9:2, June 2000
1059-1516/00 $15.00 + .00

Functional Progression of a Patient Through a Rehabilitation Program

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The functional progression of a patient through a rehabilitation program is critical to return a patient efficiently and safely to activities of daily living, vocational activities, and recreational or competitive sporting activities. Many criteria and methods are used by clinicians to evaluate and progress a patient. Although there is consensus in the literature that there needs to be a systematic process to return the patient to his or her activities, there are limited techniques described to accomplish this. Several articles have described performance testing[1, 2, 16, 17, 20, 24, 28]; however, none of them integrate the functional progression with objective criteria into a systematic process. This article describes the scientific and clinical rationale for using a functional testing algorithm (FTA) to progress a patient through a rehabilitation program.[3, 4, 8, 10] One example of the functional progression of the patient through the rehabilitation program is described. The focus of this article is on closed kinetic chain (CKC) testing within the context of the entire FTA.

FUNCTIONAL TESTING ALGORITHM

The algorithm-based rehabilitation program is a systematic, objective process that uses quantitative and qualitative criteria to progress a patient from one level of performance to the next higher level of activity. The FTA testing strategies are based on the concept of progression and clinical control. The initial testing is in a *protected* situation, in which most extraneous variables are controlled for the patient's safety. As the patient progresses through the FTA, clinical control is gradually eliminated, and the *stages* of the FTA become progressively more difficult and challenging. Progression from one level to the next in the algorithm

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is based on passing a series of tests with specific criteria. Figure 1 illustrates the stages in the FTA.

Criteria for the Functional Testing Algorithm

Specific objective criteria at each functional level have been established. Other considerations, however, such as the patient's willingness to perform an activity as well as subjective responses to an activity, are monitored and recorded. For example, if the patient performs the lower extremity functional test (LEFT) with a time (score) that is within the descriptive normative data but has pain and antalgia, the patient has not satisfactorily completed that portion of the FTA and cannot be progressed to the next higher level. In other words, qualitative as well as quantitative criteria are assessed. The criteria used to progress the patient through the FTA are presently based on limited published research, the authors' descriptive normative data, empirically based clinical guidelines, and clinical experience and judgments (Table 1).

Basic Examination Measurements

The FTA begins with basic examination techniques, such as a visual analogue scale regarding the patient's symptoms, range of motion measurements, manual muscle testing, and kinesthetic and proprioceptive testing. After the patient passes through the basic rehabilitation considerations and it is appropriate

