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Exercise Program to Modify Risk Factors For Shoulder Injury in Collegiate and Professional Pitchers

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EXERCISE PROGRAM TO MODIFY RISK FACTORS FOR SHOULDER INJURY IN COLLEGIATE AND PROFESSIONAL PITCHERS

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EXERCISE PROGRAM TO MODIFY RISK FACTORS FOR SHOULDER INJURY IN COLLEGIATE AND PROFESSIONAL PITCHERS

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Upper extremity injuries are very common in collegiate and professional baseball pitchers. Approximately 60% of all injuries in collegiate baseball are due to throwing, and pitchers suffer over 70% of throwing-related injuries. In Major League Baseball (MLB), about 50% of players on the disabled list were pitchers, and the injury rate for pitchers is 34 % higher than position players. Therefore, there is a significant need for injury prevention programs to effectively reduce injuries in the population. Although numerous research has been devoted to the study of risk factors and treatment of baseball-related injuries in youth and adolescent players, there have been very few studies on exercise-based injury prevention programs for collegiate or professional baseball pitchers. Therefore, the purpose of this project is to create an evidence-based exercise prescription that clinicians can use to alter factors that may be related to a higher risk of shoulder injury in collegiate and professional baseball pitchers. In order to create an evidence-based program to prevent shoulder injuries in baseball pitchers, three steps were taken: (1) risk factors for shoulder injury were defined via a review of prospective studies; (2) interventions that target and change each risk factor were identified in the literature; and (3) an injury-prevention exercise program was designed using effective interventions. The evidence-based review of the risk factors for shoulder injuries revealed that range of motion (ROM) deficits in the throwing shoulder, preseason rotator cuff weakness, and poor lumbopelvic control (degree of anterior-posterior pelvic tilt) are major factors that increase injury risk in collegiate and professional baseball pitchers. The cross-body stretch is effective at improving ROM deficits including posterior shoulder tightness and glenohumeral internal rotation deficit. Rotator cuff muscles are strengthened by exercises which efficiently activate dynamic stabilization around shoulder girdle. The pelvic tilt is corrected by exercises that target the multifidi and transverse abdominus. This injury-prevention exercise program can be used by clinicians in the preseason and early season to potentially reduce the risk of injury in collegiate and professional baseball players. This can also serve as a model for injury-prevention research in this population.

Introduction

Baseball players are at significant risk of both acute and chronic injuries. Between 1998-2015, 8,357 professional baseball players were placed on the disabled list (DL), an average of 464 designations per year.[1] During the study period, the number of players on the DL steadily increased.[1] Similar to Major League Baseball (MLB), analysis of game and practice injury rates over 16 seasons in collegiate baseball players found no change in either the game injury rate or the practice injury rate.[2] In collegiate baseball players, approximately 45% of all game and practice injuries were to the upper extremity, with shoulder muscle-tendon strain and elbow ligament sprain reported the most often.[2] In MLB players, upper extremity injuries continue to represent approximately half of all injuries resulting in missed playing time. Pitchers are at highest risk for sustaining injuries, especially upper extremity injuries, when compared to position players in both collegiate and MLB players.[1,3] Upper extremity injuries place a significant burden on collegiate and professional baseball players, and thus care should be taken to prevent these injuries.

The prospectively-identified risk factors for shoulder injuries may be classified into two elements: range of motion (ROM) factors and strength and neuromuscular control factors. ROM factors include the glenohumeral internal rotation deficit (GIRD), the difference in external rotation (ER) between the throwing and non-throwing shoulder, and the difference in total rotation motion (TRM).[4,5] Strength and neuromuscular factors include preseason shoulder ER muscle weakness and poor lumbopelvic control. Both ROM and strength factors are largely modifiable, meaning that rehabilitation or exercise programs may be able to change these to decrease the risk of shoulder injury. Finding ways to reduce the incidence of shoulder injury should be a primary objective of sports medicine professionals working with baseball players. However, there is limited literature regarding evidence-based injury prevention programs for collegiate and professional baseball pitchers. Therefore, the purpose of this professional paper was to define risk factor for shoulder injury via a review of prospective studies, to identify interventions that target and change each risk factor in the literature, and to create an injury prevention program based on these risk factors. The injury prevention program was developed by addressing each risk factor with exercises or treatments that have been shown in the literature to directly affect the specific factor identified. The results of this paper and proposed injury prevention program was completed to create a framework for future research to evaluate the efficacy of an evidence-based injury prevention program in collegiate and professional pitchers.

Epidemiology of injuries in MLB and collegiate baseball players

Collegiate and professional baseball players suffer a significant number of injuries to the shoulder. Studies on National Collegiate Athletic Association (NCAA) collegiate baseball players found the greatest number of injuries was to the upper extremity (58%), followed by the lower extremity (27%), trunk/back (15%), and head/neck (7%).[2] During the 16-year period of collegiate baseball injury study conducted by Dick et al.[2], 1623 shoulder injuries were recorded, of which 972 (59.5%) were associated with throwing. Pitchers accounted for 709 (73.0%) of these injuries. The data show that 23.4% and 16.0% of all injuries during practices and games, respectively, were to the shoulder.[2] In collegiate baseball players, most common shoulder injuries were muscle tendon strain, tendinitis, dislocation, and ligament sprain.[2]

Pitchers experienced significantly higher incidence rates for injury when compared with fielders in MLB as well as college. Conte et al.[6] studied disability days in MLB and found that injuries to pitchers represented an average of 48.4% of those on the DL and 56.9% of the total DL days over 11 years. Shoulder injuries accounted for an average of 27.8% of DL days for all DL reports over a 5-year period in MLB players.[6] According to another study by Posner and colleagues[7], the incidence rate for injury among pitchers was 34% higher when compared with fielders. Posner et al.[7] analyzed incidence rates by month of the season across all years in MLB. The result showed that the majority of injuries occurred in the first half of the season.[7] The highest rate of injury was observed in the first month of the regular season and the lowest rate was in the last month, and there was a significant decrease in the incidence of injury as the season progressed.[7]

Grana et al.[8] reported on the injury statistics within a single organization. A total of 52 elbow and shoulder injuries occurred among 84 pitchers in the Major and Minor Leagues; the most common injuries were contusions, inflammation, strains, sprains, bursitis, fractures, nerve compressions, and ligament tears.[8] Forty-nine injuries resulted in time-loss and 26 resulted in surgery. Looking at some examples of shoulder injuries that resulted in longer disabled days, Xinning and colleagues[9] investigated the epidemiology of injuries over the course of a single season in professional baseball players. They found that the injury that accounted for the longest recovery time (in terms of disabled days) was a subscapularis strain/superior labral tear anterior posterior (SLAP) repair, which resulted in

157 days on the disabled list.[9] Another player suffered biceps tendinitis, which resulted in a total of 86 days on the DL.[9] Shoulder injuries accounted for significant time on the injury/disabled list for players in the study.

