

Is there any correlation between functional and clinical tests in anterior cruciate ligament reconstructed knees after three years?

Ozge Cinar Medeni,¹ Gul Baltaci,² Hamza Ozer³

¹ Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation ² Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation ³ Gazi University, School of Medicine, Department of Orthopedics and Traumatology

OBJECTIVE: Hop and jump tests are frequently used in clinical situations in patients with anterior cruciate ligament injury and reconstruction. We are not aware of any study that analyses correlation of functional tests with clinical tests after three years of reconstruction. The purpose of this study was to analyze the relationship between functional and clinical tests.

METHOD: Twelve male patients with unilateral anterior cruciate ligament reconstruction were assessed. They performed a one-legged hop test and one-legged jump and reach test, to evaluate knee function. Clinical assessments were: (a) instrumental knee laxity measurement, (b) Q angle, (c) knee flexor and (d) extensor muscle strength. To determine the relationship between functional and clinical tests, a correlation analysis was performed by means of the Spearman correlation coefficient. A p value ≤ 0.05 was considered significant.

RESULTS: In anterior cruciate ligament reconstructed vs. healthy knees, hop and jump performance correlated well with muscle strength. Knee laxity did not affect hop and jump performance.

CONCLUSIONS: The correlation of functional and strength tests in each group showed functional performance was restored and was independent of anterior knee laxity three years after reconstruction when compared with the contralateral healthy knee. The single-legged hop test correlated better with knee muscle strength and could give information about muscle strength three years after reconstruction. Q angle and extensor strength must be considered together when evaluating hop performance.

KEYWORDS: Anterior Cruciate Ligament; Knee Reconstruction; Test; Outcome.

Ozge Cinar Medeni OC, Baltaci G, Ozer H. Is there any correlation between functional and clinical tests in anterior cruciate ligament reconstructed knees after three years? MEDICALEXPRESS. 2014;1(1):22-26.

Received for publication on December 17 2013; First review completed on December 29 2013; Accepted for publication on January 7 2014

E-mail: ybaltaci@hacettepe.edu.tr

INTRODUCTION

Outcome measurement in sports physiotherapy is directed at identifying an athlete's ability to tolerate the physical demands inherent to sport-specific activity and prevent re-injury on return-to-competition. The functional performance test currently utilized following anterior cruciate ligament injury simulates the forces encountered during sport-specific activity under controlled clinical conditions. The use of the functional performance test is increasing because traditional clinical outcome measures, such as knee joint laxity and isokinetic quadriceps muscle strength, demonstrate weak to moderate and often insignificant relationships with functional tasks. Many functional performance tests, such as hop, leap, jump, sprint, and agility functional performance tests, may be administered to an athlete following knee ligament injury. However, when selecting

a functional performance test for the assessment of knee function, the clinician must acknowledge issues relating to reliability, validity, and data analysis. The need to determine when in the rehabilitation process a functional performance test should be administered if the data generated are to be meaningful and useful.¹⁻⁴

To demonstrate functional performance, hop and jump tests are frequently used in clinical situations in patients with anterior cruciate ligament injury and reconstruction. Jump tests⁵ and hop tests are reliable, valid and performance based outcome measurements.⁶ They have been able to discriminate the hop performance and deficit between injured and uninjured knees as well as knees of anterior cruciate ligament injured⁷ or reconstructed patients.³

A correlation of functional tests with clinical tests in anterior cruciate ligament injured patients and patients after reconstruction has been reported.^{8,9} We are not aware of any study that analyzes correlation of functional tests with clinical tests three years after reconstruction. Therefore, the purpose of this study was to analyze the relationship of functional

tests, including the single-legged hop test and evaluation of jump height with clinical tests including isokinetic muscle strength, anterior translation of tibia, and quadriceps (Q) angle three years (average) after reconstruction.