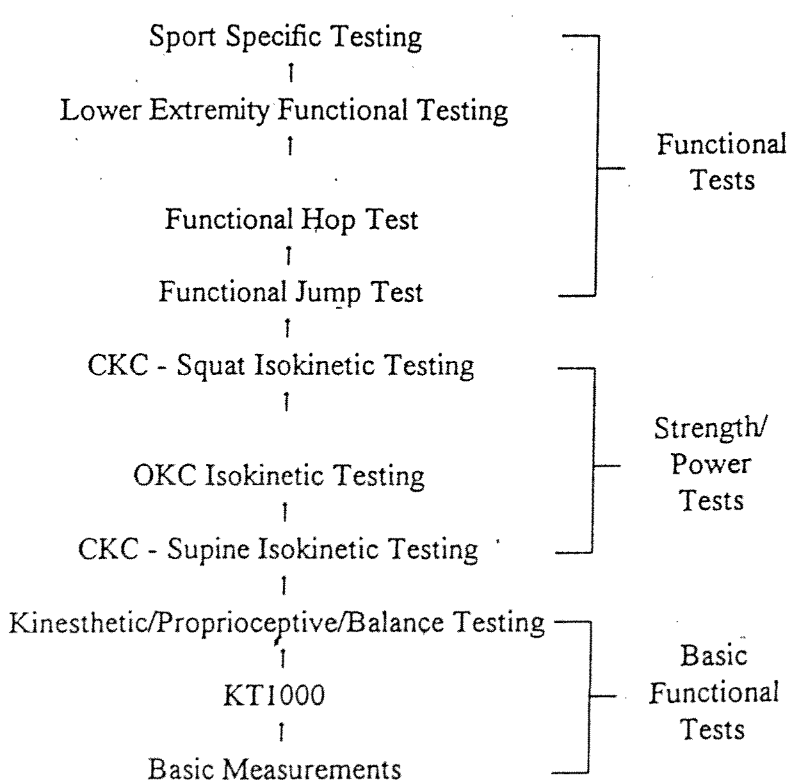

Figure 1 Functional testing algorithm: lower extremity. KT1000 = knee tester 1000.

TABLE 1 Research and Empiric Guidelines for Patient Progression in the Functional Testing Algorithm—Lower Extremity

Tests	Empiric Guidelines
Sport-specific testing	
Lower extremity functional test	Female < 2:00 min; male < 1:30 min
Functional hop test	<15% bilateral comparison and norms
Functional jump test	<20% compared with body height and norms
Closed kinetic chain (standing)	<20% bilateral comparison
Open kinetic chain	<25% bilateral comparison
Closed kinetic chain (supine)	<30% bilateral comparison
Digital balance evaluation	<0.6
KT1000	<3 mm bilateral comparison
Basic measurements	<10% bilateral comparison
Subjective	Pain <3 (analogue pain scale: 0–10)

KT1000 = knee tester 1000.

based on time from injury or soft tissue healing constraints after a surgical procedure, the CKC testing begins. The FTA basic examination measurements are outlined as follows:

- History and subjective examination
- Objective examination
  - Observation and posture
  - Vital signs
  - Gait evaluation
  - Anthropometric measurements
  - Leg length measurements
  - Referral and related joints
  - Palpation
  - Neurological examination
    - Sensation
    - Reflexes
  - Balance, proprioception, kinesthesia
  - Manual muscle testing
  - Active range of motion
  - Passive range of motion
  - Flexibility tests
  - Special tests
  - Medical tests

BALANCE, KINESTHESIA, AND PROPRIOCEPTION TESTING

Objective documentation of balance, kinesthesia, and proprioception is important as part of the basic fundamentals of performance. Static and dynamic balance should be performed. Simple balance tests, such as a stork stand test or a Rhomberg test, can be used for assessment. At present, the authors use a Fastex (Fig. 2) computerized neuromuscular assessment system (Cybex International, Inc., Medway, MA). This system evaluates static as well as dynamic balance. The protocols currently being used are described in Figures 3 and 4.

Because there is no consensus in the literature on the best way to measure balance and because of the various testing protocols and technology used to assess this parameter, the authors use the internally generated testing results as empiric guidelines for the evaluation and progression of the patient through the rehabilitation program. Johnson Stuhr completed a test-retest reliability on the Fastex and found that it was a reliable device for measuring balance within the limitations of the study (unpublished research, 1997). The test results determine whether or not the patient participates in balance exercises as part of the rehabilitation program.

SCIENTIFIC AND CLINICAL RATIONALE FOR USING CLOSED KINETIC CHAIN TESTING

There are many purported advantages of performing CKC testing, as follows:

- Functional, in that CKC exercises simulate the weight-bearing position during the CKC phase of the gait and running cycle
- CKC exercises more effective in improving function
- Increased osseous stability as a result of the congruency of the articular surfaces

