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RESEARCH STUDY

Comparison of Performance-Based and Patient-Reported Measures of Function in Anterior-Cruciate-Ligament-Deficient Individuals

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There is a dearth of reliable and valid instrumentation that measures disability following injury and/or surgery of the knee joint that is responsive to clinically significant changes over time. The purpose of this investigation was to determine whether performance-based or patient-reported measures of function are more effective in estimating disability in individuals with an anterior-cruciate-ligament (ACL)-deficient knee. Subjective rating of knee function was used as the criterion measure for disability, and selected performance-based and patient-reported measures were used as estimation variables. Twenty-nine individuals with an ACL-deficient knee participated in this investigation. Step-wise regression analysis revealed that the Cincinnati Knee Scale, Lysholm Knee Scale, and hop index were the most effective estimates of disability. The results demonstrate that patient-reported measures are more related to the patient's level of disability in individuals with an ACL-deficient knee. More research is necessary to substantiate these findings.

Key Words: *functional disability, anterior cruciate ligament deficiency, knee, assessment*

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There is a dearth of reliable and valid instrumentation that measures disability following injury and/or surgery of the knee joint that is responsive to clinically significant changes over time. Current methods of assessing patient disability as a result of knee ligament injuries involve performance-based (3,4,14,17,21,23,29) and patient-reported measures of function (2,7,10, 22,26,31,32). Performance-based measures of function are commonly used in the reporting process of outcomes for knee ligament injuries but may be impractical and unsafe for acute cases or when mechanical loading of the knee joint is contraindicated (3). Examples of performance-based measures designed to assess function in individuals with an anterior-cruciate-ligament (ACL)-deficient knee include agility tests for time (20,21), one-leg hop tests for distance and time (3,4,23), isokinetic tests for muscular power output (21,31), and tests for proprioceptive sensibility (5,8).

Utilization of patient-reported measures of function in the reporting process of ACL tears with and without surgical intervention are becoming more widespread (7,14,16,17). Patient-reported measures are questionnaires that contain items relating to symptoms and functional limitations experienced by the patient during activities of daily living and sports. Items are graded on a hierarchical point scale, with more points allotted for less symptoms and greater function. The final outcome measure for these scoring systems provides a measure of disability for the patient. The purpose of this investigation was to determine whether performance-based or patient-reported measures of function are more effective in estimating disability in individuals with an ACL-deficient knee.

METHODS

Subjects

Twenty-nine physically active individuals with an ACL-deficient knee (15 males, 14 females) participated in this investigation ($\bar{X}$ ± SD, 28.7 ± 1.7 years, range = 18–50 years). Subjects were screened at the initial examination to determine inclusion in the study. The clinical diagnosis of ACL deficiency was made by an orthopaedic surgeon who used the following criteria: *1)* presence of positive Lachman and pivot shift, *2)* excessive anterior laxity using the KT-1000 (MEDmetric Corp., San Diego, CA) and the criteria presented by Daniel et al (9), and *3)* magnetic resonance imaging. At some designated point during the rehabilitation program, all subjects completed a series of tests which included selected patient-reported and performance-based measures of function.

Patients were tested at an average of 41.7 ± 11.7 months postinjury (range = 2–228 months) and spent an average of 2.4 ± .33 months in postinjury rehabilitation. The postinjury rehabilitation protocol for ACL deficiency emphasized hamstring strengthening with functional progression. Prior to participation, all patients reviewed and signed a consent form approved by the Human Subjects Committee. Twenty-four subjects (83%) indicated that they had significantly decreased their level of sports activity as a result of the injury, although Tegner activity ratings indicated that the sample remained physically active postinjury (levels 0–3 activities of daily living, N = 12; levels 4–6 recreational sports, N = 13; levels 7–10 competitive sports, N = 4) (30). Most injuries were sports-related, with 12 (41%) occurring as a result of a downhill skiing accident, five (17%) from football, and five (17%) from basketball. Nine (31%) subjects underwent arthroscopic exploratory surgery; five (17%) had partial medial meniscectomies; and two had grade III medial collateral ligament tears, with one of these tears being repaired.

