulder adduction torque (N·m)	82 ± 34	119 ± 51	0.032*
<i>Arm deceleration phase</i>			
Maximum elbow anterior force (N)	181 ± 61	151 ± 56	0.011*
Maximum elbow compressive force (N)	973 ± 172	879 ± 114	0.030*
Maximum elbow flexion torque (N·m)	32 ± 17	21 ± 11	0.015*
Maximum shoulder superior force (N)	188 ± 81	186 ± 42	0.929

Maximum shoulder compressive force (N)	1220 ± 289	1061 ± 188	0.044*
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6                      \* indicates that value was found to be statistically significant

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