IJSPT

SYSTEMATIC REVIEW

# THE IMPACT OF LUMBOPELVIC CONTROL ON OVERHEAD PERFORMANCE AND SHOULDER INJURY IN OVERHEAD ATHLETES: A SYSTEMATIC REVIEW

**Thane Cope**[1]
**Sarah Wechter**[1]
**Michaella Stucky**[1]
**Corey Thomas**[1]
**Mark Wilhelm**[1]

## ABSTRACT

***Background:*** The lumbopelvic region is utilized in almost all functional tasks and has been proposed to provide dynamic stability to distal extremities.

***Purpose:*** To systematically evaluate the current literature that examined the effect of lumbopelvic control on overhead performance and shoulder injury in overhead athletes.

***Study Design:*** Systematic Review

***Methods:*** A comprehensive systematic electronic search was conducted using PubMed, CINAHL, ProQuest, Scopus, and SPORTDiscus. Articles were considered for inclusion if they included a measure of lumbopelvic control and assessed shoulder pain, disability, injury, or overhead performance outcome. Cohen's *d* effect size was calculated when necessary statistical data were available to determine the impact of lumbopelvic control.

***Results:*** The search revealed 3,312 total articles and 2,883 articles were screened after duplicates were removed. After titles and abstracts were screened, 45 full text articles were reviewed. Fifteen full-text articles ultimately met inclusion criteria. Effect sizes ranged from trivial (0.10) to large (0.86), indicating a varying degree of positive effects on performance and shoulder injuries. The majority of included articles concluded individuals with greater lumbopelvic control demonstrated improved performance and decreased occurrence of injury.

***Conclusion:*** Results suggest that improved lumbopelvic control relates to improved athletic performance and decreased shoulder injury. Additional higher quality research is needed to further support these findings, establish a standard measure for lumbopelvic control, and determine preventative factors for injury, pain, and disability.

***Level of Evidence:*** 2a

***Keywords:*** Core stability, injury, lumbopelvic control, movement system, overhead athletes

**CORRESPONDING AUTHOR**
Mark Wilhelm, PT, DPT, PhD
Assistant Professor, Doctor of Physical Therapy Program
School of Behavioral and Health Sciences
Walsh University
North Canton, OH 44720
Phone: (330) 244-4747
E-mail: MarkPWilhelm@gmail.com

[1] Walsh University, North Canton, OH, USA.

**Conflicts of Interest:** None of the authors have any conflicts of interest to declare.

## INTRODUCTION

Between 2003 and 2015, sports and exercise participation increased by 3.6%, with 18% of the US population participating in sports each day.[1] It is not surprising that with the rise in sports participation, the occurrence of sport related injuries has resulted in increased public health awareness. Furthermore, the current trend of early sports specialization may be related to an increased risk of injury.[2] General exercise is the most frequently reported activity resulting in injury in males and females while recreational sports are the fourth most commonly reported activity in males. From 2011 through 2014, an estimated 8.6 million sports and recreation related injuries occurred in the United States annually with nearly one third of these injuries sustained in the upper extremity.[3] Shoulder injuries have a significantly higher incidence than any other injury in overhead athletes. More specifically, collegiate overhead athletes have a 30% risk of developing a shoulder injury at some point in their college career, with a 25% risk of subsequent shoulder injury.[4]

The lumbopelvic region has been shown to provide dynamic stability for distal extremity movement by functionally linking the upper and lower extremities. Researchers have recently demonstrated that risk of injury increases with disruption of elements within the kinetic chain, causing alterations in shoulder biomechanics.[5] Additionally, it has been shown that decreasing the lumbopelvic energy production by 20% can lead to increased load on the shoulder complex by up to 34%, meaning less lumbopelvic control leads to increased forces on the glenohumeral joint.[6] These recurrent alterations of inadequate proximal stability, coupled with repetitive stresses placed on an athlete's body over time, may further increase the risk of developing shoulder injury.[7]

In addition to impacting an athlete's likelihood of developing injury, core stability has been suggested to influence athletic performance.[8] An increase in proximal stability may improve distal mobility by improving a proximal to distal pattern of force generation.[9] Additionally, core stability may improve performance through a number of mechanisms including improved efficiency with neurological recruitment patterns, improved motor unit synchronization, lowering neural inhibitory reflexes, and increasing nervous system activation.[10]

Increased sport participation and prevalence of injury highlights the importance of determining the effect of integrating lumbopelvic training. De Blaiser et al. has examined the benefits of core stability training in rehabilitation of back pain and lower extremity injuries.[11] However, current literature is lacking agreement on the overall relationship between lumbopelvic control and shoulder performance and injury.[8,9] In addition, there is no systematic review evaluating this relationship. Therefore, the purpose of this study was to systematically evaluate the current literature that examined the effect of lumbopelvic control on overhead performance and shoulder injury in overhead athletes.

## METHODS

### *Study Design*

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were used during the design and reporting phases of this systematic review.[12] The systematic review was prospectively registered with PROSPERO (CRD42018081526). PROSPERO is the international prospective register of systematic reviews governed by the National Institute for Health Research, which aims to provide a comprehensive list of all ongoing systematic reviews to avoid duplication of studies.[13]

### Eligibility Criteria

Studies were considered for review if they met the following criteria: 1) Discussed lumbopelvic control (motor control, strength, and stability of lumbopelvic, core, and hip regions); 2) Assessed shoulder pain, injury, self-reported disability, or an overhead performance outcome; 3) Contained quantifiable measures for lumbopelvic control; and 4) Reported necessary statistical data. Level 4 and higher evidence was included. Studies were excluded if subjects presented with history of shoulder surgery in the past five years, or if the full text was not available in English.

### Search Strategy

A systematic literature search was completed in November 2017 within the following electronic databases: PubMed, CINAHL, Proquest, Scopus, and SPORTDiscus. Electronic searches utilized MeSH terms, keywords, and subject headings related to lumbopelvic region, overhead sports, performance, and injury outcomes. Searches in CINAHL and SPORTDiscus utilized sport specific injury subheadings rather than general athletic injuries in order to refine the search to more relevant results. The search was limited to the English language, human subjects, and scholarly articles where applicable (the full search strategies from PubMed and CINAHL can be found in Appendix 1). Athletes of all levels were included in the review. A hand search was completed by two reviewers to identify articles that may have been missed using the search strategy. In addition, Google Scholar, Open Grey, Grey Matters, and Grey Literature Report were searched for relevant articles for potential inclusion.