Limp (5 points)	none	5	Pain (25 points)	none	25
	slight or periodical	3		inconstant and slight during heavy exertion	20
	severe and constant	0		marked during heavy exertion	15
Support (5 points)	none	5		Marked on or after walking more than 2 km	10
	cane or crutch	2		Marked on or after walking less than 2 km	5
	weight-bearing impossible	0		constant	0
Locking (15 points)	no locking or no catching sensations	15	Swelling (10 points)	none	10
	catching sensations but no locking	10		on heavy exertion	6
	occasional locking	6		on normal exertion	2
	frequently	2		constant	0
	locked on exam.	0	Stair-climing (10 points)	no problems	10
Instability (25 points)	no giving way	25		slightly impaired	6
	rarely, during sports or heavy exertion	20		one step at a time	2
				impossible	0
	frequently, during sports or heavy exertion	15	Squatting (5 points)	no problems	5
				slightly impaired	4
	occasionally in daily activities	10		not beyond 90°	2
	often in daily activities	5		impossible	0
	at every step	0			

FIGURE 1. *The Lysholm Knee Scale. (From Tegner Y, Lysholm J: Rating systems in the evaluation of knee ligament injuries. Clin Orthop Rel Res 198:43–49, 1985, reprinted with permission).*

Research Design

We estimated patient disability using a regression equation model. Our dependent variable was disability and was measured utilizing a visual analog scale. The independent (estimation) variables are the collective or sum of both the patient-reported and performance-based measures. The patient-reported measures are the Lysholm Knee Scale and the Cincinnati Knee Scale. The performance-based measures are the quadriceps index, hop index, static balance index, and proprioception index.

Disability Measure

Subjective rating of knee function Each patient was asked to numerically rate their level of knee function on a visual analog scale from 0 to 100, with 100 being their level of knee function prior to injury and 0 being complete loss of function due to their knee injury. The use of a visual analog scale in orthopaedic research has been shown to be a valid and reliable assessment of function in patients with knee injuries (11,12,18). The subjective rating identifies the patient's impression of how their knee functions and is used as the dependent variable for our regression model.

Patient-Reported Measures

The patient-reported knee scoring systems used in this study were the Lysholm and a modified version of the Cincinnati Knee Scales. Both scales were self-administered with standardized instructions provided. The cumulative score ($\bar{X}$ ± SD) for each scale provided a measure of disability and indicates the functional outcome for the involved limb comparing the status of the limb prior to injury or surgery with the current status of the limb. Higher mean scores indicate a lower level of disability.

Lysholm Knee Scale The Lysholm is a popular knee scale used following knee injury and/or surgery. The scale consisted of eight items related to common symptoms and functional limitations experienced by individuals who sustain a knee ligament injury. The items within the scale are associated predominantly with activities of daily living (Figure 1). Validity and reliability has been reported in the literature (7,14,30).

Cincinnati Knee Scale The modified version of the Cincinnati Knee Scale consisted of a three-part questionnaire that measures the patient's

SPORTS ACTIVITY

Last name ______________________ SS# ______________

Please check the boxes that indicate your level of sports activity before and after your injury, your highest level after surgery, and your current level of sports activity.

Before Injury	After Injury	Highest Post-op	Current Level	
				Level 1 (4-7 days/week)
100 ☐	100 ☐	100 ☐	100 ☐	Jumping, hard pivoting cutting
95 ☐	95 ☐	95 ☐	95 ☐	running, twisting, turning
90 ☐	90 ☐	90 ☐	90 ☐	No running, twisting, jumping
				Level 2 (1-3 days/week)
85 ☐	85 ☐	85 ☐	85 ☐	Jumping, hard pivoting cutting
80 ☐	80 ☐	80 ☐	80 ☐	running, twisting, turning
75 ☐	75 ☐	75 ☐	75 ☐	No running, twisting, jumping
				Level 3 (1-3 times/month)
65 ☐	65 ☐	65 ☐	65 ☐	Jumping, hard pivoting cutting
60 ☐	60 ☐	60 ☐	60 ☐	running, twisting, turning
55 ☐	55 ☐	55 ☐	55 ☐	No running, twisting, jumping
				Level 4 (no sports)
40 ☐	40 ☐	40 ☐	40 ☐	Jumping, hard pivoting cutting
20 ☐	20 ☐	20 ☐	20 ☐	running, twisting, turning
0 ☐	0 ☐	0 ☐	0 ☐	No running, twisting, jumping ☐

Note on activity levels
- Jumping, hard pivoting, cutting includes basketball, football, gymnastics, soccer.
- Running, twisting, turning includes tennis, hockey, skiing, wrestling.
- No running, twisting, jumping includes cycling, swimming, golf.