Collectively, these injury data in collegiate and professional baseball players tend to substantiate the clinical experience and observation that most shoulder injuries resulted from throwing and most of those injuries are related to pitching.[2] In addition, the pitching motion places tremendous stress on the shoulder joint, placing those joints at risk of injury. Since the greatest number of game injuries occur in season, whereas the greatest number of practice injuries occur during the preseason, proper preseason and in-season conditioning to prevent injuries is important to reduce these conditions, particularly throwing injuries in pitchers.[7]

Kinetic Chain and Scapular Stabilization

The pitching motion is a complex compilation of motion at the lower leg, hip, trunk, shoulder, and elbow.[10] The pitching motion is described in six phases: wind up, early cocking, late cocking, acceleration, deceleration, and follow through.[10] Of these phases, the early cocking, late cocking, acceleration and deceleration are associated with the highest forces and moments applied to the shoulder and elbow. In the early cocking phase, a rapid sequential rotation of the pelvis, upper torso and shoulder occurrs, ending with planting of the striding foot.[11] The shoulder moves into horizontal abduction resulting in tensile stress within the anterior shoulder structures and compression/impingement of the posterior rotator cuff and labrum between the posterior glenoid and the humeral head.[11] This motion has been linked to anterior shoulder instability and posterior rotator cuff impingement.[11] Decreased hip ROM during this phase may cause excessive shoulder horizontal abduction to compensate, which may increase the risk of shoulder injury.[12] During the late cocking and acceleration phase, the shoulder reaches maximum ER.[11] When pitchers move into ball release in the deceleration phase, a significant distraction force is placed at the long head of biceps tendon of the shoulder and elbow joints.[11] Since the eccentric work by posterior rotator cuff and biceps brachii muscles help achieve arm deceleration, the joint capsule and ligaments as well as these muscles bear the distraction force which may equal 1.0-1.5 times body mass at the shoulder joint.[11] Extreme shoulder ER tends to result in SLAP lesions, placing increased tension on the long head of biceps and labrum.[11]

The kinetic chain referred to a biomechanical principle that means parts of the body work together to accomplish functional movement and force development.[12] The kinetic chain plays an important role during the pitching motion when transferring energy from the lower extremities through the trunk to the upper extremities.[10] Since evaluation of the kinetic chain throughout the whole body is difficult, Kibler et al.[12] suggested evaluating the pitching motion at five key positions: weight on back leg with trunk straight, hip and trunk synchrony, elbow at or above 90° of abduction with scapular retraction and hand on top of ball, front foot directly toward home plate, and long-axis rotation (shoulder IR and forearm pronation). Evaluation of these positions and motions is helpful to identify alternations of kinetic chain because deviations at these five positions are associated with poor throwing mechanics and shoulder injury.[12] However, it is unknown whether these deviations would be mechanisms of injury, or potential consequences of underlying injury processes. Also, clinicians are unsure whether early identification and fixing the alternations can decrease injury incidence.[12]

In addition to the kinetic chain, scapular stabilization is essential during the pitching motion. The scapula functions to provide a stable platform for the humeral head during rotation and elevation, while transferring kinetic energy from the lower limbs and trunk to the upper extremity.[10] Scapular dyskinesis, which is an abnormal scapular position and motion, is associated with external shoulder impingement, internal shoulder impingement, anterior capsular laxity, labral injury, and rotator cuff weakness.[13] However, it is unknown whether scapular dyskinesis is precisely correlated with shoulder injury and whether correction of scapular dyskinesis has a positive impact on injury prevention.[12]

Shoulder Pathology

Common pathologic conditions seen in baseball pitchers are SLAP lesions, rotator cuff tears, internal impingement, and subacromial impingement.[10,13] SLAP lesions are labral tears of the superior aspect of the glenoid labrum that run anteriorly and posteriorly to the long head of biceps tendon. Snyder et al.[14] defined four types of SLAP lesions. Type I is a fraying and degenerative appearance of the superior labrum, but the peripheral labral edge remained firmly attached to the glenoid, and the attachment of the biceps tendon to the labrum was intact.[14] Type II is characterized by a detachment of the superior labrum with or without the long head of biceps tendon from the supraglenoid tubercle.[14] Type III is a bucket-handle tear in the superior labrum that the central portion of tear is displaceable into the joint and the peripheral portion and the long head of biceps tendon are intact.[14] Type IV is also a bucket-handle tear of the superior labrum, but in addition, the tear extends to the long head of biceps tendon.[14] The mechanism of injury varies from acute traumatic events to repetitive microtraumatic injuries. Traumatic events include a direct blow compression force to the superior labrum, falling on an outstretched arm, and a forceful traction of the upper extremity.[15,16] Repetitive microtraumatic events occur through the deceleration and follow-through phase of pitching when high eccentric biceps activity works to decelerate the elbow, and tension of the long head of biceps tendon pulls the labrum away from the glenoid fossa.[16] Despite a number of cadaveric, imaging, and arthroscopic studies, the true incidence of SLAP lesions in the overhead athlete remains unclear. In Snyder's original description, the authors reported on 27 SLAP tears in over 700 arthroscopic shoulder cases, for an incidence of just under 4%.[14] Since the study, the incidence and number of SLAP lesions has been increasing. Kim et al.[17] reported an overall incidence of 26% in 544 shoulders; and 74 % were type I, 21 % were type II, 0.7 % were type III, 4 % were type IV.[17]

