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|  | Authors | Type of Study | Methods | Results | Conclusions |
| Altered LT Relationships | Meyers et al. 2005 | 42 healthy participants (21 baseball athletes and 21 matched males)Case-control design | Participants had max isometric elevation measured and 25% used as weight during elevation exAssessed scapular kinematics using MotionMonitor for 10 trials of scaption | Throwing group had significantly inc upward rotation at 0, 30, 60, 90, 120 deg elevationScap int rotation sig inc for throwers at 0, 30, 60, 90, 120 Scap retraction sig inc at 90 and 120 degNo sig diff in tilting/elevation/depression | Inc scap upward rotation can be significant for clearing impingement Inc IR can result in decreased subacromial space and inability to clear greater tubercleIndicate the “healthy” OH athlete scapular position? |
|  | Cools et al. 2007  | 69 subjects testing both shoulders (healthy vs. impingement) Volleyball, tennis, swimming | Tested EMG activity in max contraction for UT (GH abd), MT (horz abd in GH ER, LT (elevation with arm in diagonal plane aligned with muscle fibers)Then tested abduction-adduction and IR-ER in scapular plane on Biodex (max contractions at 120deg/sec for abd-add and 60 for IR-ER) while recording EMG activity | Found that UT activity was increased on the injured side and LT activity is decreased during GH abdUT activity increased in ER and MT activity decreased MT showed highest level of activity during ER movement – it plays a crucial role for stability during this motionUT is main stabilizer during abd, with MT And LT providing secondary stab roles | Any changes in ratios of muscle tension (i.e. when UT inc activity) it can alter the neuromuscular control of the scapula during motions of the arm |
|  | Merolla et al. 2010 | 31 vb athletes with “inhibition due to pain” in case series type design without a control group | Tested baseline infra strength with scapula free and scapula retracted Rehab program instituted for 6 mo focused on restoring strength ratios for UT, MT, LT (included S/L flex, ER, prone hor abd and ext)  | Sig increase in infra strength when tested with scapula free at 3 mo and 6 moSig decrease in difference between infra strength when scap retracted and when scap free Sig decrease in pain after rehab  | There was an increase in infra strength, but no data on changes in scapular positioning  |
|  | Smith et al. 2006 | Case-control study where 20 healthy subjects acted as own control  | Tested max isometric IR and ER with arm in full IR, midrange IR, and ER – all with scapula protracted or in neutral.  | Found that IR strength was diminished significantly no matter what starting position (-13, 24, 23% in IR, MR and ER start respectively)ER strength significantly decreased when in ER starting position (-20%) | Protraction of the scapula affects the IR and ER L-T relationships differentlyProtraction lengthens lats and dec moment of pec majorProtraction shortens the ER and starting in a position of ER makes this even worseDid not test overhead athletes and only studied isometric strength |
|  | Tate et al. 2008 | 142 OH athletes (baseball, swimming, volleyball and water polo) used in case-control where participants served as own control  | Scapula reposition test: emphasize post tilt and ER of scapula in more neutral position vs. protractionTest isometric strength in Jobe’s position and then tested Neer’s, Hawkins kennedy and Jobes with and without scap repositioning | 46 of 98 athletes with + impingement test had reduction of sx’s 1 pt or greater with scap repositioning26% (n=98) of the impingement group became stronger with repositioning29% (n=44) of the non-impingement group was stronger with repositioning | SRT gives post tilt, ER and retraction of scapula and could alter LT relationships of RTC and deltoidAlso encourages upper thoracic extension (otherwise supra and deltoid in shortened position)SRT could be indication of who would benefit from scapular strengtheningManual repositioning (how effective?) |
|  | Kabaetse et al. 1999 | 34 healthy subjects (non-athletes) in cross-sectional, repeated measures design | Recorded scapular positioning and orientation in 3 different humerus positions: 1. At rest 2. Scaption at 90deg 3. Max scaptionMeasured while the subject in slouched and erect sitting postures | Significantly less max shoulder abduction ROM in slouched position (-23.6deg)No difference in muscle force with arm at rest Significantly less force generated when arm at 90deg scaption (-1.7kg)Significantly less scapular upward rotation from 90deg to max abduction; more IR  | Found that the scapula in the slouched position exhibited more superior translation from neutral to 90; less upward rotation and post tilt between 90 and max; slightly more IR at all levels of abdAcromion creates a bony block due to superior translation and lack of upward rotation/post tilt |
