Soft Tissue Surgery for Equinus Deformity in Spastic Hemiplegic Cerebral Palsy: Effects on Kinematic and Kinetic Parameters

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The purpose of this study was to evaluate how soft tissue surgery for correcting equinus deformity affects the kinematic and kinetic parameters of the ankle and proximal joints. Sixteen children with spastic hemiplegic cerebral palsy and equinus deformities (age range 3-16 years) were included. Soft tissue surgeries were performed exclusively on the ankle joint area in all subjects. Using computerized gait analysis (Vicon 370 Motion Analysis System), the kinematic and kinetic parameters during barefoot ambulation were collected preoperatively and postoperatively. In all 16 children, the abnormally increased ankle plantar flexion and pelvis anterior tilting on the sagittal plane were significantly improved without a weakening of push-off ($p < 0.05$). In a group of 8 subjects with a recurvatum knee gait pattern before operation, the postoperative kinematic and kinetic parameters of the knee joint were significantly improved ($p < 0.05$). In a group of 8 subjects with ipsilateral pelvic external rotation before operation, the postoperative pelvic deviations on the transverse plane were significantly decreased ($p < 0.05$). These findings suggest that the soft tissue surgery for correcting equinus deformity improves not only the abnormal gait pattern of the ankle, but also that of the knee and pelvis.

Key words: Cerebral palsy, equinus, soft tissue surgery, gait analysis.

INTRODUCTION

About 75% of children with spastic cerebral palsy (CP) walk independently, but most still show abnormal gait patterns as a consequence of

contractures across the joints and muscle spasticity.[1,2] Despite the many etiologies and varying severity of CP, these children exhibit several common gait abnormalities for which researchers have been trying to devise clinically useful classifications.[1,3,4]

In spastic hemiplegic CP with prevailing gait pathology on the involved side, the contralateral limb often elicits kinematic deviations that can be described as compensatory motions.[5] This may induce asymmetry not only on the sagittal plane, but also on the transverse plane. Therefore, the gait disturbance pattern is different from that of spastic diplegic CP. Winters et al.[6] defined 4 homogenous patterns of gait in spastic hemiplegic CP by analyzing kinematic data in the sagittal plane and electromyographic data. In the group I pattern, there is a 'drop foot' during the swing phase due to the inability to selectively control ankle dorsiflexors. The group II pattern is characterized by a disruption of ankle motion during the stance phase related to the equinus deformity. Individuals with the group III pattern present with a flexed stiff knee and equinus deformity in the sagittal plane. In the group IV pattern, there is a much more marked proximal involvement such as flexed hip, anterior pelvic tilting, hip adduction and hip internal rotation. Among these gait patterns, the group II pattern is characterized by a disruption of ankle motion during the stance phase caused by tight and spastic ankle plantar flexors, which is combined with the neutral or the recurvatum gait of the knee joint. The knee joint motion of the group II pattern is identical to the

recurvatum knee pattern described by Sutherland et al.[1]

The above-mentioned results suggest that the abnormal ankle motion during the gait cycle can influence proximal joints including the knee joint, and that treatment for spasticity and contracture of the triceps surae might improve the abnormal motion of the proximal joints, especially the recurvatum knee pattern. Gastrocnemius-soleus lengthening surgeries, such as tendo-achilles lengthening and lengthening of the gastrosoleus aponeurosis, have been performed for equinus deformities caused by the spasticity and contracture of the triceps surae, and several studies have reported post-surgical improvements of the movement pattern in proximal joints.[7-10] But, it is difficult to assess the efficacy of isolated gastrocnemius-soleus lengthening from these studies, because multiple surgical procedures which might affect the movement of proximal joints, such as hamstring release, psoas release, and femoral derotational osteotomy, were performed simultaneously. In addition, to our knowledge, the changes of gait pattern after correction of equinus deformity exclusively in children with spastic hemiplegic CP or with a recurvatum knee gait pattern have not been assessed.

The aim of this study was to determine whether the gait disturbance pattern of proximal joints as well as the ankle joint could be improved by surgical treatments to correct equinus deformities, especially in individuals with a recurvatum knee pattern or asymmetry on the transverse plane. We selected individuals with group II spastic hemiplegic CP who underwent soft tissue surgeries performed exclusively on the ankle joint area and analyzed preoperative and postoperative gait findings.

