

A Preliminary Examination of Shoulder Joint Function Following Shoulder Complex Training and In-Season Play in Youth Baseball Players

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ABSTRACT

Background: As shoulder care continues to be a concern for youth baseball players, coaches, parents, researchers and clinicians, shoulder complex care should remain a point of emphasis especially for in overhead athletes. The impact of throwing volume and shoulder care is important for us to understand. **Objective:** The purpose was to examine the changes in shoulder complex function during a playing season combined with shoulder complex training in young male baseball players. **Methods:** Eleven male baseball players (11-15 y/o) served as subjects. Pre-testing included shoulder joint internal/external rotation peak torque and average work as measured with isokinetic dynamometry (Biodex System 4Pro). Training over the 18-week project duration was Crossover Symmetry "Activation" and "Strength" protocols completed per manufacturer recommendations. Adherence was tracked via a weekly email sent to the subject's guardian to self-report completed training. Post-testing was conducted at the conclusion of the 18th week. Paired sample t-tests compared pre-test and post-test mean differences for peak torque and average power ($p < 0.05$). **Results:** All-subject average for training was 54 sessions over the 18 weeks. Estimated number of throws completed during practice and games over the 18 weeks was 8,400. For both testing speeds and for both internal and external shoulder joint rotation, peak torque increases ranged from ~50% for external rotation at 60 deg/s up to ~200% for internal rotation at 120 deg/s. Statistical differences ($p < 0.001$) were noted between all pre-test and post-test internal and external rotation peak torque values. For both testing speeds and for both internal and external shoulder joint rotation, average power increases ranged from ~38% at 60 deg/s for external rotation up to ~200% at 120 deg/s for internal rotation. Statistical differences ($p < 0.005$) were noted between all pre-test and post-test internal and external rotation average power values. **Conclusions:** Substantial increases in shoulder joint rotation peak torques and power were seen across the 18-week study duration. As this was a preliminary investigation, we have yet to discern if these increases are due to the shoulder complex training or volume of throwing that was completed.

Key words: Torque, Baseball, Shoulder Joint, Adolescent, Muscle Strength, Injuries

INTRODUCTION

The majority of athletes that play high school baseball began their play at a young age ranging from recreational to travel-team baseball (Salamh et al., 2020). Along with this increased participation, there has been an increased incidence of injury to the throwing extremity. (Salamh et al., 2020). It is thought that some upper extremity throwing injuries that receive medical attention may result from cumulative micro trauma that began in early participation and competition (Stephan et al., 2002). In an effort to decrease injury rates, youth baseball shoulder care continues to be a point of emphasis for players, coaches, parents, researchers and clinicians (Stephan et al., 2002). In

addition, and deservedly so, increased attention has been given to baseball pitch counts and innings thrown by Little League International, USA Baseball, and the United States Specialty Sports Association (USSSA), among others (Schwab & Strand, 2020). One injury prevention tool we have at our disposal is shoulder complex training. This is emphasized by the Major League Baseball "Pitch Smart" program as it highlights a number of risk factors for injury in youth baseball pitchers, one of which is *not* following proper strength and conditioning routines. Proper shoulder complex function in overhead athletes is paramount as the shoulder complex must play two important, yet contrary roles; 1) be sufficiently mobile to complete the required

movement pattern, and 2) be sufficiently stable for optimal movement pattern function and thus, decreased risk of injury (Wilk et al., 2011). In addition to tracking the amount of pitching and throwing that occurs in a given time period, there has been an increase in arm care programs that include both training hardware and their respective training protocols (Escamilla et al., 2011; Stephan et al., 2002). The reported purpose of such programs is to improve shoulder complex neuromuscular function. In addition, some programs incorporate trunk and lower extremity training to increase throwing performance beyond shoulder care (Escamilla et al., 2011; Murray et al., 2001; Oliver et al., 2015). Evidence for the effectiveness of shoulder complex training programs is available and comparisons are beginning to be made amongst the more recent training programs. Sims et al. (2016) compared the Crossover Symmetry and Jaegar J-Band systems on shoulder joint internal/external rotation range of motion and strength. They concluded that both systems were effective in improving the measured variables and that length of training seemed to be a primary factor. Currently, there has not been an examination of these more recent training implements and protocols with youth baseball players. In addition, changes in shoulder joint isokinetic performance in youth baseball players has not been examined over the duration of a playing season (Murray et al., 2001). In a recent review by Salamh et al. (2020) it was recommended to further examine risk factors associated with youth baseball pitchers within and across seasons. If we can better understand the changes that occur during the season, then more appropriate playing and training guidelines could be developed. Due to these gaps in the literature relative to youth throwing and unknowns for training guidelines, it was the purpose of this project to take a step towards an understanding of the changes of shoulder complex neuromuscular function during a playing season along with shoulder complex training within a cohort of youth baseball players. It was hypothesized that isokinetic strength of the shoulder joint would increase over the course of the 18-week project duration.