MATERIALS AND METHODS

Twelve male volunteer patients (average age: 33.2 ± 7.7 yrs.) who had one ACL reconstructed knee (postoperative: 38.9 ± 14.6 months) were assessed in this study. The anterior cruciate ligament reconstructed knees were defined as the study group; the contralateral non-operated knees were defined as the control group. All reconstructions were performed with semitendinosus grafts by the same surgeon. The investigation was approved by the university ethical committee. All of the patients signed informed consent forms before participation.

Inclusion criteria for study knee were (i) to have reconstructed the anterior cruciate ligament by semitendinosus graft, (ii) not to have any complications related with surgery and (iii) not to have any other knee or lower extremity injury. Inclusion criteria for control knee were not to have ruptured knee ligaments, or any other knee or lower extremity injury. Patients who had lower extremity injury, detached anterior cruciate ligament graft, or a revision operation were excluded from the study group, and patients who had any other knee or lower extremity injury were excluded from the control group. Overall, 12 knees were included in the study group and 12 knees in the control group from the same patients.

Assessments

Age, body weight, body height and body mass index were recorded. The patients performed a one-legged hop test and one-legged jump and reach test as evaluations of knee function. Clinical assessments were (i) instrumental knee laxity measurement, (ii) Q angle, (iii) knee flexor, and (iv) extensor muscle strength.

Functional tests

Single-legged hop test. Participants stood on one leg and were instructed to perform one hop along a straight line, landing on the same foot. They were encouraged to hop as far as possible. Their arms were free to ensure balance. Hop distance was measured from toe to toe. After one training hop, the test was performed 3 times. Unsuccessful hops, touching down on the contralateral lower extremity or either upper extremity, loss of balance or an additional hop on landing were discarded. The average value of 3 valid hops was recorded.¹⁰

Jumping height was tested with a jump and reach test.⁵ Participants stood on one leg and were encouraged to jump as high as possible, landing on the same leg. Arms were free to ensure balance. The test value was calculated by subtracting standing reach height from jumping reach height. After one training jump, the test was performed 3 times and the average of the three values was recorded.

Instrumental knee laxity testing

Instrumented anterior translation of knee was tested with the Kneelax 3 (MRS Systems, USA) arthrometer by the application of 89 N.¹¹ Patients laid supine with relaxed knee muscles, and the arthrometer was fixed to the limb with the knee flexed 20 to 30 degrees. Measurement was done in

the Lachman test position, and the laxity value was recorded. One tester (OC) performed all the measurements.

Q angle

This was measured with the patient in supine position, knee in extension, foot in neutral position and quadriceps relaxed. A line was drawn from the anterior superior iliac spine to the center of the patella; a second line was drawn from center of the Patella to the Tuberositas Tibiae. The angle between these two lines was measured with a universal goniometer. All measurements were collected by a single tester.¹²

Muscle strength tests

The patients underwent a standardized isokinetic evaluation of knee flexor and extensor muscles with the Isomed 2000 (Ferstl, Germany) isokinetic system.¹³ Subjects were placed in an upright position with 90° of hip flexion on the dynamometer chair and stabilized with straps across the chest, pelvis, thigh, and ankle. The resistance pad was placed as distally as possible on the tibia while still allowing full dorsiflexion at the ankle. The center of motion of the lever arm was aligned as accurately as possible with the slightly changing flexion-extension axis of the knee joint. The subjects gripped the edge of the dynamometer chair to stabilize their body during the test. Concentric flexor and extensor strength and power were tested at 60°/s velocity in the range of 0-90° by performing 5 repetitions. During the test, the therapist encouraged the patients to maximize their effort. Maximal concentric and eccentric quadriceps and hamstring muscle strength was obtained by measuring maximal force moments (torque) during isokinetic knee extension and flexion movements. Output data from the isokinetic evaluation were: peak torque of flexor (FPT) and extensor muscles (EPT), (H/Q) strength ratio, and the angle at which peak torque was recorded for both flexor and extensor muscles. The sum of peak torque (Nm) of quadriceps and hamstrings (ST) provided a muscle strength index. This was used in addition to the hamstring/quadriceps ratio, previously used.^{2,9}

Statistical analysis

For statistical analysis the Statistical Package for Social Science (SPSS) was used. The homogeneity of the two groups was tested with a Man-Whitney U test. Correlation analyses were performed through the Spearman correlation coefficient to determine the relationship between functional and clinical tests,. A p value ≤ 0.05 was considered significant.