MATERIALS AND METHODS

Subjects

This study included 16 individuals with spastic hemiplegic CP and equinus deformities caused by fixed contracture of the triceps surae. Preoperative evaluations of these subjects, including physical examination and radiographic measurement,

didn't show disabling shortenings of the hamstring muscles, hip adductor muscles or hip flexor muscles, nor rotational deformities of the femur and tibio-fibular unit. Therefore, they underwent soft tissue surgery on the ankle joint area for equinus deformities and accompanying varus deformities. The surgical methods included lengthening of the gastrosoleus aponeurosis in 3 subjects and the tendo-achilles in 13 subjects. The accompanying operations were tibialis posterior split transfer to peroneus brevis in 5 subjects, tibialis posterior lengthening in 2 subjects and flexor digitorum longus lengthening in 1 subject. General characteristics of the subjects are shown in Table 1.

All 16 subjects were able to walk independently for at least 10 meters without the aid of orthoses prior to and after the surgery, and the 3-dimensional computerized gait analysis was feasible. The subjects had no history of muscle-tendon surgery, botulinum toxin injection within the previous six months or other surgeries such as rhizotomy that may affect gait. Their age at the time of surgery ranged from 3 to 16 years with an average age of 8.25 ± 3.55 years and the interval between surgery and follow-up gait analysis ranged from 9 months to 25 months with an average of 14.64 ± 4.66 months.

Subgroups of subjects

Of the 16 subjects, 8 showed minimal deviations of the knee and the other 8 showed recurvatum changes of the knee during gait. The subgroup with the recurvatum knee pattern was defined by the hyperextension of the sagittal angle of the knee by more than 1 standard deviation from the mean of normal values during the mid-stance phase, based on the definition by Sutherland et al.[1]

The preoperative gait analysis on the transverse plane revealed that 8 of the 16 subjects showed an external rotation of the paralytic pelvis more than 1 standard deviation from the mean of normal values during the entire gait cycle. They were classified as subjects with 'ipsilateral pelvic external rotation' (Table 1).

The reference values were collected from 72 normal subjects and used for subdividing the study group.

Table 1. Characteristics of Subjects

Case	Sex	Involved side	Age (yrs)	Etiology	Follow-up interval	Clinical findings	Surgical procedures
1	M	Left	5	Hypoxic brain injury during heart surgery	17	Pelvic external rotation Genu recurvatum	TAL, TPL
2	M	Left	14	-	14	Genu recurvatum	TAL, TP to PB
3	M	Left	11	Prematurity	15	Pelvic external rotation	TAL, FDL lengthening
4	F	Left	7	Neonatal hypoxia	25	Pelvic external rotation	GAL, TP to PB
5	F	Left	9	-	10	Pelvic external rotation	TAL
6	F	Left	6	Prematurity	14	Pelvic external rotation	TAL, TP to PB
7	M	Left	9	Prematurity	12	-	TAL, TP to PB
8	F	Left	5	-	9	Genu recurvatum	TAL
9	M	Left	8	-	22	-	TAL
10	M	Left	7	Prematurity	17	Genu recurvatum	GAL
11	M	Right	3	Neonatal hypoxia	14	Pelvic external rotation Genu recurvatum	TAL
12	M	Right	10	Sepsis Neonatal hypoxia	9	Pelvic external rotation Genu recurvatum	TAL, TP to PB
13	M	Right	4	-	13	-	TAL
14	F	Right	11	Prematurity	16	-	GAL
15	M	Right	16	Neonatal hypoxia	13	Pelvic external rotation Genu recurvatum	TAL, TPL
16	M	Right	7	Prematurity	17	Genu recurvatum	TAL

M, male; F, female; TAL, tendo-achilles lengthening; TPL, tibialis posterior lengthening; TP to PB, split transfer of tibialis posterior to peroneus brevis; FDL, flexor digitorum longus; GAL, gastro-soleus aponeurosis lengthening.

Data collection

Prior to the analysis of preoperative and postoperative gait, the dorsiflexion angle of the ankle was measured by physical examination in the knee flexion and extension state. The minimum angle unit measured by physical examination was 5 degrees.

