COMPARISON OF CORE STABILITY AND BALANCE IN ATHLETES WITH AND WITHOUT SHOULDER INJURIES

Marisa Pontillo, PT, PhD, DPT, SCS^{1,6}

Sheri Silfies, PT, PhD²

Courtney M. Butowicz, PhD, CSCS⁶

Charles Thigpen, PT, PhD, ATC⁴

Brian Sennett, MD⁵

David Ebaugh, PT, PhD⁶

ABSTRACT

Background: Relationships between core stability and lower extremity injuries have been described in the literature; however, evidence of the relationship between upper extremity injuries and core stability and balance is limited.

Hypothesis/Purpose: The purpose of this study was to compare clinical measures of core stability and balance between athletes with and without non-traumatic shoulder injuries.

Study Design: Cross sectional.

Methods: Eighty athletes (54 males, age: 21.2 + 3.3 years) participated in this study. Forty athletes with a current shoulder injury were matched to healthy athletes by age, gender, BMI, and sport. Athletes completed clinical core stability tests including flexor and extensor endurance tests, double leg lower test (°) and balance tests including single leg stance under eyes open and eyes closed conditions, and the Y-balance test. MANOVAs were used to assess group differences.

Results: No statistically significant differences existed between athletes with and without shoulder injuries for clinical tests of core stability, $F(1,78) = 0.97$, $p = 0.41$; $\eta^2 = 0.04$. No statistically significant differences existed between injured athletes with and without shoulder injuries for static and dynamic balance measures, $F(1,78) = 0.86$, $p = 0.53$; $\eta^2 = 0.07$.

Conclusions: Although core stability is widely incorporated in rehabilitation of athletes with shoulder injuries, performance on these clinical tests did not differ in the group of athletes assessed in this study.

Level of evidence: 3.

Key words: Core stability, kinetic chain, shoulder injuries

¹ GSPP Penn Therapy at Penn Sports Medicine Center, Philadelphia, PA, USA

² University of South Carolina, Columbia, SC, USA

³ Walter Reed National Military Medical Center, Washington, D.C., USA

⁴ ATI Physical Therapy, Greenville, SC, USA

⁵ Penn Orthopedics, University of Pennsylvania Health System, Philadelphia, PA, USA

⁶ Drexel University, Philadelphia, PA, USA

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CORRESPONDING AUTHOR

Marisa Pontillo, PT, PhD, DPT, SCS

GSPP Penn Therapy at Penn Sports Medicine Center, Philadelphia, PA

E-mail: Pontillo77@gmail.com

INTRODUCTION

Shoulder injuries account for up to 40% of athletic injuries at the high school, collegiate, and elite levels.¹ It is difficult to determine the percentage of injuries that result from a single traumatic episode. However, it is reasonable to believe that a large number are due to overuse caused by repetitive loads through the joint, and are affected by proximal movement patterns and/or the inability to properly transmit force.²

The kinetic chain theory states that optimal shoulder function requires contribution from the legs and core (trunk and pelvis) to maximize performance while minimizing potentially harmful forces from being applied to the shoulder.^{3,4} Optimal core stability requires muscle capacity (strength and endurance) and neuromuscular control of trunk and pelvic musculature to produce, transfer, and control forces during activity.^{4,5} Pelvic musculature is often considered to be important for core stability as these muscles maintain pelvic position and are the link between the trunk and lower extremities. Likewise, the scapula is the link responsible for transferring energy from the lower extremities and trunk to the upper extremity. This theory is used in clinical and research settings as a rationale for inclusion of core stability training after injury, or for extremity injury prevention; however, a paucity of literature exists to support this approach.² Deficits in lower extremity dynamic balance (the ability to maintain lower extremity stability whilst moving) are thought to be a proxy for core stability and to impair upper extremity function.⁶

Direct relationships between core stability and lower extremity injuries have been described in the literature.⁷⁻⁹ However, literature to support evidence of the relationship between upper extremity injuries and poor core stability and balance is limited.¹⁰⁻¹⁴ Elucidating this relationship is important to improve athletic shoulder injury prevention and performance programs. The purpose of this study was to determine if differences exist in clinical measures of core stability and balance between athletes with and without a current non-traumatic shoulder injury. The hypothesis was that athletes with a current injury would have poorer performance on clinical measures of core stability and balance than athletes without injury.