Similar to SLAP lesions, rotator cuff tears can result from acute tensile overload and/or repetitive microtrauma from eccentric failure.[10] The most vigorous phase of rotator cuff muscle activation is during arm deceleration.[18] Eccentric contraction the rotator cuff muscles during arm deceleration places significant stress on the surrounding soft tissues of the shoulder. Weakness or poor coordination of the external rotators leads to a lack of muscular control during late cocking and deceleration, which, in turn, predispose pitchers to shoulder injury.[19] Poor coordination between internal and external rotator cuff muscle activation has been linked to pain during the throwing motion.[19] The prevalence of rotator cuff tears varies in studies. Connor et al.[20] reported partial or full-thickness cuff tears in 8 of 20 (40%) dominant shoulders, compared with none in the nondominant shoulder in overhead athletes. Miniaci and Dowdy[21] found that 80% of throwing and non-throwing shoulders in 14 professional baseball players had some signal changes or abnormalities on magnetic resonance (MR) imaging in the supraspinatus and infraspinatus tendons.

Internal impingement is a physiological phenomenon in which the undersurface of the rotator cuff contacts the posterosuperior aspect of the labrum with the arm in maximum ER and abduction.[10] Internal impingement is most likely caused by anterior instability.[13] When mild anterior instability first develops, the rotator cuff muscles compensate by increasing their activity. With continued throwing, however, these dynamic stabilizers become fatigued, no longer able to prevent anterior translation of the humeral head.[10,13] With the arm abducted and maximally externally rotated during late cocking, forward subluxation of the humeral head may cause direct contact between the greater tuberosity of the humeral head and the posterosuperior labrum.[13] The rotator cuff tendons and posterosuperior labrum may be pinched between the greater tuberosity and glenoid, leading to the internal impingement syndrome.[13] Pitchers with anterior instability typically present with shoulder pain during the late cocking or early acceleration phases, although pain may occur during other phases as well. The true incidence of internal impingement in baseball pitchers is unknown due to the variety of associated pathologic conditions, such as SLAP lesions and rotator cuff tears.[13]

Secondary subacromial impingement occurs when the space between the acromion process and humeral head is decreased due to weakness or poor neuromuscular control in the glenohumeral joint. Secondary subacromial impingement is typically diagnosed in older throwing athletes with a stable shoulder. These athletes often have loss of internal rotation (IR) without the increase in ER.[10] Subacromial impingement causes compression of the rotator cuff muscles and the subacromial bursa against the anteroinferior aspect of the acromion and the coracoacromial ligament.[22] This condition may lead to pain experienced through overhead movements as the shoulder abducts, because the arc of movement causes increased contact pressure of the upper surface of the tendon of the rotator cuff and the subacromial bursa on the undersurface of the acromion and the coracoacromial ligament.[22,23] In general population, subacromial impingement accounts for 44-65% of all shoulder pain in orthopedic clinics.[24]

Risk factors

Study Selection

A risk factor selected for this professional paper was any specific variable that has been shown to change the risk of suffering a shoulder injury. Using prospective or retrospective cohort studies provides the strongest evidence when establishing a risk factor for injury. The inclusion criteria for this paper are as follows:

- Prospective or retrospective cohort study must be performed using collegiate or professional baseball pitchers.
  - Physical examination for risk factors must have taken place in a group of uninjured players prior to injury identification.
- Study must provide results specific to shoulder injuries.

- The identified risk factor must be modifiable.
- The identified risk factor had to be potentially changed by specific exercise intervention. (stretching, strengthening, improving neuromuscular control, etc.)

There are other risk factors for shoulder injury in baseball players such as pitch counts, pitching velocity, lack of rest between outings, or bony structures like humeral torsion which are not readily modifiable using specific exercise interventions..[25,26,27] In addition to these possible factors, risk factors in other body parts may increase the risk of shoulder injury. However, these possible factors have not been appropriately studied using a prospective or retrospective cohort study. Therefore, they did not meet the inclusion criteria for this professional paper.

ROM Factors

ROM deficits in the throwing shoulder may lead to shoulder injuries. Several recent prospective studies have identified ROM risk factors for injuries to the shoulder in MLB pitchers. Most pitchers exhibit unique ROM characteristics, including excessive ER and decreased IR at 90° of shoulder abduction referred to as GIRD.[4,28] GIRD has been defined as a loss of IR of the throwing shoulder of 20° or more as compared with the non-throwing shoulder.[4] Pitchers with GIRD were 1.9 times more likely to suffer a shoulder injury than those without GIRD, however this increase in risk did not achieve statistical significance (P=0.17). The lack of significance was likely due to a smaller sample size, both for injuries and for those with GIRD.[4] Although GIRD and shoulder injury did not have a statistically significant relationship, the result indicated that pitchers with GIRD were potentially more susceptible to shoulder injury.

A loss of IR at the shoulder may play a role in the development of SLAP lesions. Burkhart et al.[29] described the mechanism of a SLAP lesion following GIRD caused by posterior capsule tightness. The tight posterior capsule allows hyperexternal rotation of the shoulder by shifting the glenohumeral contact point posteriorly.[29] Hyperexternal rotation is possible to minimize the cam effect of the proximal humerus and greater tuberosity clearance off the labrum resulting in a magnified arc of ER before the greater tuberosity contacts the posterior labrum.[29] Pitchers with a tight posterior capsule and GIRD need greater ER in the late cocking phase to maximize angular velocity that contributes to the velocity of the baseball at ball release.[29] Although the longer arc of rotation through which angular acceleration is achieved occurs by the hyperexternal rotation, it may lead to a peel-back phenomenon which produces a twist at the base of the biceps tendon posteriorly and transmits a torsional force to the posteriosuperior labrum. This peel-back force in the late cocking phase can result in a posterior SLAP lesion.[29]

GIRD may also increase the risk of subacromial impingement. McClure et al.[30] also noted that selective tightness of the posterior capsule may lead to anterior and superior translation of the humeral head with passive shoulder flexion. The abnormal humeral head motion may result in a decrease in the subacromial space during overhead activities, which can lead to impingement and supraspinatus pathology.[4,30]