**Study Selection**

Titles and abstracts were independently screened by two reviewers and assessed for inclusion. If a discrepancy existed between the two reviewers, the reviewers met for discussion and came to a consensus. Full-text articles were reviewed by two different independent reviewers. Again, when the two reviewers who screened full text articles did not agree with an article for inclusion, a decision was made by consensus. Reliability of author agreement was calculated for each step using percentage agreement and an unweighted Kappa (κ) score. Kappa scores less than 0.00 are considered poor, 0.00 to 0.20 are considered slight, 0.21 to 0.40 are considered fair, 0.41 to 0.60 are considered moderate, 0.61 to 0.80 are considered substantial, and 0.81 to 1.00 are considered almost perfect.[14]

**Quality Assessment**

Included articles were independently assessed for methodological quality by two reviewers using McGill Mixed Methods Appraisal Tool (MMAT).[15] Variations in scoring were resolved through consensus between the two reviewers. The MMAT contains four criteria for qualitative studies, four criteria for each quantitative study designs (randomized controlled, non-randomized, descriptive), and three criteria for mixed-method designs. A total of 19 criteria are available to be scored depending on study design with options "yes", "no", or "can't tell". Each design category contains three to four questions that are scored. Scores range from 0% to 100%, where 100% indicates the study contains necessary components. The validity of the McGill MMAT meets accepted standards of measuring methodological quality and the intra-class correlation is 0.8, indicating excellent interrater reliability.[15] Reliability of author agreement was calculated using an unweighted Kappa.

**Data Extraction**

All data were independently extracted by one author on all included studies using a standardized extraction form and verified by a second author. The following data were extracted: 1) Participant details (including mean age and standard deviation, gender, and sport); 2) Study details (sample size, design type, setting, and adherence rate); 3) Intervention information if applicable; 4) Outcome measures or dependent variables assessed; 5) Results (means, standard deviations, p-value, effect size, odds ratio, r value when applicable).

**Outcomes/Summary Measures**

Data were grouped and analyzed by performance and injury. The injury construct included pain, injury, and self-reported disability. A variety of outcome measures were accepted for this systematic review, as long as the outcome assessed a performance or injury construct.

The outcome measures accepted for performance were throwing speed, throwing distance, throwing accuracy, serving speed, swimming speed, and pitching performance. Throwing accuracy was measured using the Functional Throwing Performance Index (FTPI), which assesses the ability to consistently hit a mark target under different throwing conditions. The reliability of the FTPI is 0.91.[16] Pitching performance was assessed using game-time pitching statistics.

The outcomes measures accepted for injury included Disabilities of the Arm, Shoulder, and Hand Outcome Measure (DASH) and the shortened version *Quick*DASH, Penn Shoulder Score (PSS), Sports and Symptom Survey Form, Simple Shoulder Test, Kerlan-Jobe Orthopaedic Clinic shoulder and elbow score (KJOC), and Visual Analog Scale (VAS). The DASH is a 30-item questionnaire that assesses activities of daily living and pain in the last week. A higher score reflects a greater disability for both categories. The DASH has been shown to be valid and reliable measure of shoulder disability.[17] The minimal detectable change (MDC) for the DASH is 10.81, and the minimally clinically important difference (MCID) is 10.83.[18] The PSS is a questionnaire in which subjects rate level of satisfaction and pain during different activities on a visual analog scale from 0 (no pain) to 10 (worst pain). The PSS has been shown to be reliable and valid and has an MDC of 12.2 and an MCID of 11.4.[19] The Sports and Symptom Survey Form is a questionnaire consisting of questions relating to subject demographics, sport participation, and pain or shoulder symptoms. Included in the survey is the PSS and the sports section from the DASH, where a higher total score from the combined outcome measures reflects a greater disability. Reliability and validity of the Sport and Symptom Survey Form is currently unknown. However, a portion of this form is comprised of the DASH and PSS, both of which have established reliability and validity.

The Simple Shoulder Test is a questionnaire that assesses shoulder function and has been shown to be reliable and valid.[20] The MDC and MCID have not been well defined.[21] The KJOC collects information regarding pain, weakness, instability during activity and impact on performance on ten separate items using one 10 cm-long line for each of the ten items, where a lower score represents greater disability. The athlete is asked to place an "x" along the 10-cm line corresponding to the athlete's current level of physical functioning for each of the ten items. The KJOC has high validity and reliability in assessing upper extremity dysfunction in overhead throwing athletes including professional baseball players.[22] The VAS is a subjective measure to assess pain which has been shown to have good reliability and construct validity.[23] The minimally clinical important difference (MCID) for the VAS is 1.4 cm for patients being treated conservatively for rotator cuff disease.[24] The outcome measures accepted for injury include days missed due to injury which was collected from respective team personnel. Self-reported pain during throwing was also an accepted measure.

When effect size data, including odds ratio (OR) and correlation coefficient, were reported, they were included in this review with confidence intervals when available. If effect sizes were not reported but means and standard deviations were reported, Cohen's d effect size (ES) was calculated for the outcomes utilized in the included articles. Effect size is a calculated value which represents the magnitude of effect of the independent variable on the dependent variable. This value can be used to apply the effect to a larger population to represent the magnitude of effect size of interventions.[25] Additionally, effect sizes for correlations were extracted when presented in the included articles. For this review, effect sizes represented as a positive value indicates greater lumbopelvic control resulting in improved performance or decreased disability. Likewise, a negative effect size indicates decreased lumbopelvic control resulting in improved performance or decreased disability.

## RESULTS

### Study Selection

The systematic electronic search revealed a total of 3,312 articles. After removing duplicates, 2,883 article titles and abstracts were screened. Inter-rater reliability for title and abstract screening prior to discussion was 96% ($\kappa$ = 0.23 (fair); 95% CI, 0.09-0.37). After titles and abstracts were screened, 45 full text articles were independently reviewed for inclusion. Inter-rater reliability for full text articles prior to discussion was 89% ($\kappa$ = 0.76 (substantial); 95% CI, 0.55-0.95). A total of 15 articles met the inclusion criteria, and therefore were included in the study; nine assessing performance and six assessing shoulder injury including pain, injury, and self-reported disability. Articles assessed during full text screen were most frequently excluded due to outcomes not being related to lumbopelvic control, injury, or overhead performance. In addition, articles were excluded if no outcomes were measured. One article was excluded due to the full text publication not being available in English. Figure 1 outlines the screening process for study inclusion.

### Study Characteristics

Five articles were identified as cross-sectional studies, five articles were cohort, three were quasi-experimental, and two were randomized control trials (RCT). Articles included a range of 25 to 422 participants each with a total of 977 participants included in the current systematic review assessing symptomatic and asymptomatic athletes. Six studies included baseball or softball athletes; the remaining studies included swimming, handball, water polo, lacrosse,