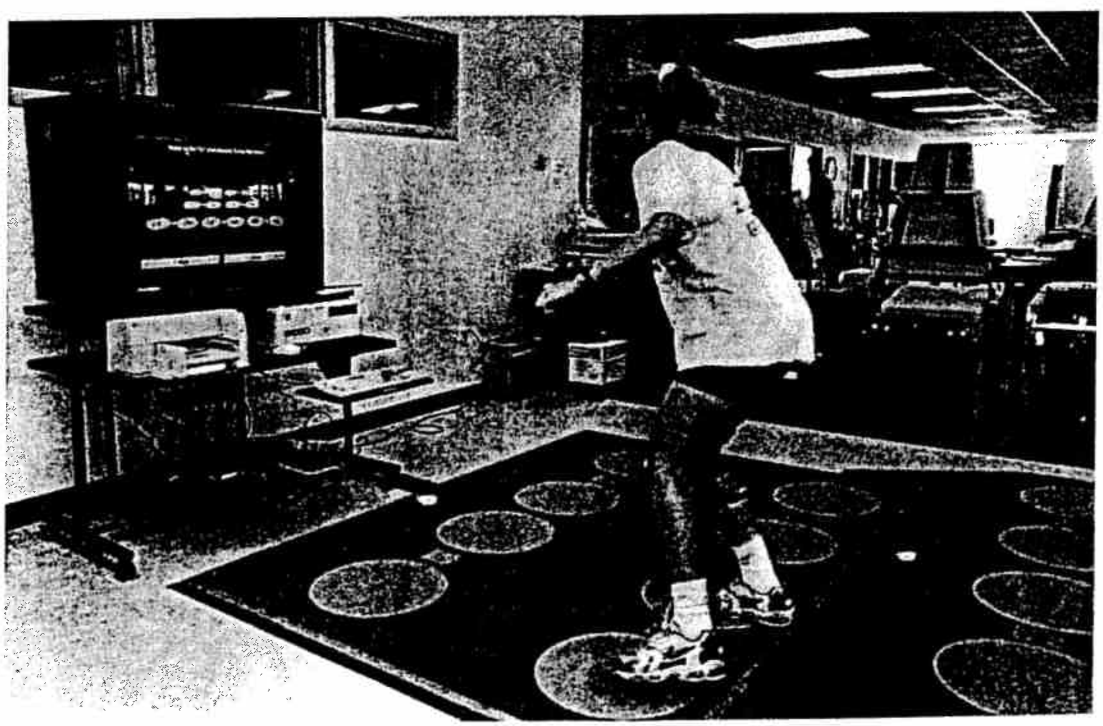

Figure 2 Fastex computerized interactive functional training system.

Gundersen Lutheran SPORTS MEDICINE

STATIC BALANCE TEST
FASTEX

Data:
Name________ DOB________ Gender M/F
GC #________ P.T.________ M.D.________
Injury/Surgery________ DOS/DOI________

Procedure:
1. Patient stands on uninvolved leg facing away from the computer, with head and eyes looking straight forward focusing on an object.
2. Non Weight Bearing knee is flexed to approximately a 90 degree angle and the shin is held parallel to the floor.
3. NWB knee is abducted and not touching opposite leg.
4. Hands are clasped behind the back.
5. Allow one practice test for 20 seconds.
6. Each test is 20 seconds.
7. Repeat the test 3 times with a 20 second rest period in between each test.
8. Record the Total Stability Index for each trial.
9. Repeat #'s 1-8 on involved leg.

DATE	UNINVOLVED L/R	INVOLVED L/R	% DEFICIT
TRIAL 1			
TRIAL 2			
TRIAL 3			
AVERAGE			

DATE	UNINVOLVED L/R	INVOLVED L/R	% DEFICIT
TRIAL 1			
TRIAL 2			
TRIAL 3			
AVERAGE			

DATE	UNINVOLVED L/R	INVOLVED L/R	% DEFICIT
TRIAL 1			
TRIAL 2			
TRIAL 3			
AVERAGE			

Figure 3 Static balance test protocol and data collection sheet. (Courtesy of Gundersen Lutheran Sports Medicine, La Crosse, WI.)

at 6 and 12 weeks after reconstructions of the anterior cruciate ligament using a similar protocol, and there were statistically significant differences in their weight-bearing ability.