If your level of sports activity now is less than that before your injury is this because of your knee? ☐ Yes ☐ No

Do you currently wear a knee brace when participating in sports? ☐ Yes ☐ No

SPORTS FUNCTION

Please indicate any difficulty you have during

Straight running	Jumping/landing on leg	Hard twists/cuts/pivots
☐ Fully competitive	☐ Fully competitive	☐ Fully competitive
☐ Some limitations	☐ Some limitations	☐ Some limitations
☐ Definite limitations	☐ Definite limitations	☐ Definite limitations
☐ Unable to perform	☐ Unable to perform	☐ Unable to perform
☐	☐	☐ ☐

FIGURE 2. *The Cincinnati Knee Scale. (Adapted from Noyes FR, Barber SD, Mooar LA: A rationale for assessing sports activity levels and limitations in knee disorders. Clin Orthop Rel Res 246:238–249, 1989, with permission). Continued on next page.*

level of activity, as well as symptoms and functional limitations associated with both activities of daily living and sports (Figure 2). Criterion-referenced validity is also well reported for this scale, although test/retest reliability has not yet been reported in the literature (7,14,24,25).

Performance-Based Measures

Proprioception index Proprioception was measured using a proprioception testing device that measured the subject's threshold to detect passive motion (Figure 3) (8,19). The proprioception testing device moved the knee at a slow, constant angular velocity (0.5°/sec). A rotational transducer interfaced with a digital microprocessor counter provided angular displacement values to the nearest tenth of a degree. Test-retest reliability for the proprioception testing device has been established with an intraclass correlation coefficient (ICC) = 0.92 (8,19).

Testing order was randomized and counterbalanced relative to the ACL-deficient and normal limb, starting position, and direction of movement. The subjects were seated in a neutral angle of lumbar flexion (75°), with the popliteal fossa situated 4–6 cm from the edge of the seat to prevent any cutaneous stimulation of the joint. Both feet were placed in pneumatic compression sleeves inflated to 30 mm Hg. The limb being tested was attached to a movable shaft while the contralateral limb was fastened to a stationary shaft. The movable shaft was connected to a motor-driven rotational transducer interfaced with the digital microprocessor counter which measured angular displacement of the movable shaft. Subjects manipulated an on/off switch to start and stop angular rotation. Also, each subject was blindfolded and wore headphones with "white noise" to eliminate any audiovisual cues.

Threshold to detect passive motion for flexion and extension was randomly tested from starting positions of 15° (near end range of extension) and 45° of flexion (midrange of motion) on both the ACL-deficient and normal limb. Subjects were alerted with a tap on the thigh. The subjects responded with a "thumbs-up" sign to signal their readiness prior to engaging the motor. At some random time after the thumbs-up signal (between 1 and 10 seconds), the motor was engaged and moved slowly into flexion or extension. Subjects pressed the on/off switch as soon as they perceived motion. Angular displacement values were recorded from the digital microprocessor counter to the nearest tenth of a degree. The score for each angle and direction was recorded as the quotient between the ACL-deficient and normal limb, and the sum total is referred to as the proprioception index (PI). The composite score for proprioception consisted of the following formula:

$$PI = \frac{\text{TTD15E(ACL-def)} + \text{TTD15F(ACL-def)} + \text{TTD45E(ACL-def)} + \text{TTD45F(ACL-def)}}{\text{TTD15E(normal)} + \text{TTD15F(normal)} + \text{TTD45E(normal)} + \text{TTD45F(normal)}}$$

SYMPTOMS

Last name ______________________ SS# ______________

Directions: Using the key (at right), check the appropriate boxes on the scales below which indicate the highest level you can reach without having symptoms.

Key:

Scale:	Description
10	Normal knee, no limitations
8	Able to do moderate activities with running, turning, or jumping; symptoms with strenuous activities
6	Able to do light activities with no running, turning, or jumping; symptoms with moderate activities
4	Able to do actvities of daily living; symptoms with light activities
2	Moderate symptoms (frequent, limiting) with activities of daily living
0	Severe symptoms (constant) with activities of daily living

Pain

10 8 6 4 2 0 ☐

Swelling (actual fluid in knee; obvious puffiness)

10 8 6 4 2 0 ☐

Partial giving way (no fall to the ground)

10 8 6 4 2 0 ☐

Full giving way (knee collapses and you fall to the ground)

10 8 6 4 2 0 ☐

Following my last visit to the doctor, I am

☐ Making good progress ☐ Slowly progressing

☐ Staying the same ☐ Having worse symptoms ☐ Does not apply

On a scale of 1 to 100, I would rate my knee as a ______.

