ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 8(S9), 390–396, May 2015* DOI: 10.17485/ijst/2015/v8iS9/68300

Relationship between Isokinetic Strengths, Subjective Knee Scores, and Functional Performance after ACL Reconstruction

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Abstract

The purpose of this study is to examine the relationship between isokinetic strengths, subjective knee scores, and functional performance in patients with an ACL-reconstructed knee. **Methods:** Fifty-five male patients between the ages of 16~53 years were enrolled in this study. At the time of testing, a mean 19.7 months had elapsed since the patients had received ACL reconstruction. Muscle strength of the affected knee was measured using an isokinetic dynamometer at the following velocities; 60, 180, 240°/s. The patients scored their affected knee function using 3 subjective knee scores: Lysholm, IKDC, and the Tegner Scores. Functional performance of the affected knee was measured using the one leg hop test for distance. **Results:** Isokinetic measurements showed a significant correlation only with the Tegner score. At 60°/s, peak torque ($r=.322$, $p<.05$) and peak torque to weight ratio, also written as peak torque % body weight ($r=.395$, $p<.01$), were positively correlated with the Tegner score. At 180°/s, peak torque % body weight ($r=.336$, $p<.05$), total work ($r=.354$, $p<.05$), and total work % body weight ($r=.400$, $p<.01$) were positively correlated with the Tegner score. At 240°/s, peak torque % body weight ($r=.304$, $p<.05$), total work ($r=.318$, $p<.05$), and total work % body weight ($r=.331$, $p<.05$) were positively correlated. At 60°/s, all isokinetic measurements for both extensors and flexors were significantly correlated with the functional performance of that knee ($p<.01$), of which the total work % body weight showed the strongest correlation ($r=.600$, $p<.001$). At 180°/s, all isokinetic measurements, except for total work by flexor muscles, were significantly correlated with functional performance ($p<.05$). At 240°/s, all isokinetic measurements were significantly correlated with functional performance ($p<.05$). **Conclusion:** The clinical information derived from measuring total work, as a reflection of knee function, has been undervalued and is as good as that derived from peak torque.

Keywords: Anterior Cruciate Ligament Reconstruction, Functional Performance Test, Isokinetic Test, Subjective Knee Score

1. Introduction

Different muscle strength testing measures are used to get an indication of knee function in patients after interventions such as the Anterior Cruciate Ligament (ACL) reconstruction. Isokinetic testing to measure isokinetic strength of muscles is widely used during assessments of sports-related injuries for its high reliability[1]. Previous studies have shown that as long as isokinetic testing is performed at least 6 months after the ACL reconstruction, it is a relatively safe method without side-effects such as an anterior tibial displacement[2]. For this reason, isokinetic evaluation is one of the most important considerations made by physicians to see whether a patient with an ACL-reconstructed knee is ready to return to sports.

Different isokinetic measurements compose the isoki-

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netic test of muscles, such as peak torque and total work, which can be measured at varying angles and velocities. Assessing these different types of measurements that give different information may unnecessarily confuse the analysis or interpretation of results. A preceding study by Morrissey[3] suggested that total work may be a better indicator for muscle function than peak torque; despite the latter being the most often studied isokinetic strength testing measurement. Although their study on the correlation between peak torque and total work after ACL reconstruction does not give direct evidence to support this hypothesis, theoretically, we believe this possibility cannot be ruled out because the peak torques of knee extensors and flexors at the specified angulation may not be an appropriate reflection of knee function that is required during sports activity[3]. Conversely, total work as in Figure 1, which refers to the area under the torque curve, is the accumulated force generated across all range of motions and may be more inclusively reflective of knee function required during sports activity.

Another type of measure to assess knee function is the subjective knee score, a scaled method for patients to self-evaluate the clinical outcome of their damaged knees after treatment. Commonly used subjective knee scores are the Lysholm score, the International Knee Documentation Committee (IKDC), and the Tegner score. Although only one type of score (subjective knee score questionnaire) was used for the correlation study, a study by Wilk, Romaniello, Socia, Arrigo, and Andrews[4] has already reported that scores from subjective knee score questionnaire correlate with isokinetic strength parameters in patients who underwent an ACL reconstruction.

Lastly, functional performance tests are relatively newer measures of knee function in patients recovering from ACL reconstruction[5]. Designs of functional performance tests closely resemble motions executed during sports activities. The one leg hop test, a common functional performance test, is used to assess knee function pre- and post-ACL reconstruction[6,7], as well as throughout rehabilitation of the knee[6]. Furthermore, the single leg hop test is an assessment tool recommended by the IKDC for knee function[8], and has been used with high reliability in patients who received ACL reconstruction[5].