FUNCTIONAL TESTING

Particularly when using CKC testing for power assessment, functional testing is the most important part of the testing algorithm. By definition, once functional testing is started, the clinical controls of the testing situation are removed (e.g., range-of-motion blocks, speed control). These tests when performed in a progressive sequence give a true indicator of the functional ability of the recovering patient and the limb.

Jump Test (Double Legged)

The functional testing sequence begins with the jump test, which by operational definition includes a double-legged motion. Because the purpose of the jump test is to measure functional lower extremity power, the patient must perform the test with the following technique: The patient jumps with both hands clasped behind the back. This position prevents additional segmental contributions by the head, trunk, and arms.[13,18] Four progressive gradient warm-ups are performed with a 25%, 50%, 75%, and 100% effort. The patient then performs three maximum volitional efforts (Fig. 6).

Patients may perform well in controlled clinical testing situations, but when the functional testing begins necessitating less clinical control, the patient may become apprehensive and reluctant to perform the test. One of the reasons the warm-ups are performed in a gradient manner is to allow the patient the opportunity to get used to the movement pattern and for the clinician to see if the patient is willing to perform the testing. The quality of the movement pattern being performed is part of the assessment of the performance of the test. Often, patients can perform the concentric jumping portion of the test but are hesitant to have the eccentric deceleration landing on the involved extremity, although it appears that they land on both feet equally. Consequently, they end up favoring the involved leg by compensating and putting more weight on the uninvolved side. This test evaluates controlled reactive movements (jumping phase) and uncontrolled reactive movements (landing phase).

Quantitatively the distance the patient jumps is measured, then normalized to the patient's height. The data are normalized to the patient's height because the absolute numbers are not always useful with data interpretation. Men are expected to jump 100% of their height and women 90% of their height. Table 3 provides the descriptive normative data that the authors have accumulated and used for the past 20 years. The authors use the normative data as a performance standard to evaluate patients as a standard for progression. There is limited research, however, on the use of the jump test in patients with various lower extremity injuries.

Hop Test (Single Leg)

The single-leg hop test is the recommended test to assess lower extremity function by the International Knee Documentation Committee. Similar guide-

- Increased muscular cocontraction of the muscles that surround and support the lower extremity joints
- CKC exercises minimize translatory stresses to the ligaments, particularly the anterior cruciate ligament

Because of the increasing emphasis on CKC exercises being used in rehabilitation programs, the performance of safe CKC testing that is reliable and valid is necessary. The philosophy that if one does not test, one does not know the status of the involved area is appropriate when starting any rehabilitation program. A concern is how to test safely without iatrogenically creating more concerns or problems with the patient. Performing an isotonic 1-repetition maximum or a 10-repetition maximum too soon after an injury or surgery may produce inappropriate stresses to the injured or healing tissue structures.

SUPINE OR SEMISITTING LINEA COMPUTERIZED ISOKINETIC CLOSED KINETIC CHAIN TESTING

The CKC testing begins with the use of a Linea (Loredan Biomedical, West Sacramento, CA) computerized isokinetic CKC testing system in the supine or semisitting position (Fig. 5). This is a safe position for most patients because they are non–weight bearing, the range of motion is limited, the velocity is controlled, and any rotational or varus and valgus forces on the knee are controlled. Testing in the CKC position promotes cocontraction of the muscles surrounding the knee. The CKC position enhances the osseous stability because of the weight-bearing position.

The Linea provides numerous options to perform different types of testing, including isometric, isotonic, and isokinetic testing. It also allows testing the different modes of muscle contractions, including isometrics, concentric, and

Figure 5 Lido Linea computerized isokinetic testing and training system.

eccentric. Different lower extremity patterns can be tested, including coupled and tandem leg press patterns and bilateral reciprocal lower extremity patterns.