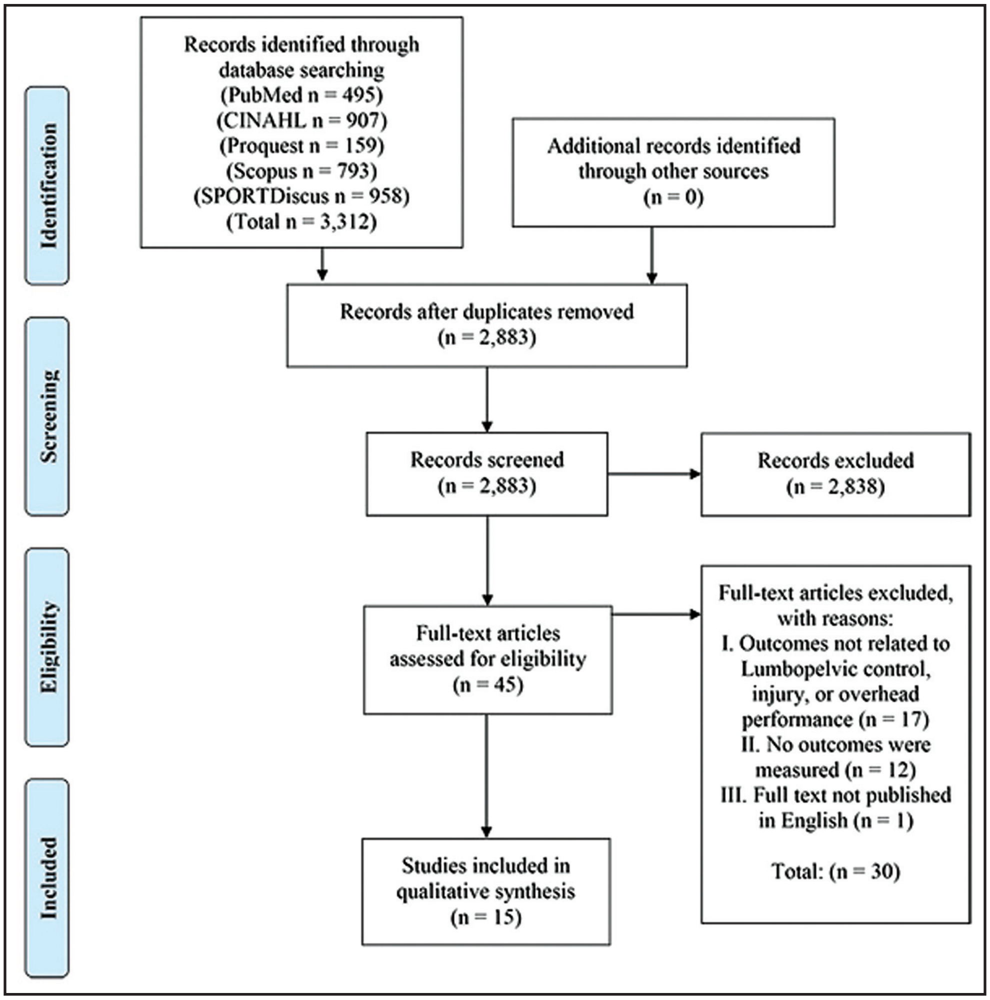


**Figure 1.** *PRISMA Flow Diagram.*

basketball, football and field throwing. Additionally, subjects ranged from 8 to 77 years of age and included untrained individuals, youth, high school, collegiate, and professional level athletes. Table 1 contains the sample demographics of the individuals who participated in each of the included studies.

## Risk of Bias

Scores for the included studies ranged from 0% to 100% on the MMAT. Two studies were scored using the Quantitative Randomized (RCTs) section with quality scores of 0% and 50%. The remaining studies were scored using the Quantitative Non-randomized section (cross-sectional, cohort, and quasi-experimental); two studies scored 50%, seven studies scored 75% and four studies scored 100%. Six studies did not meet the fourth criteria of the quantitative non-randomized section, which assessed follow up and adherence rate. Five studies did not report these statistics, and one study did not meet the criteria of 60% follow up rate. Agreement for the quality assessment between authors was 88% ($\kappa = 0.70$ (substantial); 95% CI, 0.49-0.91). Table 2 provides the results for each quality assessment.

## Performance

Nine studies examined the correlation of lumbopelvic control to overhead throwing performance. Eight of the nine studies found lumbopelvic control to have a statistically significant correlation with throwing velocity, distance, and accuracy, tennis serve velocity, or sport performance. Table 3 contains the results of the articles assessing performance variables including velocity, distance, accuracy, and sport performance.

## Velocity

Of the nine studies, four found a significant increase in velocity following core stability training,[26-29] while

**Table 1.** *Sample Demographics by Study.*

| Author | Participants | Characteristics (mean±SD) | Sport(s) |
|---|---|---|---|
| Chaudhari et al., 2011[33] | 48 male professional minor-league pitchers | Age=22.5±2.1 years | Baseball |
| Chaudhari et al., 2014[34] | 347 professional baseball pitchers from 5 Major League Baseball Organizations | Age=23.3±2.1 years | Baseball |
| Clayton et al., 2011[30] | 29 male college baseball players | Moderately to highly trained | Baseball |
| Endo et al., 2014[37] | 39 male junior high school students belonging to baseball clubs | | Baseball |
| Harrington et al., 2014[39] | 37 female NCAA D1 swimmers | Age=19.5±1.19 years<br>Height=170±7 cm<br>Weight=64.7±6.8 kg<br>No history of shoulder surgery in past 10 months | Swimming |
| Krishnan et al., 2013[31] | 80 untrained individuals | Age=18-25 years<br>Subjects were normal and asymptomatic | n/a |
| Lust et al., 2009[32] | 25 D3 college baseball players; 15 age, gender, and activity matched subjects | Age=20.00±1.54 years<br>Height=177.12±5.67 cm<br>Weight=90.39±22.59 kg | Baseball |
| Manchado et al., 2017[25] | 30 male handball players | Age=18.8±3.4 years<br>Height=179.3±7.0 cm<br>Weight=78.9±7.7 kg | Handball |
| Palmer et al., 2015[26] | 17 female D2 softball players; 29 male baseball players | Sport experience=12±3 years | Softball, Baseball |
| Radwan et al., 2014[36] | 28 male and 33 female D3 overhead athletes | Age=19.3±1.1 years;<br>Height=172±8.6 cm;<br>Weight=78.7±16.7 kg | Football, Swimming, Water Polo, Lacrosse, Baseball, Field Throwing, Basketball |
| Reeser et al., 2010[35] | 286 male and 136 female volleyball players participating in the 2006 NIRSA Volleyball Championship | | Volleyball |
| Saeterbakken et al., 2011[27] | 28 female handball players | Age=16.6±0.3 years<br>Height=169±7 cm<br>Weight=63±6 kg<br>Sport experience=8.0±1.4 years | Handball |
| SÖĞÜT, 2016[29] | 14 male and 15 female junior tennis players participating in national and international tournaments | **Male:**<br>Age=13.64±1.65 years<br>Height=163.1±0.13 cm<br>Weight=52.2±10.57 kg<br>Sport experience=4.86±0.95 years<br>**Female:**<br>Age=13.60±1.72 years<br>Height=159.2±0.08 cm<br>Weight=51.9±10.22 kg<br>Sport experience=4.60±0.91 years | Tennis |
| Tate et al., 2012[38] | 236 female youth, high school, or US Masters swimmers | Age=8-77 years | Swimming |
| Weston et al., 2015[28] | 10 male and 10 female national-level junior swimmers | **Intervention Group:**<br>5 male and 5 female<br>Age=15.7±1.2 years<br>Height=172±6 cm<br>Weight=63±5 kg<br>**Control Group:**<br>5 male and 5 female<br>Age=16.7±0.9 years<br>Height=170±3 cm<br>Weight=63±5 kg | Swimming |

