Test–Retest Reliability of the Closed Kinetic Chain Upper Extremity Stability Test: A Clinical Field Test

Todd G. Goldbeck and George J. Davies

Context: Functional testing of patients is essential to clinicians because it provides objective data for documentation that can be used for serial reassessment and progression through a rehabilitation program. Furthermore, new tests should require minimal time, space, and money to implement.

Purpose: To determine the test–retest reliability of the Closed Kinetic Chain (CKC) Upper Extremity Stability Test.

Participants: Twenty-four male college students.

Methods: Each subject was tested initially and again 7 days later. Each subject performed 1 submaximal test followed by 3 maximal efforts. A 45-second rest was given after each 15-second test. The 2 maximal-test scores were averaged and compared with those from the retest.

Results: The intraclass correlation coefficient was .922 for test–retest reliability. A paired-samples t test (.927) was conducted, and the coefficient of stability was .859. The results indicate that the CKC Upper Extremity Stability Test is a reliable evaluation tool.

Key Words: closed kinetic chain, upper extremity, functional testing

Functional testing of patients is becoming increasingly important to the rehabilitation clinician. We need to develop new tests that provide objective data to help the clinician determine a patient’s readiness to return to activities, resume competition, or continue further rehabilitation. These tests should be easy for clinicians to use and for patients to understand. They also must be cost-efficient, take up minimal space in the clinic, be generalizable to many different patient populations, and be reliable.

The concept of body segments interacting with each other in a kinetic chain has existed in the rehabilitation profession for many years. It was first introduced by Steindler,1 and since then the terms have been defined in many ways. In a kinetic chain, all segments are interdependent. Each moving
segment exhibits force on every other and affects those segments’ motions in a predictable manner.\textsuperscript{1,4} There is a continuum of activities along the kinetic chain, ranging from the open kinetic chain to the closed kinetic chain. \textit{Open kinetic chain} is commonly defined as an activity in which the distal segment of the extremity terminates freely in space. The following are characteristics of open kinetic chain activities: They occur in isolated joint movements; motion occurs only distal to the axis; and the axis is relatively stable, with 1 part of the extremity that forms the joint stabilized and 1 segment moving.\textsuperscript{3,9-11} \textit{Closed kinetic chain} is commonly defined as an activity in which the distal segment of the extremity is fixed to an object and can be stationary (push-ups) or moving (bench press). The following are characteristics of closed kinetic chain activities: They occur with multiple joint movements or multiple joint axes, the primary axis is translatory, motion occurs both proximal and distal to the axis, and both segments of the extremity that form the joint are moving simultaneously.\textsuperscript{3,9,10}

These terms are used freely in rehabilitation settings, yet there is no strict adherence to a standard definition of what open or closed kinetic chain exercises are.\textsuperscript{1,5,10,12,13} Dillman et al\textsuperscript{12} have pointed out the various inconsistencies in the literature concerning clinicians’ use of the terms \textit{open} and \textit{closed kinetic chain} and their subsequent application to patient treatment. A system of classification was proposed that includes 3 categories: fixed boundary, external load; movable boundary, external load; and movable boundary, no external load. They suggest a move from the existing classification, which has no accepted standards of criteria, to a description of each exercise based on the biomechanics involved, the load placed on the body, and the muscle activation required.

Lephart and Henry\textsuperscript{5} have also suggested an alternative method for classifying rehabilitative exercises. It is called the functional classification system and is based on the boundary, the load, and the direction in which the load is applied to the upper extremity. This 4-class system consists of fixed boundary, external axial load; movable boundary, external axial load; movable boundary, external rotary load; and movable boundary, no load. Lephart and Henry also feel that a more comprehensive set of criteria is needed to accurately define the various exercises in a rehabilitation program, as opposed to the traditional terms of \textit{open} and \textit{closed kinetic chain}.

In both the upper and the lower extremity, there has been an increase in the use of closed kinetic chain exercises in clinical rehabilitation. Research and rationale for using closed kinetic chain exercise in the lower extremities is prevalent in the literature,\textsuperscript{10,14-25} but carryover to the upper extremities is still unclear. Because of the lack of information in the current literature, there has been a recent increase in the interest of testing and rehabilitation procedures for the upper extremities, particularly with emphasis on closed kinetic chain activities.