The primary testing pattern used is an isokinetic, concentric bilateral reciprocal lower extremity pattern because it replicates functional movement patterns. Isokinetic testing allows for muscle performance assessment through the velocity spectrum to sample the muscle's ability at slow, medium, and fast speeds. Previous research[6,9,15] and more recent research by Wojtys et al[26,27] have illustrated the functional importance of assessing the quadriceps and hamstrings at faster angular velocities. The faster angular velocities test power deficits or muscle reaction times, which is important in functional performance. Because isokinetics is an accommodating resistance, it is the safest form of testing. It prevents the patient from meeting more resistance than the patient can handle. If a painful arc is present, the force at that point in the range of motion is accommodated by the isokinetic resistance. Davies and Heiderscheit[7] have published the results of reliability testing performed on the Linea, which demonstrated intraclass correlation coefficients ranging from 0.85 to 0.94, which demonstrates good-to-excellent test-retest reliability.

LIMITATIONS OF CLOSED KINETIC CHAIN TESTING

A limitation of performing only CKC testing has been illustrated through various studies that have demonstrated selective weakness in the kinetic chain.[12,19] These studies illustrate the concept that if one does not test the individual components of the kinetic chain, a deficit may exist without even knowing it. When the entire lower extremity is tested in a CKC position, individual muscles can compensate for other muscles that have weaknesses.

A study[14] showed that in an unloaded bilateral squat, there was minimal electromyographic hamstring activity and minimal electromyographic gastrocnemius activity. This study brings into question the frequently quoted cocontraction theory that CKC exercises should provide dynamic stability. Another study[23] using a prospective, randomized, controlled clinical trial showed that just using *aggressive* CKC exercises in rehabilitation of patients with anterior cruciate ligament reconstructions did not strengthen the quadriceps muscles. Gait evaluation using motion analysis and electromyography showed that the patients still had quadriceps weaknesses, as evidenced by increased knee flexion angles and prolonged knee flexion during the gait cycle.

OPEN KINETIC CHAIN TESTING

Open kinetic chain (OKC) testing of selected muscles in the lower extremity is performed to isolate individual muscles. In studies that compared OKC and CKC testing,[5,11,21] the authors found that the CKC tests demonstrated symmetry in a bilateral comparison, whereas when the quadriceps muscles were isolated with OKC testing, there were major deficits present (Table 2).

STANDING LINEA COMPUTERIZED ISOKINETIC CLOSED KINETIC CHAIN TESTING

The patient is then tested in the standing (CKC) position with the Linea computerized isokinetic testing system. This position replicates the most functional position and provides objective documentation of the CKC position.

TABLE 2 Closed Kinetic Chain: Computerized Isokinetic Testing (Lido Linea) Compared with Open Kinetic Chain Computerized Isokinetic Testing (Cybex)*

Cybex		Linea	
Test Data	**% Deficit**	**Test Data**	**% Deficit**
PT 60°/sec quads U—142 ft-lb I–101 ft-lb	29	PT 10 in./sec U–462 lb I—420 lb	9
PT BW 60°/sec quads U—95% I—66%	31	PT % BW 10 in./sec U—298 lb I—266 lb	11
PT 10°/sec U—99 ft-lb I—78 ft-lb	21	PT 20 in./sec U—374 lb I—331 lb	11
PT BW 180°/sec U—64% I—48%	25	PT % BW 5 in./sec U—239 lb I—216 lb	11
PT 300°/sec U—80 ft-lb I—64 ft-lb	20	PT 30 in./sec U—302 lb I—253 lb	16
PT BW 300°/sec U—51% I—41%	20	PT% BW 30 in./sec U—193 lb I—171 lb	11

* *n* = 250 patients (different knee injuries).
PT = peak torque; BW = body weight; U = uninvolved; I = involved.

