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Weak Relationships Between Three Clinical Assessments and Core Stability Tests

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Abstract

Core stability measurements are commonly used to identify individuals who may be at risk for athletic injuries. However, the relationship between core stability tests and other clinical assessments used to assess injury risk are not well established. The purpose of this study is to determine the relationships between three clinical assessments and core stability tests. We anticipate the relationships between the three clinical assessments and core stability tests will be low and not significant.

Participants included 36 college-aged males and females. The three clinical assessments consisted of the Star Excursion Test and the Frontal Plane Projection Angel (FPPA) of the knee during a single leg squat and drop. The core stability tests included isometric trunk and hip strength tests and core muscular endurance measurements. A Pearson correlation coefficient analysis was performed to estimate the relationship between the two groups of measurements.

The results found low coefficients of determination (R^2) between the clinical assessments and core stability tests. R^2 between the star excursion, single leg squat, and the single leg drop tests and the core stability tests ranged from $R^2 = .0001$ to $.179$, $.0001$ to $.194$ and $.00004$ to $.068$, respectively.

Weak relationships between the three clinical assessments and core stability tests were observed. Therefore, we suggest these clinical assessments should not be used to evaluate core stability. Although this study was conducted in a laboratory, the tests and measures performed are commonly used in a clinical setting.

Keywords: Clinical Assessments; Core Stability; Injury Prevention; Functional Tests

Introduction

Core stability has become a popular concept in sports medicine since it is believed to play an important role in the prevention and rehabilitation of athletic injuries. Ireland and associates observed that females who demonstrated core weakness were more likely to suffer from patellofemoral pain [1]. The authors reported that individuals with weaker cores were unable to prevent excessive knee valgus and internal rotation moments, which may encourage lateral tracking of the patella and pain. Similarly, Leetun and colleagues suggested an increased risk of injury in college athletes with significant core weakness and noted the importance of a proximal stabilization program in order to prevent lower extremity injuries in athletes [2]. Recently, Abdelraouf and Abdel-asiem observed male college athletes with non-specific low back pain had decreased core muscular endurance compared to the health control group [3]. McGill suggested the ultimate goal of a core stability program was to train core muscles to maintain a sufficient spinal stability [4]. He stated muscle strength may not be the optimal aspect of a rehabilitation core stability program. Instead, he recommended core endurance exercises to be more important in the prevention of and recovery from injury. Despite the popularity of the concept of core stability in the field of sports medicine, a universal definition or a gold standard assessment of core stability currently does not exist.

The definition of core stability has varied in throughout the literature due to its complex description. Hodges was the first to provide a core stability definition when he developed a model of lumbopelvic stability, defining it as the “dynamic process of controlling static position in the functional context, but allowing the trunk to move with control in other situations [p.13,5].” Hodges described three inter-dependent hierarchy levels of lumbopelvic stability: the control of whole-body equilibrium, control of lumbopelvic orientation, and inter-vertebral control [5]. Subsequent definitions of core stability took a simpler, but similar approach. Bliss and Teeple defined the dynamic stabilization of the spine as the ability to use muscular strength and endurance to maintain a neutral spine posture and then control the spine beyond the neutral zone when performing activities [6]. Willson, *et al.* defined core stability as the ability of the lumbopelvic-hip complex to return to equilibrium following a perturbation without buckling of the vertebral column [7]. According to Kibler, Press, and Sciascia, core stability refers to the ability to control the position and motion of the trunk over the pelvis and leg to produce, transfer, and control force and motion to the terminal segment during kinetic chain activities [8]. Although several definitions of core stability exist, without a universal definition, performing an effective measurement of core stability has been virtually impossible.

