ASSESSMENT OF HIP ROTATION AFTER GAIT IMPROVEMENT SURGERY IN CEREBRAL PALSY

G. STEINWENDER, V. SARAPH, E. B. ZWICK, C. UITZ, W. LINHART

Sixteen children with diplegic type of cerebral palsy and spastic internal rotation gait were evaluated using gait analysis before and an average of 3 years after multiple soft tissue surgery. Significant correction of the internal rotation gait was observed after multi-level soft tissue surgery which included medial hamstring lengthening in all cases. Our results suggest that for children with spastic internal rotation gait, multi-level soft tissue surgery effectively corrects the dynamic internal rotation gait in the absence of fixed bony rotational deformities.

Keywords : cerebral palsy ; diplegia ; surgery ; gait analysis ; internal rotation.
Mots-clés : IMC ; diplégie ; chirurgie ; analyse de la marche ; marche en rotation interne.

INTRODUCTION

Spastic internal rotation gait is defined as internal rotation of the femur when the child stands, walks, or runs. Various muscles have been incriminated by different investigators in the past as being responsible for this muscle imbalance and gait deformity. It is well accepted that the adductors of the hip, in the presence of flexion, act as internal rotators (3, 18, 28). The internal rotators of the hip (tensor fasciae latae, gluteus maximus, and anterior fibres of the gluteus medius) have been considered important deforming muscles (4, 12, 24). Some consider this group of muscles too weak to be an important deforming factor (6, 7, 23). Electromyography studies have demonstrated that the iliopsoas contributes little to hip rotation (5). The medial hamstrings have been implicated as important rotators of the hip (2, 10). Sutherland *et al.* reported on seven spastic children whose medial hamstrings were the cause of internal rotation. The basis of their diagnosis was clinical, with electromyographic confirmation (26).

This gait deformity, secondary to muscle imbalance, if severe enough and not corrected early in life, leads to a fixed muscle contracture and bony femoral anteversion, resulting in a fixed internal rotation deformity. With the development of fixed bony deformities, derotation osteotomies are needed to correct the internal rotation gait (9, 13, 16, 17, 27).

Internal rotation gait if corrected prior to the development of bony deformities by muscle-tendon surgery has a better chance to correct the gait abnormalities and possibly decrease requirements for bony surgery. In this study, gait function after multiple soft-tissue surgeries in diplegic children was evaluated using gait analysis with an emphasis on changes in hip rotations after hamstring lengthening.

METHODS

Multiple soft tissue surgeries for gait improvement were performed on sixteen children with diplegic type of

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cerebral palsy. Average age of the patients at surgery was 10.2 years (range 6-14 years). Evaluation was done on average 1.04 months before surgery, and on average 3.4 years postoperatively (range 2.0-5.7 years).

Selection of cases

Selection of the subjects was done from the neuro-orthopaedic department based on the following inclusion criteria : diplegic type of cerebral palsy, ability to ambulate at least 10 meters without the use of walking aids, no previous surgery on the lower limbs, and ability to comprehend instructions. Exclusion criteria included non-ambulatory patients or patients who were able to ambulate only with walking aids, moderate to severe mental retardation, athetotic type of cerebral palsy, and patients with torsional deformities severe enough to warrant osteotomies.

Patient evaluation

In the physical examination, active and passive range of motion of the lower limb joints was measured, and manual muscle power testing of various muscle groups in the lower limb were recorded. Instrumented gait analysis, performed with a 6-camera video based motion capturing system (Vicon 370, Oxford Metrics, UK) and a floor-mounted force-plate (Kistler Instruments Limited, Switzerland) provided three dimensional kinematic and kinetic data and time-distance parameters. Time-distance parameters, and kinematics in the transverse planes were evaluated in this study.