Gait analysis was performed preoperatively and postoperatively using a computerized gait analysis system (Vicon 370 Motion Analysis System with 6 infrared cameras, Oxford Metrics Inc., Oxford, U.K.) to measure the kinematic data (angle of each joint) and the kinetic data (moment and power of each joint) during the gait cycle. A trained investigator placed thirteen reflective markers on the first sacrum, the anterior superior iliac spines, the mid-points of the lateral femur, the lateral knee joint axis, the midpoints of the lateral tibia, the lateral malleolus, and the dorsal foot between metatarsal heads 2 and 3. All subjects walked barefoot at a self-determined speed along an 8-meter path with the markers in place. Force-plates (AMTI OR 6-5, Advanced Mechanical Technology, Newton, MA, USA) under the path recorded ground reaction forces during the walking trials with a 480-Hz sampling frequency and joint moments were expressed as internal moments to counter the ground reaction force. Data collection continued until the subject achieved at least three 'clean' force-plate strikes. Kinematic and kinetic data from successful trials were averaged and the averaged data were used for statistical analysis.

Statistical analysis

To determine the influence of the surgical procedures on all 16 subjects, Wilcoxon signed rank tests were performed to compare the preoperative and postoperative data on ankle dorsiflexion angles by physical examination, temporospatial parameters, and kinematic and kinetic parameters on the sagittal plane. Wilcoxon signed rank tests were also used to assess the effects of surgery on the 8 subjects with the recurvatum knee gait pattern and the 8 subjects with ipsilateral pelvic external rotation during the gait cycle. *P*-values less than 0.05 were considered statistically significant.

RESULTS

Comparison of all 16 subjects pre- and post-operation

Postoperative physical examination of the joint range of motion showed an increase of the median passive ankle dorsiflexion from 0° to 20° with the knee flexed and from 0° to 15° with the knee

extended ($p < 0.05$). Popliteal angles were decreased from 25° to 10° ($p < 0.05$) (Table 2).

In a comparison of the temporospatial parameters, significant differences for cadence, velocity, step length, and single limb support phase were not detected (Table 3).

Kinematic data in the sagittal plane (Table 4) demonstrated a significant change in the ankle and pelvic joint after operation. At initial contact, the ankle dorsiflexion angle was increased from the preoperative median of -3.26° to the postoperative median of 2.52°, and the average ankle dorsiflexion angle was increased from a median of 2.75° to 9.81° during the stance phase and from a median of -6.54° to 3.34° during the swing phase ($p < 0.05$). The angle at the onset of push- off and toe-off was increased from 10.57° to 20.58° and from -13.04° to 0.41°, respectively ($p < 0.05$). The anterior tilt angle of the pelvis at initial contact was decreased from the preoperative median of 13.11° to the postoperative median of 12.26°, and the overall average anterior tilt angle was decreased from a median of 14.60° to 14.30° ($p < 0.05$). But the difference between the preoperative and postoperative kinematic data for the pelvis was less significant than that of the ankle joint.

Table 2. Changes of Ankle Dorsiflexion and Popliteal Angle Revealed by Clinical Examination in All 16 Patients Following Operation

Parameters	Range of motion (degrees)		*p* value
	Preoperative data (n = 16)	Postoperative data (n = 16)	
Ankle dorsiflexion			
with knee flexion	0 (-30 ~ 20)	20 (5 ~ 30)	0.002
with knee extension	0 (-30 ~ 10)	15 (0 ~ 20)	0.001
Popliteal angle	25 (0 ~ 45)	10 (0 ~ 30)	0.002

Values are the median (minimum - maximum).

Table 3. Changes of Temporospatial Parameters in All 16 Patients Following Operation