Assessing core stability remains difficult due to the number of tests that claim to evaluate core stability and the lack of a standard measure. For instance, Leetun, *et al.* Stanton, Reaburn, and Humphries [9] and Chaudhari, *et al.* all assessed core stability differently in their studies [2,9,10]. Leetun, *et al.* assessed core stability by measuring hip abduction and external rotation strength and trunk muscular endurance when they examined the relationship between core stability and lower extremity injuries in athletes [2]. Stanton, *et al.* used the Sahrman Core Stabilizing Test to evaluate core stability, whereby they investigated the effect of a Swiss ball training program on maximal aerobic power and running economy of male athletes [9]. The Sahrman Core Stabilizing Test uses a Stabilizer Pressure Biofeedback Unit (Chattanooga Group, Inc., Hixson, TN), which was placed under a participant’s lumbar spine while they perform different movements in the supine position. Chaudhari, *et al.* measured total anterior and posterior pelvic tilt during a standing single leg raise to quantify core control when they determined the role of lumbopelvic stability as a risk factor for injury in professional baseball pitchers [10]. In addition to these tests, in order to evaluate core stability accurately, the testing technique should have the individual in a function position [8]. Functional assessments associated with core stability are commonly used in clinical settings; however, such measurements may not directly evaluate specific components of core stability. One of the most popular clinical assessments used was the Star Excursion Test which is a functional assessment used to evaluate lumbopelvic control and balance, hip and ankle stability, and hip strength [6]. Similarly, other clinical assessments are available which may evaluate some aspect of core stability, including a single limb squat and drop tests. During the single leg squat test, standing balance, lower extremity coordination and core strength during a closed chain activity are assessed [8]. In addition to the single leg squat, the more dynamic, single leg drop test has been used in the clinical setting to evaluate neuromuscular control of the trunk and lower extremities [11]. Although the single leg squat and drop tests are commonly assessed clinically through observation, there are tools available to generate an objective measurement.

It is evident from the above that currently available clinical assessments, although extremely popular, may not accurately and thoroughly evaluate core stability. Therefore, the objective of this study was to determine the relationships between three clinical assessments and core stability tests, which assess core strength and muscular endurance. We hypothesize that the relationships between the three stability assessments and the core stability tests will be minimal.

Materials and Methods

Participants

Thirty-six healthy, active, college-age individuals (18 males, age: 21.0 ± 1.2 yr, weight: 69.4 ± 13.2 kg, height: 1.7 ± 0.1 m), who were recruited from a local university, volunteered for participation in the study. The applicants that reported an orthopedic injury to their trunk or extremities within the past year were not allowed to participate in the study. Lower extremity dominance was determined by the answer to this question: “If you were to kick a soccer ball as hard as you could, which leg would you use?” Among all of the participants, three females were classified as left lower extremity dominate, the others were right leg dominate. The participants provided informed consent as approved by Institutional Review Board, Louisiana State University, Baton Rouge, LA, prior to testing.

Procedures

The testing was performed in a laboratory setting. Participant's age, weight, height, and dominant leg length (anterior superior iliac spine to lateral malleolus) were recorded. All tests were first demonstrated by the evaluator and the participant performed a practice trial to become familiar with the equipment and procedure of each test. No verbal encouragement was given to the participant during the tests or assessments. The clinical assessments were performed first and in a random order followed by the core stability tests. The core stability tests followed the exact protocol explained in Waldhelm and Li [12]. Strength tests were performed first and randomized followed by the muscular endurance tests. The endurance tests were performed last, due to their fatiguing nature and were also randomized. Participants walked on a treadmill for five minutes at their preferred walking speed as warm-up prior to the actual testing.

Star Excursion Test

The Star Excursion Test is a clinical test used to assess neuromuscular control of the trunk, pelvis and lower extremities for the purposes of injury prevention and rehabilitation [13]. Although several methods of performing the Star Excursion Test have been presented, in this study, we used a protocol modified from those described by Kinzey and Armstrong [14]. The layout of the test includes two pairs of perpendicular lines. The first two lines were in the anterior-posterior and medial-lateral directions, while the second pair of lines were placed at 45° angle with respect to the horizontal and vertical lines. A box, large enough for the participant to stand in, was placed centrally at the intersection of the four lines. The test was initiated with the participant standing inside the starting box. Without the foot making contact with the ground, the participant reached as far as possible in one of the four diagonal directions (marked by the second set of perpendicular lines), returning to the starting box. The furthest distance reached was marked along the line and then measured with a tape measure from the center. As a part of one trial, the participant reached in all four directions with each leg. Three trials were performed with a rest time of three minutes between consecutive trials.

The participant was instructed to perform the maximum reach using any method possible without moving the stabilizing foot. The average length of three trials for each of the four directions and each leg was recorded. These eight scores were summed, establishing a total score. In order to normalize the test to an individual's leg length, the total score was divided by eight times the participant's leg length and multiplied by 100, yielding an outcome that was a percentage of the participant's leg length. This procedure followed the normalization method described by Gribble and Hertel [13].