Mean±SD = Mean ± Standard Deviation; kg = kilogram; cm = centimeters

**Table 2.** *Methodological Quality of Included Studies (Mixed Methods Appraisal Tool).*

| Quantitative Non-Randomized | 1 | 2 | 3 | 4 | Total Score |
|---|---|---|---|---|---|
| Chaudhari et al., 2011[33] | Y | Y | Y | Y | 100% |
| Chaudhari et al., 2014[34] | Y | Y | Y | Y | 100% |
| Clayton et al., 2011[30] | Y | Y | Y | C | 75% |
| Endo et al. 2014[37] | Y | Y | Y | Y | 100% |
| Harrington et al., 2014[39] | Y | Y | Y | C | 75% |
| Krishnan et al., 2013[31] | C | Y | C | Y | 50% |
| Lust et al., 2009[32] | N | Y | Y | Y | 75% |
| Radwan et al., 2014[36] | Y | Y | N | Y | 75% |
| Reeser et al., 2010[35] | Y | Y | Y | N | 75% |
| Saeterbakken et al., 2011[27] | C | Y | Y | Y | 75% |
| SÖĞÜT, 2016[29] | C | Y | Y | C | 50% |
| Tate et al., 2012[38] | Y | Y | Y | Y | 100% |
| Weston et al., 2015[28] | Y | Y | Y | C | 75% |
| **Quantitative Randomized** | **1** | **2** | **3** | **4** | **Total Score** |
| Manchando et al., 2017[25] | N | N | Y | Y | 50% |
| Palmer et al., 2015[26] | N | N | C | C | 0% |

Y=Yes; N=No; C=Can't Tell
For Quantitative Non-Randomized (trials):
1. Are participants (organizations) recruited in a way that minimizes selection bias? 2. Are measurements appropriate (clear origin, or validity known, or standard instrument; and absence of contamination between groups when appropriate) regarding the exposure/intervention and outcomes? 3. In the groups being compared (exposed vs. non-exposed; with intervention vs. without; cases vs. controls), are the participants comparable, or do researchers take into account (control for) the difference between these groups? 4. Are there complete outcome data (80% or above), and, when applicable, an acceptable response rate (60% or above), or an acceptable follow-up rate for cohort studies (depending on the duration of follow-up)?
For Quantitative Randomized Controlled (trials):
1. Is there a clear description of the randomization (or an appropriate sequence generation)? 2. Is there a clear description of the allocation concealment (or blinding when applicable)? 3. Are there complete outcome data (80% or above)? 4. Is there low withdrawal/drop-out (below 20%)?

one study found no correlation between core stability and velocity.[30] Throwing velocity[26-28] and swimming velocity[29] were shown to improve, while tennis serving speed[30] did not. Increases in maximum velocity were reported to range from 4.3% to 6%.[26-28]

### Distance

One study found a statistically significant correlation between core strength and throwing distance.[31] Another study assessed the correlation between core endurance and throwing distance and found a statistically significant correlation between these variables.[32]

### Accuracy

One study examined the effects of lumbopelvic control on throwing accuracy measured using the FTPI.[33] Lust et al. tested the effect of core stability training on throwing a ball accurately into a marked zone. There was a significant difference in the FTPI scores between the two groups, where the core stability training group improved throwing accuracy by 6.1% on average.[33]

### Sport Performance

One study assessed the correlation between sport performance and core stability. Pelvic deviation

**Table 3.** *Results of Studies Involving Performance.*

| Author | Sport(s) | Outcome | Correlation/Intervention | Results (Mean±SD or Correlation Coefficients) | Effect Size d (95% CI)* | Conclusions |
|---|---|---|---|---|---|---|
| Chaudhari et al., 2011[33] | Baseball | Pitching performance and injuries | Lumbopelvic control with Level Belt: Good (<7°) and Poor (≥7°) and pitching performance. | **Poorer control (LB≥7°; n=16):** IP=53.4±42.5; WHIP=1.584±0.360; BAA=0.280±0.059; Kin=0.689±0.160; BBin=0.437±0.279; Number injured during season=8 of 16<br>**Good control (LB<7°; n=32):** IP=78.9±38.7; WHIP=1.353±0.251; BAA=0.260±0.033; Kin=0.767±0.180; BBin=0.334±0.182; Number injured during season=12 of 33<br>p-Value: IP=0.043; WHIP=0.013; BAA=0.133; Kin=0.147; BBin=0.131; Age=0.727 | IP=0.64 (-0.02 to 1.25)<br>WHIP=0.79 (0.17 to 1.41)<br>BAA=0.46 (-0.14 to 1.07)<br>Kin=0.45 (-0.16 to 1.06)<br>BBin=0.47 (-0.14 to 1.08) | Subjects with good lumbopelvic control demonstrated improved performance |
| Clayton et al., 2011[30] | Baseball | Throwing distance | BOMB distance and isokinetic core strength | **Correlations:**<br>Trunk Flexion: BOMB; r=0.680<br>Trunk Ext: BOMB; r=0.594<br>L Trunk Rot: BOMB; r=0.607<br>R Trunk Rot: BOMB; r=0.572 | | Statistically significance between BOMB and core strength. BOMB and trunk flexion greatest significance |
| Krishnan et al., 2013[31] | N/A | Throwing distance | Core endurance and seated throwing distance strapped and unstrapped in chair | **Correlations:**<br>Seated Throw: r=0.3850; 95% CI=0.1746 to 0.5624; 2-sided p value=0.0004<br>Strapped Throw: r=0.3925; 95% CI=0.1827 to 0.5682; 2-sided p value=0.0003 | | All physical factors show a positive correlation. Lumbar core should be focused on more particularly while training |
| Lust et al., 2009[32] | Baseball | Throwing accuracy | 6-week core stability program included with OKC/CKC exercises, 3x/week. Exercises included partial sit-ups, dead bug, bridging, wall slides, prone and quadruped physio ball exercises | **FTPI Pretest**:<br>OKC/CKC/CS=0.53±0.14<br>Control=0.51±0.13<br>**FTPI Posttest**:<br>OKC/CKC/CS=0.63±0.14<br>Control=0.49±0.08 | 0.57 (-0.01 to 1.14) | The core stability group demonstrated significantly greater scores than the control group after training |
| Manchado et al., 2017[25] | Handball | Throwing velocity | 10-week core program, seven exercises targeting rectus abdominis, obliques, lumbar and glutes. | Throwing velocity (km/h):<br>**Experimental Group:**<br>7m Pre-test= 76.1±10.9, Post-test= 80.0±10.8<br>9m+3 steps Pre-test= 81.8±12.2, Post-test= 85.7±11.7<br>9m jump Pre-test= 80.4±9.1, Post-test= 83.6±8.6†<br>**Control Group:**<br>7m Pre-test= 73.6±11.6, Post-test= 73.7±11.3<br>9m 3 steps Pre-test= 79.1±13.4, Post-test= 79.3±12.8<br>9m jump Pre-test= 76.7±10.9, Post-test= 75.3±11.5<br>(p<0.001) | Throwing velocity: 0.64 | Players in the experimental group improved average throwing velocity compared to the control group |
| Palmer et al., 2015[26] | Softball, Baseball | Throwing velocity | 7-week power stability core program, 2x/week. Correlated peak throwing velocity and core endurance | **Correlations:**<br>Peak throwing velocity/kg BW, km/h: Prone-plank hold time (sec)=0.31 [p=0.007]; Side-plank hold time (sec)=0.39 [p=0.001]. | | The power-training program has a significant effect on the power of muscles that support the proximal segments and throwing velocity |
| Saeterbakken et al., 2011[27] | Handball | Throwing velocity | 6-weeks, 2x/week SET program compared to core stability program | SET group had significant increase in throwing velocity after training: 4.9% (p=0.01). Throwing velocity on control group was unchanged (p=0.418). | | SET group has significant increase in throwing velocity |
| SÖĞÜT, 2016[29] | Tennis | Tennis serve velocity | Core stability and maximal serve velocity | **Correlations:**<br>Male: Max serve velocity: r= -0.257, p=0.375<br>Female: Max serve velocity: r=0.478, p=0.072 | | No significant correlation between core stability and other variables in either gender |
| Weston et al., 2015[28] | Swimming | Swim velocity | 12-week core training program, 3x/week. Exercises included prone bridge, side bridge, bird dog, straight leg raise, overhead squat, and medicine ball sit twists. | **Core Training Group:**<br>50m swim time (sec): Baseline=29.7+/-2.1<br>Adjusted change score= -2.7, -4.2 to -1.1<br>**Control Group:**<br>50m swim time (sec): Baseline=28.0+/-1.9<br>Adjusted change score= -0.7; -1.6 to 0.2 | | Swim velocity improved by 2.0% following core stability training |