Weight bearing through the upper extremities, as in the case of closed kinetic chain activities, increases the dynamic stability of the glenohumeral
joint through joint approximation and by producing a muscular cocontraction of the agonists/antagonists about the joint.\textsuperscript{1,7,26-32} Static stability is enhanced via stimulation of joint mechanoreceptors resulting from compression of the capsule.\textsuperscript{1,26-28,31-33} There is also some information that suggests that weight bearing through the upper extremities increases overall stability because of the anatomical structures of the glenohumeral joint.\textsuperscript{1,8,31,32,34}

Joint proprioception has been found to be negatively affected after injury.\textsuperscript{7,17,20,26,27,29} Therefore, rehabilitative procedures should maximize the use of mechanoreceptors to allow for more accurate joint-position sense. Proprioceptive deficits must be addressed in order for the rehabilitation program to be complete. Closed kinetic chain exercises should help accomplish this goal.

Stone\textsuperscript{35} stated that the use of closed kinetic chain activities in rehabilitation should be used, based on the concept of specificity of training. Rehabilitation should be structured in a manner that most closely simulates the way that the muscles and joints are used in sport. For example, athletes that function with their upper extremities in a closed kinetic chain during sport would receive the greatest benefit from closed kinetic chain rehabilitation.

When a new functional test is developed that is relevant to multiple upper extremity injuries and can be used in any clinical setting, its reliability must be examined. New and innovative testing procedures must continually be scrutinized to ensure that they provide the most accurate account of a patient’s progress. The purpose of this study was to determine the test–retest reliability of the Closed Kinetic Chain Upper Extremity Stability Test.

\section*{Methods}

\subsection*{Subjects}

Twenty-four male college students (mean age = 20.3 years) volunteered to participate in the study. Because the study tested the reliability of the evaluation tool, the subjects did not start a new training program or alter their current workouts during the course of the study. Therefore, data collected were not affected by neuromuscular adaptations to exercise. Each subject read and signed an informed consent form, which was approved by the University of Wisconsin-LaCrosse institutional review board, before participating in the study.

\subsection*{Instrumentation}

Two pieces of standard athletic tape (1.5-in width) were placed on the ground parallel to each other 36 in apart. A standard tape measure of at least 36 in was used to measure the distance between the hand lines. To ensure that all tests were of equal duration, a standard battery-operated stopwatch was used.
Protocol

To begin, the subject assumed a push-up position, with 1 hand on each piece of tape and body as straight and parallel to the ground as possible. The shoulders were positioned directly over the hands (Figure 1). When the examiner said "go," the subject removed 1 hand from the floor (either one), touched the opposite line (Figure 2), and then replaced the hand on the original line (Fig-
ure 3). He then removed the other hand from the floor, touched the opposite line (Figure 4), and returned it to its original line (Figure 5). A single test consisted of continuing this alternating procedure for 15 seconds.

Each subject performed a submaximal test and then 3 maximal efforts. Subjects attempted as many “touches” as possible in the allotted time during the maximal tests. A touch was defined as when a hand was crossed over and touched the opposite line. The 3 maximal tests were averaged and became

![Figure 3](image1.png) Subject returns hand to original position.

![Figure 4](image2.png) Subject touches the opposite line.
the subject's test score. The same procedure was followed for the retest 1 week later. A test–retest period of 1 week was chosen to simulate the period of time used to serially test a patient in the clinic. When a patient is thought to be ready for return to activities, several tests are performed to determine his or her functional level. If not deemed ready for competition, the athlete is tested again 1 week later after further rehabilitation of the injury. A single rest period of 45 seconds was given after every trial. The work–rest ratio was 1:3, which allows for optimal recovery following a short-duration, high-intensity test such as this.\textsuperscript{36-38} All subjects were videotaped, and the tapes were reviewed to ensure accuracy of test scores. All tests were administered and data collected by the principal investigator.