Selection of surgical procedures

Criteria for selection of surgical procedures were based on evaluation of clinical and gait analysis data and were uniform in all the cases. Intrapelvic psoas tenotomy was performed for hips showing a fixed flexion contracture on examination under anaesthesia, and a double bump pattern on walking. Hamstring lengthening was performed when full passive knee extension was lacking, and persistent knee flexion in single-limb stance was noted. Transfer of the rectus femoris distally to the semitendinosus was performed in cases showing rectus spasticity on clinical examination, and a restriction in the peak flexion in swing. Hamstring lengthening and distal rectus transfer was performed in all the cases in this group. Intramuscular gastrosoleus lengthening was performed when passive ankle dorsiflexion, measured with the hindfoot in neutral position and with the knee extended, did not reach the neutral position when examined under anaesthesia preoperatively, and when an equinus was noted early in single-limb stance. Details of surgical procedures performed are shown in table I.

Table I. — List of surgical procedures performed

Procedure (16 patients, 29 limbs)	No.
Intrapelvic psoas tenotomy	18
Medial hamstring lengthening	29
Lateral hamstring lengthening	5
Distal rectus transfer	29
Intramuscular psoas lengthening	6
Foot tendon lengthenings/transfers	4
Total surgical procedures	91

Postoperative rehabilitation followed a standardised protocol. Passive physiotherapy in the form of joint mobilisation was started 4 to 7 days after surgery. Standing therapy in a standing frame and gait training was started 7 to 10 days after surgery. The patients received rigid knee-foot orthoses (KFO) to maintain knee extension during resting periods and dynamic ankle-foot orthoses (AFO) during walking to provide passive knee extension in the stance phase of gait. The AFOs were discontinued when the muscle power in the calf was sufficient to stabilise the knee during stance. The KFOs were used until muscle balance at the knee was stabilised. Criteria for discontinuation of the KFOs were the ability of the patient to actively extend the knees fully. Hospital stay ranged from 4 to 6 weeks during which daily physiotherapy, strength and gait training was provided. The patients were discharged when they could walk with reasonable confidence using the dynamic AFOs and Kaye-walkers. After discharge, the patients had physiotherapy on an outpatient basis as required, and were monitored in the orthopaedic outpatient department at monthly intervals.

Preoperative time-distance parameters, and kinematics were compared with the values obtained at follow-up using the paired t-test ; p-values of less than 0.05 were considered statistically significant.

RESULTS

Changes in the time-distance parameters are shown in table II and the kinematic parameters in table III. Averaged kinematic curves are illustrated in fig. 1. There was a non-significant increase in the

walking velocity. A significant reduction in the cadence and a significant increase in the stride length were observed.

No changes were seen in the pelvis motions in the transverse plane. At the hip joint, the range of motion was also maintained. However, on observing motions in individual events of the gait cycle, significant changes were noted. The mean hip angle at initial contact, in the first double support and during single support changed from internal rotation to external rotation. Internal rotation in the second double support decreased significantly from a mean value of 13.6° to a mean value of 2.0° after surgery.

Table II. — Time distance parameters evaluated

Time distance parameters	pre	post	p value
Cadence (Steps/min)	140 (16)	132 (11)	0,039
Velocity (cms/sec)	110 (26)	118 (13)	0,183
Stride length (cms)	95 (18)	107 (13)	0,029
Stance duration (% of gait cycle)	60 (4)	62 (2)	0,059

Values in brackets denote standard deviation.

DISCUSSION

With the development of gait analysis, the surgical management of patients with cerebral palsy has evolved toward addressing musculotendinous contractures as well as bony malrotations at multiple levels and during a single surgical procedure (1, 8, 14, 15, 19, 20, 21). These studies have focused on sagittal plane kinematics and kinetics. Evaluation of information obtained from computerised gait analysis generally leads to a reduction in the number of procedures recommended for gait improvement (11). While it is obvious that fixed rotational deformities need surgical correction, it is preferable to correct rotational gait patterns prior to the development of fixed deformities.