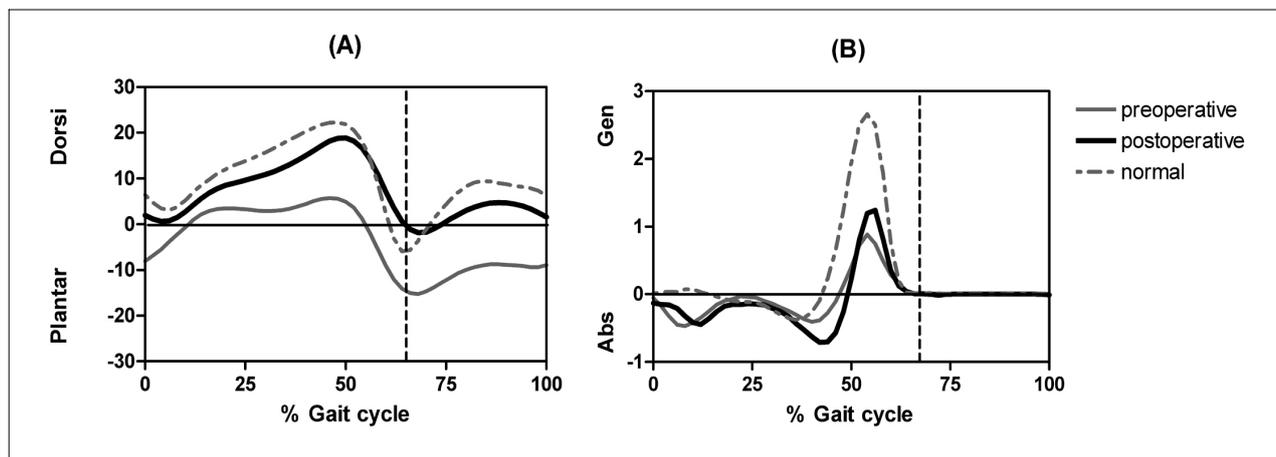| Parameters	Preoperative data (n = 16)	Postoperative data (n = 16)	*p* value
Cadence (steps/minute)	121 (97 ~ 61)	118 (87 ~ 146)	0.268
Velocity (m/sec)	0.86 (0.44 ~ 1.20)	0.74 (0.42 ~ 1.39)	0.532
Step length (m)	0.45 (0.23 ~ 0.60)	0.42 (0.30 ~ 0.63)	0.753
Single limb support (%)	33.3 (27.4 ~ 43.2)	33.0 (29.9 ~ 39.5)	0.469

Values are the median (minimum - maximum).

Table 4. Changes of Sagittal Kinematic Parameters in All 16 Patients Following Operation

Parameters	Preoperative data (n = 16)	Postoperative data (n = 16)	*p* value
Ankle angle (degrees)			
Angle at initial contact	-3.26 (-41.58 ~ 5.74)	2.52 (-7.67 ~ 10.20)	0.002
Mean average dorsiflexion during stance phase	2.75 (-36.86 ~ 21.28)	9.81 (3.67 ~ 13.50)	0.010
Angle at onset of push-off	10.57 (-28.45 ~ 29.55)	20.58 (10.30 ~ 27.87)	0.004
Angle at onset of toe-off	-13.04 (-39.87 ~ 11.66)	0.41 (-35.84 ~ 12.55)	0.004
Mean average dorsiflexion during swing phase	-6.54 (-36.96 ~ 3.63)	3.34 (-14.07 ~ 12.08)	0.001
Knee angle (degrees)			
Angle at initial contact	21.49 (-2.97 ~ 54.03)	23.78 (9.00 ~ 58.04)	0.163
Angle at onset of push-off	9.83 (-0.79 ~ 22.47)	14.40 (3.97 ~ 28.08)	0.278
Maximal extension in swing phase	23.47 (2.58 ~ 61.18)	25.83 (9.82 ~ 52.49)	0.501
Hip angle (degrees)			
Angle at initial contact	40.00 (30.41 ~ 66.98)	40.19 (27.21 ~ 64.05)	0.438
Maximal extension in stance phase	-0.16 (-6.33 ~ 13.40)	2.71 (-19.85 ~ 13.53)	0.134
Pelvis tilt (degrees)			
Angle at initial contact	13.11 (6.27 ~ 35.77)	12.26 (1.23 ~ 28.44)	0.031
Mean average tilt angle during gait cycle	14.60 (9.59 ~ 33.18)	14.30 (5.67 ~ 30.68)	0.030

Values are the median (minimum ~ maximum).
Ankle angle, positive = dorsiflexion and negative = plantar flexion; Knee angle, positive = flexion and negative = hyperextension; Hip angle, positive = flexion and negative = extension; Pelvis tilt, positive = anterior tilt and negative = posterior tilt.

Fig. 1. Postoperative ankle kinematic and kinetic parameters on the sagittal plane in all 16 patients, as compared with preoperative and normal values. (A) ankle flexion (degrees), (B) ankle power generation (watts/kg). Dorsi, Dorsiflexion; Plantar, Plantarflexion; Gen, Generation; Abs, Absorption.

During push-off, as the triceps surae contracts, the power generated by the plantar flexion of the ankle joint did not significantly change (Fig. 1).