Data analysis for this test can occur in 1 of 3 ways. First, the number of touches can be counted for each subject. This is the method that was used for this study. This method is the easiest because it provides absolute numbers that can be used for statistical analysis. Second, the number of touches can be divided by the patients' height to normalize the data to each patient. By normalizing the data to each patient, instead of continually changing the width of the hand lines based on each patient's size, the test becomes more efficient in a busy clinical setting. Third, a power score can be developed by multiplying the average number of touches with 68% of the patient's body weight in kilograms, which is the weight of the arms, head, and trunk. That score is then divided by 15, which is the duration of the test in seconds. The power score reflects the amount of work performed in a unit of time.

**Statistical Analysis**

The SPSS 6.1 statistical package was used for all data analysis.\textsuperscript{39} The intraclass correlation coefficient was determined to establish reliability of

![Figure 5](image-url) Subject returns hand to original line.
the test and retest scores. A paired-samples \( t \) test was also used to compare the 2 groups of scores. An \( p \) value of .05 was used for all analyses, which yielded a 95% confidence level. The coefficient of stability was also calculated.

According to Shrout and Fleiss, it is necessary to assess the reliability of a test in order to know the extent to which the measurements are measuring what they say. The intraclass correlation coefficient provides that measure of reliability.

**Results**

The results indicate that the reliability of measurements obtained with the Closed Kinetic Chain Upper Extremity Stability Test has a high correlation. The single-measure intraclass correlation coefficient was .922 for test–retest reliability. The paired-samples correlation coefficient was .927. The coefficient of stability \( (R^2) \) was .859. The test mean was 27.8, with a standard deviation of 1.77, and the retest scores had a mean of 27.9 and a standard deviation of 1.97.

**Comments**

Functional tests are useful when gathering baseline data for a patient, as well as performing serial reassessments. The purpose of this study was to determine the test–retest reliability of the Closed Kinetic Chain Upper Extremity Stability Test. By determining the reliability of this clinical evaluation tool, we can now say that it can be used confidently as a method to objectively show a patient's progression of recovery from an upper extremity pathology.

There is a need for the development and research of new functional tests that can be used in a clinical rehabilitation setting for assessing closed kinetic chain upper extremity activities. More and more clinicians, as well as many recent publications, are emphasizing the use of closed kinetic chain exercises in the rehabilitation of patients with upper extremity injuries. This causes a dilemma, because there are no commonly used clinical tests to identify deficits in upper extremity closed kinetic chain function.

Borsa et al. address rehabilitation techniques to improve the proprioceptive ability of an unstable glenohumeral joint. They suggest many closed kinetic chain exercises including plyometric push-ups, press-ups, and single-arm dynamic stabilization on a multidirectional surface.

Davies and Dickoff-Hoffman discuss several methods of upper extremity rehabilitation. The exercises are derived from kinesthetic training, closed kinetic chain exercises, and plyometrics. Each of the techniques suggests using the upper extremity in a closed kinetic chain manner with varying degrees of difficulty. Exercises include dynamic stabilization and push-ups on uneven surfaces.

Lephart and Henry propose a functional classification system to be used to restore proprioceptive deficits and reestablish neuromuscular control during the rehabilitation of upper extremity injuries. They describe many
closed kinetic chain exercises, such as 1-arm balancing on an uneven surface in a tripod position and upper extremity exercise on a slide board in a push-up position.

Stone et al. suggest using rehabilitative methods that replicate function as closely as possible. They rehabilitate the upper extremity using the same type of closed kinetic chain exercises that are commonly used for the lower extremity. The exercises described include slide board in all directions, inverted push-ups on a shuttle, plyometric step-ups and step-downs, and stair stepping.

Wilk et al. encourage the use of closed kinetic chain activities in an upper extremity rehabilitation program. They illustrated many exercises in which the patient is bearing weight with the upper extremity while performing activities of varying difficulty.

If no tests exist that objectively measure closed kinetic chain performance of the upper extremity, clinicians should not incorporate such exercises into a rehabilitation program. Typically, in clinical practice, a measurement or test is performed to evaluate the status of a particular parameter, and then, based on the test results, appropriate intervention strategies are applied to improve the deficit. A common clinical example is the use of anthropometric measurements to determine whether effusion or edema is present in an injured area. If it is present, appropriate treatments that are effective in decreasing swelling are implemented. Another example is the use of goniometry to measure joint ranges of motion. If a patient has range-of-motion deficits caused by noncontractile tissues, heating, stretching, and mobilizations are performed to create a plastic deformation of the tissue to improve range of motion and return it to normal. In addition, muscle weakness can be identified through manual muscle testing, dynamometer testing, or functional performance testing. Appropriate strengthening exercises are indicated if weakness is found, depending on the severity of injury and soft tissue healing constraints.