Although hyperexternal rotation may cause a posterior SLAP lesion or impingement, insufficient ER of the throwing shoulder also increases the risk of shoulder injuries. When the side-to-side shoulder ER difference is less than 5° (the throwing shoulder ER is less than 5° greater than that of the non-throwing shoulder), it is defined as "insufficient ER".[5] MLB pitchers with insufficient ER were 2.2 times more likely to be placed on the DL for a shoulder injury and were 4 times more likely to require shoulder surgery.[5] Wilk et al.[5] reported that 46% of pitchers had insufficient ER when they evaluated shoulder ROM in 288 professional baseball pitchers. Twenty-three percent of pitchers who were placed on the DL for a shoulder injury had insufficient ER, whereas only 12% were on the DL without insufficient ER.[5] A total of 75 shoulder injuries occurred to 51 pitchers.[5] The majority of the surgeries were combined labral and rotator cuff debridements (35%) and labral repairs (30%), followed by simple labral debridements (20%), rotator cuff repairs (10%), and subacromial decompression (5%).[5] Under the assumption that decreased throwing shoulder ER is one of the risk factors for shoulder injuries, shoulder ER is protective to the glenohumeral joint in pitchers, at least to a certain degree. Polster et al.[31] reported the ROM threshold that resulted in an increased risk of subscapularis injury was <106° ER of the throwing shoulder at 90° of abduction. In the study, a retrospective review of MR scans of the shoulder in 133 professional baseball players over the course of five years was performed to identify cases with findings suggestive of subscapularis injury.[31] These findings were graded, and the medical record was reviewed to assess clinical findings, treatment, and follow-up.[31] Preinjury baseline measurements of arm external rotation at 90° of abduction were compared to measurements from a non-injured cohort to evaluate whether this measure is a risk factor for injury.[31] MR scans demonstrated ten players had a clinical diagnosis of throwing-related subscapularis strain.[31] As throwing arm

ER at 90° abduction decreased, the chance of subscapularis injury increases with odds ratio 1.12 among the ten players.[31] Although this study was a retrospective review, the measurement of the threshold may help clinicians to identify pitchers who have higher risk of shoulder injuries.

Those shoulder IR and ER characteristics in pitchers may lead to TRM deficit. TRM is defined as the sum of ER and IR ROM in a shoulder, and TRM deficit means that throwing shoulder TRM is less than non-throwing shoulder by 5° or more.[4] Wilk et al.[4] conducted shoulder measurements (passive IR and ER at 90° of abduction) in 170 professional baseball pitchers during spring training over three consecutive seasons (2005-2007). Days in which the player was unable to participate because of injury or surgery were recorded during the season and defined as an injury. The authors reported that a series of 78 out of 170 shoulders showed a TRM deficit with the shoulder abducted 90°.[4] They were 2.5 times more likely to be injured compared to pitchers without the risk factor.[4] Of the 37 injuries reported, 29 (78%) occurred in pitchers whose throwing-arm TRM was greater than 176°; 6 injuries (16%) occurred in pitchers whose TRM was less than 176°; and 2 pitchers (5%) sustained injuries with a TRM of 176°.[4] These results indicated that caution should be taken to not exceed TRM greater than 176° in the throwing shoulder or outside the 5° acceptable window, compared with the contralateral shoulder.

In summary, the changes in ER and IR ROM typically seen in pitchers are likely the result of the soft tissue adaptations which include an posterior shoulder tightness.[29,30] GIRD is one of the common characteristics in pitchers that may cause peel-back phenomenon which allows for greater ER.[26] To throw at higher angular velocity, greater ER in the late cocking phase should be achieved because it allows a greater time of acceleration.[26] This throwing mechanism leads to selective stretching of the anterior capsule by repetitive microtrauma and tightening of the posterior capsule and results in a change in side-to-side ROM.[10,28] As a result of changes in shoulder ER and IR in the throwing shoulder, TRM may also be affected. Pitchers with TRM deficit greater than 5° had a higher risk of injury. In addition, TRM greater than 176° should be viewed with caution.

Strength and Neuromuscular Control Factors

The primary role of the eccentric contraction of external rotators during arm deceleration is to dissipate the kinetic energy created by the concentric contraction of the internal rotators during late cocking and acceleration.[18] Repetitive eccentric overloading may result in a cycle of connective tissue tearing in the muscle, inflammation, and weakness. Weakness of the external rotators can also lead to a lack of muscular control during late cocking and deceleration, which may in turn predispose pitchers to shoulder injury.[32] Byram et al.[18] analyzed the predictive value of preseason shoulder strength measurements in identifying players at risk for in-season throwing-related injury. Over a five-year period (2001-2005), isometric strength was assessed in the throwing arm for prone internal rotation (PIR), prone external rotation (PER) with the scapula free, seated external rotation (SER) with the scapula fixed against the wall, and supraspinatus (SS) in 144 professional baseball pitchers.[18] There were a total of 70 injuries in 50 players, of which 41 injuries occurred at shoulders.[18] Shoulder injuries included rotator cuff strain/tendinitis, biceps tendinitis, SLAP lesions, shoulder impingement syndrome, rotator cuff tears, posterior labral tears, pectoralis major strains, latissimus strains, and scapular stress fracture.[18] The authors found a statistically significant association between PER strength (*P*=.05) and SS strength (*P*=.038) and shoulder injury requiring surgical intervention.[18] Pitchers with PER strength at the 5th percentile (23.3kg) had an estimated 31.3% likelihood of injury requiring surgery as compared with 4.6% in those at the 95th percentile (52kg).[18] Pitchers with SS strength at the 5th percentile (19.25kg) had an estimated 32.8% likelihood of injury requiring surgery as compared with 5.3% in those at the 95th percentile (38.75kg).[18] They also noted a statistically significant association between SS strength (*P*=.031) as well as the ratio of PER/ PIR (*P*=.037) and the likelihood of any shoulder injury. Pitchers with a PER/PIR ratio at the 5th percentile (0.724) had an estimated 39% likelihood of injury as compared with 17.5% in those at the 95th percentile (1.42).[18] These findings may be helpful in preventing injuries by focusing preseason and in-season strength training on the posterior rotator cuff and SS, especially in players found to be weaker in these areas.