Would you be willing to undergo this procedure again? ☐ Yes ☐ No

FIGURE 2. *Continued from previous page.*

Static balance index A commercially available instrumented unstable balance testing device (K.A.T. 2000, Breg Inc., San Marcos, CA) was used for measuring balance proficiency. The balance system consisted of a circular platform with varying degrees of stability centered by a small pivot. The platform is instrumented with a two-axis electrolytic tilt sensor (Accustar II, Lucas Sensing Systems, Phoenix, AZ) fixed at the anterior edge of the circular platform. The objective of the balance test is to maintain a level platform relative to the X and Y axis for the duration of the test. The static balance score is the summed coordinate position of all data acquired for the duration of the test.

The testing protocol consisted of having the individual stand barefoot on the platform. The subjects were randomly tested with one foot on the platform in order to compare the ACL-deficient and normal limbs. The bladder pressures were adjusted according to body weight based on the normalization algorithm in order to standardize the level of difficulty for each individual. Each subject was tested at a 0.5 difficulty level. The knees were slightly bent (~20° of flexion), arms were folded across the chest, and the subject's eyes were fixated on a point 3 m from the wall straight ahead. The individuals were not permitted to view their feet. The subject was instructed to maintain a level base of support for the duration of the test. A 1-minute practice session was provided in order to familiarize oneself with the apparatus. Testing was initiated when the subject establishes equilibrium about the origin, as denoted by an audible beep, followed by the examiner starting the 20-second test. Each subject completed three trials, and the average was recorded. The static balance index was recorded as the quotient between the ACL-deficient and normal limb. The lower the score, the better is the proficiency in static balance. We have determined test/retest reliability to be ICC = 0.84.

One-leg hop index The one-leg hop test is a standardized functional performance test widely used by sports medicine practitioners (3,4,8, 14,17,23,29). Function of the knee is emulated in this test by the ability of the subject to propel the body forward and land on the same limb. The test protocol was consistent with the protocol by Barber et al and Noyes et al (3,4,23). With hands placed behind the back, each subject jumped for distance, taking off and landing on the same limb. This method measured the horizontal distance in cm, three trials were performed for each limb, and the best score for each limb was recorded. The criterion measure was recorded as the quotient between the ACL-deficient and normal limb and is referred to as the hop index. The test has demonstrated validity and test/retest reliability (3,4,6,23).

Quadriceps isometric strength index Quadriceps strength was assessed isometrically using a dynamometer (Cybex II dynamometer, Lumex, Inc., Ronkonkoma, NY). The knee was tested at 60° of flexion, eliminating any sagittal shear force placed on the ACL-deficient knee. Subjects performed three maximal isometric contractions against the force pad, and the best of the three trials was recorded as the criterion measure. Strength was measured as peak force generation (N) and compared bilat-

Name ______		SS# ______		
Date of exam ______				
Sports activity (20 points)	______	/5		______
Sports function (30 points)				
Straight running	______			
Jumping/landing on leg	______			
Hard twists/cuts/pivots	______			______
Symptoms (50 points)				
Pain	______		______	
Swelling	______		______	
Partial giving way	______	X1.5	______	
Full giving way	______	X1.5	______	______
Subjective knee rating				/100
Personal rating				/100

FIGURE 2. *Continued from previous page.*

Measure	Index
Subjective rating	72
Cincinnati Knee Scale	63
Lysholm Knee Scale	79
Static balance index	100
Hop index	84
Quadriceps strength	87
Proprioception index	65

TABLE 1. *Index scores for the independent and dependent variable(s).*

erally. The measure was recorded as the quotient between ACL-deficient and normal limb and will be referred to as the quadriceps isometric strength index.

Data Analysis

All measures were reported as index scores based on a percentage scale of 100. This procedure indicates that the measures for the ACL-deficient limb were compared with some standard. For the patient-reported measures, the current status of the ACL-deficient limb was compared with the status of the limb prior to the injury. For example, the index for the Cincinnati Knee Scale is 63. This indicates that the ACL-deficient limb is currently functioning 37% less than prior to the injury. The indices for the performance-based tests were calculated by comparing the scores for the ACL-deficient limb with the healthy limb. Therefore, the index is defined as the quotient of the ACL-deficient limb divided by the healthy limb. Index scores for the dependent and independent variables are listed in Table 1.