It is appropriate to state that, ethically, no clinician would apply treatment modalities to decrease swelling in a joint if anthropometric measurements were similar with bilateral comparison and there were no other indications of swelling. The same argument can be made for the other 2 examples, as well. With these clinical examples, clinicians must ask themselves why closed kinetic chain upper extremity exercises are being integrated into treatment programs when no testing has been performed to demonstrate any deficits in those areas.

Therefore, there is a need to develop a test that is easily administered in any clinical setting, requires minimal set-up, and is reliable. We found no commonly used closed kinetic chain upper extremity tests in the literature after performing a thorough MedLine search. After many pilot test procedures, the senior author (G.J.D.) developed the test described in this paper. The purposes of the test are to determine whether there are deficits in closed kinetic chain upper extremity functional performance and to use the re-
sults to guide the progression of a rehabilitation program. As discussed previously, to randomly implement therapeutic exercises without any basis from a clinical examination or testing is not the ideal scientific or clinical method to design a rehabilitation program.

Our test has been used for several years as an assessment tool for upper extremity closed kinetic chain function in an orthopedic and sports medicine clinic. Hundreds of patients have been evaluated with this test on their willingness to use their upper extremities in a closed kinetic chain manner and their ability to perform the test for an objective score.

Empirically based clinical observations by a clinician with over 30 years of clinical experience (G.J.D.) have shown that patients who were unwilling or unable to perform or developed pain during the test were not able to participate in their sport pain-free in the glenohumeral complex. In addition, few patients who had difficulty while performing this test—from pain, apprehension, or low scores—were able to return to their previous level of performance in their sports.

There are several limitations to this study. First, the patient must be willing and able to accept his or her body weight with the upper extremities, especially during the eccentric deceleration phase of the test. Also, certain patients are contraindicated to perform the test, such as the elderly and patients with wrist or elbow pathologies or posterior instabilities of the shoulder. In addition, no studies have correlated closed kinetic chain tests with other functional activities. More specificity regarding descriptive norms, relating to gender, age, and specific sports, must be compiled. Finally, correlations between test performance and sport-specific skills must also be developed.

Ongoing research is evaluating the validity of our test relative to return-to-sport performance. In a recent paper, R. C. Manske, G. J. Davies, D. Carney, and A. A. Elfessi (unpublished data, 1999) evaluated the correlation of the Closed Kinetic Chain Upper Extremity Stability Test to other tests of the shoulder complex. Similar to the findings of Sekiya et al, they found that no single test is sufficient in itself to determine overall functional performance from subjective responses to objectively evaluating sport-specific performance tasks. The work of Manske et al supports that concept and demonstrates that the function of the shoulder complex should be evaluated with various tests.

**Conclusion**

This study demonstrated that the Closed Kinetic Chain Upper Extremity Stability Test is a reliable clinical evaluation tool. It is an easy test to perform in the clinic, requires a minimal amount of floor space to set up, and costs nothing to maintain. The test is clinically useful because it can be applied to many upper extremity injuries, and it provides objective data on closed kinetic chain testing that can be used to chart a patient's progress through a rehabilitation program.
References


22. Palmitier R, An KN, Scott S, Chao EYS. Kinetic chain exercise in knee rehabilita-
23. Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate liga-
24. Wilk KE, Andrews JR. Current concepts in the treatment of anterior cruciate liga-
25. Wilk KE, Escamilla RF, Fleisig GF, Andrews JR. The biomechanical and elec-
26. Borsa PA, Lephart SM, Kocher MS, Lephart SP. Functional assessment and re-
Physical Therapy Principles and Methods.* 3rd ed. Philadelphia, Pa: Lippincott-
Raven; 1996.
267.
35. Stone JA, Lueken JS, Partin NB, Timm KE, Ryan EJ. Closed kinetic chain reha-
Hall, Inc; 1994.