RESULTS

Descriptive statistics of study and control groups are given in Table 1.

Table 1 - Descriptive Statistics of Subjects

	Mean ± SD
Age (years)	33.3 ± 7.39
Height (cm)	176.33 ± 9.33
Weight (kg)	77.5 ± 9.69
BMI (kg/cm ²)	24.93 ± 1.95
Postoperative months	38.88 ± 14.57

Table 2 - Comparison of two groups

	Study group	Control group
	N = 12	N = 12
	Mean ± SD	Mean ± SD
Knee laxity*	7.75 ± 1.91	3.75 ± 2.22
SLH	152.85 ± 31.7	165.97 ± 31.96
JH	23.34 ± 4.61	24.37 ± 4.86
EPT	195.58 ± 61.21	208.75 ± 58.3
FPT	121.75 ± 50.96	127.5 ± 45.85
H/Q	0.61 ± 0.09	0.61 ± 0.16

* Significant difference was found ($p < 0.05$).
Abbreviations. SD: Standard deviation. SLH: Single leg hop, JH: Jump height, EPT: Extensor peak torque, FPT: Flexor peak torque, H/Q: Hamstring/quadriceps ratio, ST: Sum of extensor and flexor peak torques.

Comparing the study and control knee groups the only significant difference occurred in anterior knee laxity values ($p < .05$) as shown in Table 2.

No strength, power or functional differences were recorded between reconstructed vs. healthy knees. There was no significant correlation of laxity vs. functional tests in either group.

In the study group, single-legged hop distance was correlated with the peak torque of extensor, flexor and the summed hamstring/quadriceps, respectively ($r=.72$, $r=.739$, $r=.718$; $p < .01$). However jump height was not correlated with muscle strength. Hamstring/quadriceps ratio also correlated with FPT ($r=.6$, $p=.03$). The correlation results of functional tests versus strength outputs are shown in Table 3.

In the control group, single-legged hop distance was also correlated with the peak torque of extensor, flexor and the summed hamstring/quadriceps, respectively ($r=.599$, $p=.04$; $r=.705$, $p=.01$; $r=.63$, $p=.02$). The jump height was correlated with peak flexor torque ($r=.676$, $p=.016$) (Table 4).

The Q angle values for the two groups were within normal ranges and they correlated with single-legged hop distance in anterior cruciate ligament reconstructed knees ($r=.582$, $p=.04$). However, in control knees, no significance was observed ($r=.56$, $p=.058$).

DISCUSSION

This study hypothesized that a significant difference would be found on passive knee joint laxity between reconstructed patients with anterior cruciate ligament and healthy knees after 39 months. However, no correlations were found between functional tests and knee laxity in reconstructed or in healthy knees. In a previous study,

Table 3 - Correlation analysis of study group

	SLH	JH	EPT	FPT	H/Q	ST
SLH	-	0.243	.720**	.739**	0.19	.718**
JH	0.243	-	0.365	0.438	0.543	0.434
EPT	.720**	0.365	-	.956**	0.42	.977**
FPT	.739**	0.438	.956**	-	.601*	.986**
H/Q	0.19	0.543	0.42	.601*	-	0.552
ST	.718**	0.434	.977**	.986**	0.552	-

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.
Abbreviations. SLH: Single leg hop, JH: Jump height, EPT: Extensor peak torque, FPT: Flexor peak torque, H/Q: Hamstring/quadriceps ratio, ST: Sum of extensor and flexor peak torques.