Another strength and neuromuscular control risk factor is poor lumbopelvic control. Lumbopelvic control is an important component to successful pitching. The lumbopelvic region, including the "core" muscles crossing the lumbar spine and abdomen as well as the muscles crossing the hip joints, has received considerable attention due to its location bridging the legs to the arms. The core is defined as, "the axial skeleton (which includes the pelvic girdle and shoulder girdles), and all soft tissues with proximal attachment originating on the axial skeleton, regardless of whether the soft tissue terminates on the axial or appendicular skeleton (upper and lower extremities)."[33, p.1684] All of the muscles of this region influence motion of the pelvic girdle in the sagittal as well as frontal and transverse planes.

Chaudhari and colleagues[34] investigated lumbopelvic control utilizing a single-leg step test in 347 professional baseball pitchers pre-season. In this test, participants performed single leg balance for two seconds lifting of their stride foot approximately 10cm, and then returned to double-leg-stance under control.[34] Each participant performed two repetitions for each leg. This motion was chosen because it is similar to the beginning of the pitching motion and it requires the participant to shift weight onto a single leg and maintain stability through the hip and trunk.[34] The degree of anterior-posterior tilting of the pelvis, relative to its' starting position, was measured in degrees using an iPod-based tilt sensor.[34] The largest deviation from the starting position was recorded and utilized for analysis.[34] Based on these deviations, participants were divided into three groups: poor lumbopelvic control (>8.0°), moderate lumbopelvic control (4.0°-7.9°), and good lumbopelvic control (<4.0°).[34] Injuries that resulted in designated time on the disabled list was tracked across a single season. The pitchers with the poorest lumbopelvic control were 3.0 times more likely to miss >30 days due to injury, compared to the good lumbopelvic control.[34] Pitchers with poor lumbopelvic control were also 2.2 times more likely to miss >30 days due to injury compared to those with moderate lumbopelvic control.[34] Shoulder injuries accounted for approximately 29.9 % of all 144 injuries over a single season.[34]

A lack of lumbopelvic control may lead to an inability of the pitcher to efficiently transfer energy from the lower extremity to the upper extremity, leading to excessive use of the shoulder, arm and wrist muscles to generate ball velocity. It could also lead to early "opening up" of the torso towards the target, forcing the torso, shoulder and elbow to the extremes of the ROM in a whip-like motion, which may cause excessive joint moments that strain the ligaments and other soft tissues leading to overuse injuries.[34] Also, poor lumbopelvic control may be associated with poor ball control or velocity if pitchers are unable to transfer energy efficiently from the lower extremities to the throwing arm.[34] In this case, pitchers may overexert the muscles of the shoulder and arm to create velocity, perhaps sacrificing arm control in the process.[34] Because of the high velocities that occur and the large forces that are generated, if compressive energy transferring do not counteract the high distraction forces on the upper extremity, injuries may occur.

Summary of Risk Factors of Shoulder Injuries

Through the literature review, there are potentially three ROM factors and two strength and neuromuscular factors related to shoulder injuries as listed below:

ROM Factors

- GIRD[4,28]
- Insufficient ER (<5° greater external rotation in the throwing shoulder, or <106° in the throwing shoulder)[5,31]
- A throwing-arm TRM is more than 5° compared to the non-throwing -arm[4]

Strength and Neuromuscular Control Factors

- Weak posterior rotator cuff and supraspinatus in preseason[18]
- Poor lumbopelvic control during a set-up task[34]

Exercises and Treatments to Change the Risk Factors

The next step of this professional paper is to create a preseason and in-season exercise program, designed to address each of the risk factors based on the literature. An intervention selected for this professional paper was any stretching or exercises that has been shown to modify a specific identified risk factor for shoulder injury. The inclusion criteria for study selection for interventions were as follows:

- Experimental study must be performed to examine the outcomes of the intervention.
- Systematic review must include experimental studies.
    - Study for ROM interventions must provide outcomes ROM measurements on shoulder IR, ER, or TRM.
    - Study for strength and neuromuscular control interventions must use provide EMG values on rotator cuff muscles, multifidi (MF) and transverse abdominus (TrA) muscle.

Existing Injury Prevention Program

Although there are plenty of rehabilitation programs for shoulder injuries, very few injury prevention programs for shoulder injuries are found. Most injury prevention research in baseball has focused on pitch counts, rest days, and overlapping seasons, not on exercise-based programs. Moreover, the few prevention programs in the literature have not focused on baseball pitchers nor identified multiple risk factors and interventions. There is only a single study that has evaluated the efficacy of an exercise-based injury prevention program on the risk of injury in youth baseball players aged 8 to 11 years old.[35] The prevention program consisted of nine strengthening and nine stretching exercises that were performed at least once a week. The risk of medial elbow injuries was significantly lowered by increasing dominant side TRM ROM, increasing nondominant side hip IR, and decreasing thoracic kyphosis.[35] However, the authors did not report on whether this program impacted shoulder injuries.

Although the prior study demonstrates positive effect on the risk of medial elbow injury in young athletes, the effectiveness of injury prevention programs on shoulder injury in collegiate and professional pitchers is unknown. Melugin and colleagues[36] introduced injury prevention recommendations in baseball players from youth to professionals. For youth to high school baseball players, they included restricted pitching and participation in games, stretching and strengthening, and acquiring proper pitching mechanics.[36] However, they mentioned there was a limited amount of injury prevention literature specific to collegiate and professional baseball.[36] McCrary and colleagues[37] conducted a systematic review of upper-body warm-ups, and reported there has been no investigation of the effects of upper body warm-up on injury prevention outcomes. The authors concluded that there are no studies that support the use of an upper-body warm-up to prevent injury, despite the fact that warm-up programs are often used for injury prevention.