* a negative effect size indicates the pain or dysfunction group did better than the control group
Mean±SD = Mean ± Standard Deviation; 95% CI = 95% Confidence Interval; LB = Level Belt Score; IP = Innings Pitched; WHIP = Walks plus Hits per Inning; BAA = Batting Average Against; Kin = Strikeouts per Inning; BBin = Walks per Inning; BOMB = Backward Overhead Medicine Ball Throw; OKC = Open Kinetic Chain; CKC = Closed Kinetic Chain; CS = Core Stability; FTPI = Functional Throwing Performance Index; m = meter; km = kilometer; h = hour; BW = Body Weight; sec = seconds; SET = Sling Exercise Training; 90% CI = 90% Confidence Interval

obtained from Level Belt testing was correlated to performance data. This study demonstrated increased core stability correlated with improved performance. Pitching performance, including innings pitched, walks plus hits per inning, batting average against, strikeouts per inning, and walks per inning, showed moderate effect sizes ranging from 0.45 to 0.79.[34]

## Injury

Six studies examined the correlation between lumbopelvic control and injury, including pain, injury, and self-reported disability.[35-40] Five of the six studies found lumbopelvic control to have a significant correlation with the occurrence of injury,[35-39] with three of these five demonstrating moderate to strong correlations.[35-37] The remaining study found no significant correlation between lumbopelvic control and injury.[40] Table 4 contains the results from these articles.

## Pain

Endo et al. examined the relationship between core endurance and the development of arm pain during

**Table 4.** *Results of Studies Assessing Shoulder Injuries.*

| Author | Sport(s) | Outcome | Correlation/Intervention | Results (Mean±SD or Correlation Coefficients) | Effect Size (95% CI) * | Conclusions |
|---|---|---|---|---|---|---|
| Chaudhari et al., 2014[34] | Baseball | Injury | Divided into three groups based on pelvic deviation: Low (LO)=<4.0°, Moderate (MD)=4.0-7.9°, High (HI)=≥8.0°. Then categorized based on number of days missed. | APScore LO: <30 days=122; ≥30 days=16<br>APScore MD: <30 days=159; ≥30 days=30<br>APScore HI: <30 days=13; ≥30 days=7<br>Total: <30 days=294; ≥30 days=53 | | Poor lumbopelvic control was significantly associated with missing ≥30 days |
| Endo et al., 2014[37] | Baseball | Pain | Development of pain while throwing was correlated with core stability using prone bridge and side bridge | Non-pain group:<br>**Early in the season (sec):**<br>Prone bridge=98.1±27.8<br>Dominant side bridge=86.6±28.5<br>Nondominant side bridge=83.5±26.4<br><br>**End of the season (sec):**<br>Prone bridge=94.9±28.2<br>Dominant side bridge=80.9±26.1<br>Nondominant side bridge=80.8±21.3<br><br>Pain group:<br>**Early in the season (sec):**<br>Prone bridge=92.2±26.2<br>Dominant side bridge=71.0±31.1<br>Nondominant side bridge=77.5±21.1<br><br>**End of the season (sec):**<br>Prone bridge=82.8±22.0<br>Dominant side bridge=73.2±25.1<br>Nondominant side bridge=71.0±26.0 | **Early in the season:**<br>Prone bridge= 0.22 (-0.49 to 0.92)<br>Dominant side bridge= 0.52 (-0.19 to 1.24)<br>Nondominant side bridge= 0.25 (-0.46 to 0.96)<br><br>**End of the season:**<br>Prone bridge= 0.48 (-0.24 to 1.19)<br>Dominant side bridge= 0.30 (-0.41 to 1.01)<br>Nondominant side bridge= 0.41 (-0.30 to 1.13) | Pain group demonstrated lower values in two of three bridge tests suggesting a correlation between core stability and occurrence of upper extremity pain |
| Harrington et al., 2014[39] | Swimming | Pain and disability | Divided into pain (pos) or no pain (neg) based on Sports and Symptom Survey scores, and correlated to core endurance measured by prone bridge and side bridge | Dominant Arm Measures:<br>**Bridge prone (sec):**<br>Pos=84.87±18.90; 95% CI=69.17, 100.57<br>Neg=88.95±29.7; 95% CI=78.07, 99.83; P=0.67<br>**Bridge dominant arm (sec):**<br>Pos=55.85±16.56; 95% CI=45.38, 66.32<br>Neg=58.55±18.44; 95% CI=51.30, 65.81; P=0.67 | **Dominant Arm Measures:**<br>Bridge Prone: 0.16<br>Bridge dominant arm: 0.15 | 12 participants had pain in dominant arm. No significant correlation was found between core strength and shoulder pain |
| Radwan et al., 2014[36] | Football, Swimming, Water Polo, Lacrosse, Baseball, Field Throwing, Basketball | Pain and disability | Divided into healthy (n=48) or shoulder dysfunction (n=14) group based on KJOC and the DASH scores. Correlated with core stability testing including single-leg balance, double leg lowering, and Sorenson test | **Athletes with shoulder dysfunction:**<br>Double leg lowering test=9.4±4.9 degrees<br>Modified side plank R=43±28.6 sec; L=52.1±36.8 sec<br><br>**Athletes without shoulder dysfunction:**<br>Double leg lowering test=8.4±7.5 degrees<br>Modified side plank R=35.1±25.7 sec; L=47.4±41.9 sec<br><br>DLL and KJOC: r = 0.394, p>0.05 | Double leg lowering test= 0.14 (-0.45 to 0.74)<br>Modified side plank R= 0.30 (-0.30 to 0.90); L= 0.12 (-0.48 to 0.71)<br><br>DLL and KJOC: 0.86 | Greater shoulder disability is significantly correlated with greater balance and core stability deficits |
| Reeser et al., 2010[35] | Volleyball | Pain and disability | Questionnaire assessing shoulder pain and disability was correlated with core stability including single-leg stance on each leg with knee straight and knee bent. | 70% of athletes performed single leg stance with no difficulty. 38% of athletes were able to perform single-leg squat without any postural instability on either side.<br><br>X^2=8.83, p=0.032 | Estimated relative risk=1.2 | Individuals who have difficulty with SLS are more likely to experience shoulder injuries |
| Tate et al., 2012[38] | Swimming | Pain and disability | Four groups based on age, classified as positive (pos) or negative (neg) based on PSS and DASH scores. Correlated with core endurance measured by prone bridge and side bridge | Side Bridge (sec):<br>8-11 Neg=14.61±11.43, Pos=13.51±11.34, p=0.80<br>12-14 Neg=24.62±16.61, Pos=16.13±6.17, p=0.02<br>15-19 Neg=35.60±18.33, Pos=28.14±17.78, p=0.13<br>23-77 Neg=40.78±21.84, Pos=30.10±14.12, p=0.10<br><br>Prone Bridge (sec):<br>8-11 Neg=19.13±14.62, Pos=17.15±20.79, p=0.75<br>12-14 Neg=33.09±21.47, Pos=23.94±9.97, p=0.08<br>15-19 Neg=54.78±25.85, Pos=42.71±27.96, p=0.08<br>23-77 Neg=52.21±24.36, Pos=55.16±19.53, p=0.69 | Side Bridge:<br>8-11: 0.10 (-0.64 to 0.83)<br>12-14: 0.55 (-0.22 to 1.33)<br>15-19: 0.41 (-0.11 to 0.92)<br>23-77: 0.52 (-0.09 to 1.13)<br><br>Prone Bridge:<br>8-11: 0.12 (-0.61 to 0.86)<br>12-14: 0.46 (-0.32 to 1.23)<br>15-19: 0.46 (-0.06 to 0.97)<br>23-77: -0.13 (-0.73 to 0.48) | Decreased core endurance was correlated with increased symptoms |