Table 4 - Correlation analysis of control group

	SLH	JH	EPT	FPT	H/Q	ST
SLH	1	0.245	.599*	.705*	0	.630*
JH	0.245	1	0.434	.676*	0.503	0.552
EPT	.599*	0.434	1	.809**	-0.049	.972**
FPT	.705*	.676*	.809**	1	0.445	.907**
H/Q	0	0.503	-0.049	0.445	1	0.147
ST	.630*	0.552	.972**	.907**	0.147	1

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.
Abbreviations. SLH: Single leg hop, JH: Jump height, EPT: Extensor peak torque, FPT: Flexor peak torque, H/Q: Hamstring/quadriceps ratio, ST: Sum of extensor and flexor peak torque.

investigators found that there was no relationship between anterior laxity and functional outcome tests in patients who had their anterior cruciate ligament reconstructed by bone-patellar tendon-bone autograft.¹⁴ In another report, patients' knees reconstructed with semitendinosus graft were evaluated. No correlation was found between laxity and hop test results.¹⁵ Two other studies arrived at similar conclusions.^{7,16} Therefore, our results are consistent with the literature in that passive knee joint laxity did not influence hop performance in patients 3 years after cruciate ligament reconstruction. As regards the correlation of jump and reach test with instrumental anterior translation of knee, we are not aware of any study focusing on this. We found no correlation in this study. As far as can be determined from our results, anterior knee joint laxity did not influence functional performance; it is possible that measuring anterior translation of the knee joint during performance could yield significant results.

This study demonstrates a high correlation of single-legged hop distance with peak extensor and flexor torque in anterior cruciate ligament reconstructed knees. Varying results can be found in the literature. According to one study, quadriceps strength indices were positively correlated with hop tests 1 week before and 6 months after reconstruction; hamstring strength indices were correlated with hop tests 6 months after reconstruction.¹⁷ A different study supported the relationship between single-legged hop distance and quadriceps strength, but not with flexor strength.¹⁴ Two studies supported a correlation between single-legged hop distance and hamstring strength.^{18,19} In our study, the correlation of with both flexor and extensor peak torque shows that as a functional test the single-legged hop distance could provide information about concentric flexor and extensor knee strength and might be useful in clinical situations 3 years after reconstruction where isokinetic assessment could not be done. According to one report, 54 weeks after reconstruction the vertical jump test correlated with quadriceps strength tested with an isokinetic system at 15°/sec.¹⁰ In our study correlation of jump height with quadriceps strength was not significant 3 years after reconstruction. However the control group's jump height correlated positively only with flexor peak torque (i.e., jump height increases with flexor strength in healthy knees). This was the only intergroup difference in terms of the correlational results of functional tests with knee muscle strength.

According to Roberts,⁹ the frequently used hamstring/quadriceps ratio has its obvious limitations, and, as a functional index, the sum of the hamstring and quadriceps

torque might be more logical. The sum of the hamstring and quadriceps torques was used first by Ageberg et al.² In this study, the parameter correlated moderately with single-legged hop distance. This suggests that the sum of knee flexor and extensor torques might be used as a functional strength index. However, we believe that assessing flexor and extensor torques separately is also important because of the relationship between jump height and knee flexor strength in the control group.

The Q angle is an index of the vector for the combined pull of the extensor mechanisms and the patellar tendon. We observed a moderate correlation of the Q angle with hop distance in both groups. However, a non-significant correlation in the control group may be due to the low number of subjects. It is worth noting that the "p" value was borderline, at 0.058. This might still be important. This correlation suggests that the quadriceps force vector is a determinant of hop distance, which is a performance-based activity both in reconstructed and in healthy knees. We believe that the Q angle must be considered in conjunction with knee extensor strength, because it is a vector for the combined pull of extensor mechanisms. Patients' Q angle degrees for both knees were within normal ranges; nonetheless, a decreased Q angle and a decreased extensor torque were seen with decreased hop performance and this may have an important bearing on hop performance. We found no studies analyzing the relationship between the Q angle, hop performance and jump height. The Q angle was not correlated with jump height in either of our groups and according to our results knee extensor strength was not correlated with jump height.