There is one evidence-based study observing a prevention program for shoulder injuries in overhead athletes, however it is not specifically targeting baseball pitchers.[38] The study evaluated possible risk factors for injury in the shoulder, in particular GIRD, rotator cuff strength, and scapular performance.[38] Then the author suggested specific interventions such as stretching of the posterior shoulder capsule, strengthening of the posterior rotator cuff, and restoration of flexibility and muscle balance of the scapular muscles.[38] Stretching strategies included cross-body stretching and the sleeper stretch.[38] Eccentric and plyometric exercises for the external rotators in the shoulder were introduced to increase posterior rotator cuff strength.[38] For scapular motion, the study did not provide any specific exercises, but suggested a science-based algorithm for scapular dyskinesis.[38]

One of the common exercise programs for baseball players is Thrower's Ten. The Thrower's Ten is an organized and concise exercise regimen specifically designed for pitchers and throwers.[39] Each movement is designed to improve strength, power, and endurance of the shoulder and forearm muscles. This has been used as a prevention and rehabilitation exercise program for baseball players. However, this program only focuses on strengthening the major shoulder musculatures necessary for throwing. The Thrower's Ten does not include any shoulder stretching exercises or trunk, abdominal, or lower extremity exercises. Based on the preceding review of risk factors, the Thrower's Ten may not adequately address several established factors related to injury, and thus may not effectively prevent throwing injury in collegiate and professional baseball pitchers. Adding stretches that address IR, ER, and TRM, as well as core stability, may enhance the ability of this exercise program to potentially prevent pitching-related injury.

Changing Shoulder IR, ER, and TRM ROM

Stretching is a common intervention to resolve ROM deficits. Mine and colleagues[40] analyzed randomized controlled trial studies examining effects of stretching on posterior shoulder tightness (PST). The use of active, passive or muscle-energy technique (MET) forms of cross-body stretch are recommended to improve PST and GIRD for asymptomatic young overhead athletes.[40] The active and passive cross-body stretches had the strongest evidence compared to other stretching or mobilization techniques. Since stretching parameters were different in each of the articles, there is no specific recommendation for stretching parameters. In general, the cross-body stretches were performed once daily over 4 weeks for 5 repetitions, holding for 30 seconds.[40] Muscle energy technique were applied to the glenohumeral joint horizontal abductors. The participants performed a 5 seconds isometric contraction in the direction of horizontal abduction.[41] Following the contraction, the participants applied a 30 seconds active cross-body stretch.[41] Other moderate quality-studies suggested the active sleeper stretch, all-fours posterior stretching or prone-passive stretching technique can be attempted instead when cross-body stretch causes pain or is not effective, but neither of these methods is as effective as the cross-body stretch.[40] The parameters of these stretching exercise were similar to that of the cross-body stretch. The use of multiple active stretching exercises such as cross-body stretch, sleeper stretch, and, triceps brachii muscle stretching between innings might also be beneficial for pitchers to decrease GIRD.[40]

To correct insufficient ER, proprioceptive neuromuscular facilitation (PNF) stretching is effective at increasing ER shoulder ROM.[42] Three PNF stretching techniques becoming techniques of choice are the contract-relax (CR), hold-relax (HR), and slow reversal-hold methods. Decicco and Fisher[42] compared the effects of CR and HR on shoulder ER in healthy male and female overhead athletes. Subjects were randomly assigned to CR, HR, and control groups, and their ER ROM were recorded pre-and post-treatment by goniometer. The PNF stretch started with prestretch of internal rotator cuff for 10 second, then the participants performed a 6 seconds concentric or isometric contraction in the direction of IR.[42] After the contraction, a 10 seconds passive stretch for external rotator cuff was applied.[42] After six weeks, both CR and HR produced a significant increase in ER ROM from pre-treatment to post-treatment, increasing 13.5° and 14.6° respectively.[42]

There is another stretching drill, called the two-out-drill, that can be implemented between innings.[43] The purpose of this short-duration stretching drill is to increase IR, ER, total rotational motion, and elbow extension in professional baseball pitchers after pitching. The drill is a short-duration stretching/calisthenics program that consists of seven exercises including an IR stretch, elbow extension stretch, big arm circles, small arm circles, forearm touch, 90/90IR and ER, and trunk rotation.[43] The seven exercises effectively restored the decreased IR and ER ROM after pitching to pre-pitching values.[43] TRM also demonstrated similar results to ER and IR results. They concluded that after a 40-pitch bullpen session, IR and ER passive range of motion (PROM) as well as TRM were significantly lower than pre-pitching values; however, these deficits were restored back to their pre-pitching levels after the players performed the two-out drill, which may increase pitching performance and decrease the risk of shoulder and elbow injuries.[43]

In summary, stretching exercises can improve shoulder IR and ER. The active, passive or MET forms of cross-body stretch improves IR.[40] The active sleeper stretch, all-fours stretch or prone passive stretch should only be used as a supplementary method, if the cross-body stretch is not possible. To increase ER, CR and HR PNF stretches are effective.[42] As a result of changing IR and ER, TRM is improved using both methods. The use of two-out-drill between innings may prevent a decrease in both IR and ER seen during a single outing, and may be implemented to maintain ROM during a game or practice.[43]

Increasing Posterior Rotator Cuff and Supraspinatus Strength

Efficient dynamic stabilization and neuromuscular control of the glenohumeral joint is necessary for overhead athletes to avoid injuries. As Byram reported[18], preseason PER strength and SS strength measurements may be one tool to identify pitchers at risk for shoulder injuries. Muscles that externally rotate the glenohumeral joint are the posterior deltoid, as well as three of the four rotator cuff muscles (supraspinatus, infraspinatus, and teres minor). Therefore, it is beneficial to understand the function of those rotator cuff muscles, and find exercises that activate the rotator cuff to use as injury prevention exercises.

