Predictive Value of the Duncan-Ely Test in Distal Rectus Femoris Transfer

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Abstract: Fifty-six patients who underwent 94 distal rectus femoris transfers and pre- and postoperative gait analyses were retrospectively reviewed. The patients were divided into three groups based on pre- and postoperative Duncan-Ely tests. Group A (34 limbs) had positive tests both before and after surgery. Group B (46 limbs) had positive tests before surgery and negative tests after surgery. Group C (13 limbs) had negative tests both before and after surgery. One limb had a negative test before surgery and a positive test after surgery and was not included in any group. Knee arc increased significantly in both groups with positive preoperative Duncan-Ely tests (groups A and B), but not in the group with negative preoperative tests (group C). The timing of peak knee flexion in swing improved in all groups, but the change was smaller and not statistically significant in the group with negative preoperative tests (group C). The findings of the current study indicate that the Duncan-Ely test may be a helpful predictor of outcome in children for whom distal rectus femoris transfer is being considered. Caution should be exercised when patients have weak quadriceps and a negative Duncan-Ely test before surgery, particularly when concurrent calf lengthening procedures are planned.

Key Words: gait analysis, spasticity, surgery, cerebral palsy

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Stiff-knee gait is a well-recognized problem for individuals with cerebral palsy (CP).[5,9,11] The stiff knee often causes difficulties with foot clearance, which can result in tripping and/or the use of compensatory mechanisms that increase energy cost. Previous authors have reported the benefits of proximal or distal rectus femoris release as a treatment of stiff-knee gait in patients with CP.[4,10] Waters et al recommended proximal rectus femoris release, in isolation or combination with distal vastus intermedius release, to treat stiff-knee gait in hemiplegic individuals.[12] Perry, an author in the aforementioned study, subsequently recommended distal rectus femoris release or transfer rather than proximal release to prevent deleterious effects on hip flexor strength.[9] More recent studies comparing rectus femoris release to distal rectus femoris transfer using computerized gait analysis have demonstrated the superior efficacy of distal rectus femoris transfers.[2,7,11] Computer modeling has suggested that distal rectus femoris transfer should be more efficacious than rectus release as well.[3]

Current indications for distal rectus femoris transfer include decreased magnitude and/or delayed timing of peak knee flexion and prolonged rectus femoris activity in swing phase. Previous authors have noted that if the dynamic arc of knee motion is at least 80% of normal preoperatively, then neither distal rectus femoris transfer nor release appears to enhance knee motion.[7]

Though the Duncan-Ely test is commonly performed clinically, the importance of a positive Duncan-Ely test for rectus femoris spasticity is uncertain. Perry et al[8] showed that the Duncan-Ely test is not a specific indicator of rectus tightness or spasticity since it elicits electromyographic (EMG) responses in both the rectus femoris and the iliacus in many subjects with CP. Chambers et al[2] reported that the Ely test has no predictive value for abnormal rectus femoris EMG activity. The purpose of this study was to assess the value of the Duncan-Ely test as a predictor of outcome following distal rectus femoris transfer in children with CP.

MATERIALS AND METHODS

The charts of all patients who had undergone distal rectus femoris transfers and pre- and postoperative computerized gait analyses from 1992 through 2001 at our institution were retrospectively reviewed. Data were available for 56 patients who had undergone 94 distal rectus femoris transfers (Table 1). Most of the subject limbs had additional simultaneous surgeries, including 66 hamstring lengthening and 42 calf lengthening procedures. The postoperative gait analysis assessments took place an average of 19.6 ± 11.3 (mean ± SD) months postoperatively.

