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Outcomes of Combined Hamstring Release and Rectus Transfer in Children with Crouch Gait

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SUMMARY

Background. Our aim was to evaluate the outcomes of combined hamstring release and rectus transfer in children with crouch gait using physical examination and gait analysis.

Materials and methods. A total of 19 patients (38 knee joints) with crouch were evaluated by static examination and computerized analysis with dynamic EMG. The Ely test was positive together with prolonged and increased activity in the rectus muscle bilaterally in all patients. These patients underwent hamstring release and rectus transfer. Intensive rehabilitation was provided following the surgery and the patients were evaluated again by static examination and gait analysis after an average of 6.3 (4-7.5) months after surgery. The preoperative and postoperative static examination findings, knee and ankle joint kinematics and time-distance parameters were compared in 19 children.

Results. There was a significant improvement in static examination findings, knee and ankle kinematics and time-distance parameters. However, there was no significant difference between the preoperative and postoperative swing phase peak knee flexion.

Conclusions. This study demonstrated that static parameters, time-distance parameters, knee and ankle kinematics were improved following combined hamstring release and rectus transfer in children with cerebral palsy without any cases of stiff knees.

Key words: cerebral palsy, crouch gait, knee deformity, gait analysis, rectus transfer, hamstring release

INTRODUCTION

Crouch gait is a common problem in children, adolescents and young adults with spastic cerebral palsy. Crouch gait is the results of contractures of hamstrings, hip flexors and inadequate strength of triceps surae to decelerate the forward advance of the tibia [1]. This pattern may also be iatrogenic, as in primary hamstring contractures seen after injudicious or isolated lengthening of contracted triceps surae [2]. Sagittal knee kinematics show increased knee flexion, hip flexion and ankle dorsiflexion at stance in crouch gait.

Excessive rectus activity gradually develops in the rectus femoris, the antagonist to the shortened hamstrings, resulting in increased spasticity, especially in ambulatory patients [3]. The co-spasticity of the hamstrings and quadriceps produces a complex problem because the hamstring muscles are extensors of the hip joint and flexors of the knee joint while the rectus femoris flexes the hip and extends the knee [4,5]. This co-spasticity decreases the knee range of motion during the swing phase in children with crouch gait.

Hamstring lengthening is a common procedure to improve knee extension at swing in crouch gait. However, previous studies have shown that hamstring lengthening without rectus transfer improves knee extension in the stance phase of gait but reduces knee flexion in the swing phase [6,7]. This procedure produces stiff knee gait, which is another common pathologic gait, because increased and prolonged action of the rectus femoris prevents knee flexion at swing [8,9]. Recently, rectus tendon transfer procedures have been introduced to improve peak knee flexion, timing of peak knee flexion and range of motion in stiff knee gait [10]. In addition, combined rectus transfer and hamstring lengthening increased knee function in children with crouch gait [11].

The purpose of this study was to review the outcomes of combined hamstring release and rectus transfer in children with crouch gait using static examination and gait analysis.

MATERIAL AND METHODS

Crouch gait in 19 diplegic patients (10 females and 9 males) with a mean age of 12.1 years (11-27). Sixteen had been born prematurely while 3 were term babies. Six had been born by cesarean section and 13 by vaginal delivery. Twelve of the patients were mobile without support while 7 were mobile with support. All patients had heel cord lengthening, 7 had adductor tenotomy, 2 had Green Grice procedure, 1 had psoas lengthening previously (Tab. 1). All patients had a crouch gait pattern due to excessive heel cord lengthening without hamstring release. The patients were evaluated by physical examination and computerized gait analysis with dynamic EMG. The popliteal angle, passive knee extension, active knee extension and Ely test results also were measured during a static examination. Initial contact and midstance knee extension, peak knee flexion at swing, ankle dorsiflexion at midstance and push-off were measured with computerized gait analysis. Dynamic EMG was used to assess the rectus femoris activity throughout the gait phase. A positive Ely test, increased and prolonged rectus activity was detected during the swing phase in both rectus femoris muscles in all patients. Bilateral combined hamstring lengthening and rectus transfer was performed. This procedure was additionally combined with adductor tenotomy in 10 patients, psoas lengthening in 1 patient and distal femur derotation osteotomy in 1 patient during the same session. Seven patients had no additional surgery. A superficial skin lesion developed in one patient and rehabilitation was started 2 weeks after surgery.