The purpose of this study is to examine the relationship between these 3 measures of knee function; isokinetic strengths (peak torque and total work for knee extensors and flexors), subjective knee scores (Lysholm score, IKDC, and Tegner score), and functional performance tests (one leg hop test), in patients with an ACL-reconstructed knee. In particular, we want to see which isokinetic measurement, peak torque or total work, has a stronger correlation with clinical outcomes; subjective knee scores and functional performance.

2. Materials and Methods

2.1 Subjects of Study

From January 2006 and January 2009, 55 male patients who underwent ACL reconstruction using an autogenous hamstring tendon at our hospital were enrolled into the current study. The inclusion criteria were patients with only a unilateral ACL-reconstructed knee of male sex aged between 16~53 years. The patient demographics are recorded in Table 1. At the time of muscle function testing, the mean total time that elapsed since the surgical intervention for each patient was 19.71±5.65 months (range, 12~ 41 months). The difference in the laxity of the affected to the unaffected knee, measured using KT-2000 (MED metric, USA), was on average 2.01±1.66mm (range, –1.00~7.20mm). The patients had participated in an average 10.16±5.07 days (range, 2~27days) of rehabilitation, and were educated as to the home exercise by the same specialist clinician. All patients underwent the same follow-ups at 3-week, 6-week, 12-week, 6-month, 1-year post-reconstruction, and had received during each follow-up the same sessions of therapy, medical treatment, and advice. This study was approved by the Institutional Review Board at the Seoul Paik Hospital of Inje University (number of approval: IIT-2015-031).

Table 1. Demographic data of the subjects

Group	N	Age (yrs.)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Post-Op	55	28.45(9.18)	174.35(6.54)	76.19(10.64)	25.01(2.76)

2.2 Experimental Approach

2.2.1 ACL Reconstruction

The patients had undergone arthroscopic ACL reconstruction using the 4-bundle autogenous hamstring tendon technique. The femoral tunnel was made at the femoral notch in the 10 o'clock and 2 o'clock direction for the right and left knees, respectively. All arthroscopic interventions were performed by a single orthopedic surgeon.

2.2.2 Isokinetic Extensor and Flexor Muscle Strength Testing of the Knee

For all isokinetic measurements, the isokinetic dynamometer Biodex system 3-model (Biodex Medical Systems, Inc., N.Y., U.S.A) was used. The isokinetic muscle testing was performed at the following angular velocities; 60, 180, and 240°/s for 4, 10, and 20 times, respectively. The range of motion was limited from 0 to 90°.

2.2.3 Subjective Knee Scores

The subjective knee scores in the form of scaled questionnaires were taken by the patients themselves after isokinetic and functional performance tests. The subjective knee scores were measured using the Lysholm, IKDC, and Tegner scores.

2.2.4 One Leg Hop Test

To measure functional performance, we used the single hop test out of the various one leg hop tests that are available. The patients, standing on one leg, were asked to jump as far as possible using the force from that leg only. The patient was asked to hop 3 times. The total distance was measured as the distance from the toe-tip at the starting line to the heel at landing was measured. The same test was performed on the opposite leg. Since taking the distance of the furthest of 3 hops has been shown to be more reliable than taking the average of 3 hops[9], in this study, we decided to record the distance of the furthest of the 3 hops for each leg. All patients were required to wear trainers.

2.2.5 Statistical Analysis

All statistical analyses were performed using SPSS 21.0 for window. The correlation between isokinetic strengths, subjective knee scores, and the one leg hop test were analyzed using partial correlation whilst adjusting for age. The statistical significance was set to α=.05.

3. Result

3.1 Relationship between Isokinetic Strengths and Subjective Knee Scores

The average Lysholm score was 91.37±10.62, the average IKDC score was 82.26±13.98, and the average Tegner score was 5.44±1.99. Results from correlation analyses of the isokinetic strengths and the 3 types of subjective knee scores are shown in Table 2. Isokinetic measurements showed a significant correlation only with the Tegner score. Depending on the angular velocity at which the isokinetic measurements were taken, the correlation between isokinetic strengths of knee flexors and the Tegner score varied. At 60°/s, peak torque (r=.322, p<.05) and peak torque to weight ratio, also written as peak torque % body weight (r=.395, p<.01), were positively correlated with the Tegner score. At 180°/s, peak torque % body weight (r=.336, p<.05), total work (r=.354, p<.05), and total work % body weight (r=.400, p<.01) were positively correlated with the Tegner score. At 240°/s, peak torque % body weight (r=.304, p<.05), total work (r=.318, p<.05), and total work % body weight (r=.331, p<.05) were positively correlated. These correlations were only seen in knee flexors, and the isokinetic strengths of knee extensors did not show any significant correlation with Tegner scores. No isokinetic measurements showed a significant correlation with either the Lysholm or the IKDC score.