During physical examination, the Duncan-Ely test was administered as previously described.[6] The same physical therapist performed the test in all subjects. With the patient prone, the knee was rapidly flexed. If ipsilateral hip rise oc-

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TABLE 1. Subject Demographics

	Group A (+/+) (n = 34)	**Group B (+/−) (n = 46)**	**Group C (−/−) (n = 13)**
Sex	21 F, 13 M	23 F, 23 M	3 F, 10 M
Age at surgery (yr)	10.6 ± 5.2	9.3 ± 4.4	8.9 ± 3.4
Time to follow-up (mo)	19.2 ± 11.6	19.1 ± 9.7	22.8 ± 15.6
# additional surgeries	2.5 ± 1.6	2.9 ± 1.4	2.5 ± 1.8
# hamstring procedures	25 (74%)	32 (70%)	8 (62%)
# calf procedures	12 (35%)	27 (59%)	5 (38%)

Each limb is included separately.

curred, the test was positive; if hip rise did not occur, the test was negative. For positive tests, the knee flexion angle at which hip rise began was estimated and recorded, and rectus femoris spasticity was graded using the Modified Ashworth Scale.[1] Subjects were grouped according to the results of their pre- and postoperative Duncan-Ely tests (group A +/+, group B +/−, group C −/−). The groups did not differ significantly with respect to age, number of simultaneous surgeries, or time between surgery and follow-up. Group C had a greater proportion of boys than groups A and B. One individual whose Duncan-Ely test changed from negative preoperatively to positive postoperatively was excluded from the statistical analyses but is included in the discussion section below.

The gait analysis used a seven-camera three-dimensional motion analysis system (Vicon Motion Systems, Oxford, UK). This system uses a set of 15 to 19 passive retro-reflective markers attached over specific bony landmarks of the pelvis and lower extremities. Subjects made several passes down a 15-meter path with the markers in place. Kinematic data from at least three trials were averaged, and the averaged data were used for statistical analysis. The kinematic parameters analyzed in this study were maximum knee extension in stance, peak knee flexion in swing, knee arc (range of motion from maximum extension in stance to peak flexion in swing), and the timing of peak knee flexion in swing (as a percentage of swing phase).

Rectus femoris EMG was analyzed for the subjects who had undergone EMG testing as part of their gait analysis examinations (91 limbs preoperatively and 84 limbs postoperatively). Surface EMG data were collected using a 10-channel MA-300 system (Motion Laboratory Systems, Baton Rouge, LA) and processed using the EMG Analyzer software (B&L Engineering, Santa Fe Springs, CA). The processed rectus femoris EMG was analyzed for prolonged activity in stance and swing.

Quadriceps and plantar flexor strength were also analyzed for the subjects who had undergone strength testing as part of their gait analysis examinations (85 limbs for quadriceps strength preoperatively, 69 limbs for plantar flexor strength preoperatively, 89 limbs for quadriceps strength postoperatively, and 67 limbs for plantar flexor strength postoperatively). Muscle strength was graded by an experienced physical therapist using the traditional 0-to-5 scale, allowing patterned motion if necessary to assess full muscle strength capacity. For analysis purposes, strength scores were grouped as less than 3, 3+ through 4−, and 4 or greater.

Paired *t* tests were used to compare pre- and postoperative measurements for the kinematic variables. The z-statistic was used to compare the proportions of limbs in each group with overactive recti in stance and swing. The Wilcoxon rank sum (Mann-Whitney) test was used to compare the strength measures between groups.

RESULTS

Eighty limbs (85%) had a positive Duncan-Ely test preoperatively, of which 34 (42.5%) remained positive (group A) and 46 (57.5%) became negative (group B) postoperatively. Fourteen limbs (15%) had a negative test preoperatively, of which 1 (7%) became positive and 13 (93%) remained negative (group C) postoperatively. Knee arc increased signifi-