Single leg squat and drop tests

Single leg squat and drop tests were used to help identify athletes at risk for a lower extremity injuries [15]. It was hypothesized that greater control of the femur, by decreasing knee valgus angle (hip adduction and internal rotation) during athletic activities, will reduce the number of injuries [11,16]. As the single leg squat test requires control of the body over a planted leg, it was used to screen for poor hip strength and trunk control [16]. Similarly, the single leg drop test was a dynamic test that requires the control of the lower extremity and trunk to limit excessive forces and absorb energy upon landing [17].

Most studies that examined lower extremity kinematics of a single leg squat or drop were performed in a laboratory setting using expensive three-dimensional motion analyses equipment. These methods are typically not available in a clinical setting. Recently a two-dimensional method that could be performed in a clinical setting, designed to measure knee valgus angle, the Frontal Plane Projection Angle (FPPA), was introduced by McLean and associates [18]. This method requires only a digital camera and photo editing software.

We measured the FPPA of the knee using the method described by Willson, Ireland, and Davis for the single leg squat and the single leg drop [15]. To measure the FPPA of the knee, three markers were placed on the dominant leg: at the mid-thigh between the anterior superior iliac spine and the midpoint of the tibiofemoral joint (mid-thigh marker), the midpoint of the tibiofemoral joint (knee marker), and between the midpoint of the medial and lateral malleoli (ankle marker). To develop the anatomical alignment FPPA of the knee, the

participant stood on one leg facing a digital camera (AIPTEK INC., Irving, CA), we measured FPPA using the angle formed by the markers of the mid-thigh, the knee, and the ankle. We measured the FPPA of the knee a single leg squat to 45° limited by a bicycle pump and a single limb drop from a height of 50.8 cm. We then compared the average of three FPPAs for the single limb squat and drop to the anatomical alignment FPPA. The differences between the FPPA of the single limb squat and the anatomical alignment and between the FPPA of the drop and anatomical alignment were recorded.

Strength tests

The strength tests included eight isometric tests, trunk flexion and extension, bilateral hip extension, abduction, and external rotation, were performed on a Biodex System 3 Pro (Biodex Medical Systems, Inc., Shirley, NY) The isometric strength tests followed modified protocols described by Essendrop, Schibye, and Hansen and Nadler, Malanga, DePrince, Stitik, and Feinberg [19,20]. The average of three maximum force measurements was recorded and the participants held each contraction for five seconds. All eight strength measurements were adjusted for body weight.

A one-minute sit-up test was also included in the strength category. The objective is to perform as many full sit-ups as possible in one minute and the American Alliance of Health, Physical Education, Recreation, and Dance developed the protocol [21].

Endurance tests

Four core endurance tests included the trunk flexion test, trunk extension test and bilateral side bridge/plank tests following protocols described by McGill, Childs, and Liebeson [22]. For each test, the participants held a static position for as long as possible and the test was terminated when the participant was no longer able to hold the position.

Statistical analyses

The test results were analyzed using SPSS for Windows (version 17.0; SPSS Inc, Chicago, IL). Baseline statistics (mean, standard deviation, range, and coefficient of variance) were used to report the individual results for each clinical assessment and core stability related tests. Correlation analyses within the clinical assessments associated with core stability and between the clinical assessments and the core stability related tests were evaluated using the Pearson correlation coefficient. Statistical significance was set at P < .05.

Results and Discussion

Mean, standard deviation, minimum and maximum values, and coefficient of variation for each of the core stability tests and clinical assessments are presented in Table 1. The overall coefficient of variance (CV, Standard Deviation/Mean) ranged from 0.035 to 0.714 for the core stability tests, while CV for the clinical assessments ranged from 0.055 to 12.9.