COMPARISON OF CLOSED KINETIC CHAIN VERSUS OPEN KINETIC CHAIN TESTING

Davies,[5] Feiring and Ellenbacker,[11] and Rosenthal et al[21] performed CKC and OKC testing on the same patients and found similar results. For example, often when testing the entire lower extremity as one functional composite unit, the results showed minimal deficits of the involved compared with the uninvolved sides. When the OKC testing was performed, however, there were significant deficits identified in the quadriceps. Consequently, when only CKC testing is performed, the multiple muscles being tested simultaneously compensate and *mask* an existing deficit. Although the emphasis of this article is on the concept of CKC testing, these studies show that there should be an integrated approach to testing the patient so that a weak link in the kinetic chain is not missed. If a test is not performed, the status of the structures is not known.

STANDING (CLOSED KINETIC CHAIN) WEIGHT-BEARING TESTING OF PATIENTS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTIONS USING PEDAR (NOVEL ELECTRONICS, ST. PAUL, MN) FOOT INSERTS

Rudrud et al[22] tested 25 normal subjects and found that there is symmetric weight bearing performing a squatting motion. Twenty-five patients were tested at 6 and 12 weeks after reconstructions of the anterior cruciate ligament using a similar protocol, and there were statistically significant differences in their weight-bearing ability.

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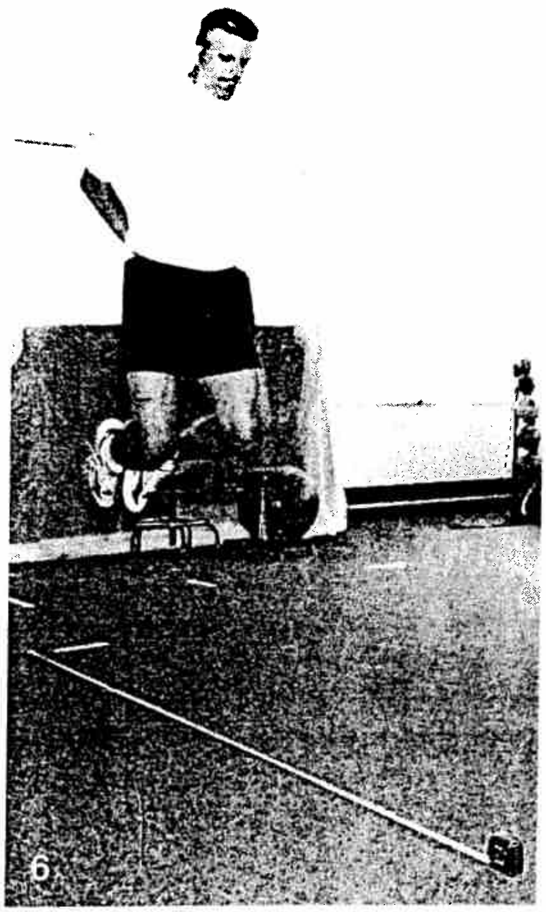