MATERIALS AND METHODS

Eighty athletes were recruited from two Division I universities and athletic organizations in the area through flyers, athletic trainers, coaches, and team physicians. Athletes between the ages of 18 and 35 years old were included. Inclusion criteria were athletes who participated in any sport at an elite, varsity, or club level, with a minimum participation of 10 hours per week in practice and/or strength and conditioning workouts. Exclusion criteria were current cervical or lumbar spine injury, or any previous injury that affected the ability to play their sport. Subjects with a shoulder injury had additional inclusion criteria: shoulder injury that was non-traumatic in nature, affected their ability to perform their usual sport, and injury onset within the prior six months. Non-traumatic shoulder injury was defined as any episode which did not result from a single incident of the athlete in contact with the ground, equipment, or another player. If the subject was currently undergoing intervention for a shoulder injury, additional core training could not be part of the rehabilitation program. Forty control subjects were matched by age within five years, gender, sport group [1) overhead athletes; 2) non-overhead athletes], and body mass index (BMI) within 5 kg/m².

Subjects attended one testing session lasting approximately two hours. All subjects read and signed a written informed consent approved by the Human Research Protection Program of the university. Demographic and morphological data were collected: age, sex, height, weight, leg length, hand dominance/leg dominance, sport, if they were in season, and a description of current strength and conditioning workouts, including core stabilization exercises (Table 1). Following this, the subject was given a survey (Baecke questionnaire) regarding activity level and the Penn Shoulder Score to determine their self-reported level of shoulder disability.¹⁵ A shoulder screen was completed for all subjects, including range of motion (ROM; flexion, abduction, external rotation at 90 degrees of abduction, and functional internal rotation), manual muscle testing of the shoulder musculature (flexion, abduction, and internal and external rotation at neutral abduction; strength and presence/absence of pain noted), and provocative testing (anterior and posterior

Table 1. Subject Demographics and Group Differences, presented as Mean (SD), unless otherwise indicated.

	Control (n=40)	Shoulder Injury (n=40)	Group Differences
Age (y)	21.0 (3.4)	21.4 (3.2)	t(78)= 0.51, p = 0.61, d = 0.11
Sex (M/F, n)	27/13	27/13	
Height (cm)	176.5 (9.5)	176.2 (9.9)	t(78)= 0.11, p = 0.92, d = 0.02
Weight (kg)	84.9 (18.5)	84.6 (20.5)	t(78)= .083, p = 0.93, d = 0.02
BMI (kg/m ²)	27.0 (4.1)	26.9 (4.5)	t(78)= 0.13, p = 0.90, d = 0.03
Penn Shoulder Score	97.5 (3.8)	78.2 (11.7)	t(78)= 10.0, p < 0.001*, d = 2.2
Baecke Sports Score	6.2 (1.0)	6.1 (1.1)	t(78)= 0.33, p= 0.74, d = 0.07
Sport Type (n, overhead/ non-overhead)	14/26	14/26	
Currently in season (n)	18	18	
Participation in Strength and Conditioning (n)	40	39	
*statistically significantly different			

apprehension, biceps load I and II, Jerk, empty can, external rotation lag, and Neers tests). The shoulder screen was performed by the primary author (a licensed physical therapist) for all subjects. Subjects with shoulder pain were classified into one of the following primary diagnoses (n): rotator cuff tendinopathy (15), rotator cuff tear (2), anterior instability (9), posterior instability (1), multidirectional instability (1), and labral pathology (12).

Overhead athletes were operationally defined as athletes who performed repetitive overhead motion during practice and competition, and included throwing, racquet, and swimming sports. Athletes who participated in strength and conditioning training (79/80) reported performing core stability exercises as part of their usual regimen (indicated on the intake questionnaire; included: bridges, back extension, planks, side planks, sit-ups/crunches). Out of forty athletes with a shoulder injury, 26 were currently attending formal physical therapy.

None reported performing additional core stability exercises as part of their physical therapy intervention.

DATA COLLECTION

testing of core stability focused on the muscle capacity component. Static and dynamic standing balance assessment was also performed. Test descriptions are included in Table 2.

These clinical tests were chosen based upon prior test performance in athletes. The extensor endurance test correlates with trunk and hip extensor muscle activity.¹⁶ Additionally, normative values have been established,^{16,17} and this test has also been shown to be able to discriminate between subjects with and without low back pain.² The flexor endurance test correlates with trunk flexor muscle activity, and reference values have been established.¹⁶ The double leg lowering test (DLLT) is a test of abdominal muscle performance, activating rectus abdominis,