TABLE 2. Pre- and Postoperative Knee Kinematics

	Group A (+/+) (n = 34)		**Group B (+/−) (n = 46)**		**Group C (−/−) (n = 13)**	
	Preop	**Postop**	**Preop**	**Postop**	**Preop**	**Postop**
Max extension in stance (°)	22.2 ± 1.83	11.1 ± 21.6*	17.6 ± 14.2	11.4 ± 11.7*	14.9 ± 20.2	21.2 ± 15.0
Peak flexion in swing (°)	52.3 ± 16.3	49.8 ± 11.7	51.9 ± 14.1	53.3 ± 9.2	48.7 ± 15.4	58.7 ± 9.6*
Arc (°)	30.1 ± 12.6	38.7 ± 16.4*	34.3 ± 10.9	41.9 ± 13.7*	33.8 ± 17.0	37.5 ± 13.4
Timing of peak flexion (% swing phase)	48.7 ± 16.5	39.5 ± 12.6*	54.7 ± 12.2	42.7 ± 11.2*	45.8 ± 13.7	40.8 ± 10.4

Lower values indicate more extension and less flexion.
*Significant change from preoperative based on paired *t* test ($P < 0.05$).
Data are given as mean ± SD.

TABLE 3. Duncan-Ely Test Results for Patients with Positive Preoperative Tests

	Group A (+/+) (n = 34)		Group B (+/−) (n = 46)	
	Preop	**Postop**	**Preop**	**Postop**
Knee position at hip rise (°)	55.3 ± 18.8	71.4 ± 21.3	62.1 ± 18.9	NA
Spasticity	1.9 ± 1.1	1.3 ± 0.2	1.4 ± 0.6	NA

cantly in the limbs with positive Duncan-Ely tests preoperatively ($P = 0.0002$ for group A, $P = 0.0004$ for group B) as they achieved greater extension in stance postoperatively ($P = 0.002$ for group A, $P = 0.007$ for group B) with no significant change in peak swing-phase knee flexion ($P = 0.36$ for group A, $P = 0.45$ for group B) (Table 2). In group A, though the Duncan-Ely test remained positive postoperatively, rectus femoris spasticity decreased ($P = 0.02$) and hip rise occurred at a greater knee flexion angle postoperatively ($P < 0.0001$) (Table 3).

In group C, peak knee flexion in swing increased postoperatively ($P = 0.04$), but knee arc did not change ($P = 0.24$) (see Table 2). The knee tended to lose extension in this group postoperatively, although the change was not statistically significant ($P = 0.18$). Of the 13 children in group C, 7 (54%) had an increased knee arc while 6 (46%) had a decreased arc. Five of the six (83%) patients with a decreased arc lost knee extension in stance, compared with three of the seven (43%) patients with an increased arc.

The timing of peak knee flexion in swing improved for groups A ($P = 0.001$) and B ($P < 0.0001$) (see Table 2). The timing improved to a lesser extent in group C, and this change was not statistically significant ($P = 0.16$).

Preoperatively, all limbs but one had prolonged rectus EMG during swing (Table 4). There were no significant differences in rectus overactivity between groups A and B ($P > 0.50$). More limbs in group C had rectus overactivity in both stance and swing compared with groups A and B combined ($P = 0.04$), while fewer limbs in group C had prolonged rectus activity in swing only ($P = 0.051$). Postoperatively, there were no significant differences in rectus overactivity between any of the groups ($P > 0.05$). There were no significant differences in quadriceps or plantar flexor strength between groups either before or after surgery ($P > 0.05$).

Post hoc analysis of group C revealed that knee arc increased in approximately half of the children (7/13) but decreased in the other half (6/13). Comparing these two subgroups, the frequency of simultaneous hamstring lengthening surgeries was similar (Table 5). However, none of the children who gained arc had simultaneous calf lengthening procedures, while five of six children who lost arc underwent gastrocnemius recession. The children with increased arc tended to have greater preoperative quadriceps strength than those with decreased arc. Calf strength was poor in both groups.

DISCUSSION

This study demonstrates that patients who have positive Duncan-Ely tests preoperatively appear to achieve better results following distal rectus femoris transfers than those who have negative tests preoperatively. The patients with positive preoperative Duncan-Ely tests demonstrated an increased dynamic knee flexion-extension arc due to maintenance of peak knee flexion in swing and improvement of knee extension in stance. Even those patients whose Duncan-Ely tests remained positive after surgery (group A) demonstrated a significant improvement in the arc of knee flexion, less rectus femoris spasticity (on the Modified Ashworth Scale), and later hip rise on Duncan-Ely testing postoperatively.

