

# Relationship of Knee Extensor Strength and Hopping Test Performance in the Assessment of Lower Extremity Function

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**I**sokinetic strength testing has been used as a primary assessment tool to determine a patient's strength, ability to progress to advanced activities, and ability to return to a maximum level of function (1,24). This type of training and testing is referred to as open kinetic chain exercise, where the muscle acts in isolation to perform a task, accomplished through incorporation of a combination of several joints united successfully where the end segment is not fixed (11,23). This method was previously viewed as the optimal rehabilitation approach for various lower extremity injuries as rehabilitation protocols from the late 1970s and early 1980s emphasized open kinetic chain exercise throughout treatment. Success with open kinetic chain isokinetic strength tests was used as an indication to progress to higher levels of activity (5,6,24).

Recently, literature has suggested that isolated muscle testing does not give enough information on a patient's functional ability, especially in the sports arena (11,18). Additionally, training only in an open kinetic chain cannot sufficiently prepare the patient to return to a dynamic functional level (18,21). Hence, closed kinetic chain testing and rehabilitation were developed. Closed kinetic chain exercise of the lower extremity is a dynamic incorporation of several

Traditionally, open kinetic chain rehabilitation and evaluation have been used as the prime tool to assess a patient's strength and readiness to progress to a higher functional level. More recently, closed kinetic chain activities have been developed and well documented as an alternate means to prepare and evaluate a patient's ability to return to a higher functional level. However, a dearth in recent literature comparing the correlation between an open kinetic chain isokinetic strength test and performance on a functional performance test exists. Therefore, the purpose of this study was to examine the relationship between a knee extensor strength and functional performance test, specifically the one-legged hop for distance. Twenty subjects ( $\bar{X} = 20.7$  years), with no prior history of lower extremity injury, participated in the study consisting of isokinetic evaluation of the quadriceps muscle using a Kinetic Communicator and a one-legged hop for distance. Isokinetic testing was performed at 240°/sec. All tests were performed on the dominant and nondominant limbs. Pearson product moment correlation coefficients for peak torque and distance hopped were .78 for the dominant leg and .65 for the nondominant leg ( $p < .05$ ). These results support the belief that isokinetic strength does not correlate strongly with functional tasks.

**Key Words:** functional testing, muscle strength, knee

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muscles necessary to accomplish a functional task through the use of a combination of several joints successively when the end segment is fixed (11,23).

Literature suggests that rehabilitation in a closed kinetic chain is a safer and more functional way to treat and evaluate lower extremity injuries (4,10,23,29). This suggestion is particularly true in the rehabilitation of patients following anterior cruciate ligament injury as the forces produced with closed kinetic chain activities result in less anterior tibial translation than open kinetic chain activities (10,23,30,31). Several authors have agreed that lower extrem-

ity functional performance tests performed in a closed kinetic chain are an extremely valuable evaluative tool (1,4,8,17,18,20,22,26). Since functional performance tests attempt to reproduce an environment with forces experienced daily, they are considered more functional and should be included in the assessment of a patient's readiness to return to their previous level of function (2-4, 8,9,16,22,25-27). Specifically, the one-legged hop for distance simulates a task frequently needed in various sports and functional activities. In fact, the International Knee Documentation Committee (IDKC) has incorporated a functional one-legged

Subject	Male (N = 7)		Female (N = 13)		Combined (N = 20)	
	X	SD	X	SD	X	SD
Age (years)	21.9	2.9	20.1	0.8	20.7	2.9
Height (cm)	180.7	7.1	166.7	6.0	171.7	9.3
Weight (kg)	75.6	9.7	59.7	5.7	65.1	10.6

TABLE. Subject characteristics.

hop into its knee ligament evaluation form as its only determinant of a patient's functional level, further fortifying the belief that horizontal hopping is an aspect of function (7).

Recently, various functional performance tests have been developed to better assess the patient's ability to return to a higher level of function. Functional performance tests such as shuttle runs (10,19,20), carioca runs (10,19,20), and single-leg hops (1,8) have been studied to determine their usefulness in the evaluation of patients with lower extremity dysfunction. Specifically, these tests were designed to evaluate the patient's dynamic functional level, taking into account strength, endurance, power, and coordination (21).

Isokinetic testing in an open chain has been used to evaluate strength. However, studies have indicated a lack of strong correlation between involved extremity physical characteristics, such as the results of resisted strength tests and functional tests. This weak correlation

### ***There was a significant correlation between distance hopped and knee extensor strength.***

has been shown in patients with ACL-deficient knees (18) as well as with patients following total hip replacement (28).

Based on this review of the literature, it might be surmised that isokinetic strength may not necessarily guarantee patient success with closed

kinetic chain functional performance tests. Therefore, the purpose of this study was to determine the relationship between knee extensor strength of the quadriceps and performance on a one-legged hop for distance test on subjects with no prior history of knee injury.