Table 2. *Clinical Tests Descriptions and Metrics.*

Test	Description	Metrics
Extensor Endurance Test ¹⁵	The subject was positioned prone on a treatment table with their iliac crests at the edge of the table and upper trunk hanging down from the edge of the table. Mobilization belts were used to secure the subject across the buttocks, posterior thigh above the knee, and ankles. The subject was instructed to cross their arms across their chest and extend their back until their torso was parallel to the floor. The examiner used an inclinometer on the thoracic spine to determine when the subject could no longer maintain the test position (indicated by a 10 degree change in trunk alignment).	1 trial, measured in seconds.
Flexor Endurance Test ¹⁵	This test required the subject to sit in hooklying with a custom built 60 degree wedge placed behind their back. The subject was asked to cross their hands across their chest, the wedge was removed, and they were asked to maintain that position for as long as possible. The test was terminated when the subject changed their hip flexion angle, indicated by pressing into or coming off the wedge. Figure 2?	1 trial, measured in seconds.
Double-leg lowering test ¹⁶	Subjects lie on their back with their legs straight and their hips flexed to 90°. From this position, subjects slowly lower their legs towards the floor without changing the pressure in the blood pressure cuff under their lumbar spine. Once the pressure changes 10 mm Hg, the angle of the legs relative to the horizontal is recorded. Figure 3?	Measured in degrees with wall display goniometer.

Table 2. *Clinical Tests Descriptions and Metrics. (continued)*

Test	Description	Metrics
Static balance (SLS in EO and EC) ¹⁷	Single leg stance (SLS) was assessed under eyes open (EO) and closed (EC) conditions, consisting of one practice trial and 2 trials on each leg for each condition, with a rest period of 30 seconds between trials. This was performed by having the subject stand in bare feet, and lift their right leg until the toes cleared the floor by approximately 15 cm. Subjects kept their arms crossed across their chest during the trial, and stayed as still as possible. This was repeated with the right leg.	The Balance Error Scoring System (BESS), which provides criteria for scoring the SLS test related to the quality of performance, was used to score the SLS test by counting the number of errors.
Y-Balance Test Composite ^{18,19}	<p>The Y-balance test was used as the measure of dynamic balance, using a custom-built PVC frame. Following six practice trials, the subject was asked to perform three consecutive trials of reaching in anterior, posteromedial, and posterolateral directions for each lower extremity. Subjects were instructed to keep their hands on their hips for the duration of each trial, pick the opposite foot up, and in a controlled manner, place their toes on the end of the box and push it as far as possible, then. Subjects were instructed to return to the start position, without putting their foot down. Following successful completion of the anterior reach, they then completed three trials of the posteromedial and posterolateral directions were completed. Trials were repeated if any of the following occurred during the trial: 1) the non-stance leg touched the floor; 2) the subject stepped off the testing platform; 3) the subject removed their hands from their hips; and 4) the subject put weight on the plastic box while sliding it forward.</p>	Reach distances were recorded by noting the distance the box was pushed; measurements were averaged across trials and normalized to leg length, and a composite score was calculated as the sum of the three directions.

obliquus internus abdominis, and obliquus externus abdominis muscles, and reference values have been published for collegiate athletes.¹⁷ The Y-balance test (YBT) is a commonly utilized test of lower extremity postural stability, and normative values have been established for collegiate athletes.¹⁹

After each test, exertion was assessed by the Borg scale. If any test(s) resulted in a rating of $>13/20$, the subject was allowed additional rest until the rating reached $\leq 8/20$ before the subject continued. If any test caused a two point increase (out of 10 points) on a pain rating scale, the session was terminated. All subjects completed the entire testing protocol without any reported increased pain.

DATA ANALYSIS

Data were collected for all variables on 80 athletes. SPSS Statistics software (SPSS 23, IBM, Armonk NY), was used for assessing normality and descriptive statistics. Independent T-tests examined group differences for all demographics, with significance set to $p = 0.05$. Group differences were assessed with 2 MANOVAs: 1. core stability tests (FLEX, EXT, DLLT) and 2. balance tests (BESS EO and EC left and right; YBT, normalized composite score, left and right). Significance was set to $p = 0.05$.

A logistic regression was used to determine if group differences could be detected based upon a battery of tests. In order to determine which clinical tests would be included in the logistic regression, univariate tests were used to assess for group differences for each variable, with $p = 0.10$. Variables that reached statistical significance were used in the logistic regression. For the logistic regression, significance was set to $p = 0.05$.

Sample Size

An a priori power analysis using G*Power 3,²⁰ for a large effect size ($f^2=0.15$), $\alpha= 0.10$, $\beta= 0.80$, two groups, and a maximum of six response variables, a sample size of 80 was suggested to find a difference between groups. A more liberal α was used for the initial analysis, and then variables that were found to differ significantly between groups would be looked at separately by univariate analysis. Recruitment of a total sample size of 80 allowed us to use up to four predictors in our regression equation.