	Mean	Standard Deviation	Min - Max	CV
Strength Tests				
Trunk flexion (N/kg)	0.709	0.253	0.31 - 1.44	0.367
Trunk extension (N/kg)	0.999	0.416	0.34 - 2.31	0.416
D hip extension N/kg)	0.690	0.245	0.36 - 1.45	0.355
ND hip extension (N/kg)	0.761	0.212	0.40 - 1.28	0.279
D hip abduction (N/kg)	0.821	0.212	0.48 - 1.45	0.258
ND hip abduction (N/kg)	0.800	0.176	0.50 - 1.32	0.220
D hip ER (N/kg)	0.679	0.156	0.38 - 1.08	0.106
D hip ER (N/kg)	0.679	0.156	0.38 - 1.08	0.106
ND hip ER (N/kg)	0.645	0.164	0.37 - 0.99	0.254
Sit up test (Repetitions)	44.0	9.00	26 - 65	0.204
Endurance Tests				
Trunk flexion (s)	53.1	33.9	12 - 161	0.638
Trunk extension (s)	87.4	33.0	24 - 174	0.378
Right side bridge (s)	70.6	31.8	23 - 163	0.450
Left side bridge (s)	69.6	35.4	32 - 202	0.509
Clinical Assessments				
Star Excursion Test (%)	104	5.77	91.96 - 118.04	0.055
Single leg squat (°)	- 5.72	8.19	- 17.3 - 19.3	1.43
Single leg drop (°)	0.612	7.90	- 12.0 - 19.0	12.9

Table 1: Descriptive Statistics.

Note: D: Dominate; ND: Non - Dominate; CV: Coefficient of Variation (Standard Deviation/Mean); ER: External Rotation; IR: Internal Rotation; S.L.B.: Single Leg Balance Test; S.L.: Single Leg

The overall correlations between the clinical assessments and the core stability were rather low (see Table 2), ranging from .00004 to .194. The correlations between the Star Excursion Test and the core stability tests ranged from $R^2 = .0001$ to $R^2 = .179$. A significant correlation was observed between the Star Excursion Test and trunk extension strength ($R^2 = .177$). R^2 ranged from .0001 to 0.194 for correlations between the FPPA of the single leg squat and the core stability tests. The relationship between the single leg squat and trunk flexion endurance test ($R^2 = .194$) was the only statistically significant correlation within the group. Overall, the correlations between the FPPA of the single leg drop and the core stability tests were the weakest of the three clinical tests ($R^2 = .00004$ to .068) and were not statistically significant.

	Star Excursion Test	S.L. Squat Test	S.L. Drop Test
Strength Tests			
Trunk flexion	.024	.004	.00008
Trunk extension	.177	.012	.003
D hip extension	.019	.006	.032
ND hip extension	.081	.009	.020
D hip abduction	.082	.002	.00004
ND hip abduction	.093	.001	.004
D hip ER	.0001	.020	.003
ND hip ER	.069	.056	.023
Sit up test	.008	.015	.001
Endurance Tests			
Trunk flexion	.0003	.194	.068
Trunk extension	.001	.060	.054
Right side bridge	.019	.005	.001
Left side bridge	.021	.0001	.007
Clinical Assessments			
Star Excursion Test	1	.001	.038
Single leg squat	.001	1	.384
Single leg drop	.038	.384	1

Table 2: Correlations (R^2) between Core Stability Tests and Clinical Assessments.

Note: **Bold:** significant at the 0.05 level; D: Dominate; ND: Non - Dominate; ER: External Rotation; IR: Internal Rotation; S.L.B.: Single Leg Balance Test; S.L.: Single Leg

Among the clinical assessments, there was a significant correlation between the single leg squat and drop ($R^2 = .384$). There were low, non-significant correlations between the Star Excursion Test and the single leg squat ($R^2 = .001$) and single leg drop tests ($R^2 = .033$).

In support of the initial hypothesis, the overall relationships between the three clinical assessments and the core stability tests were minimal and varied between assessments. The Star Excursion Test and single leg squat each had one significant correlation with the core stability tests, while none were found for the single leg drop. The single leg squat and drop tests had a significant relationship with each other; however, this may be due to the use of the same instrumentation when measuring the knee valgus angle. There was virtually no correlation between the Star Excursion Test and the single limb squat and drop tests. Thus, it can be assumed the Star Excursion Test evaluates different components or aspects of stability compared to the other clinical assessments. Examining the methods used in each

assessment, the Star Excursion Test may be more complex than the two other clinical assessments, requiring the individual to disturb their equilibrium by reaching outside of their base of support and returning to the starting position [13]. Furthermore, performing the Star Excursion Test may require a greater number of physiological factors such as lower extremity coordination, flexibility, strength, and postural control, in comparison with the single leg squat and drop tests.