## **METHODS**

### **Subjects**

Twenty subjects (seven males and 13 females) from a college community, representing a sample of convenience, served as participants for this study. Subject characteristics are outlined in the Table. To be included in the study, subjects had to meet the following criteria: 1) no prior history of unresolved pain, injury, or surgery to either hip, knee, or ankle and 2) currently not taking prescription medication for pain. Approval for the study was obtained from the Ithaca College Human Subjects Review Board. Prior to any testing, informed consent forms were signed by all participants.

### **Procedure**

All subjects participated in two 20-minute sessions separated by at least 72 hours of rest. On the first day, patient medical screening and selected physical characteristics were assessed. Leg dominance was assessed by asking the subject to take a step forward and kick a soccer ball which was rolling toward the center of their legs "as if you were kicking a ball into a soccer goal."

## **Functional Test**

On the day of functional testing, the subject warmed up for 5 minutes on a stationary bike. Following this, the subject received an explanation of the one-legged hop for distance. Subjects were asked to stand on one leg and their heel was positioned on a piece of athletic tape, which was affixed to a standard linoleum block floor. Subjects were instructed to keep both hands behind their back to eliminate their use in generating momentum. The subject was then asked to execute three warm-ups by hopping horizontally and landing on the supporting leg. This was followed by a 30-second rest. Finally, three maximal efforts, with the subject hopping as far as possible, were executed. The subject was required to land on one leg. Failure to land on the supporting leg resulted in a re-hop. This occurred in approximately 5-10% of the subjects. Prior to maximal hopping, charcoal was placed on the heel of the subject's shoe to mark the floor surface upon landing. Measurements were taken from heel to heel with a standard measuring tape. Following each hop, the subject was positioned 2 feet lateral to the previous hop. Large cardboard plates were placed over the recorded mark of the previous hop to eliminate its use as a visual cue. The subject then repeated this protocol two more times for a total of three trials. The same protocol on the opposite leg was then performed. The leg tested first was randomized by a coin flip. No audio cues were given and subjects were asked to wear the same pair of athletic shoes on both testing days.

### **Isokinetic Test**

On the day of isokinetic testing, the subjects had their right and left quadriceps evaluated on a Kinetic-Communicator (Kin-Com, Chattecx Corp., Chattanooga, TN). The subject was stabilized in a seated position with four Velcro® straps. Individual

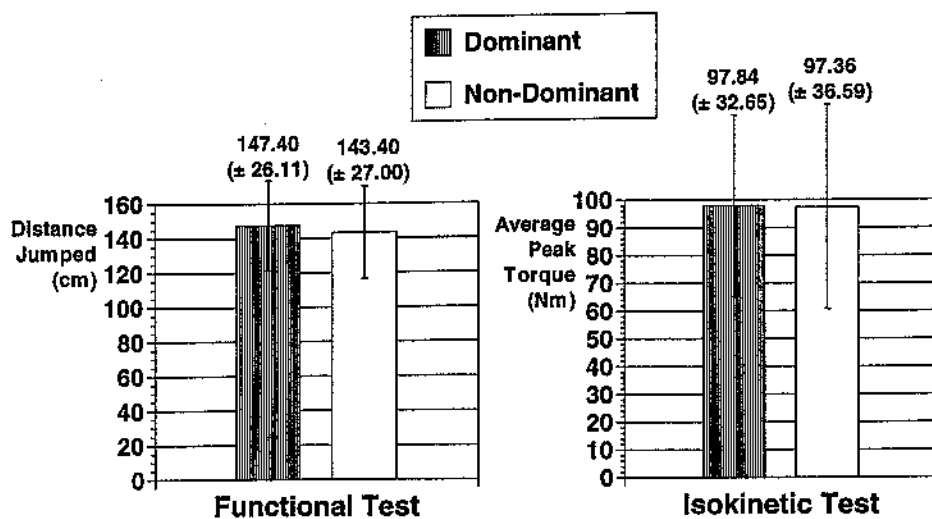


FIGURE. Mean values and standard deviation of dominant and nondominant distance hopped (cm) and dominant and nondominant average peak torque (Nm) of the quadriceps at 240°/sec.

straps stabilized the trunk, waist, thigh, and leg. Stabilization at the leg was as far distal as possible, while still allowing full dorsiflexion at the ankle. The subject executed five sub-maximal concentric warm-ups at 240°/sec followed by one maximal concentric contraction at 240°/sec. Following a 60-second rest, the subject executed three maximal concentric extensions at 240°/sec, which were recorded and used for data collection. The same protocol was repeated on the contralateral leg. The leg tested first was randomized as well as the order of testing days. The test speed of 240°/sec was chosen secondary to its functional nature. Functional activities such as walking, jogging, running, and hopping all require angular velocities at the knee of speed in excess of 200°/sec. However, a limitation of the Kin-Com is that its fastest speed is 300°/sec. Two-hundred-and-forty degrees/sec were determined to be a speed which was most frequently used for testing in the clinic and was closer to angular velocities which may be occurring at the knee during the one-legged hop for distance. Similar speeds of 300°/sec and 270°/sec were used by Barber et al (4) and Lephart et al (18), respectively. Both of these studies examined the relationship between functional testing and physical characteristics, including isokinetic testing.