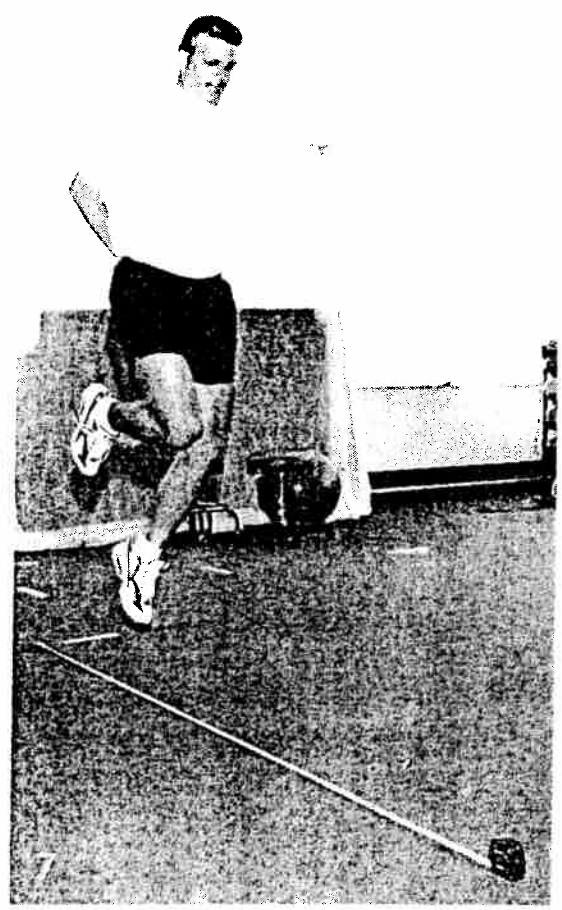

Figure 6 Functional jump test (double legged).

Figure 7 Functional hop test (single leg).

lines as previously described for the jump test are used for conducting the single-leg hop test. In the authors' opinion, this is one of the most discriminating tests for determining a patient's willingness to perform functional activities on the involved lower extremity and for determining their qualitative and

TABLE 3 Descriptive Normative Data for Functional Jump Tests and Functional Hop Tests

	Men	Women
Jump test (R + L)	90%–100%/Ht.	80%–90%/Ht.
Hop test (U)	80%–90%/Ht.	70%–80%/Ht.
Hop test (I)	80%–90%/Ht	70%–80%/Ht

R = right, L = left, U = uninvolved, I = involved, Ht = height.

quantitative performances. Often, patients perform the concentric push-off phase of the hop test easily because they control this component of the test. The real test of function comes, however, when the patient must eccentrically load the extremity in functional activities. Part of the reason the loading is so challenging is that it is an uncontrolled reactive movement pattern. In this motion, the patient must eccentrically decelerate the involved extremity, land on the individual leg, and maintain control of the limb (Fig. 7).

Data analysis and interpretation are calculated in the same way for the single-leg hop test as for the jump test. The data are normalized to the patient's height and should be approximately 90% for men and 80% for women. A bilateral comparison is also performed. The bilateral comparison that is used is to have a 10% to 15% difference in the side-to-side performance jumps (see Table 3).

Lower Extremity Functional Test

To consolidate the numerous lower extremity movement patterns that are used in various activities, several years ago the authors developed the LEFT (Fig. 8). The purpose of the test is to attempt to use a variety of different movement patterns in a particular sequence under timed conditions. The authors evaluate the patients' performance of the test by assessing their ability to perform the test qualitatively (with or without any pain or antalgia).

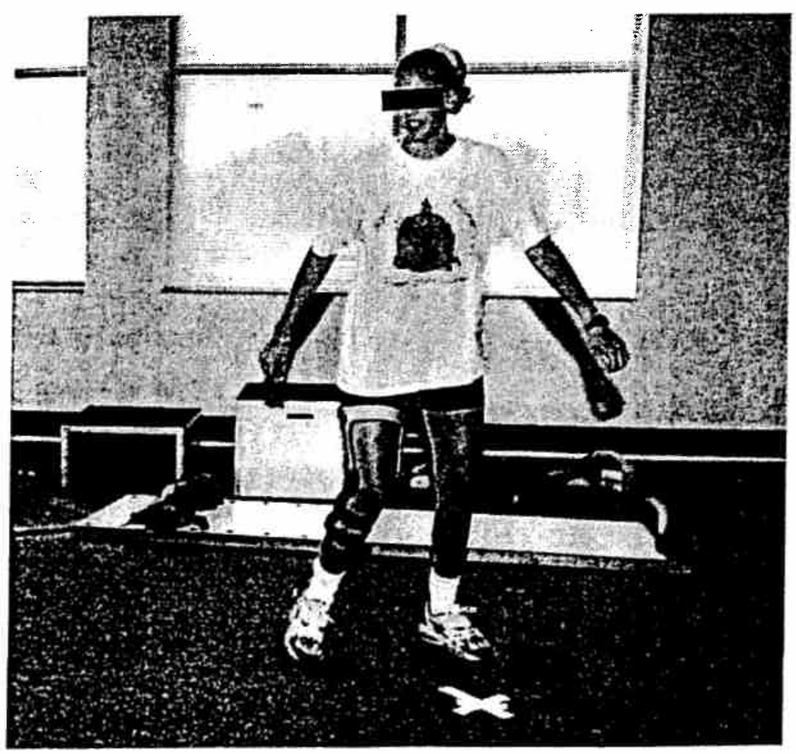

Figure 8 Lower extremity functional test (LEFT).