RESULTS

Eighty subjects (40 with a current shoulder injury, 40 control) completed this study. Outliers were removed on a case-wise basis. Less than 5% of data were removed; thereafter, data were found to be normally distributed for all variables. Means and standard deviations of all measures are presented in Table 3.

There were no statistically significant differences between athletes with and without shoulder non-traumatic injuries for the clinical core stability measures, $F(3,76) = 0.97$, $p = .41$; $\eta^2 = 0.05$, or for standing balance measures, $F(6,73) = 0.86$, $p = .53$; $\eta^2 = 0.07$.

In this study, 28/80 athletes were overhead athletes. Analyses on this subgroup (comparing overhead athletes with and without a current shoulder injury) revealed no significant differences between the overhead athlete subgroup for any of our measures (core tests; $F(3,21) = 0.69$, $p = .57$; $\eta^2 = 0.09$; balance tests; $F(6,18) = 1.3$, $p = .32$, $\eta^2 = 0.29$).

No single variable was found to differ between groups; therefore, for the logistic regression, the following predictor variables were used: 1. DLLT; 2. FLEX; 3. EXT; 4. YBT COMP. DLLT was used as better performance on this is associated with better performance on an upper extremity functional test¹⁴ and the univariate test approached significance ($p = 0.13$). FLEX and EXT were included to ensure both anterior and posterior trunk musculature was represented in the regression equation. The YBT was included as there is an association between decreased test performance and UCL tears in baseball.⁶ Only one side (right side) was included since there was no significant difference between sides. The logistic regression was not significant, $\chi^2 = 4.4$, $df = 4$, $p = 0.36$ indicating that none of the variables differentiated between the injured and uninjured groups.

DISCUSSION

The surprising results of this study show that clinical measures of core stability utilized in this study were not different between athletes with and without a current non-traumatic shoulder injury. This was the first study to compare core muscle endurance

Table 3. Core Stability and Balance Mean Scores and Group Differences for Subjects with and without Shoulder Injury.

Clinical Test	Controls (n=40) Mean (SD)	Shoulder Injury (n=40) Mean (SD)	Statistics
FLEX (s)	95.0 (47.0)	102.8 (47.8)	$F(3,76) = 0.97$ $p = .41$ $\eta^2 = 0.05$
EXT (s)	83.5 (37.9)	79.5 (36.0)	
DLLT (°)	19.1 (14.0)	24.6 (18.6)	
BESS EO L	0.1 (0.5)	0.1 (0.4)	$F(6,73) = 0.86$ $p = .53$ $\eta^2 = 0.07$
BESS EO R	0.1 (0.3)	0.2 (0.5)	
BESS EC L	3.2 (2.1)	3.3 (2.1)	
BESS EC R	2.8 (1.8)	3.3 (2.2)	
YBT COMP L	1.35 (0.2)	1.33 (0.2)	
YBT COMP R	1.34 (0.2)	1.36 (0.3)	
FLEX= flexor endurance test; EXT= extensor endurance test; DLLT= double leg lowering test; BESS: Balance Error Scoring System, EO and EC, left (L) and right (R), recorded in number of errors; YBT COMP L/R= Y Balance test, composite score normalized to leg length, left and right			

testing, DLLT, and YBT between groups of injured and uninjured athletes. The findings can be attributed to several factors. First, the sample tested in this study was homogeneous in training and groups were matched on age, gender and sport. All subjects were high level athletes, participating at the collegiate or elite level of competition. Over, ninety-eight percent (79/80) of the athletes participated in practice and strength and conditioning workouts, all of which included core muscle training. The most commonly reported core exercises were planks, side planks, bridges, and abdominal curls, which involve the same core musculature as the FLEX, EXT, and DLLT tests. Second, there were no group differences found in the Baecke Sports Score between groups. The Sports Score captures information regarding whether an athlete is in season, the level at which they compete, and the number of hours/week and months/year they participate in their sport(s). Training volume was similar across athletes; thus, the lack of group differences cannot be attributed to training load. Other potential confounding factors (e.g., pain, fatigue) were controlled and did not differentiate groups. Therefore, the subjects were well matched and relevant confounding factors were accounted for in the design and analysis.