### Data Analysis

Means and standard deviations were calculated for all variables. Scores on the functional test represented a mean of the three maximal effort hops. Scores on the isokinetic test represented the average peak torque of the three maximal effort concentric extensions. Paired *t* tests were used to compare the dominant with the nondominant limb. Pearson product moment correlation coefficients were used to determine the relationship between the functional test and isokinetic test for both the dominant and nondominant limb. An alpha level of .05 was used to determine the significance level for all analyses.

### RESULTS

Paired *t* tests comparing mean distance hopped in cm revealed no significant difference between the dominant and nondominant limb on the functional performance test nor on the isokinetic test at 240°/sec (Figure). Pearson product moment correlation coefficients revealed a statistically significant correlation ( $p < .05$ ) between the distance hopped and the average peak torque for the dominant ( $r = .782$ ) and the nondominant ( $r = .649$ ) leg.

### DISCUSSION

Results of this study revealed that no significant difference existed between the dominant and nondominant limb when testing with the one-legged hop for distance. This finding agrees with the study by Barber et al (4) who also found no significant difference between dominant and nondominant limbs. When testing isokinetically at 240°/sec, no significant difference was found between the dominant and nondominant limb. This finding, too, is in agreement with a study by Hageman et al (13) who tested dominant and nondominant concentric quadriceps strength on a Kin-Com. However, the tests were performed at velocities of 30 and 180°/sec slower than what were used in this study.

Only a moderate correlation existed for both dominant and nondominant limbs when comparing the functional test with the isokinetic test. These results are consistent with the findings of other authors, such as Tegner et al (26), Tibone et al (27), Lephart et al (18), and Barber et al (4), who found a low correlation between isokinetic testing and other various functional tests. Tegner et al (26) reported that 35% of patients with ACL deficiency had normal quadriceps strength at 30°/sec, but failed to achieve normal values on a performance test consisting of figure-eight running, a one-legged hop, running up and down a special staircase, and running up and down a slope.

Tibone et al (27), while studying a functional analysis of anterior cruciate ligament instability, stated that achieving quadriceps torque of 96% of the uninvolved limb was not sufficient to eliminate the subjective need for surgical reconstruction. In addition, Tibone et al stated that even though adequate quadriceps strength was attained, the patient continued to demonstrate a significant difference between limbs with a cross-cut maneuver. Lephart et al (20) re-

ported results consistent with Tibone et al (27) when recording isokinetic peak torque deficits in patients with ACL insufficiency.

Barber et al (4), while testing patients with healthy and ACL-deficient knees, stated that "no correlation" existed between results at 60°/sec and 300°/sec and four functional tests, including a one-legged vertical hop, a one-legged timed hop, and two shuttle run tests. However, Barber et al did report a statistically significant relationship with the 60°/sec quadriceps percent deficit scores and normal symmetry scores in a one-legged hop for distance in patients with ACL deficiency.

Isokinetic strength testing alone may be an insufficient criterion for returning patients to functional activities. Several authors have stated that dynamic functional capacity cannot be ascertained from isokinetic strength performance (18,21), and the results of this study support this belief. However, one single functional performance test may also be insufficient in the dynamic assessment of a patient's functional level. Rather, several functional performance tests may need to be used to attain a functional profile and attain an accurate assessment of a patient's functional level and readiness to return to activity. This suggestion is consistent with the beliefs of Gray (11) and Harter et al (14), who state there is no one single adequate measure of function.

The belief that functional performance tests, when compared with isokinetic measurements, mimic a more functional environment is well supported (17-21,23). However, a limitation which exists with this study is the lack of tested validity. Unfortunately, the validity of the one-legged hop for distance and most other functional performance tests which are believed to better mimic functional activities is unknown (4) and, in some cases, reliability has not been tested. However, the one-legged hop for distance has been found to be

reliable with healthy subjects in studies by Hu et al (15), who found ICC values ranging from .79 to .96. In our lab (12), 27 subjects with no prior history of lower extremity injury were used to evaluate the reliability of a one-legged hop for distance. The protocol used was the exact protocol used in this current study. Intraclass correlation coefficient values ranged from .92 to .96, indicating a high degree of reliability.

It is important to continue this type of research on various other reliable functional performance tests to determine how they correlate with isokinetic strength tests. Finally, further research in the area is needed to investigate if the same correlation exists with various patient populations.

## CONCLUSION

The results of this study support the belief of other researchers that isokinetic strength does not correlate strongly with functional tasks. Therefore, in the assessment of healthy subjects, isokinetic strength alone may not be an appropriate determinant of a subject's functional level and ability to return to functional activities. This information helps demonstrate the need to develop more functional performance tests similar to the one-legged hop for distance, which will help to better assess a patient's dynamic functional level and readiness to return to activity.

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