Table 5. Changes of Knee Kinematic and Kinetic Parameters in Patients with and without Recurvatum Knee Gait Patterns Following Operation

Parameters	Preoperative data	Postoperative data	*p* value
With recurvatum knee (n = 8)			
Angle at initial contact (degrees)	20.57 (-2.97 ~ 54.03)	26.45 (9.00 ~ 58.04)	0.012
Maximal extension in stance phase (degrees)	5.71 (-7.98 ~ 13.14)	10.66 (7.45 ~ 25.56)	0.036
Angle at onset of push-off (degrees)	6.54 (-0.79 ~ 18.96)	15.75 (5.23 ~ 28.08)	0.161
Mean Average moment during stance phase (Nm/kg)	-0.10 (-0.37 ~ 0.05)	0.06 (-0.05 ~ 0.11)	0.018
Peak flexion moment in stance phase (Nm/kg)	-0.36 (-0.72 ~ -0.23)	-0.1 (-0.29 ~ -0.03)	0.018
Without recurvatum knee (n = 8)			
Angle at initial contact (degrees)	32.10 (9.83 ~ 54.03)	26.39 (11.96 ~ 58.04)	1.000
Maximal extension in stance phase (degrees)	16.07 (4.87 ~ 20.95)	12.02 (4.62 ~ 20.93)	0.779
Angle at onset of push-off (degrees)	18.06 (5.76 ~ 22.47)	16.46 (5.23 ~ 27.27)	0.889
Mean Average moment during stance phase (Nm/kg)	0.11 (-0.09 ~ 0.23)	0.08 (-0.02 ~ 0.37)	0.463
Peak flexion moment in stance phase (Nm/kg)	0.28 (0.20 ~ 0.46)	0.34 (0.09 ~ 0.42)	0.893

Values are the median (minimum ~ maximum).
Knee angle, positive = flexion and negative = hyperextension; Knee moment, positive = extension moment and negative = flexion moment.
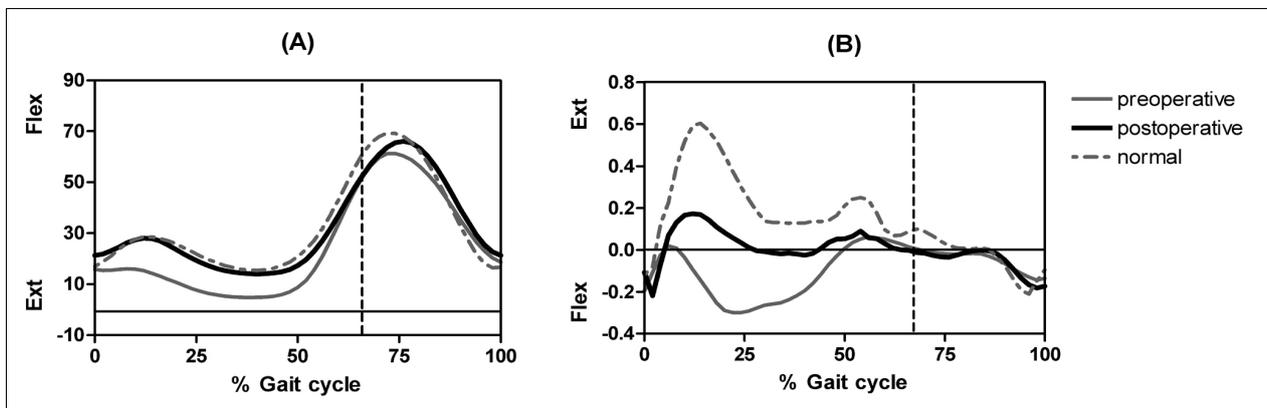
Fig. 2. Postoperative knee kinematic and kinetic parameters in 8 patients with recurvatum knee gait patterns, as compared with preoperative and normal values. (A) knee flexion (degrees), (B) knee moment (Nm/kg). Flex, Flexion; Ext, Extension.

Comparison of subjects with and without the recurvatum knee gait pattern

In the 8 subjects with the recurvatum knee gait pattern, kinematic and kinetic data in the sagittal plane demonstrated a significant change in the knee joint after operation (Table 5 and Fig. 2). The knee flexion angle was increased from the preoperative median of 20.57° to the postoperative median of 26.45° at initial contact, and from 5.71° to 10.66° at maximal knee extension during stance phase ($p < 0.05$). The knee flexion angle at onset of push-off was increased from a median of 6.54° to 15.75°, however, this difference was not significant. As for the kinetic data of the knee joint, the average moment during stance phase was increased from a median of -0.10 Nm/kg to 0.06 Nm/kg, which changed from the flexion moment to the extension moment. The peak internal moment during stance phase was also increased from