In contrast, those with negative preoperative Duncan-Ely tests did not demonstrate a statistically significant increase in the dynamic sagittal arc of knee motion. These children gained knee flexion in swing but had worse knee extension in stance. Interestingly, none of the seven patients with an increased arc had undergone lengthening of the triceps surae, while five of the six patients with a decreased arc had undergone gastrocnemius recession. Similar percentages of each group had undergone simultaneous hamstring lengthenings. These findings suggest the importance of the knee extension–plantarflexion couple in the maintenance of knee extension

TABLE 4. Rectus Femoris Overactivity

	Group A (+/+)		Group B (+/−)		Group C (−/−)	
	Preop	**Postop**	**Preop**	**Postop**	**Preop**	**Postop**
None	0	0	0	2 (5%)	0	0
Stance only	0	4 (13%)	1 (2%)	12 (29%)	0	2 (18%)
Swing only	13 (42%)	3 (10%)	16 (35%)	3 (7%)	2 (15%)	2 (18%)
Stance & swing	18 (58%)	23 (77%)	29 (63%)	25 (60%)	11 (85%)	7 (64%)

TABLE 5. Post hoc Analysis of Group C (−/−)

	Simultaneous Surgeries		Quadriceps Strength ≥4		Calf Strength ≥3	
	Hamstring Lengthening	Calf Lengthening	Preop	Postop	Preop	Postop
Increased arc	5/7	0/7	6/7	5/6	2/7	1/5
Decreased arc	4/6	5/6	1/4	5/5	0/3	2/5

and improvement of knee arc of motion in children with negative preoperative Duncan-Ely tests.

Since there was only one patient in the current study with a negative Duncan-Ely test preoperatively and a positive test postoperatively, the patient's data were not analyzed statistically. The child had a 15° improvement in the arc of knee motion postoperatively and improved timing of peak knee flexion in swing phase. Even if those data had been included with the subjects in group C, the results in group C would still have been statistically worse than those in groups A and B.

There were no significant differences between preoperative quadriceps and triceps surae strength when group C patients were compared with those in groups A and B. However, preoperative quadriceps strength in the subgroup of group C patients whose knee arc diminished postoperatively tended to be less than in the subgroup whose arc increased postoperatively. These same patients demonstrated worsening of peak knee extension in stance phase. These results suggest that caution should be exercised when considering distal rectus femoris transfer in patients with weak quadriceps and a negative Duncan-Ely test preoperatively. Though previous studies have almost universally reported no deleterious effects of distal rectus femoris transfer on stance phase knee kinematics, one previous study reported marked (18°) worsening of maximum knee extension in stance in one group of patients.[10]

The timing of peak knee flexion improved in all groups in the current study, although the change was statistically significant only in the children with positive Duncan-Ely tests preoperatively (groups A and B). Even without an increased magnitude of peak knee flexion, more rapid knee flexion in swing facilitates foot clearance in children with CP and stiff-knee gait. Previous authors have reported conflicting data regarding the effect of distal rectus transfer on the timing of peak knee flexion in swing.[2,6,11]

The type of rectus femoris EMG overactivity did not appear to influence the results of distal rectus femoris transfer in the current study. This contrasts with the previous article by Miller et al, which reported the greatest increase in peak knee flexion in those with rectus overactivity predominating in swing phase.[6] Interestingly, data from the same study revealed that the arc of knee motion actually increased most in the group with continuous EMG activity throughout the gait cycle.[6]

This study differs from previous studies in the literature by demonstrating that the Duncan-Ely test has prognostic significance in assessing children with CP prior to potential distal rectus femoris transfer surgery. It neither confirms nor denies the previous reports that the Duncan-Ely test is not specific for the rectus femoris and that it does not predict dynamic EMG activity of the rectus.

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