Data were initially analyzed using Pearson product moment correlation coefficients to screen for multicolinearity among independent variables (Table 2) (28). If any two independent variables demonstrated a correlation of $r \geq .70$, one of the variables would be eliminated from the model. Step-wise regression analysis using a forward selection procedure was used to identify significant estimates of disability. Our default criteria was set at an F-to-enter = 2.00 and an F-to-remove = 1.5. Alpha was set at 0.05. All data were reduced and analyzed using Statview® 4.02 statistical software for Macintosh (Abascus Concepts, Inc., Berkeley, CA).

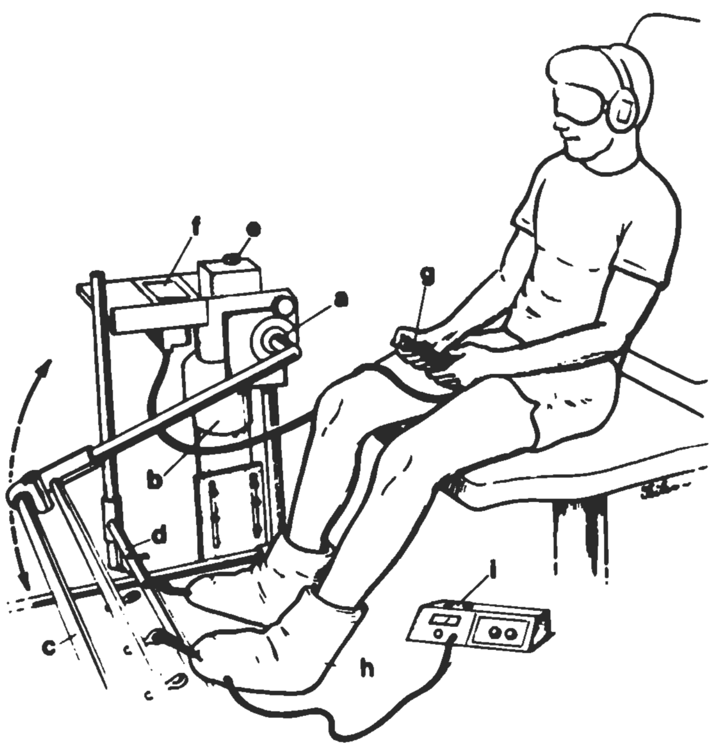

FIGURE 3. *Proprioceptive testing device: rotational transducer (a), motor (b), moving arm (c), stationary arm (d), control panel (e), digital microprocessor (f), hand-held disengage switch (g), pneumatic compression sleeve (h), pneumatic compression device (i). Threshold to detection of passive motion (TTDPM) is assessed by measuring the angular displacement (degrees) until the subject senses knee joint motion. (From Lephart SM, Kocher MS, Fu FH, Borsa PA, Harner CD: Proprioception following anterior cruciate ligament reconstruction. J Sports Rehabil 1:186–196, 1992, reprinted with permission).*

	CKS	LKS	Hop Index	SBI	Str Index	Prop Index
CKS	1.00					
LKS	.66	1.00				
Hop index	−.11	.02	1.00			
SBI	.36	.09	−.02	1.00		
Str index	.30	.24	.06	.24	1.00	
Prop index	−.34	−.19	−.40	−.07	−.29	1.00

CKS = Cincinnati Knee Scale.
LKS = Lysholm Knee Scale.
SBI = Static balance index.
Str Index = Strength index.
Prop Index = Proprioception index.

TABLE 2. *Correlation matrix for all independent variables.*

RESULTS

Pearson correlation analysis demonstrated no relationships ≥.70; therefore, all independent variables were included in the regression analysis model. Step-wise regression analysis revealed that the Cincinnati, Lysholm, and hop index were the most effective estimates of disability (R = .80, R^2 = .64, adjusted R^2 = 0.60, $F_{(3,25)}$ = 14.9; $p < .0001$). Data for steps 1 through 3 of the regression analysis are listed in Table 3.