The Star Excursion Test was observed to have a significant, yet low, correlation with trunk extension strength. To the authors' knowledge, the role of trunk extensor strength with the Star Excursion Test has not previously been examined. The essential role of the trunk extensor muscles during single leg stance with lower extremity movement may explain the significant correlation found between trunk extensor strength and the Star Excursion Test. Hodges and Richardson observed an anticipatory contraction of the abdominal and multifidus muscles before lower extremity movement [23]. This feedforward response allows for the stabilization of the spine before a perturbation was introduced. Therefore, the trunk extensor muscles may stabilize the trunk and spine during the Star Excursion Test, allowing for maximum reach distance and a controlled return back to the starting position. Gordon, Ambegaonkar, and Caswell studied the relationship between hip external rotation strength and the Star Excursion Test in female lacrosse players and found similar outcomes although their correlations were stronger [24].

The single leg squat had a significant correlation with the trunk flexion endurance test only. Similar to the Star Excursion Test, the significant relationship may be a result of the abdominal muscles attempting to stabilize the trunk and spine in preparation for a movement. This theory was further supported by the fact that the objective of the endurance test was to stabilize the entire body while attempting to hold a posture for as long as possible. It has been suggested that trunk and hip strength were important when performing a single leg squat [15]. Unlike the results reported here, Willson, *et al.* found significant correlations between the FPPA during a single leg squat and trunk extension strength and single leg squat and hip external rotation strength [15]. The differences in observations may be attributed to the use of different instrumentation and testing positions. Willson, *et al.* used a hand held dynamometer to measure maximum isometric force, while the Biodex System 3 Pro was employed in this study [15]. Second, the authors tested for trunk extension strength in the prone position, while in the current experiments the individual was tested while standing, which may require more control and stability. Claiborne, Armstrong, Gandhi, and Pincivero observed a significant relationship between hip abduction strength and knee valgus direction during a single limb squat [25]. The choice of instrumentation could again be the reason for the different outcome when compared to the present study. Claiborne, *et al.* tested hip abduction strength isokinetically, rather than isometrically, as was the case here [25]. Furthermore, they also assessed knee valgus direction using three-dimensional analyses, compared to present two-dimensional analysis.

The single leg drop test did not have a significant correlation with any of the core stability tests. Similar to the single limb squat, hip strength was believed to play a vital role in lower extremity control during landing [26]. Although, the present observations did not suggest a significant correlation between the hip strength and the single leg drop, early research suggests the presence of a relationship. Lawrence, *et al.* observed that females with greater hip external rotation strength had a significant decrease in knee valgus angle and vertical ground reaction force during a 40 cm single leg drop. Differences in testing protocol (drop height, subjects, 3D kinematics) may have contributed to the disparity in results [26].

The three clinical assessments used in this study, although important in identifying an individual potentially at risk of injury, may not be the best tools for assessing core stability, as this is a complex concept and thus difficult to evaluate. The current results indicate that the three clinical assessments do not measure the same stability component. We suggest in order to truly assess core stability, individual components of core stability, trunk strength or muscular endurance, must be taken into consideration.

As stated before, caution must be taken when attempting to generalize the results beyond the population of healthy, college-aged individuals without recent orthopedic injury. In this study, males and females were grouped together, which may have affected the clinical assessments results. It has been observed that males and females use different techniques and strategies when performing a single

limb squat and drop [11,16]. More research must be performed to identify valid core stability tests, which would allow identification of individuals at risk of injuries, and enable them to improve athletic, work, and functional performance.

Conclusion

Core stability continues to be a somewhat novel concept and continues to be difficult to evaluate because it lacks an accepted definition and a gold standard assessment. In the current study, the relationships between three clinical assessments and core stability muscular strength and endurance tests were weak and not identical. Therefore, the observations may suggest that each clinical assessment could rely on different components of core stability or may not rely on core stability at all. Furthermore, because of its complexity evaluating core stability using only one assessment or testing only one component of core stability will not be thorough and may not be valid. Further research must be conducted to create a valid core stability assessment to help identify individuals at risk for injuries.

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Conflict of Interest

No financial interest or conflict of interest exists.

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