METHODOLOGY

Study Design

The study was a quasi-experimental design with dependent variables of shoulder joint internal and external rotation peak torque and power. The independent variables include the training program and throwing volume. The study was approved by the University Institutional Review Board (#2018-19091). Participants, and their guardians, volunteered to participate and were required to read and sign a university-approved informed consent prior to participation.

Participant Characteristics

A convenience sample (Etikan, 2016) recruited from a local youth baseball team elicited eleven male baseball players ranging in age from 11-15 served as subjects for this project. All but one of the subjects was in the 11-12 year age range

and all of these subjects played on the same USSSA team. All subjects played a variety of fielding positions, including pitcher. All subjects had been playing on the same team for the previous two baseball seasons. Exclusion criteria were any known pathologies of the throwing upper extremity. No subject reported any upper extremity injury or pain prior to, during, or following the study.

Test Protocol and Procedures

Subjects were divided into three groups based on height. This grouping was done out of convenience to allow for easier set-up of subjects on the Biodex isokinetic dynamometer (Biodex System 4Pro). The same researcher for each of the three groups led a general dynamic warm-up of the shoulder complex. Internal/external rotation peak torque and average work were measured with isokinetic dynamometry (Biodex System 4Pro). The shoulder joint internal/external rotation set-up and testing protocol per manufacturer recommendations were followed (Figure 1). This protocol called for 1 set of 5 concentric/concentric repetitions to be performed at speeds of 60 and 120 degrees per second with 30 seconds of rest between changes in joint angular velocities (Wimpenny, 2019). While the throwing motion required much greater angular velocities the researchers wanted to ensure safety for subject isokinetic testing. Thus, these submaximal speeds were chosen. Submaximal trial repetitions were provided for each speed prior to data collection. Shoulder joint isokinetic testing has been shown to be a valid and reliable measure of shoulder complex strength (Wilk, et al., 1991). Subjects were taught the Crossover Symmetry "Activation" and "Strength" protocols by researchers IM and CS (Figure 2). These researchers had been trained on the instruction of the Crossover Symmetry system and had completed their own shoulder complex training with the system.

Post-testing: Subjects returned for post-testing at the conclusion of the 18th week of training to complete the same isokinetic testing as was done for the pre-test.

Throwing: The 18 weeks of Crossover Symmetry training began as the subjects were just underway with their pre-season baseball routine. Pre-season practices were held



Figure 1. Set-up for testing per the Biodex manual



Figure 2. Crossover Symmetry exercise card with “Strength” and “Activation” protocols

indoors for approximately 3 weeks, 2 times per week. Once the teams were able to move outside practices took place 2-3 times per week. Along with practice, games were played primarily on the weekends for the final 11 weeks of this project averaging 3 games per weekend. For this phase of the project, we did not count every throw and/or pitch that each player completed. However, an estimate of total throws is provided in the Results section.

Training Protocol

Each subject was provided a *Crossover Symmetry Individual, Novice-Level* training package. This package included a drawstring backpack for storage and transport, one pair of 3-lb. resistance bands and one pair of 10-lb. resistance bands, door belts or rack straps for band attachment, exercise card, and web access to Crossover Symmetry training resources. Subjects were instructed to complete the “Activation” protocol prior to every baseball practice, throwing session or game. The “Strength” protocol was to be completed at least 2-3 times per week not immediately following days where the subject pitched or did more than an average volume of throwing. These recommendations were per the Crossover Symmetry training guidelines. Crossover Symmetry training was prescribed for a total of 3-5 days per week for 18 weeks. Each session takes 4-5 minutes to complete. To track adherence a weekly email was sent to the subject’s parent/guardian to provide self-report of completed number of training days and type of training (“Activation” or “Strength”).

Statistical Analysis

Each data set was examined for normality by exploring the kurtosis and skewness values of the pre-test and post-test data across the peak torque and average power data (Hopkins, 1990). Paired sampled t-tests were utilized to compare pre-test and post-test mean differences for peak torque and average power (Microsoft Excel, 2016). Alpha level was set at $p < 0.05$.