Table 6. Changes of Pelvic Kinematic Parameters on Transverse Plane in Patients with and without the Ipsilateral Pelvic External Rotation during Gait Cycle Following Operation

Parameters	Preoperative data	Postoperative data	*p* value
With pelvic external rotation (n = 8)			
Angle at initial contact (degrees)	-4.28 (-15.59 ~ 1.13)	1.43 (-6.31 ~ 3.80)	0.036
Mean average angle during gait cycle (degrees)	-7.07 (-20.23 ~ -4.58)	-5.31 (-18.00 ~ -0.73)	0.012
Without pelvic external rotation (n = 8)			
Angle at initial contact (degrees)	5.36 (1.43 ~ 18.20)	1.49 (-5.11 ~ 12.95)	0.161
Mean average angle during gait cycle (degrees)	-0.44 (-4.92 ~ 4.39)	-1.47 (-4.24 ~ 9.84)	0.779

Values are the median (minimum ~ maximum).
Pelvis angle, positive = internal rotation and negative = external rotation.
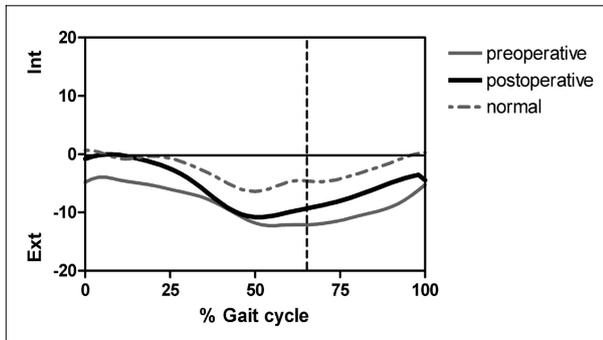
Fig. 3. Postoperative pelvic kinematic parameters on the transverse plane in 8 patients with the ipsilateral pelvic external rotation during gait cycle, as compared with preoperative and normal values. Int, Internal rotation; Ext, External rotation.

a median of -0.36 Nm/kg to -0.1 Nm/kg (*p* < 0.05).

In the 8 subjects without the recurvatum knee gait pattern, the difference between the preoperative and postoperative values was not significant during the overall gait cycle.

Comparison of subjects with and without ipsilateral pelvic external rotation during the gait cycle

In the 8 subjects with ipsilateral pelvic external rotation during the gait cycle, the external rotation of the pelvis was decreased from the preoperative median of -4.28° to the postoperative median of 1.43° at initial contact, and the average external rotation during gait cycle was decreased from a median of -7.07° to -5.31° (*p* < 0.05) (Table 6 and Fig. 3).

In the 8 subjects without ipsilateral pelvic external rotation during the gait cycle, the difference between the preoperative and postoperative values was not significant for the overall gait cycle (Table 6).

DISCUSSION

Equinus is the most common foot deformity in individuals with spastic CP and may adversely affect standing and walking ability.[7,10-13] This deformity is caused by the spasticity of the triceps surae being greater than that of the anterior tibial muscles and consequently induces an abnormal gait pattern. In the equinus gait, the rocker bottom action at the heel is lost because of initial contact by a toe or flat foot. In the rocker bottom action at the ankle, loading of the body-weight on to the ankle and foot causes lengthening of the triceps surae, which is terminated abruptly by a reflex contraction or contracture of the triceps surae.[14] This disruption of the normal sagittal plane ankle motion may contribute to the compensatory deviations at the proximal joints. Goodman et al.[15] examined 12 normal adult subjects with one ankle constrained in equinus using a taping method. The ankles of the subjects were fixed at -24° for the passive ankle dorsiflexion. They found that the knee flexion during the stance phase and the maximal pelvic anterior tilt were significantly increased on the ipsilateral side as a result of the ankle constraint. Our results show that the pelvic anterior tilt was increased preoperatively and