The test batteries discriminated better between the injured and uninjured legs than the single tests, in agreement with previous studies.^{3,20} Thus, these two tests may be more sensitive in detecting differences between the injured and uninjured legs than the single tests. Moreover, an advantage of using test batteries instead of single tests is that different qualities of the performance are evaluated.²⁰

A limitation of this study is the lack of a true control group, which would have provided a better basis for the condition's natural history (time) and any potential power effect. Another potential limitation was the number of the patients and underlying pathology of the subject group recruited. The subjects were young (approximate average age 33 years), a point which needs to be considered when generalizing our results to clinical practice.

We did not find correlations between functional performance and knee laxity, indicating that better functional performance is associated with isokinetic test difficulty. However, moderate correlations also show that functional performance and flexor and extensor peak torque difficulty reflect different aspects of function in patients with anterior cruciate ligament injury. This indicates that these measurements cannot be used interchangeably. This is consistent with previous findings in subjects with ligament reconstruction. However, these two tests could provide information about muscular strength. We hypothesized normal muscle function 2–3 years after surgery and our findings are consistent with this even though reconstructed knees have greater laxity values.

■ CONCLUSION

Knee laxity did not influence functional performance 3 years after reconstruction. The similar correlation results of

functional and strength tests in each group showed that functional performance was restored, and was independent of anterior knee laxity 3 years after reconstruction when compared with the contralateral healthy knee. The single-legged hop test correlated better with knee muscle strength, and could give information about muscle strength after 3 years of reconstruction. The Q angle and extensor strength should also be considered together when evaluating hop performance.

■ AUTHOR CONTRIBUTIONS

All authors contributed equally to planning, executing and writing.

■ RESUMO

OBJETIVO: Testes "Hop and Jump" são frequentemente utilizados em situações clínicas em pacientes com lesão do ligamento cruzado anterior e de reconstrução do mesmo. Não temos conhecimento de nenhum estudo que analisa a correlação de testes funcionais com testes clínicos após três anos de reconstrução. O objetivo deste estudo foi analisar essa relação.

MÉTODO: Doze pacientes do sexo masculino com reconstrução unilateral do ligamento cruzado anterior foram avaliados. Eles realizaram testes "hop and jump" e "jump and reach" com uma perna, para avaliar a função do joelho. As avaliações clínicas foram: (a) medida instrumental da frouxidão do joelho, (b) ângulo Q, (c) força flexora do joelho; (d) força dos músculos extensores. Para determinar a relação entre os testes clínicos e funcionais, uma análise de correlação foi realizada por meio do coeficiente de correlação de Spearman. Um valor de $p \leq 0,05$ foi considerado significativo.

RESULTADOS: Comparando ligamentos cruzados anteriores reconstruídos vs joelhos saudáveis, o desempenho "hop and jump" correlacionou bem com a força muscular. A frouxidão do joelho não afetou o desempenho do "hop and jump".

CONCLUSÕES: Os resultados dos testes funcionais e de força nos joelhos reconstruídos e normais foram semelhantes e independente da frouxidão anterior do joelho, três anos após a reconstrução. O teste correlacionou melhor com a força muscular do joelho e poderia dar informações sobre a força muscular, três anos após a reconstrução. Ângulo Q e força extensora devem ser consideradas em conjunto para avaliar o desempenho "hop and jump".