DISCUSSION

The purpose of this investigation was to identify the most effective estimate(s) of patient disability using selected performance-based and patient-reported measures in individuals with an ACL-deficient knee. Selecting appropriate and practical clinical measures of function is an important decision for the clinician dealing with knee ligament injuries. These clinical measures should accurately reflect the current level of patient disability and be responsive to changes over time (2,7,14,26). Previous studies recommend integrated models for assessing disability with knee ligament injuries (1,15,17,22,24,27,31). The models use clinical measures of pathology (ie., X-rays, magnetic resonance imaging) and impairment (ie., laxity, range of motion), as well as patient-reported and performance-based measures of function to determine the clinical outcome. Recent advances in outcome-based assessment has indicated a need to report results from the patient's perspective (13,14,16). Our rationale for using the subjective rating of knee function as our criterion measure reflects this need.

Step	Variables in Model	p value	R^2
1	Cincinnati	<.0001	.56
2	Cincinnati, Lysholm	<.0001	.58
3	Cincinnati, Lysholm, Hop index	<.0001	.60

TABLE 3. *Regression summary for steps 1, 2, and 3.*

When determining the success or failure of a clinical outcome, it is important for both the patient-reported and performance-based measures to strongly correlate with the level of disability that the patient is experiencing (14,16). A common problem that the clinician experiences is obtaining data on symptoms and functional limitations that may be difficult to discriminate, such as neuromuscular inhibition due to pain, residual swelling, weakness from atrophy and deafferentation, as well as apprehension due to feelings of giving way. In order for any clinical measure to be valid, it must possess sensitivity and specificity to the physical impairment (13). Research has demonstrated low sensitivity of certain performance-based measures due to the inability to discriminate among symptoms and functional limitations that may significantly affect functional performance (23). Conversely, patient-reported measures have been reported to accurately reflect the level of patient disability (7,14).

Our results demonstrate that the patient-reported measures were collectively the better estimates of disability. According to step 1 of our regression analysis, the adjusted R^2 = .56. The only measure included in this step was the Cincinnati Knee Scale. This finding indicates that 56% of the variability can be accounted for by the Cincinnati Knee Scale. In step 2 of our step-wise regression analysis, the adjusted R^2 improved to .58 when the Lysholm Knee Scale is included into the model. This finding indicates that only an additional 2% of the variability could be explained when the Lysholm is combined with the Cincinnati. When the hop index was included into the regression model at step 3, the adjusted R^2 improved slightly again to .60. Therefore, only an additional 2% of the variability can be accounted for by the inclusion of a performance-based measure. These findings indicate that the Cincinnati is the best estimate, and that the addition of the Lysholm and hop index does not significantly improve our ability to estimate disability.

An inherent limitation of performance-based measures is that they require physical exertion on the part of the patient and, in some instances, may transmit too much stress on the injured limb. Therefore, performance-based measures may not always be practical for the patient in the early stages of rehabilitation. Barber et al (3) suggest that patients with an ACL-deficient knee should refrain from performance-based functional testing until after the rehabilitation protocol is completed and the patient is asymptomatic with respect to pain, swelling, and episodes of giving way. Examples of performance-based tests that may be too provocative in the early stages of rehabilitation include the one-leg hop, agility, and isokinetic tests for muscular power and work.

A practical alternative to performance-based measures of function are patient-reported measures. Patient-reported measures can be self-administered at any time throughout the rehabilitation program and are not limited by patient apprehension or other physical limitations as a result of the injury. There are many patient-reported measures currently used in clinical and research practice, and utilization is usually based on personal preference rather than proven effectiveness. Due to a lack of generalizability, no knee scoring system has been presently identified as the "gold standard." For example, the Cincinnati has demonstrated limitations in its generalizability to nonathletic populations, while the Lysholm has been shown to have a ceiling effect when used on physically active individuals (2,7,14,26). In our study, the Cincinnati was the best estimate of disability, followed by the Lysholm. We feel that the Cincinnati was a stronger estimate than the Lysholm due to the high level of physical activity of our patients. In order to overcome these limitations, knee scoring scales should be similar in item content and designed to delineate between symptoms and functional limitations that arise due to activities of daily living or sports activity.