The results are quantitatively evaluated by measuring the performance time to complete the test by comparing it with descriptive normative data that have been developed at Gundersen Lutheran Sports Medicine over many years (Table 4). The following is the sequence of the LEFT:

1 Sprint (frontward)
2 Sprint (retro-run)
3 Side shuffles (both ways)
4 Cariocas (both ways)
5 Figure eights (both ways)
6 45° angle cuts (outside foot) (both ways)
7 90° angle cuts (outside foot) (both ways)
8 Crossover step (both ways)
9 Sprint (frontward)
10 Sprint (retro-run)

The LEFT is a stressful test for the anaerobic system as well as the involved extremity as a whole. If an individual is deconditioned, the cardiorespiratory system may be the limiting factor in the performance of the test rather than the musculoskeletal system. Usually the only individuals that progress this far up the FTA are either recreational or competitive athletes who aspire to regain cardiorespiratory and musculoskeletal fitness.

Tabor et al[25] have completed a multicenter reliability study of the LEFT. This reliability study was unique because this testing was performed at two different sports medicine clinics using identical protocols. Twenty-seven subjects from the University of Wisconsin-La Crosse and 30 subjects from the University of Central Florida performed identical test protocols. The subjects participated in a submaximal training session, performed the initial test, then 1 week later performed a second repeat test. The mean maximal effort time measurements from trial one and trial two were analyzed using intraclass correlation coefficients to determine the test-retest reliability of each facility. An intraclass correlation coefficient value of 0.95 was established at the University of Wisconsin-La Crosse and 0.97 at the University of Central Florida. Reliability at each facility was excellent. Further studies to establish validity of the LEFT need to be performed.

TABLE 4 Descriptive Normative Data for the Lower Extremity Functional Test (LEFT)

Men			Women		
90 sec	100 sec avg	125 sec	120 sec	135 sec avg	150 sec

Specificity Testing

The final assessment of function is dictated by the patient's preinjury activities. In many cases, a patient is tested only part of the way through the FTA because of the demands of their usual activities. If the individual does not participate in a vocation that is physically stressful to the lower extremities or if the individual does not participate in a recreational or competitive sport, he or she may never enter the formal functional testing activities (e.g., jump test, hop test, or LEFT). These patients would perform the strength and power testing, then skip to the specificity testing. The specificity testing is based on a patient's required physical activities, such as activities of daily living, vocational activities, avocational activities, and sports. It is appropriate to perform specificity testing so that the patient can be advised about his or her readiness to return to preinjury activities.

SUMMARY

This article has described a FTA as one means for facilitating progression of a patient through a rehabilitation program. Individual clinicians need to design their own FTA based on their patient population, available equipment, and space considerations. It is recommended that the FTA be based on objective criteria with integrated clinical judgments so that patients can be progressed safely and rapidly through their rehabilitation program.

Because of imposed limitations on rehabilitation by managed care in today's health care system, using a FTA can increase the efficiency of the clinician. The FTA allows the clinician always to know where the patient is in the rehabilitation program because of the serial testing. Physical therapy treatments and home program can then be based on test results. The patient's progression can be more goal oriented, more efficient, and less time-consuming. The FTA is a systematic, objective, progressive testing sequence that forms the scientific and clinical rationale for testing a patient to determine his or her status, then using the FTA results to guide the appropriate rehabilitation program. The emphasis is on the goals and the patient's accomplishments and successes and has been an effective tool in the authors' hands.

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