* a negative effect size indicates the pain or dysfunction group did better than the control group
Mean±SD = Mean ± Standard Deviation; 95% CI = 95% Confidence Interval; L = Left; R = Right; Sec = seconds; APScore = anterior/posterior pelvic deviation; PSS = Penn Shoulder Score; DASH = Disabilities of the Arm, Shoulder, and Hand Outcome Measure; Pos = positive; Neg = negative; DLL = Double Leg Lowering Test; KJOC = Kerlan-Jobe Orthopaedic Clinic shoulder and elbow score; SLS = Single-Leg Stance

the season.[38] Prone bridge time decreased by 9.4 seconds in the pain group and 3.2 seconds in the non-pain group. In addition, nondominant side bridge time decreased by 6.5 seconds in the pain group and 2.7 seconds in the non-pain group. However, dominant side bridge time increased by 3.2 seconds in the pain group and decreased by 5.7 seconds in the non-pain group between the beginning and end of the season. The pain group had lower scores in two of the three measures from the beginning to the end of the season, therefore suggesting a correlation between lumbopelvic control and presence of pain.[38]

## Pain and Self-Reported Disability

Four studies assessed pain and self-reported disability and examined its relationship to core stability.[36,37,39,40] One study found core endurance was correlated with shoulder pain and disability,[39] while another found no correlation.[40] Core endurance and decreased single leg stance were negatively correlated with increased shoulder pain and disability.[36] One study found a positive correlation with double leg lowering (DLL) and the KJOC questionnaire, indicating decreased core stability correlated with increased shoulder pain and disability.[37]

### Injury

Chaudhari et al. (2014) examined the role of lumbopelvic control and time missed due to injury.[35] Individuals with poor lumbopelvic control missed more days (mean = 98.6 days) than individuals with moderate or good (mean = 43.8 days; $p = 0.017$) lumbopelvic control. In addition, subjects with poor lumbopelvic control were approximately four times as likely to miss 30 days of playing time (OR: 4.11; 95% CI, 1.43-11.8).[35]

## DISCUSSION

The purpose of this systematic review was to examine the effect of lumbopelvic control on overhead performance and shoulder injury in overhead athletes. The overall results suggest greater lumbopelvic control is related to improved athletic performance and decreased prevalence of injuries in overhead athletes. However, this finding was not consistent across all included studies. Among the included studies, multiple methods were used to assess lumbopelvic control which made it difficult to directly compare lumbopelvic control across studies. Due to the importance of both strength and motor control on lumbopelvic control, both measures were included. The most frequently reported measures included variations of single-limb stance, isokinetic strength (flexion, extension, and rotation), and isometric endurance. Lumbopelvic strength was measured using isokinetic machines which allowed consistent speed and resistance throughout range of motion. Lumbopelvic stability was measured by isometric control of the hip and core. While single-limb stance can be used as a measure of balance, studies utilizing this measure assessed pelvic deviation from neutral or self-selected neutral, making it a measure of lumbopelvic control. Static measures assessed single-plane movements while dynamic measures assessed multi-plane movements.

Eight studies used static measures to quantify lumbopelvic control,[30,32,34-36,38-40] six studies used dynamic measures,[26-29,31,33] and one study used both static and dynamic measures.[37] Of the nine studies utilizing static measures, seven found a correlation[32,34-39] between lumbopelvic control and overhead performance or shoulder injuries. Despite these correlations, this does not indicate lumbopelvic control was the cause for change but does demonstrate the relationship between lumbopelvic control and performance and injury rate. All seven studies utilizing dynamic measures found statistically significant correlations between lumbopelvic control and overhead performance/injuries or differences between intervention and control groups.[26-29,31,33,37] The study that examined both static and dynamic control only found statistically significant differences in the dynamic measure.[37] Since athletic performance is dynamic, these findings may indicate dynamic lumbopelvic control assessments may be more appropriate for this population as static measures may have a ceiling effect when used with an athletic population.

The results of the lumbopelvic training programs suggest dynamic exercises have a larger positive impact on velocity and accuracy when compared to isometric exercises.[26-29,33] Five studies utilized a dynamic program training the lumbopelvic region in multiple planes. These findings suggest that improving lumbopelvic control has a positive effect on performance. However, there were inconsistencies in program duration, resulting in difficulty in defining the optimal time frame for improvements to be observed.

Interestingly, Sogut et al. was the only study to find a negative correlation between lumbopelvic stability and overhead performance. The negative correlation was seen in male subjects, however there was a positive correlation in female subjects. This peculiar finding may be due to the small sample size used in this study.[30] A larger, more representative sample may provide more clarity and consistency with results between males and females. Additionally, this study used static assessments of core stability where as previously mentioned, a dynamic measure may have been more applicable.

Endo et al. found an inverse relationship between lumbopelvic control and pain development indicating that poorer lumbopelvic control may be related to higher prevalence of pain development.[38] However, it is unclear if the development of pain occurred due to diminished lumbopelvic control, or if pain was the cause for diminished control. Physical fatigue over the course of the season may be a key factor in this relationship, however causative factors and timeframe of pain development are not clear. When lumbopelvic control diminishes due to fatigue, the body may compensate and alterations in throwing mechanics change, which may contribute to the development of injury.