reduced after surgical treatment correcting equinus, even though the knee flexion was not increased preoperatively. Perry[16] reported that the rigid 30° plantarflexion contracture of the ankle makes the knee more flexed during stance phase because this adaptation facilitates progression. But the elastic 15° plantarflexion contracture of the ankle leads to an inappropriate foot position only at initial contact and in mid swing, and the rigid 15° plantarflexion contracture leads to a lack of tibial advancement after early footflat in the loading response. Sutherland et al.[1] also suggested this mechanism to explain the recurvatum knee gait pattern in CP children. Actually, 8 of the total 16 subjects showed the preoperative recurvatum knee pattern in this study. In a separate analysis of these 8 subjects, the kinematic analysis revealed that the flexion of the knee was increased at initial contact and the flexion angle of the knee during the maximum extension period at mid-stance was also increased (Fig. 2). In addition, the initial motion of the knee flexion during the loading response for the absorption of shock at initial contact was lost in the preoperative gait analysis and reappeared after operation, thus indicating that the abnormal knee motion was improved not only in quantity but also in quality (Fig. 2). In the kinetic analysis, the average internal moment of the knee during the stance phase changed from the flexion moment to the extension moment, and the maximum internal flexion moment was decreased. The recurvatum knee gait pattern places the center of gravity to the front of knee joint during stance phase resulting in the external extension moment and the excessive internal flexion moment of the knee joint.[17] Such findings were improved after operation. However, the gastrocnemius-soleus lengthening has been reported to be a risk factor for calcaneus deformity[18] and may induce a weakness of the plantar flexion at the push-off phase.[19,20] The weakness of the ankle plantarflexors after surgical lengthening may induce the crouch knee pattern; this may have contributed to the increase of knee flexion in the 8 subjects with recurvatum knee pattern in this study. Therefore, this increase of the knee flexion might not actually be an improvement since it can be a complication caused by over-lengthening of the ankle plantarflexors. However,

through kinetic analysis, several studies have shown that the power generation at push-off after operation is increased rather than decreased.[7,8,10] Rose et al.[7] suggested two reasons for this improvement. First, the stretch and reflexive response of the triceps surae is delayed until the late stance phase when push-off occurs. Second, the dorsiflexion of the ankle at the onset of push-off is increased, resulting in a better mechanical position for power generation. Our results also showed that after operation, the dorsiflexion of the ankle at the onset of push-off was increased and that the power generation at push-off was not significantly changed. The reduction of power generation due to muscle weakness did not occur (Fig. 1).

In addition to the sagittal plane deviations used to classify the hemiplegic gait pattern, the subjects with spastic hemiplegic CP also presented with transverse plane deviations. In particular, the ipsilateral pelvic external rotation on the transverse plane is often detected during the gait cycle.[5] This abnormal gait pattern can be caused by the compensation for excessive femoral anteversion or tibial internal torsion, or both.[5,21,22] But the pelvic external rotation in 8 subjects of this study might be caused by other factors because the preoperative evaluations of these subjects, including physical examination and radiographic measurement, didn't show rotational deformities of the femur or tibio-fibular unit. It is known that pelvic external rotation can be induced by the difficulty of foot clearance secondary to the spasticity of the triceps surae, the internal foot rotation related to gastrocnemius and tibialis posterior spasticity, or the weakness of hip flexor and extensor muscles.[1,5,23] In this study, 8 subjects with ipsilateral pelvic external rotation revealed a significantly decreased pelvic external rotation angle at initial contact and average pelvic external rotation angle during gait cycle following operation (Table 6, Fig. 3). These findings suggest that the increase of ankle dorsiflexion during the stance phase facilitates tibial progression, and the increase of ankle dorsiflexion during the swing phase facilitates foot clearance, thus improving pelvic external rotation. Other possible factors such as weakness of the hip muscles and rotational deformities of feet can influence the pelvic external

rotation, but were not evaluated in the present study.

Several limitations of this study should be considered. Because we selected patients with plantarflexor spasticity as the main or only problem, this study does not suggest that isolated gastrocnemius-soleus lengthening will improve the abnormal motion of knee and pelvis in all spastic hemiplegic patients. The limited number of patients and short duration of follow-up also make the interpretation difficult. So, further investigation of a larger group of subjects with various gait patterns will be necessary to establish the influence of isolated gastrocnemius-soleus lengthening on the gait pattern of spastic hemiplegic CP children with equinus deformities.

In conclusion, the equinus gait due to spasticity of the triceps surae is thought to induce disturbance of the proximal joints such as the knee and pelvic joint during the gait cycle. We have confirmed that soft tissue surgery of the ankle joint area including gastrocnemius-soleus lengthening improves not only the disturbed movement of the ankle, but also that of the knee and pelvis. These suggest that the accurate assessment and treatment of gait disturbance pattern, based on the understanding of correlation of various joints, is important for better surgical outcome.

ACKNOWLEDGEMENTS

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