| Humeral Version | Crockett et al. 2002 | Cross-sectional study with 25 healthy baseball pitchers and 25 healthy controls  | Assessed GH ROM (IR, ER), anterior and posterior laxity and given a CT scan to measure humeral torsion | In throwing group: Found humeral head retroversion sig inc in dominant shoulder (17deg), glenoid retroversion sig inc in dominant shoulder, ER greater in dominant shoulder in scap plane and frontal plane with no sig diff in laxity Non-throwing group had no sig diff in version of humerus or glenoidFor throwing vs. non-throwing, sig humeral head retroversion in throwing group, greater ER in throwers, greater overall amount of motion, non-dominant versions not different in throwing vs. non-throwing  | Differences in ER vs. IR ROM may not just be due to capsular laxity but could be due to version of the GH jointGreater humeral retroversion allows for greater amounts of ER Found that capsular restraints for their population were equal from dominant to non-dominant sideClaim the retroversion is developmental because it is not present in the nondominant shoulder (an adaptation to external stress) |
|  | Pieper 1998 | 51 handball players (38 healthy and 13 with c/o chronic shoulder pain)used in case-control design (control group of 37 males) | Measured joint laxity and glenohumeral version through radiograph for both arms of the handball players and non-throwing controls | Found sig inc in retrotorsional angle of throwing arm (9.4deg) vs. non-throwing arm and no sig diff in control groupTorsional angle more pronounced in players without shoulder pain (14.4deg)Compared to control group: 7.62 degrees more of torsion  | Increased humeral retrotorsion allows for more external rotation and therefore increased cocking to accelerationLarger retroversion also leads to decreased IR and stress on post capsule earlier in motionHumeral torsion can be influenced by muscle action |
|  | Sabick et al. 2005 | 14 youth baseball pitchers involved in cross-sectional study | Videotaped pitching motion of players to determine joint kinetics | Found the torque about the shaft of the humerus to be 17.7Nm in ER Distraction force reached 214.7Nm just after ball releaseNear the end of the cocking phase, an IR torque created (by the subscap, pec major, and lat) while humerus is still externally rotating at the elbow so that the distal end is externally rotated compared to the proximal end | Repetitive torques placed on the humerus result in the retrotorsion that ossifies at skeletal maturity |
| Proprioception | Safran et al. 2001 | 18 collegiate-level baseball players in cross-sectional study | Evaluated ROM, ligament and capsular laxityTested proprioception using threshold for detection of passive mvmt and reproduction of position testsPosition of tests included neutral rotation, 75 deg ER, and 75% max ER  | All pitchers had greater ER in dominant arm vs. non-domNo diff in proprioceptive testing, but statistically more accurate in the non-dominant arm than dominant arm when moving from ER to IR Enhanced kinesthesia sense when moving into ER from IR6 pitchers with recent hx of shoulder pain had significant deficit in proprioception vs. healthy | The pitchers who reported having shoulder pain also performed poorly on threshold for detecting passive movementThis proprioception deficit can lead to inc incoordination of muscle firing and recruitment Suggest that the shift in capsular tension post- ant creates affects proprioception |
|  | Rogol et al. 1998 | RCT of 39 healthy male cadets randomized to 3 groups, OKC ex, CKC ex, or control  | Assessed passive and active shoulder joint reposition sense on dynamometer at 30 deg IR, 30 deg ER, and 10 deg from full ERCKC ex was 3x15 push-ups 3 days/wkOKC was 3x15 dumbbell press 3 days/wkOverall strength program lasted 6 wks | Both groups presented with sig improvements in error on the joint reposition tests vs control showing no change No sig differences between groups  | Conclude that the added stimulation provided by the resistance exercises improved sense\*Were not using OH athletes |
|  | Tripp et al. 2006 | 21 healthy male baseball players in cross-sectional study | Measured active multijoint position reproduction while subject in position of half-kneelingHad participants reproduce 2 functional positions: 1) arm-cock 2) ball-release 3x in a row while performing throwing motion  | Found sig less accuracy for ball-release than arm-cocking in scapthoracic IR-ER, GH hor abd-add, and GH rotationLess accuracy and greater variability with scapthoracic IR > post tilt > upward rotation GH hor abd > rotation > flexNo diff found at elbow or wrist joints  | OH athletes are less accurate and more variable in position reproduction for mid-range motions than end-range Conclude that the tension created in capsular structures at end-ranges of motion contribute to inc sense |