Procedure

The preoperative static examination and gait analysis was performed an average of 2 months before surgery. Hamstring release was performed using a medial and lateral longitudinal incision in 19 patients (39 knees). Hamstring release included release of the gracilis, release or lengthening of the semitendinosus, and aponeurotic lengthening of the semimembranosus and biceps tendons. Long leg casts were applied postoperatively with the knee at 15 degrees flexion because we believe that casting decreases spasticity and stabilizes knee more effectively after surgery. Casts were divided longitudinally from the anterior aspect on the second postoperative day and converted to a brace to start passive range of motion exercises. The patients started passive movements and isometric exercises with casts removed three times a day on the second postoperative day. The casts were discontinued 3 weeks later and the patients started active movement and standing up exercises as pain permitted. A night mold was used from then on. Walking exercises were started 4 weeks later. For the patient who had osteotomy, standing up and walking exercises were started after bone union was radiographically confirmed. During the walking exercises, an AFO (ankle-foot orthosis) was used in 5 patients and a GRAFO (ground reaction ankle-foot orthosis) was used in 6 patients. Repeat physical examinations and computerized gait analysis were performed at an average of 6.3 (4-7.5) months after

Tab.1. Patient characteristics, knee deformities and procedures performed

Patients	Age (year)	Birth Time	Birth status	Type of CP	Ambulatory status	Sugical History	Knee Surgery	Additional Surgery
1	11	Premature	Vaginal birth	Diplegic	Dependent	BAT+BAL	B HR+RFT	BPL
2	13	Full term	Vaginal birth	Diplegic	İndependent	BAT+ BAL	B HR+RFT	
3	10	Premature	Vaginal birth	Diplegic	Dependent	BAL	B HR+RFT	BAT
4	15	Premature	Cesarian	Diplegic	Independent	BAL	B HR+RFT	BAT
5	12	Full term	Vaginal birth	Diplegic	Independent	LGG+BAL	B HR+RFT	
6	11	Premature	Vaginal birth	Diplegic	Independent	LGG +TDRO+BAL	BR+RFT	BAT
7	27	Full term	Cesarian	Diplegic	Independent	BPL+BAL	BHR+RFT	RDFDRO
8	16	Premature	Vaginal birth	Diplegic	Independent	BAL	BHR+RFT	BAT
9	9	Premature	Vaginal birth	Diplegic	Independent	BAT+BAL	BHR+RFT	
10	10	Premature	Cesarian	Diplegic	Dependent	BAL	BHR+RFT	BAT
11	9	Premature	Vaginal birth	Diplegic	Independent	BAL	BHR+RFT	BAT
12	10	Premature	Vaginal birth	Diplegic	Dependent	BAT+BAL	BHR+RFT	
13	9	Premature	Vaginal birth	Diplegic	Dependent	BAT+BAL	BHR+RFT	
14	11	Premature	Cesarian	Diplegic	Independent	BAL	BHR+RFT	BAT
15	10	Premature	Cesarian	Diplegic	Independent	B AL	BHR+RFT	BAT
16	11	Premature	Vaginal birth	Diplegic	Independent	B AL	BHR+RFT	BAT
17	9	Premature	Cesarian	Diplegic	Dependent	B AT+B AL	BHR+RFT	
18	12	Premature	Vaginal birth	Diplegic	Independent	B AT+B AL	BHR+RFT	
19	15	Premature	Vaginal birth	Diplegic	Dependent	B AL	BHR+RFT	BAT

B:bilateral, R: right L: left, AT: adductor tenotomy, AL: Achilles lengthening, LGG: left Green Grice, PL: psoas lengthening, HR: hamstring release RFT: rectus femoris transfer TDRO: tibia distal derotation osteotomy, DFDRO: distal femoral derotation osteotomy

surgery. The preoperative and postoperative parameters were compared.