3.2 Relationship between Isokinetic Strengths and Functional Performance

We found that the mean one leg hop on the affected leg was 169.14±21.99cm. Results of partial correlation analyses of the isokinetic measurements and the one leg hop is shown in Table 2. Most isokinetic measurements showed a significant correlation with our indicator of functional performance. At 60°/s, all isokinetic measurements for both extensors and flexors were significantly correlated with the functional performance of that knee (p<.01), of which the total work % body weight showed the strongest correlation (r=.600, p<.001). At 180°/s, all isokinetic measurements, except for total work by flexor muscles,

Table 2. A partial correlation between isokinetic test variables and subjective knee scores

			Mean(SD)	Subjective Knee Scores			MeanFunctional Performance Test (r-value)
			Uninvolved Side	Lysholm	IKDC	Tegner	One Leg Hop
60°/s	Extension	PT†(Nm)	221.96(40.13)	.043	.023	.125	.473**
		PT%BW‡(%)	292.37(41.49)	.207	.179	.156	.564***
		TW§(Joule)	826.28(162.07)	-.025	-.063	.076	.518***
		TW%BW‖(%)	1,088.26(175.19)	.121	.073	.093	.600***
	Flexion	PT(Nm)	110.72(24.60)	-.045	.092	.322*	.445**
		PT%BW(%)	145.83(27.20)	.121	.277	.395**	.478**
		TW(Joule)	494.61(124.19)	-.009	.093	.272	.452**
		TW%BW(%)	651.66(142.48)	.115	.218	.316*	.492***
180°/s	Extension	PT(Nm)	145.80(28.04)	.017	.007	.151	.368**
		PT%BW(%)	191.90(29.65)	.169	.153	.188	.434**
		TW(Joule)	1,220.58(362.09)	.025	-.047	.096	.326*
		TW%BW(%)	1,600.97(437.65)	.153	.070	.125	.387**
	Flexion	PT(Nm)	80.73(21.04)	-.066	.018	.259	.334*
		PT%BW(%)	106.81(25.63)	.095	.193	.336*	.363*
		TW(Joule)	766.01(259.01)	-.075	.003	.354*	.274
		TW%BW(%)	1,012.70(333.99)	.056	.132	.400**	.294*
240°/s	Extension	PT(Nm)	115.95(27.10)	.002	-.055	.051	.352*
		PT%BW(%)	151.65(25.91)	.176	.114	.096	.445**
		TW(Joule)	1,586.23(426.33)	.041	-.008	.050	.357*
		TW%BW(%)	2,092.40(513.29)	.183	.129	.060	.422**
	Flexion	PT(Nm)	70.53(18.12)	.000	.051	.259	.408**
		PT%BW(%)	92.79(19.55)	.162	.228	.304*	.405**
		TW(Joule)	1,022.13(342.89)	-.108	.025	.318*	.358*
		TW%BW(%)	1,355.62(430.17)	.010	.148	.331*	.374**

* Partial correlation is significant at the 0.05 level 2-tailed. ** Partial correlation is significant at the 0.01 level 2-tailed. *** Partial correlation is significant at the 0.001 level 2-tailed. †PT: Peak Torque, ‡ PT%BW: Peak Torque % Body Weight, § TW: Total Work, ‖ TW%BW: Total Work % Body Weight

were significantly correlated with functional performance ($p<.05$). Again, at 240°/s, all isokinetic measurements were significantly correlated with functional performance ($p<.05$).

4. Discussion

The final process of ACL reconstruction is rehabilitation, during which clinicians face the most challenging problem of deciding the appropriate timing of patients' safe return to physical activity and sports[10]. Although no standardized schedules exist, in general, subjective knee scores, functional performance tests, differences in muscle strengths between the affected and unaffected are used in combination to determine when a patient's knee is deemed functionally recovered. Subjective knee scores, which include the Lysholm score, IKDC, and the Tegner score, are used to receive patients' self-assessment. Previous research has highlighted a possible relationship between subjective knee scores and isokinetic strengths in ACL-reconstructed knees. For example, Kannus[11] found that in patients with ACL deficits, the peak torques of the hamstring and quadriceps correlated with the Lysholm score by r=.76 and r=.84, respectively. Additionally, they found that the corresponding correlation between total work of these muscles and the Lysholm score were r=.75 and r=.82, respectively. However, unlike Kannus' study, this current study did not find any significant correlation between isokinetic measurements and the Lysholm score. We believe 3 reasons may have influenced this. First, Kannus[11] used the Pearson correlation, whereas our study, which included a patient sample with broadly distributed ages (16~53 years), used a partial correlation, and importantly, age was adjusted for. Second, Kannus[11] enrolled patients with ACL deficit-induced chronic knee instability, whereas in our study, only those who had at least one-year of recovery period after ACL reconstruction were enrolled, thereby demonstrating two samples with very different patient demographics. Keays, Bullock-Saxton, Newcombe, and Keays[12] reported that the triple hop index correlated more with post-ACL isokinetic measurements than pre-ACL values, which suggests that intra-patient variation of a pre- and post-ACL reconstructed knee may also occur at the inter-patient level. Third, Kannus study's sample size is very small compared to that of ours (34 vs. 55 patients). Thus, differences in statistical analyses, simple size, and patient demographics may have resulted in the difference in results.