Researchers has evaluated the electromyography (EMG) activity of the rotator cuff muscles during various motions and exercises. Marta et al.[44] quantified EMG activity of the shoulder external rotator muscles (posterior deltoid, infraspinatus, teres minor) and the upper, middle and lower trapezius in seven exercises. Twenty healthy males performed all seven exercises in random order. Both the external rotators and trapezius muscles were highly activated by prone exercises compared to other standing or side-lying exercises.[44] The prone exercises included prone horizontal abduction at 90° with full ER with thumb up; prone horizontal abduction at 90° abduction with slight ER with thumb up; prone horizontal abduction at 100º abduction with full ER; and prone ER at 90º abduction and elbow at 90º.[44] However, the authors suggested side-lying ER with elbow on trunk at 90° is the most appropriate exercise if the main concern is to isolate the recruitment of the infraspinatus muscle, because the infraspinatus is most activated when the shoulder is abducted at lower angles.[44] Similarly, a systematic review reported greatest SS activation was achieved by prone horizontal abduction at 90°-100° with ER, push-up-plus, empty can and full can.[45] Greatest infraspinatus activity was produced in prone horizontal abduction at 90°-100° with ER, push-up-plus, and standing ER at 0° abduction. In the systematic review, push-up-plus recorded the greatest average and peak infraspinatus muscle activity compared with other exercises.[45] This exercise also produced the second highest activity level in SS and the highest activation of subscapularis. Gaudet and colleagues[46] supported also found that the push-up plus elicited high subscapularis and serratus anterior activity. The subscapularis and serratus anterior were the only two muscles that were at least moderately activated for all series of maximum concentric IR, eccentric IR, concentric ER, and eccentric ER contractions.[46]

Overall, prone horizontal abduction at 90°-100° with ER and push-up plus may increase the strength of rotator cuff muscles.[44,45] When specifically targeting activation of each one of the muscles, infraspinatus is most activated by side-lying ER with elbow on trunk at 90°; SS is highly activated by push-up plus and empty/full can.[44,45] In addition to strengthening shoulder external rotators, strengthening subscapularis and serratus anterior also may produces extra support for the shoulder stabilization because they are activated during both IR and ER regardless concentric or eccentric contraction.

Improving Lumbopelvic Control

Chaudhari's study[34] showed that subjects with poor lumbopelvic control had the greatest total range of anterior and posterior pelvic tilt as the subject shifts to a single-leg stance position and back to a double-leg stance position. The understanding of which muscles are used during pelvic tilting is vital to optimize the utility of different exercises in an injury prevention program. Some previous studies investigated the activation of core muscles during a pelvic tilt by using EMG and showed the TrA, MF, and erector spinae (ES) were recruited during pelvic tilting.[47]

Takaki et al.[47] investigated muscle activity during anterior and posterior pelvic tilting, using twelve healthy males. In the study, fine-wire electrodes were inserted into the bilateral lumbar MF and TrA. Surface electrodes were placed over the bilateral rectus abdominus (RA), external oblique (EO), and ES, and the unilateral right latissimus dorsi, gluteus maximus, semitendinosus, and rectus femoris muscles.[47] The EMG activity during anterior and posterior pelvic tilting in a standing position were recorded.

During anterior pelvic tilt, the activities of the ES and MF were greater than those of muscles in the lower extremities and trunk.[47] Anterior pelvic tilting occurs when the ES and MF pull the posterior part of the pelvis upward direction.[47] Furthermore, the MF control the segmental movements of the lumbar spine because individual nerves innervate into the MF according to segments of lumbar spine.[47] This indicates that the increase in the activity of the MF may play an important role during anterior pelvic tilting by aiding the ES and hip flexors.[47] During posterior pelvic tilt, the activity of the TrA was greater than that of other muscles.[47] The TrA is located in the deepest layer of the abdominal muscles. The TrA is divided into upper, middle, and lower parts. The middle and lower parts of TrA originate from the lateral thoracolumbar fascia, the inguinal ligament, and the anterior iliac crest, and insert to the linea alba and the pubis in a horizontal or downward inner direction. The direction of these parts of the TrA corresponds to the direction of posterior pelvic tilt.[47] The findings of the study indicated that the TrA and MF may be active and participate in anterior and posterior pelvic tilting, and strengthening those muscles may improve poor lumbopelvic control.

A systematic study reviewed the existing research on EMG activity of three core muscles (lumbar MF, TrA, and quadratus lumborum) during physical exercises: traditional core (e.g. back extension/sit-up), core stability (e.g. prone plank/side bridge), ball/device (e.g. back extension on a ball/crunch on a ball), free weight (e.g. squat/deadlift), and noncore free weight (e.g. shoulder press/biceps curl).[33] The study determined which core exercises are most appropriate to improve core muscle endurance, strength, and stability. The overall quality of evidence was moderate to low.[33] However, the currently available evidence drew certain conclusions of which physical exercises are most effective to elicit EMG activity of the MF and TrA muscles.[33] The findings of the systematic review indicated that lumbar MF EMG activity is greatest during free weight exercises compared with other exercises.[33] Based on the EMG activity values elicited by MF from the included study, deadlift and squat produced higher values compared to other free weight exercises.[33] Possible explanations for the greater lumbar MF EMG activity during free weight exercises include the use of external loading and full body movements with free weight exercises compared with isolated exercises exclusively targeting the core.[33] Although core exercises with a ball/device is frequently used in training programs, the systematic review drew no conclusion about lumbar MF EMG activity when comparing ball/device and traditional core exercises.[33]

Based on the results of this systematic review, no specific type of exercise appears to be more effective than others at producing activity of the TrA muscle.[33] Due to the lack of relative effectiveness, the athlete and clinician may decide specific exercise type to be prescribed the TrA muscle based on their preference considering the available equipment and resources. Adding isolated core exercises to supplement a comprehensive training program involving multi-joint free weight exercises is probably unnecessary to activate these core muscles.[33] Although there is little difference in effectiveness among the selected physical exercises, some exercises elicited relatively higher TrA EMG activity values. For example, hanging knee-up-straps, power wheel (pike), and reverse crunch (inclined 30°) produced higher EMG activity compared to other exercises.[33] These core exercises produced 85 %, 83%, and 86% of maximum voluntary isometric TrA contraction respectively.[33]

Poor lumbopelvic control, which represented anterior and posterior pelvic tilting, may be corrected by core exercises that activate MF and TrA.[33] Pitchers with greater anterior pelvic tilt need posterior pelvic tilt by activating TrA. Since none of the core muscle exercises produced a significantly high EMG value of TrA, the athlete and clinician may select an exercise for the activation of the TrA. Hanging knee-up-straps, power wheel (pike), and reverse crunch (inclined 30°) elicited over 80% of maximum isometric TrA contraction, and thus these exercises are recommended.[33] On the other hand, pitchers with greater posterior pelvic tilt need anterior pelvic tilt by activating MF. To maximally activate MF, free weight exercises such as deadlift and squat are appropriate to be prescribed because they produce higher values of MF EMG activity compared to other core muscles exercise.