Gait analysis

Gait analysis was performed using the Vicon 512 (Oxford Metrics Co/USA) and Polygon recording system. This video-based system consists of 7 infrared cameras, 2 video cameras, 2 floor-mounted force plates, and a 16-channel telemetric EMG system. Each patient performed at least five trials with a clear foot-force plate contact; the data from the trials was averaged. A total of 15 retro-effective infrared markers of 15 mm diameter were used to obtain a three-dimensional gait record. Joint kinematics data of the knee and ankle and time-distance parameters were calculated. Changes in the joint angles over the gait cycle (kinematics) were calculated using a seven-segment model using Euler angles.

Statistical Analysis

Statistical analysis was performed with the Windows-compatible SPSS 10.0 software package. Arithmetic means and standard deviations were calculated for the descriptive data. A paired t-test was used to compare preoperative and postoperative values. A p value <0.05 was accepted as statistically significant.

RESULTS

The popliteal angle was decreased by 39 degree, active knee extension was increased by 16 degree, and passive knee extension was increased by 5 degree. The Ely test was positive in 16 knee joints preoperatively but only 3 patients postoperatively (Tab. 2).

The total arc of knee motion was increased by 18, initial contact knee extension was increased by 23, midstance knee extension was increased by 25, but no significant difference in the magnitude of peak knee flexion in swing was detected (Tab. 3). The time of maximum knee flexion in the swing phase decreased from 89% of the mean gait cycle preoperatively to 76% postoperatively. In addition, ankle dorsiflexion was significantly ($p<0.05$) decreased during initial contact and midstance (Tab. 3).

Cadence and double support phase decreased significantly in all patients while there was a significant

Tab. 2. Physical Examination Findings

Measure	Preoperative	Postoperative	P
Popliteal Angle (degrees)	61±5.2	22±3.8	0.002
Active Knee Extension (degrees)	-19±6.4	-3±2.9	0.016
Passive Knee Extension (degrees)	-6.1±1.3	-0.9±0.15	0.025
Ely test	16 knee joints (+)	3 knee joints (+)	

Tab. 3. Kinematics Parameters of Knee

Measure	Preoperative	Postoperative	P
TAKM (degrees)	14±2.1	32±1.4	0.003
ICKE (degrees)	-43.8±4.1	-20.1±2.1	0.003
MSMKE (degrees)	-40.5±	-18±7	0.002
SPKF (degrees)	54.3±3.2	52.9±8.9	0.5
TSPKF (% of gait)	89%	76%	
ICAD (degrees)	10	0	0.042
MSMAD (degrees)	16	5	0.047

TAKM: Total Arc of Knee Motion, ICKE: Initial Contact Knee Extension, MSMKE: Midstance maximum knee extension SMKF: Swing Peak Knee Flexion, TSMKF: Time of Swing Peak Knee Flexion, ICAD: Initial Contact Ankle Dorsiflexion, MSMAD: Midstance Maximum Ankle Dorsiflexion

increase in gait velocity, stride length and push-off ($p<0.05$) (Tab. 2).

Additional surgery and ambulatory level of patients did not affect the final results.

DISCUSSION

Crouch gait is the result of the knee being flexed throughout the gait cycle due to the spasticity and inadequate length of the hamstring muscles. In timing, the rectus femoris has increased and prolonged activity, corresponding to increased hamstring spasticity. If patients with crouch gait are not treated, contractures develop in the knee joint and gait function is severely affected. Crouch gait was first treated with distal hamstring transfer (Eggers' method) or proximal hamstring tenotomy. However, these procedures are no longer used because of the weakness in extension strength of the hip joint caused by proximal hamstring tenotomy and the recurvatum deformity of the knee joint caused by distal hamstring transfer [12,13,14].

Distal hamstring lengthening is frequently done with the objective of increasing knee extension in stance in children with cerebral palsy who display crouch gait [15]. Previous studies have shown that hamstring lengthening without rectus transfer improves knee extension in the stance phase of gait but reduces knee flexion in the swing phase. The consequence can be a stiff knee gait with poor knee flexion in swing and problems with foot clearance [7,8,9].