| RTC Strengthening - plyo | Carter et al. 2007 | RCT of 24 Div I baseball players in two groups | Divided groups into plyo and control groupsControl group received regular off-season training (cardio and strength)Plyo group used Ballistic six program 2x/wk for 8 wks  | Significant improvement in throwing velocity of plyo group (p<0.05) – 2.0 mph increase vs. 0.27 mphStat sig increase in eccentric strength of ER  | There was an improvement in throwing velocity but no significant difference between groups for isokinetic strength following the programs.  |
|  | Heiderscheit et al. 1996 | RCT of sedentary non-athletic females in control, isokinetic and plyo groups | Iso and plyo groups trained 2x/wk for 8 wks Used exercises to strengthen IR for each group – throwing ball at trampoline and ecc/conc on LIDO machine  | Significant inc in isokinetic testing conc/ecc for isokinetic groupNo sig change in either group for throwing distance (plyo group was farther but not stat sig)Neither group sig change in kinesthesia  | These are not athletes and plyo exercises need to be performed at max effort (could be hard to explain)Learning effects of isokinetics |
|  | Peters 2007 | Case study middle school pitcher | 13 yo male middle-school pitcher with suspected injury t infra and teres minorSeen for total of 15 appointments (started plyometrics in 2nd week after resolution of acute sxs)Plyometrics included IR, ER, chest pass, OH throwing (initially with shoulder at 0deg abd) | No significant gains in strength but significant improvement shown on sports-modified DASH scalePt with no pain, no fatigue and no muscle weakness at end of treatment and instructed to slowly progress pitching  | The case was relatively short (15 visits in 4-5 wks) and the physical therapist did not suggest a return-to-pitching progression but left it up to the coachPt with no pain or muscle weakness at end of programPlyometrics included IR, ER OH and chest passing  |
|  | Swanik et al. 2002 | RCT with 24 uninjured Div I swimmers in two groups – control and plyo  | Both groups participated in swim practice, traditional weight training, functional training (theraband ex at sport-specific angles) Plyo ex performed on same days as functional exercises (2x/wk for 6 wks) First two wks – plyo worke with tubing and then progressed to weighted ball on trampoline | Plyo group performed better on 5 of 6 proprioceptive tests (active reproduction of passive positioning) and in all 6 kinesthetic tests Improved contraction time (time to peak torque at 60deg/sec and 240deg/sec)No significant strength gains  | Suggest that plyometrics improve joint sense and detection of joint motionNo significant strength gains, but increased time to peak torwue (should be implemented when strength has been established already) |
| RTC Strengthening - fatigue | Joshi et al. 2011 | Cross-sectional study (single group with pre-test/post-test)25 healthy participants from baseball, tennis, swimming, vb  | EMG recording of infra, upper trap, lower trap and serratus anteriorRecorded initial MVIC for each musclePerformed D2 PNF pattern to determine kinematicsFatiguing exercise of prone GH ER with arm at 90 deg abd (fatigue considered when peak force dec more than 25% below baseline peak  | Sig inc in upward rotation during ascending phase post-fatigue (3deg)No differences for ant/post tilt or IR/ERDecreased lower trap activity post-fatigue (4%)Increased infraspinatus (4%) activity on descent (thought to be due to dec in lower trap) | Are these findings functionally important? Was the activity fatiguing enough to simulate the repetitive activities of sport?Lower trap fatigue could cause altered GH axis of rotation which alters L-T relationship of muscles (infra)**Force couple between infra and lower trap altered with GH ER fatigue** |
|  | Tripp et al. 2004 | Repeated cross-over design with 13 collegiate pitchers | Joint position sense testing with throwing motionFatigue protocol included throwing baseball at max velocity every 5 seconds until “fatigued” (above 15 on RPE) | Participants became fatigued after ~61 throws Significant increase in error for joint repositioning indicating a fatigue-effect on proprioception and joint sense Most sig inc in error from arm-cocking phase | Functional fatigue program (actual throwing) produced inc error in joint position sense and reproductionErrors in arm-cocking phase can be influential due to microinstabilities that are commonly present in this position |
|  | Bowman et al. 2006 | 20 healthy participants volunteered in repeated cross-over design  | Tested IR MVIC in 90deg shoulder abd/ER/elbow flexSubject would produce 25% of IR MVIC and then perturbation would occur in IR, participant stopped device and time measuredFatigue protocol of 2 bouts of throwing at max speed until threw 10% less velocity for 3 consecutive pitches | Deceleration time increased during fatiguing protocol pre-test to post-testIncreased time to decelerate could = less force needed by muscle to stop (protective mechanism to muscle) | Control group was able to effectively decelerate pre and post 20 min restIndicates that with fatigue comes increase in deceleration time = more eccentric control needed from ER |