The results of the current systematic review agree with the conclusions from the systematic review by Reed et al. to a certain extent.[41] The systematic review by Reed et al. assessed upper and lower extremity athletic performance measures, where the current review assessed performance and injuries specific only to the shoulder in overhead athletes. Their findings revealed that subjects who participated in core specific training improved in strength assessments; however, they only observed marginal improvements in athletic performance. Although it was concluded that isolated core training should be incorporated in training, it should not be the primary emphasis.

Similarly, Silfies et al. conducted a critical review of the effect of core stability on upper and lower extremity athletic performance and injury. The review discussed that current evidence is directed towards the core and lower extremity training and the authors concluded that there is a correlation between core stability and athletic performance and injury, but a causal relationship cannot be declared.[42] Wilk et al. emphasize the importance of core stability training in overhead throwing athletes, concluding that exercises linking the upper and lower extremities through the core are essential to developing power for throwing.[7] Both of these author groups emphasize the importance of the lumbopelvic complex as a part of the kinetic chain. However, Silfies et al. focused on athletes with upper extremity injuries while Wilk et al. focused on throwing athletes. Because this review focused on the shoulder joint in all overhead athletes, the current evidence synthesis compliments these articles.

The authors of this systematic review were not able to locate published MCID values for many of the included outcome variables, limiting in-depth analysis of clinical significance. Additionally, variability of statistical methods and outcome measures assessed within the included studies makes consistent assessment of clinical significance challenging. Although the presence of statistically significant differences does not indicate clinical significance, many of the included studies contained statistically significant results. Given the competitive nature of various levels of athletic competition, any improvement in performance or reduction in injury has the potential to represent a meaningful impact.

The current systematic review had several limitations. Studies were limited to those published in English, which may have caused relevant studies to be excluded. Although the kappa score for level of agreement during title and abstract screening was considered "fair", authors were able to come to a consensus before proceeding to full text screening. Additionally, several studies did not report necessary means and standard deviations, which limited the authors ability to calculate effect sizes. Included studies had quality assessment scores ranging from 0% to 100%, reflecting the quality variability of the current literature. A wide range of scores may also be attributed to the specificity of certain MMAT criteria, and open interpretation for others. Although the MMAT was appropriate for this review, quality scores may have differed if design specific tools were used. In addition, there were a multitude of outcome measures used to assess performance and injury, and not every measure was specific to the shoulder joint. Therefore, results from this review generalized to the shoulder joint, may be expanded to the upper extremity in some cases.

Although there appears to be a relationship between lumbopelvic control and performance and injury, it is difficult to determine a causal relationship due to a lack of high-quality evidence. In the future, higher quality research is needed to further support the findings of the studies included in this review. Larger sample sizes that are more representative of specific populations are needed. Future research should attempt to create a standard definition of lumbopelvic control to determine reliable and valid measures of this complex. A comprehensive list of dynamic lumbopelvic exercises would also be beneficial to readers for implementation into current training programs. It would also be worthwhile to assess the long-term benefits lumbopelvic control training has on athletic performance and injuries in the shoulder, as well as more distal joints.

## CONCLUSIONS

The results of this systematic review indicate that greater lumbopelvic control may be related to improved athletic performance and decreased prevalence of injuries in overhead athletes. Athletes, coaches, physical therapists, and other healthcare providers can utilize the results of this systematic review to inform the design and implementation of exercise programs targeting overhead athletes and potentially impact the prevention of injury.

## REFERENCES


1. Woods RA. Sports and exercise. *U.S. Bureau of Labor Statistics.* May 2017. https://www.bls.gov/spotlight/2017/sports-and-exercise/home.htm.
2. Jayanthi NA, LaBella CR, Fischer D, et al. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case control study. *Am J Sports Med*. 2015;43(4):794-801.
3. Sheu Y, Chen L, Hedegaard H. Sports and recreation related injury episodes in the United States, 2011–2014. *Nat Health Stat Re.* 2016;99:2-10.
4. Laudner K, Sipes R. The incidence of shoulder injury among collegiate overhead athletes. *J Intercollegiate Sport.* 2009;2:260-268.
5. Gilmer GG, Washington JK, Dugas J, et al. The role of lumbopelvic-hip complex stability in softball throwing mechanics. *J Sport Rehabil*. 2017;1-27.
6. Lintner D, Noonan TJ, Kibler WB. Injury patterns and biomechanics of the athlete's shoulder. *Clin Sports Med.* 2008;27(4):527-551.
7. Wilk KE, Arrigo CA, Hooks TR, et al. Rehabilitation of the overhead throwing athlete: There is more to it than just external rotation/internal rotation strengthening. *Phys Med Rehabil*. 2016;8(3):78-90.
8. Hibbs AE, Thompson KG, French D, et al. Optimizing performance by improving core stability and core strength. *Sports Med*. 2008;38(12):995-1008.
9. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. *Sports Med.* 2006;36:189-198.
10. Staron RS, Karapondo DL, Kraemer WJ, et al. Skeletal muscle adaptations during early phase of heavy-resistance training in men and women. *J Appl Physiol.* 1994;76:1247-55.
11. De Blaiser C, Roosen P, Willems T, et al. Is core stability a risk factor for lower extremity injuries in an athletic population? A systematic review. *Phys Ther Sport*. 2018;30:48-56.
12. Moher D, Liberati A, Tetzlaff J, et al. Reprint—Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Phys Ther*. 2009;89(9):873-80.
13. University of York Centre for Reviews and Dissemination. *PROSPERO International Prospective Register of Systematic Reviews*. National Institute for Health Research. https://www.crd.york.ac.uk/prospero/.
14. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159.
15. Pluye, P., Robert, E., Cargo, M., et al. Proposal: A mixed methods appraisal tool for systematic mixed studies reviews. Department of Family Medicine, McGill University. 2011.
16. Davies GJ. Protocol for functional throwing performance index. *Workshop Compendium*. 1995.
17. Desai AS, Dramis A, Hearnden AJ. Critical appraisal of subjective outcome measures used in the assessment of shoulder disability. *Ann R Coll Surg Engl*. 2010;92(1):9-13.
18. Franchignoni F, Vercelli S, Giordano A, et al. Minimal clinically important difference of the disabilities of the arm, shoulder and hand outcome measure (DASH) and its shortened version (QuickDASH). *J Orthop Sports Phys Ther*. 2014;44(1):30-39.
19. Leggin B, Michener L, Shaffer M, et al. The Penn shoulder score: reliability and validity. *J Orthop Sports Phys Ther*. 2006;36(3):138-151.
20. Godfrey J, Hamman R, Lowenstein S, et al. Reliability, validity, and responsiveness of the simple shoulder test: Psychometric properties by age and injury type. *J Shoulder Elbow Surg*. 2007;16(3):260-267.
21. Roy J, MacDermid J, and Woodhouse L. Measuring shoulder function: A systematic review of four questionnaires. *Arthritis Rheumatol.* 2009;61(5):623-632.
22. Franz J, McCulloch P, Kneip C. The utility of the KJOC score in professional baseball in the United States. *Am J Sports Med*. 2013;41(9):2167-2173.
23. Bailey B, Gravel J, Daoust R. Reliability of the visual analog scale in children with acute pain in the emergency department. *Pain*. 2012;153(4):839-842.
24. Tashjian RZ, Deloach J, Porucznik CA et al. Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual

analog scales (VAS) measuring pain in patients treated for rotator cuff disease. *J Shoulder Elbow Surg*. 2009;18(6):927-32.

25. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*. *2nd ed*. Hillsdale, NJ: Lawrence Earlbaum Associates, 1988.
26. Manchado C, Garcia-Ruiz J, Cortell-Tormo JM, et al. Effect of core training on male handball players' throwing velocity. *J Hum Kinet.* 2017;56:177-185.
27. Palmer T, Uhl TL, Howell D, et al. Sport-specific training targeting the proximal segments and throwing velocity in collegiate throwing athletes. *J Athl Train.* 2015;50(6):567-577.
28. Saeterbakken A, van den Tillaar R, Seiler S. Effect of core stability training on throwing velocity in female handball players. *J Strength Cond Res.* 2011;25(3):712-718.
29. Weston M, Hibbs AE, Thompson KG, et al. Isolated core training improves sprint performance in national-level junior swimmers. *Int J Sports Physiol Perform.* 2015;10:204-210.
30. Sogut M. The relations between core stability and tennis-related performance determinants. *J Biology Exercise.* 2016;12(2):35-44.
31. Clayton MA, Trudo CE, Laubach LL, et al. Relationships between isokinetic core strength and field based athletic performance tests in male collegiate baseball players. *J Exerc Physiol Online*. 2011;14(5):20-30.
32. Krishnan V, Naik R, Shinde V. Correlation between physical factors (shoulder strength, lumbar core stability and back extensor muscles) and throwing distance of dominant hand in normal, untrained individuals. *Indian J Physiother Occup Ther.* 2013;7(4):261-266.
33. Lust KR, Sandrey MA, Bulger SM, et al. The effects of 6-week training programs on throwing accuracy, proprioception, and core endurance in baseball. *J Sport Rehabil.* 2009;18:407-426.
34. Chaudhari AMW, McKenzie CS, Borchers JR, et al. Lumbopelvic control and pitching performance of professional baseball pitchers. *J Strength Cond Res.* 2011;25(8):2127-32.
35. Chaudhari AMW, McKenzie CS, Pan X, et al. Lumbopelvic control and days missed because of injury in professional baseball pitchers. *Am J Sports Med.* 2014;42(11):2734-40.
36. Reeser JC, Joy EA, Porucznik CA, et al. Risk factors for volleyball-related shoulder pain and dysfunction. *PM R.* 2010;2:27-36.
37. Radwan A, Francis J, Green A, et al. Is there a relation between shoulder dysfunction and core instability? *Int J Sports Phys Ther.* 2014;9(1):8-13.
38. Endo Y, Sakamoto M. Correlation of shoulder and elbow injuries with muscle tightness, core stability, and balance by longitudinal measurements in junior high school baseball players. *J Phys Ther Sci.* 2014;26:689-693.
39. Tate A, Turner GN, Knab SE, et al. Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *J Athl Train.* 2012;47(2):149-158.
40. Harrington S, Meisel C, Tate A. A cross-sectional study examining shoulder pain and disability in division I female swimmers. *J Sport Rehabil.* 2014;23:65-75.
41. Reed CA, Ford KR, Myer GD, et al. The effects of isolated and integrated 'core stability' training on athletic performance measures. *Sports Med*. 2012;42(8):697-706.
42. Silfies SP, Ebaugh D, Pontillo M, et al. Critical review of the impact of core stability on upper extremity athletic injury and performance. *Braz J Phys Ther.* 2015;19(5):360-368.

## Appendix 1.

*PubMed*

((((((((((((((hip/diagnosis[MeSH Terms]) OR hip/pathology[MeSH Terms]) OR hip/physiopathology[MeSH Terms]) OR hip/therapy[MeSH Terms]) OR hip[Text Word]) OR stabilize[Text Word]) OR lumbopelvic[Text Word]) OR "core exercise"[Text Word]) OR "core exercises"[Text Word]) OR "lumbopelvic control"[Text Word]) OR "core stability"[Text Word]) OR "core stabilization"[Text Word]) AND Humans[Mesh] AND English[lang])) AND ((((((((((((((((((((((((((((((tennis/injuries[MeSH Terms]) OR swimming/injuries[MeSH Terms]) OR swimming/physiopathology[MeSH Terms]) OR baseball/injuries[MeSH Terms]) OR volleyball/injuries[MeSH Terms]) OR football/injuries[MeSH Terms]) OR shoulder joints/abnormalities[MeSH Terms]) OR shoulder joints/injuries[MeSH Terms]) OR shoulder joints/pathology[MeSH Terms]) OR shoulder joints/physiopathology[MeSH Terms]) OR shoulder joints/therapy[MeSH Terms]) OR swimming[Text Word]) OR volleyb*[Text Word]) OR tennis*[Text Word]) OR baseball*[Text Word]) OR football*[Text Word]) OR shoulder*[Text Word]) OR racquet[Text Word]) OR racquetball[Text Word]) OR softball*[Text Word]) OR overhead[Text Word]) OR throw*[Text Word]) OR overarm[Text Word]) OR crick*[Text Word]) OR overhand[Text Word]) OR pitcher*[Text Word]) OR pitching[Text Word]) OR handball*[Text Word]) OR swimmer*[Text Word]) AND Humans[Mesh] AND English[lang])) AND ((((((((((((((((((((((((musculoskeletal pain/pathology[MeSH Terms]) OR musculoskeletal pain/physiopathology[MeSH Terms]) OR (musculoskeletal pain/prevention and control[MeSH Terms])) OR musculoskeletal pain/rehabilitation[MeSH Terms]) OR musculoskeletal pain/therapy[MeSH Terms]) OR shoulder pain/pathology[MeSH Terms]) OR shoulder pain/physiopathology[MeSH Terms]) OR (shoulder pain/prevention and control[MeSH Terms])) OR shoulder pain/rehabilitation[MeSH Terms]) OR shoulder pain/therapy[MeSH Terms]) OR athletic performance[MeSH Terms]) OR fatigue/pathology[MeSH Terms]) OR fatigue/physiopathology[MeSH Terms]) OR (fatigue/prevention and control[MeSH Terms])) OR fatigue/rehabilitation[MeSH Terms]) OR fatigue/therapy[MeSH Terms]) OR (athletic injuries/prevention and control[MeSH Terms])) OR "musculoskeletal pain"[Text Word]) OR "shoulder pain"[Text Word]) OR "athletic performance"[Text Word]) OR fatigue[Text Word]) OR "athletic injuries"[Text Word]) OR "throwing accuracy"[Text Word]) OR "throwing velocity"[Text Word]) AND Humans[Mesh] AND English[lang]) Filters: Humans; English