Perry defined the rectus tendon transfer for stiff knee gait treatment in 1978 [4]. It has been reported that rectus transfer increases knee flexion at the swing phase and is more effective than rectus release surgery [6,10,11]. In addition, combined hamstring release and rectus transfer improved knee function in children with cerebral palsy [4]. However, there are not many studies evaluating the effects of combined hamstring lengthening and rectus transfer in children with crouch gait. In these patients, the goal is to improve knee extension during stance, magnitude and peak knee flexion timing in swing, in order to increase the total arc of knee motion and foot clearance [9,15].

Tab. 4. Temporospatial parameters

Measure	Preoperative	Postoperative	P
Cadence	112 steps/min	87 steps/min	0.041
Gait velocity	0.42±0.1 m/sec	0.56±0.2 m/sec	0.020
Stride length	0.41±0.06 m	0.57±0.08 m	0.048
Double support phase	0.67±0.04 sec	0.40±0.08 sec	0.039
Push off	60±0.05%	72±0.03%	0.038

Carney BT et al. reported on 45 limbs that underwent HSL and RFT [16]. Statistically significant changes were seen in stance maximum knee flexion (decreased by 21 from 49 preoperatively to 31 postoperatively), stance minimum knee flexion (decreased by 14 from 26 preoperatively to 12 postoperatively), swing maximum knee flexion (decreased by 7 from 57 preoperatively to 50 postoperatively), and swing minimum knee flexion (decreased by 12 from 39 preoperatively to 27 postoperatively); in the timing of swing maximum knee flexion (decreased by 5% from 85% preoperatively to 80% postoperatively); and in total knee excursion (increased by 36 from 31 preoperatively to 67 postoperatively).

Yngve D.A. et al. reported on 99 limbs that underwent HSL and RFT [17]. Ninety-nine children were classified as independent community ambulatory, crutch/walker-dependent community ambulatory, or household/exercise ambulatory. They found that all three groups showed a significant increase in knee extension in stance and stride length. Only the independent ambulation group maintained knee flexion in swing, but the timing of peak knee flexion in swing and total knee range of motion improved in all groups. All groups showed increases in stride length, and the household/exercise group also showed an increase in walking speed.

A comparison of data from the current study and previous studies demonstrated increased stance maximum knee extension (by 22 degrees) and initial contact knee extension (by 23 degrees). This study demonstrated a decrease in the timing of swing maximum knee flexion similar to previous studies (decreased from 89% to 76%), but there were no significant changes in swing peak knee flexion (by 1.5 degrees) ($P>0.05$). In addition an increase in total knee excursion was found (by 18 degrees) (Tab. 3). These outcomes are similar to those obtained in the group of independent ambulatory patients by Yngve D.A. et al. [17].

In addition, increased stride length and decreased double support phase improved gait velocity. Decreased cadence and increased gait velocity mean reduced energy need during walking. One disadvantage of the study is that the knee joint kinetics and the energy expenditure of the patients were not evaluated.

The popliteal angle was decreased, active and passive extension of the knee was increased significantly following hamstring release and rectus femoris transfer. However, some limitation in passive knee extension was observed in 9 knee joints postoperatively. This indicates the presence of capsular contractures of the knee joint in these patients. The patients were observed to walk in a more erect position and more comfortably postoperatively.

In our study, ankle dorsiflexion was increased during stance by previous excessive heel cord lengthening. Excessive dorsiflexion in preswing reduces push-off, so foot clearance and stride length will decrease. After hamstring lengthening, ankle dorsiflexion decreased and push-off increased significantly. However, the ankle dorsiflexion was seen to be more than normal postoperatively. The reason is probably the lack of full knee extension during the midstance phase and previous excessive lengthening of the heel cord.

CONCLUSION

This study demonstrated that hamstring release combined with a rectus transfer procedure is suitable for patients with crouch gait with excessive and prolonged activity in the rectus muscle in dynamic EMG together with a positive Ely test. Knee static findings and kinematic parameters were improved by combined surgery without causing stiff knee gait.

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