The clinical tests of core stability used in this study (FLEX, EXT, DLLT) all have been shown to correlate with trunk muscle activity and have established reference values.¹⁶ For the DLLT, the athletes performed better (as indicated by a lower score) than previously published reference values, indicating that the athletes in this study did not exhibit poor core stability, as measured by this test. The subjects in this study exhibited similar performance on FLEX, EXT, and YBT, compared to reference values reported in previous literature, indicating that poor core stability cannot be suspected in the population tested.^{16,19}

There were no observed differences in static balance (EO and EC conditions) between athletes with and without shoulder injuries. This is in contrast with findings from Baierle and colleagues,¹⁰ who reported that patients with shoulder pain demonstrated decreased balance control in double leg stance compared to a healthy cohort; however, these patients did not represent an athletic population. Radwan and colleagues¹³ found that Division III overhead athletes with shoulder dysfunction demonstrated decreased performance with SLS versus their healthy peers; however, this difference was only significant with the right

limb. As subjects in their study were not matched, the reported differences could potentially have been due to confounding factors such as sex, BMI, activity level, sport type, or limb dominance. The BESS score was used for the clinical measure of static balance in this study. Most athletes achieved a score of zero errors for the eyes open condition, indicating that this test condition was not challenging enough for this population. A systematic review of the BESS stated that the scoring system had better reliability and validity where large differences in balance existed (for example, after an injury such as concussion compared to healthy controls), but validity should be questioned when subtler differences exist.²¹ The eyes closed condition was only somewhat more difficult. It is possible that the clinical static balance test used in this study was not difficult enough for an athletic population to be able to discriminate between those athletes with good and poor static balance.

Similarly, differences in dynamic balance test results were not observed in this study, contrasting Garrison et al,⁶ who saw differences in standing dynamic balance between baseball players with and without a current ulnar collateral ligament (UCL) injury. However, Garrison's study investigated only UCL injuries, and there was no mention as to how recently the UCL injury occurred. Thus, the difference in YBT scores between injured and uninjured baseball players could potentially be explained by a change in the activity level in the injured players (i.e., if they participated less in practice and/or strength and conditioning), which may have caused the observed dynamic balance deficits. This is plausible since both the lead and stance limbs showed decreased YBT scores versus their uninjured counterparts. In this study, subjects were captured as close to the time of injury as possible, minimizing the potential effects of deconditioning from non-participation in practice and/or strength and conditioning. Often, strength and conditioning exercises and athletic tasks require the athlete to be in single leg stance for part of the activity. Thus, single leg stance performance was expected to be similar across the athletic population tested, in the absence of a deconditioning effect secondary to injury. Future work should consider the utilization of more advanced athletic tasks, such as advanced dynamic stabilization

or unilateral plyometric activities to potentially discern differences in athletic performance.

The results show that no test combination among the DLLT, FLEX, EXT, and YBT tests differentiated injured and uninjured athletes. Additionally, none of the individual tests differentiated between groups (shoulder injury versus control). Furthermore, both the MANOVAs and logistic regression had small effect sizes, indicating that a larger sample would very likely reveal similar results.

Previous work examining the kinetic chain theory has focused on overhead athletes, most commonly baseball players.^{11,12} In this study, the overhead athlete subgroup revealed no significant differences between the overhead athlete subgroup for any of measures tested; furthermore, the small effect size for the core measures suggests that if more overhead athletes participated in this study, we would still be unlikely to find group differences. Since balance test score differences had a large effect size, future work may examine balance differences in this subset of athletes. The rationale for including other athletes (e.g., lacrosse, crew) was that all athletes who participated in this study used their upper extremity in some manner to perform their sport tasks. Additionally, the kinetic chain theory does not state that its premises are only applicable to specific athletes.

The current results do not support the premise that highly trained athletes with a current shoulder injury differ in clinical measures of strength or endurance of the core muscles nor standing balance compared to an uninjured cohort. Although core stability is widely incorporated in rehabilitation of athletes with shoulder injuries, limited evidence has demonstrated differences in core stability in athletes with shoulder injuries versus their uninjured peers.³⁻⁵ The clinical tests of core stability used in this study were geared towards assessing the muscle capacity aspect of core stability and while these tests are widely used and have documented reliability, they may not be sensitive enough, to detect deficits in highly trained athletes. Additionally, clinical tests that focus on the neuromuscular control aspect of core stability may, in isolation or combined with tests used in this study, may be able to identify group differences in core stability. Not including

clinical tests of neuromuscular control, or the transference of forces through the lower extremities, core, and upper extremities are limitations of this study. Investigating all aspects of core stability as well as other intrinsic and extrinsic risk factors for shoulder injuries in an athletic population should be the focus of future research.

CONCLUSION

No differences in clinical measures of core stability or balance were found between athletes with and without a non-traumatic shoulder injury. Although core stability is widely incorporated in rehabilitation of athletes with shoulder injuries, athletes who develop non-traumatic shoulder injuries may not have significant impairments in core stability or balance that are contributing to their injuries.

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