Table 1. Estimated number of throws

	Throws per session	Total throws
Indoor practice (2/week for 3 weeks)	150	900
Outdoor practice (2/week for 15 weeks)	200	6000
Games (3/week for 11 weeks)	100	3300
Grand Total		10,200

RESULTS

Training Adherence

The subjects could have completed approximately 90 sessions 45 “Activation” and 45 “Strength” if they trained 4-5 days per week for the 18-week project duration. All-subject average for training was 54 sessions (30 “Activation” and 24 “Strength”) over the 18 weeks. The lowest number of training sessions completed over the 18 weeks was 40 sessions (25 “Activation” and 15 “Strength”). The highest number of training sessions completed over the 18 weeks was 73 sessions (40 “Activation” and 33 “Strength”).

Throwing Number

This is a conservative estimate of number of throws over the duration of the 18-week project. Throws were counted at one indoor and one outdoor practice and the overall throwing estimation was made based on those data points. Keep in mind that the playing season for the subjects covered another 4 weeks of practice and game play. The researchers did not control the amount of throwing that was done throughout the season. We did not feel it was our prerogative to infringe on the coaches’ plan and expectation for throwing. It should be noted, that the coaches were quite conservative in volume their throwing program.

Isokinetic Testing

Peak torque is the maximal value of the moment angle position (MAP) curve. This measure is to be considered the gold standard measure in isokinetic testing (Kannus, 1994; Edourdo et al., 2012). Torque is equal to moment, or force, multiplied by the distance from the turning center, in the case of isokinetic testing this distance is the center of rotation of the lever arm on the machine. For both testing speeds and for both internal and external shoulder joint rotation, peak torque increases ranged from ~50% for external rotation at 60 deg/s up to ~200% for internal rotation at 120 deg/s. See Figures 3-6. Statistical differences ($p < 0.001$, $t = 0.005$ [largest value]) were noted between all pre-test and post-test internal and external rotation peak torque values. Differences between internal and external rotation peak torques (internal/external ratio) averaged 34% at 60 deg/s and 43% at 120 deg/s. These ratios concur with Brown (2000). Average power is the average time rate of completed work. For both testing speeds and for both internal and external shoulder joint rotation, average power increases ranged from ~38% at 60 deg/s for external rotation up to ~200% at 120 deg/s for internal rotation. Statistical differences ($p < 0.005$, $t = 0.005$ [largest value]) were noted between all pre-test and post-test internal and external rotation average power values. See Figure 7. Figures include standard error bars and symbols for indicating statistical significance.

DISCUSSION

We found that in-season play in conjunction with shoulder complex training significantly improved shoulder joint strength as measured via isokinetic dynamometry. Our initial focus in gaining an understanding of youth baseball player shoulder function was to examine the changes in isokinetic shoulder joint torque and power throughout the majority of the baseball season in conjunction with shoulder complex training via Crossover Symmetry. It has been shown that an increased volume of throwing due to extended playing seasons have led to an increase in throwing-related shoulder and elbow injuries (Hadro et al., 2019). Thus, understanding changes in shoulder complex function during a playing season and the potential impact of a sustainable shoulder-training program is imperative.

Training Adherence

An important characteristic of any training program is the likelihood of subject/athlete/patient compliance. The data indicate strong adherence to the Crossover Symmetry training protocol. On average subjects completed 3 training sessions per week with even the lowest compliance rate completing 2 sessions per week over the 18 weeks. The overall compliance was at 60% (54/90) with the lowest at 44% (40/90) and the highest at 81% (73/90). To ensure compliance, subject guardians were contacted weekly via email to collect training data, provide education and encouragement. In addition, periodic visits to practices and games were completed by researcher KC to provide feedback on Crossover Symmetry