■ REFERENCES

- Ageberg E. Consequences of a ligament injury on neuromuscular function and relevance to rehabilitation - using the anterior cruciate ligament-injured knee as model. *Journal of electromyography and kinesiology: official journal of the International Society of Electrophysiological Kinesiology* [Review]. 2002;12(3):205-12.
- Ageberg E, Roberts D, Holmstrom E, Friden T. Balance in single-limb stance in patients with anterior cruciate ligament injury: relation to knee laxity, proprioception, muscle strength, and subjective function. *The American journal of sports medicine*. [Randomized Controlled Trial Research Support, Non-U.S. Gov't]. 2005;33(10):1527-35.
- Augustsson J, Thomee R, Karlsson J. Ability of a new hop test to determine functional deficits after anterior cruciate ligament reconstruction. *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA* [Research Support, Non-U.S. Gov't]. 2004;12(5):350-6.
- Clark NC. Functional performance testing following knee ligament injury. *Phys Ther Sport*. 2001;2(2):91-105.
- Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. *Journal of strength and conditioning research / National Strength & Conditioning Association*. [Clinical Trial Comparative Study Randomized Controlled Trial Validation Studies]. 2004;18(3):551-5.
- Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Physical therapy*. [Research Support, Non-U.S. Gov't]. 2007;87(3):337-49.
- Eastlack ME, Axe MJ, Snyder-Mackler L. Laxity, instability, and functional outcome after ACL injury: copers versus noncopers. *Medicine and science in sports and exercise*. [Research Support, Non-U.S. Gov't Research Support, U.S. Gov't, P.H.S.]. 1999;31(2):210-5.
- Lee H-M, Cheng C-K, Liao J-J. Correlation between proprioception, muscle strength, knee laxity, and dynamic standing balance in patients

- with chronic anterior cruciate ligament deficiency. *The Knee*. 2009;16(5):387-91.
9. Roberts D, Ageberg E, Andersson G, Fridén T. Clinical measurements of proprioception, muscle strength and laxity in relation to function in the ACL-injured knee. *Knee Surg, Sports traumatol, Arthroscopy*. 2007;2007/01/01;15(1):9-16.
 10. Petschnig R, Baron R, Albrecht M. The relationship between isokinetic quadriceps strength test and hop tests for distance and one-legged vertical jump test following anterior cruciate ligament reconstruction. *The Journal of orthopaedic and sports physical therapy*. 1998;28(1):23-31.
 11. Siebel T, Geiger F, Pöhlmann D, Heisel J. Validity of instrumented measurement of anterior laxity of the knee at different force levels. *The Knee*. 1995;2(3):157-61.
 12. Smith TO, Davies L, O'Driscoll M-L, Donell ST. An evaluation of the clinical tests and outcome measures used to assess patellar instability. *The Knee*. 2008;15(4):255-62.
 13. Yosmaoglu HB, Baltaci G, Kaya D, Ozer H, Atay A. Comparison of functional outcomes of two anterior cruciate ligament reconstruction methods with hamstring tendon graft. *Acta orthopaedica et traumatologica turcica*. [Evaluation Studies]. 2011;45(4):240-7.
 14. Sernert N, Kartus J, Kohler K, Stener S, Larsson J, Eriksson BI, *et al*. Analysis of subjective, objective and functional examination tests after anterior cruciate ligament reconstruction. A follow-up of 527 patients. *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA*. [Clinical Trial Research Support, Non-U.S. Gov't]. 1999;7(3):160-5.
 15. Sekiya I, Muneta T, Ogiuchi T, Yagishita K, Yamamoto H. Significance of the single-legged hop test to the anterior cruciate ligament-reconstructed knee in relation to muscle strength and anterior laxity. *The American journal of sports medicine*. 1998;26(3):384-8.
 16. Risberg MA, Holm I, Tjomsland O, Ljunggren E, Ekland A. Prospective study of changes in impairments and disabilities after anterior cruciate ligament reconstruction. *The Journal of orthopaedic and sports physical therapy*. [Research Support, Non-U.S. Gov't]. 1999;29(7):400-12.
 17. Keays SL, Bullock-Saxton JE, Newcombe P, Keays AC. The relationship between knee strength and functional stability before and after anterior cruciate ligament reconstruction. *Journal of orthopaedic research: official publication of the Orthopaedic Research Society*. 2003;21(2):231-7.
 18. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *The American journal of sports medicine*. [Comparative Study Research Support, Non-U.S. Gov't]. 1991;19(5):513-8.
 19. Sachs RA, Daniel DM, Stone ML, Garfein RF. Patellofemoral problems after anterior cruciate ligament reconstruction. *The American journal of sports medicine*. 1989;17(6):760-5.
 20. Gustavsson A, Neeter C, Thomee P, Silbernagel KG, Augustsson J, Thomee R, *et al*. A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA*. [Comparative Study].