|  | Szucs et al. 2009 | 28 healthy subjects with random testing of dominant vs. non-dominant arm in case series design with each subject receiving intervention | MVIC calculated for SA, UT, LTPerformed GH scaption before and after fatiguing exPush-up with plus used as fatiguing for SA and participant performed until voluntarily stoppedRecorded EMG activity of UT, LT, and SA and kinematic data of scaption | Sig inc in UT activity during scaptionAll muscles experienced >8% decline in activation during ex | Inc in UT activity could serve to increase clavicle elevation and therefore scapula upward rotationUsed healthy subjects and mention that this push up exercise cannot be generalized to pathology |
| RTC strengthening - eccentrics | Noffal 2003 | 59 participants with health throwers and healthy non-athletes using 2x2 factorial design with testing of thrower vs. non-thrower and dominant vs. non-dominant | Performed warm-up and familiarity exercises with biodexTested concentric and eccentric strength of non-dominant and dominant GH ER/IR @ 300deg/secCalculated ratios between peak torque values of IR/ER strength | Ratios found >1 indicating greater ER eccentric strength than IR concentric strengthLower ratios in athletes compared to non-athletes indicating greater inc in IR concentric strength without similar inc in eccentric ER strength | Suggest fixing the imbalance before performing more ballistic/plyo exercises |
|  | Yildiz et al. 2006 | 40 healthy male cadets who participated in OH sports (not elite) were tested for IR/ER concentric to eccentric ratios | Testing was performed on an isokinetic dynamometer Patient given 5 warm up exercises to become used to machine Participants performed concentric IR followed by eccentric IR then concentric and eccentric ER 2 min interval given to combat fatigue | Results attempted to determine ratios of cocking phase (eccentric IR/concentric ER) and the deceleration phase (eccentric ER/concentric IR) Arm cocking phase: 2.09 in dominant and 1.58 non-domDeceleration: 1.03 for dom and 1.19 for non-dom | There was a 1:1 ratio for eccentric ER/conc IR as compared to a 2:1 ratio for ecc IR/conc ER Implications for increasing ecc ER strength to compare to IR strength gains  |
| GIRD and ROM | Trakis et al 2008 | 23 healthy male high-school pitchers in cross-sectional study | Measured ER and IR ROM in both arms as well as strength for low trap, middle trap, rhomboids, lats, supra, IR, ER | Found no difference in total ROM, but less IR than ER in dominant arm than non-dominant armGreater strength found in dominant arm for lower trap, middle trap, lats, IR, ERNo sig diff for the rhomboids or supra ER strength 67% of IR on dominant and 72% of IR on non-dominant | They are testing strength using a brake test, but concentric and eccentric demands are different for these musclesIn high school pitchers, found that there was no diff in supraspinatus strength (pointing towards it being a degenerative issue)Pitchers with greater IR strength had reported pain during the season Strength imbalances (non-dom vs. dom) greater in pitchers with previous pain for middle trap and supra |
| Kinetic Chain | DeMey et al. 2012  | 30 healthy overhead athletes (swimmers, tennis, volleyball) in cross-sectional study | Tested EMG activity of the UT and LT during MVIC Performed scapular retraction with dominant arm in a variety of positions (sitting, standing, split lunge, squat ready position, unilateral squat, dynamic squat, dynamic lunge, dynamic unilateral squat) | No significant differences found between muscle activation of the UT vs. LT during the different stances Unilateral static squat position elicited the highest overall trap EMG ratings  | Unilateral squat position mimics the position that tennis and throwing athletes assume during their motion  |
|  | Maenhout et al. 2010 | 32 healthy non-OH athlete subjects in cross-sectional design | Measured EMG activity of the UT, MT, LT and SA during exerciseRecorded MVIC of musclesExercises included: knee push up plus, KPP with contralateral leg ext, KPP with ipsilateral leg ext, KPP with wobble board, KPP with contra leg ext and wobble board, KPP with ipsilateral leg ext and wobble board, one-handed KPP | Found that ext of ipsilateral leg lowers UT/SA activation ratioExtension of the contra leg resulted in higher UT/SA ratiosUse of wobble board inc UT/SA ratio whereas one-handed does notContra leg ext creates lower SA activity in general No diff with wobble board in terms of SA EMG activity | KPP with extension of ipsilateral leg shows lowest UT/SA ration with highest SA EMG activityWhen extended contra leg, LT activity inc and SA dec |