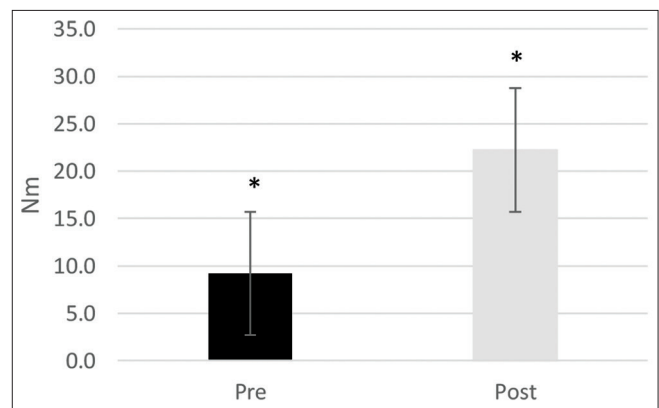


Figure 3. Pre- and post- peak internal torques at 60^{o/s}

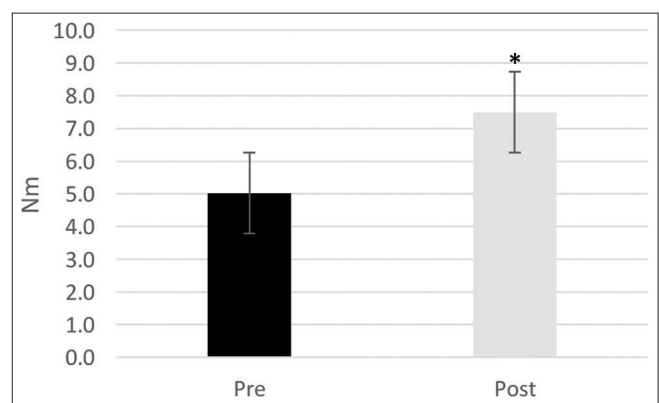


Figure 4. Pre- and post- peak external torques at 60^{o/s}

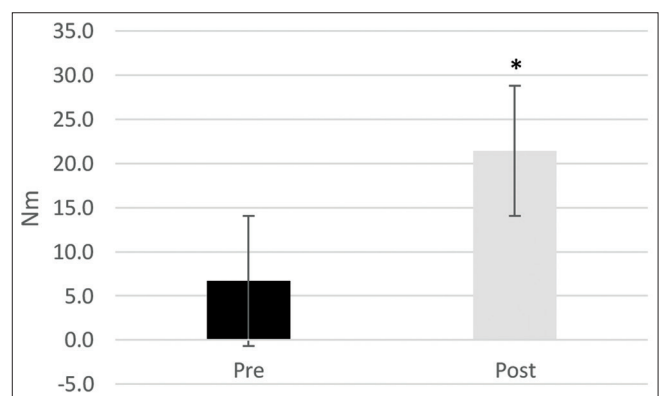


Figure 5. Pre- and post- peak internal torques at 120^{o/s}

training technique. Subjective feedback from the subjects and guardians indicated that they found the system to be easily set-up, transported, and time efficient which led to improved compliance.

Throwing Volume

Feely et al (2018) state that the increased participation in youth baseball with an emphasis on early sport specialization may lead to a continued increase in upper extremity injury. While published pitch counts (Little League International and USSSA) are likely to positively affect injury rates; athletes, coaches, and parents may disregard these limits (Feely et al., 2018). The current project provided a conservative