Selected Stretching and Strengthening Interventions

Based on the evidence reviewed for this paper, the following exercises have been selected for the injury prevention program:

- Cross-body stretch to improve IR ROM at the shoulder[40]
- CR and HR PNF techniques to increase ER ROM at the shoulder[42]
- Two-out drill to maintain IR and ER ROM during an acute pitching session[43]
- Prone horizontal abduction with ER to improve shoulder ER strength[44]
- Push-up plus to maximally activate infraspinatus and supraspinatus[45]
- Empty can/full can to increase supraspinatus strength[45]
- Side-lying ER to effectively activate infraspinatus[44]
- Deadlift and squat to strengthen multifidi[33]
- Hanging knee-up-straps, power wheel (pike), and reverse crunch (inclined 30°) to strengthen TrA[33]

The frequency, load, repetition, and set of these stretching and strengthening exercises varied between articles. Generally, the studies on the cross-body stretch used 5 repetitions of 30 seconds, performed daily for 4 weeks. Muscle energy technique and PNF added 5-6 seconds of concentric or isometric contraction followed by passive stretch for 10-30 seconds. Most articles used relatively light load (2-4 kg) for rotator cuff strengthening. Therefore, rotator cuff strengthening exercises likely needs to focus on endurance and stability, using lower loads and higher repetitions, rather than power. Deadlift and squat exercises elicited higher EMG values with 50-100% 1 RM, so the clinician should provide an individualized load for each athlete.

The flowchart at the end of this paper (see Figure 1) illustrates a possible injury prevention program that clinicians can follow when they work with baseball pitchers. The prevention program could be used to add exercises to existing conditioning programs. Specifically, this prevention program included shoulder flexibility and core strengthening exercises that Thrower's Ten does not have. The use of this prevention program in conjunction with existing exercise programs may improve the effectiveness of conditioning and injury prevention programs widely used.

Limitations

This professional paper reviewed stretching and exercises interventions to prevent shoulder injuries in collegiate and professional baseball pitchers. However, most of these interventions have not been shown to decrease injury risk due to the lack of investigation into injury prevention outcomes. Another limitation is that this was not an exhaustive review of interventions, and that there is little research examining how interventions may alter strength and lumbopelvic control specifically in baseball players or elite athletes. Therefore, further research is needed to evaluate if the suggested interventions actually decrease baseball related shoulder injuries in collegiate and professional pitchers. Also, exercise parameters such as repetitions, sets, and frequency should be investigated.

Summary

Past research has demonstrated that several ROM and strength variables are risk factors for shoulder injuries in collegiate and professional baseball pitchers. However, no research has been done to investigate the effects of interventions to alter the risk factors on injury prevention outcomes. There is a clear knowledge gap on the effects of injury prevention programs in this population. With respect to injury prevention, the clinician should evaluate possible risk factors for injury in the shoulder, in particular GIRD, insufficient ER, rotator cuff strength, and lumbopelvic control during the preseason and early season. If abnormal findings are found, the intervention should focus on stretching of the posterior shoulder capsule, strengthening of the supraspinatus and infraspinatus, and strengthening of the MF and TrA.

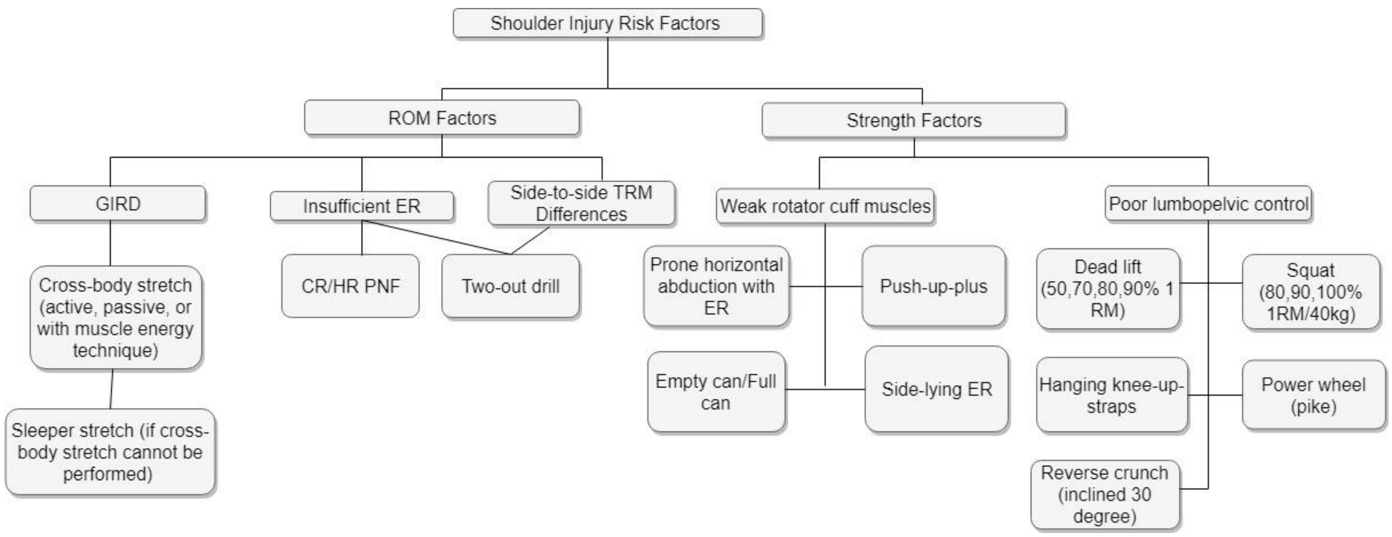

Figure 1 Recommended Therapeutic Exercise to Modify Shoulder Injury Risk Factors

∗This flowchart should be used in conjunction with a comprehensive conditioning/injury prevention program such as scapular stabilizing exercises, additional rotator cuff and core exercises, hip flexibility and strengthening exercises, and arm strengthening through the elbow and wrist.

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