Hsieh, Indelicato, Moser, Vandenborne, and Chmielewski[13] found in patients who received ACL reconstruction, the average rate of torque development and the time to peak torque for knee extensors was significantly correlated (r=.379 and r=-.407, respectively) with the IKDC-SKF score. However, the results of this study did not find any correlation between isokinetic measurements and the IKDC score. Analysis with Pearson correlation, which does not adjust for age, showed only a weak correlation between peak torque % body weight for the knee flexors at 60°/s and the IKDC score (r=.278, $p<.05$) (data not shown).

Wilk et al.[4] reported that peak torques for knee extensors at 180°/s and 300°/s were significantly correlated with results from Subjective knee score questionnaires (r=.71 and r=.67, respectively) in patients who had at least 6 months of recovery after ACL reconstruction of injured knees.

In this study, the isokinetic measurements of the knee extensors at 60, 180, and 240°/s did not show a significant correlation with the Tegner score; at 60°/s, only a select isokinetic flexor measurements showed a significant correlation, ranging r=.316~.395, with the Tegner score ($p<.05$~$.01$); at 180°/s, this range was r=.336~.400 ($p<.05$~$.01$); and at 240°/s, r=.304~.331($p<.05$).

Accumulating results from past studies[4,11,13] and ours suggest that in ACL-reconstructed knees, the correlation between isokinetic measurements and subjective knee scores depend on the type of subjective knee scores used. We believe this is due to the variation in weighting of the different sections between each of the subjective knee scoring tool.

In this study, our aim was to verify which parameter, peak torque or total work, is a better indicator for knee function. We found that the strongest correlation between an isokinetic measurement and knee function was between the value for total work for knee flexors at 180°/s and the Tegner score (r=.400, $p<.01$). At second was the peak torque for the knee flexors at 60°/s with the Tegner score (r=.395, $p<.01$). These correlations are too comparable in strength to conclude that total work is by far a better indicator for knee function than peak torque. Nevertheless, earlier studies[4,11,13] may have underestimated the value of total work index as an indicator

for knee function. From our findings, we believe that total work measured at 180°/s is as good an indicator as peak torque. Still, the overall correlation between isokinetic flexors strengths and subjective knee scores is still relatively weak, and we believe this is because other informative aspects of the subjective knee scores such as pain and edema may dilute its capability as a strong indicator for knee function.

Wilk et al.[4] found that the peak torque for knee extensors at 180°/s and the results of the one leg hop test correlated by r=.62 in patients with ACL-reconstructed knees. In this current study, all isokinetic measurements of varying velocities (60, 180, and 240°/s), save for total work of knee flexors at 180°/s, were positively correlated with the one leg hop test with statistical significance (r=.326~.600). The strongest correlation found with the total work % body weight at 60°/s (r=.600). This result differs from those of Wilk et al.[4] in which the strongest correlation was between total work and the one leg hop test, which was followed by peak torque for knee extensors at 60°/s (r=.568, p<.001). This contradiction is possibly due to the fact that factors other than muscle strength may influence outcomes of functional performance tests such as hop tests. For example, hop tests are influenced by quadriceps femoris muscle weakness and patellofemoral compression pain, and associated with abnormal scores resulting from difficulties in self-assessment of pivoting, cutting, and twisting[14]. Such involvement of factors means elements of hop tests may be correlated to fundamentally non-comparable elements of isokinetic parameters.

Further, our study did not consider the presence or absence of anterior knee pain after ACL reconstruction. Anterior knee pain can limit knee strength at certain angles meaning that total work measured at these angles can be underestimated. Thus, prospective studies looking at patients with anterior knee pain may give different findings to ours.

5. Conclusion

In individuals with ACL reconstructed knees, we found that the isokinetic measurement of total work % body weight for knee flexors at 180°/s (r=.400), followed by the peak torque % body weight for flexors at 60°/s (r=.395), was most strongly correlated with the Tegner score. Further total work % body weight for knee extensors at 60°/s (r=.600), followed by the peak torque % body weight for extensors at the same velocity (r=.564), was most strongly correlated to the Tegner score. Even though the results of this study may not support the statement that total work is a superior indicator than peak torque for knee function in patients after ACL reconstruction, but it shows that the value of total work had been underestimated so far. We believe it provides clinical information for knee function that is comparable to that of peak torque.

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