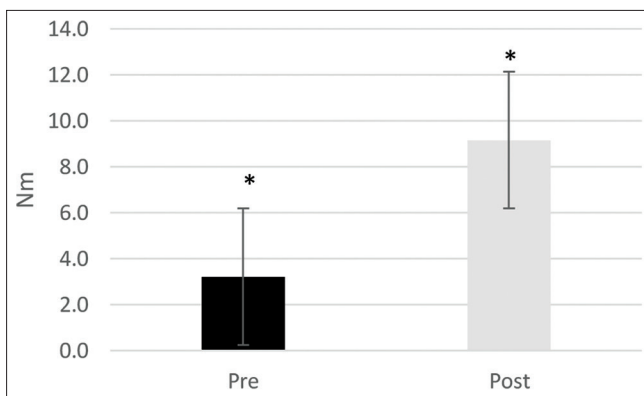


Figure 6. Pre- and post- peak external torques at 120°/s

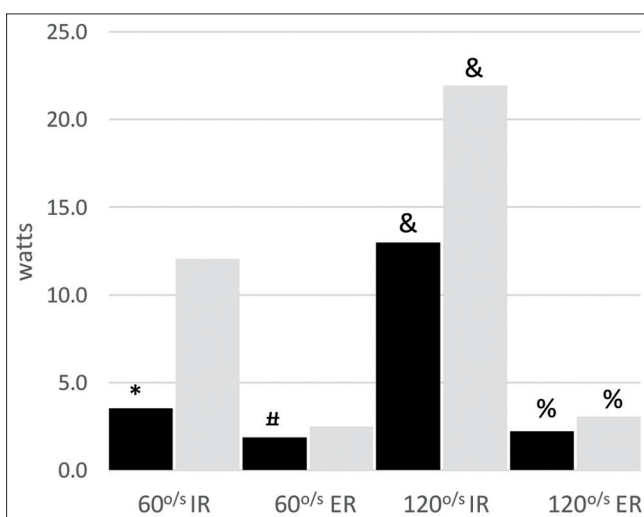


Figure 7. Pre- and post- average power across speed and joint action

estimate on throwing volume based on a single practice and single game. There are a few challenges with this approach; 1) the accuracy of the estimate, even though it was intentionally conservative; 2) the question of what is considered to be an excessive volume and intensity of workload; and 3) there are no population specific norms for comparison with this project's throwing estimates. For example, are 10,200 throws an acceptable amount for youth baseball players simply because no negative upper extremity symptoms were reported by the subjects throughout the duration of the project? In addition, volume and intensity parameters have not yet been set for throwing athletes, youth athletes in particular. Black et al (2016) conducted a systematic review that highlighted a number of simple and effective workload-monitoring techniques but, injury thresholds remain unclear in throwing-dominant sports. Considering the current state of the literature, it is likely that throwing-dominant sports would benefit from an objective, automated tool to measure "throwing-related workload" (Black et al., 2016). Until these parameters and tools are better defined, perhaps a wise approach with throwing dominant athletes is to, at the very least, appropriately train the shoulder complex neuromuscular system for the demands of overhand throwing.

Isokinetic Testing

As noted in the Results, statistical significance was found for peak torque and average power between pre- and post-tests for both joint rotation directions and velocities. In addition to positive changes across group means, individual improvements were made by all subjects. We postulate that these improvements would certainly have practical significant impacts on throwing performance in terms of the velocity ultimately imparted to the baseball during the throwing motion. One way to understand the importance of distal to proximal segmental movements is described by Knudson (2007) as the phenomenon of the "Segmental Interaction Principle." He states that the forces acting between the segments of a body can transfer energy between segments. Thus, the ability to produce torque and power about a proximal joint that could be further utilized in distal joints is a key factor in throwing. Torque and power values for internal rotation were greater than external rotation values across both velocities. These findings concur with previous work and is also supported from a skeletal muscle perspective via the greater physiological cross-sectional area of the shoulder joint internal rotators relative to the external rotators. To our knowledge, there are no norms available for isokinetic measures in subjects of this age range. The youngest subject population found for shoulder joint isokinetics were post-pubescent males. Therefore, we are not yet able to generalize these results to other 11-12 year old boys.

Gaining an understanding of shoulder joint strength changes throughout a baseball season may guide the development of shoulder care training, differentiate between training programs, and develop a baseline for tracking strength changes over a number of playing seasons, In addition, tracking throwing volume may allow for a better connection to be made between throwing volume and overuse injury. With increased participation and specialization in youth baseball, we will continue examining shoulder care programs. Future projects will include control groups for training studies; monitoring changes in throwing mechanics via motion capture throughout the playing season; developing norms for pre-pubescent shoulder joint isokinetics; monitoring of throwing volume and intensity; developing player, coach and parent education programs; and subjective measures of throwing performance and upper extremity health.

While positive changes in shoulder joint function as measured were found over the duration of the project, we are not yet able to objectively discern whether these changes are due to the Crossover Symmetry training or due to the amount of throwing that the subjects completed over the 18 weeks. Over the 18-week duration the amount of physical maturation may also have played a role in subject performance. However, strong subjective feedback for the Crossover Symmetry training was received from the subjects, their guardians, and the team's coaches. The feedback centered on the themes of decreased arm fatigue throughout the season and eliminated arm soreness that had been experienced in previous seasons.

CONCLUSIONS

The purpose of this project was to examine the shoulder joint internal and external “strength” changes following shoulder complex training and in-season baseball play. We also sought to gain a preliminary understanding of throwing volume over the same time. The avoidance of overuse injury of the upper extremity is of continued concern through the youth and the professional baseball communities. The further development of appropriate and sustainable shoulder care programs (i.e., Crossover Symmetry) is imperative to remediate injury and improve performance, especially for youth baseball players as they progress through the ranks. We found that in-season play in conjunction with shoulder complex training significantly improved shoulder joint strength as measured via isokinetic dynamometry. In addition to these objective improvements, we also garnered positive subjective feedback from the players, guardians and coaches pertaining to performance, arm fatigue and program ease of use. At this time, we have yet to discover norms relative to throwing volume to which we could compare our subjects.

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