The performance-based measures selected for this study included the one-leg hop for distance, quadriceps isometric strength, proprioceptive sensibility, and balance proficiency. The one-leg hop for distance test is a popular performance-based test used to assess knee function (3,4,8,14,17, 23,29). The one-leg hop for distance test is an indicator of the integrated effect of neuromuscular control, strength, and confidence in the limb. Individuals who view their ACL-deficient limb as functionally unstable will be less confident to jump and land on the involved limb. According to Noyes et al (23), a one-leg hop index of less than 85% is considered abnormal and increases the risk of recurrent episodes of instability. The mean one-leg hop index in our study was 84%, indicating that our sample was just below normal and, therefore, at risk for instability. In our study, subject apprehension and lack of confidence in limb performance may have diminished the actual capabilities of our patients and may explain the low correlations with the dependent variable.

Generally, tests of proprioception and balance are not considered provocative and are prescribed in the early stages of rehabilitation (10,14). However, the results of this study indicate low correlations to patient disability. Proprioceptive sensibility is a measure of sensory feedback relative to the individual's conscious perception of joint motion, while balance proficiency integrates both sensory input and motor output for task performance. Research has demonstrated that sensory feedback is diminished in individuals with an ACL-deficient knee (8), while deficits in balance proficiency have not been reported. We postulate that other confounding factors compensated for the deficits in sensory feedback in this study relative to balance or proprioception. One possible compensatory factor may include visual and vestibular input known to contribute to maintaining balance as well as somatosensory inputs from other joints within the kinetic chain (ie., hip and ankles). Also, subjects may have compensated by shifting their center of gravity during the static balance test by employing different muscle groups unaffected by knee joint sensory deficits to control for balance. This study used only static assessments of balance proficiency, and more dynamic assessments may provide more conclusive results.

The relationship between proprioception and function has been demonstrated by Barrett (5) and Borsa et al (8). Borsa et al (8) reported a strong positive correlation between proprioceptive sensibility and the one-leg hop for distance in ACL-deficient limbs, and Barrett (5) states that limb function relies more on proprioceptive input than strength during activity. However, neither the strength, hop, nor proprioception index significantly estimate disability in our study.

Valid and reliable instrumentation is necessary to measure the level of disability following knee injury from the patient's perspective (14, 16). From the results of our study, the most effective estimates of disability were patient-reported measures as opposed to performance-based. We surmise that the patient-reported measures have a higher level of estimation due to the ability of the measures to quantify the tangible symptoms and functional limitations experienced by the patient during both activities of daily living and sports. More substantial research needs to be conducted in order to identify the best models for estimating disability.

The most effective estimates of disability were patient-reported measures.

FUTURE DIRECTIONS

Future research efforts should focus on conducting prospective studies investigating the efficacy of various models on estimating disability. Significant findings will provide valid models that consistently report functional outcomes with knee injuries.

CONCLUSION

In the reporting process of functional disability for ACL deficiency, we have demonstrated that patient-reported measures provide a more accurate estimate of disability than performance-based measures of function. The results of this study demonstrate that performance-based measures have limitations in accurately addressing the level of patient disability, while patient-reported measures are clearly more related to the patient's level of disability. More research must be conducted in order to substantiate these findings. JOSPT

REFERENCES

1. Anderson AF: Rating scales. In: Fu FH, Harner CD, Vince KG (eds), Knee Surgery (Volume 1), pp 275–296. Baltimore, MD: Williams & Wilkins, 1994
2. Anderson AF, Federspiel CF, Snyder RB: Evaluation of knee ligament rating systems. Am J Knee Surg 6:67–74, 1993
3. Barber SD, Noyes FR, Mangine RE, DeMaio M: Sports medicine rehabilitation series. Rehabilitation after ACL reconstruction: Function testing. Orthopedics 15(8):969–974, 1992
4. Barber SD, Noyes FR, Mangine RE, McCloskey JW, Hartman W: Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. Clin Orthop 255:204–214, 1990
5. Barrett DS: Proprioception and function after anterior cruciate reconstruction. J Bone Joint Surg 73B:833–837, 1991
6. Booher LD, Hench KM, Worrell TW, Stikeleather J: Reliability of three single-leg hop tests. J Sport Rehabil 2:165–170, 1993
7. Borsa PA, Lephart SM, Irrgang JJ, Safran M, Fu FH: A comparison of four knee scoring systems used to assess functional disability in anterior cruciate ligament deficient individuals. Presented at the 2nd World Congress on Sports Trauma/American Orthopaedic Society for Sports Medicine Specialty Day Meeting, Lake Buena Vista, FL, June, 1996
8. Borsa PA, Lephart SM, Irrgang JJ, Safran MR, Fu FH: The effects of joint position and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament-deficient athletes. Am J Sports Med 25(3):336–340, 1997
9. Daniel DM, Stone ML, Sachs R, Malcom L: Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption. Am J Sports Med 13(6):401–407, 1985
10. Draper V, Ladd C: Subjective evaluation of function following moderately accelerated rehabilitation of anterior cruciate ligament reconstructed knees. J Athl Train 28(1):38–41, 1993
11. Flandry F, Hunt JP, Terry GC, Hughston JC: Analysis of subjective knee complaints using visual analog scales. Am J Sports Med 19(2):112–118, 1991
12. Huskisson EC, Jones J, Scott PJ: Application of visual analog scales to the measurement of functional capacity. Rheumatol Rehabil 15:185–187, 1976
13. Jette AM: Approaches to determining and measuring functional limitations and disability. Presented at Design and Management of Outcomes/Effectiveness Research in Physical Therapy, Alexandria, VA, October, 1992
14. Irrgang JJ, Safran MR, Fu FH: The knee: Ligamentous and meniscal injuries. In: Zachazewski JE, Magee DJ, Quillen WS (eds), Athletic Injuries and Rehabilitation, pp 623–692. Philadelphia, PA: W.B. Saunders Company, 1996
15. Kannus P, Jarvinen M: Conservatively treated tears of the anterior cruciate ligament. J Bone Joint Surg 69A(7):1007–1012, 1987
16. Keller RB, Rudicel SA, Liang MH: Outcomes research in orthopaedics. J Bone Joint Surg 75A:1562–1574, 1993
17. Keskula DR, Duncan JB, Davis VL, Finley PW: Functional outcome measures for knee dysfunction assessment. J Athl Train 31(2):105–110, 1996
18. Labib S, Fisher W, Laurin CA: The use of visual analog scales (VAS) in assessment of pain and function in arthroplasty patients. Orthop Trans 10:598, 1986 (abstract)
19. Lephart SM, Kocher MS, Fu FH, Borsa PA, Harner CD: Proprioception following anterior cruciate ligament reconstruction. J Sports Rehabil 1:186–196, 1992
20. Lephart SM, Perrin DH, Fu FH, Minger K: Functional performance tests for the anterior cruciate ligament insufficient athlete. J Athl Train 26:44–51, 1991
21. Lephart SM, Perrin DH, Fu FH, Gieck JH, McCue FC, Irrgang JJ: Relationship between selected physical characteristics and functional capacity in the anterior cruciate ligament deficient athlete. J Orthop Sports Phys Ther 16:174–181, 1992
22. Lysholm J, Gillquist J: Evaluation of knee ligament surgery with special emphasis on use of a scoring scale. Am J Sports Med 10:150–154, 1982
23. Noyes FR, Barber SD, Mangine RE: Abnormal lower limb symmetry determined by functional hop tests after anterior cruciate ligament rupture. Am J Sports Med 19(5):513–518, 1991
24. Noyes FR, Barber SD, Mooar LA: A rationale for assessing sports activity levels and limitations in knee disorders. Clin Orthop 246:238–249, 1989
25. Noyes FR, Mooar LA, Barber SD: The assessment of work-related activities and limitations in knee disorders. Am J Sports Med 19(2):178–188, 1991
26. Scaglione NA, Del Pizzo W, Fox JM, Friedman MJ: Critical analysis of knee ligament rating systems. Am J Sports Med 23(6):660–667, 1995
27. Sommerlauth K, Lysholm J, Gillquist J: The long-term course after treatment of acute anterior cruciate ligament ruptures: A 9- to 16-year follow-up. Am J Sports Med 19(2):156–162, 1991
28. Tabachnick BG, Fidell LS: Using Multivariate Statistics (2nd Ed), New York: Harper & Row Publishers, 1989
29. Tegner Y, Lysholm J, Gillquist J: A performance test to monitor rehabilitation and evaluate anterior cruciate ligament injuries. Am J Sports Med 14:156–159, 1986
30. Tegner Y, Lysholm J: Rating systems in the evaluation of knee ligament injuries. Clin Orthop 198:43–49, 1985
31. Wilk KE, Romaniello WT, Soscia SM, Arrigo CA, Andrews JR: The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. J Orthop Sports Phys Ther 20(2):60–72, 1994
32. Windsor RE, Insall JN, Warren RF, Wickiewicz TL: The Hospital for Special Surgery knee ligament rating form. Am J Knee Surg 1:140–145, 1988