Several studies have documented improvement in knee sagittal plane kinematics after hamstring lengthening and distal rectus transfer. However, the influence of this on hip rotations has not been evaluated so far. In normal gait, at initial contact, the ipsilateral pelvis is internally rotated, followed by a progressive external rotation to a maximum at pre-swing. The hemipelvis then rotates internally from mid-swing to initial contact, and is internally

Table III. Kinematic parameters evaluated

Kinematic parameters (degrees)	Normal		pre		post		p value
Transverse plane							
Pelvis							
Angle at initial contact	6,6	(2,4)	4,9	(7,3)	5,7	(6,0)	0,858
Mean angle in first double support	5,7	(2,0)	4,9	(7,2)	5,0	(5,5)	0,738
Mean angle in single support	0,1	(1,8)	-0,1	(6,3)	-1,2	(4,6)	0,355
Mean angle in second double support	-5,0	(2,1)	-5,8	(6,0)	-5,2	(6,0)	0,703
Mean angle in swing	-1,1	(1,1)	-2,0	(4,9)	-1,5	(5,3)	0,680
Range of motion	13,4	(4,1)	16,7	(6,6)	13,8	(6,0)	0,129
Hip							
Angle at initial contact	-12,6	(6,6)	6,9	(15,4)	-8,6	(10,3)	0,000
Mean angle in first double support	-9,8	(6,3)	7,8	(13,5)	-6,2	(10,1)	0,000
Mean angle in single support	2,5	(6,0)	9,7	(10,4)	-2,8	(9,8)	0,000
Mean angle in second double support	3,3	(7,0)	13,6	(10,7)	2,0	(9,9)	0,000
Mean angle in swing	-4,6	(6,6)	11,7	(12,1)	-1,1	(10,0)	0,000
Range of motion	16,7	(3,6)	16,6	(6,6)	16,1	(5,6)	0,750

Negative values denote external rotation. Reference values given are averaged data from ten normal children of the same age group. Values in brackets show standard deviation.

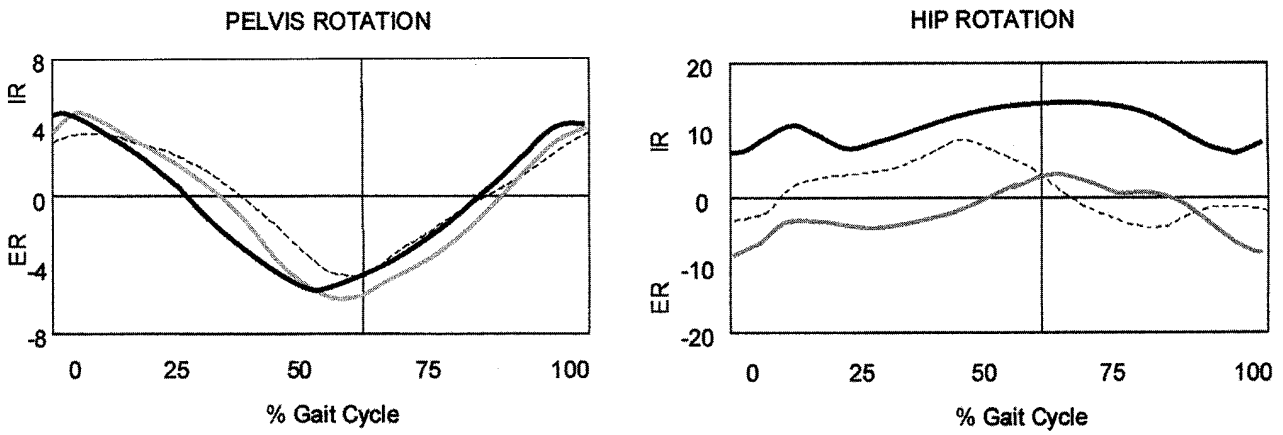

Fig. 1. — Averaged curves showing pelvis and hip rotations through the gait cycle before and after surgery.
Thick black line : preoperative curve, thick grey line : postoperative curve, dotted black line : normal curve. Abbreviations : IR – Internal rotation, ER – External rotation.

rotated again at initial contact. The hip is in neutral position at initial contact, after which it progressively internally rotates during loading response and single limb support. From pre-swing to the end of initial swing, the hip externally rotates, followed by internal rotation to a neutral position through the remainder of swing (22).

There was no significant change in the pelvis movements in the transverse plane in the patients evaluated before and after surgery. DeLuca *et al.* have mentioned that the internal rotation gait observed in diplegic children could also be due to internal pelvic rotation, and not only to hip internal rotation (11). We did not observe any internal pelvic rotation in our patients ; it is possible that this pattern develops once the deformity becomes more fixed, requiring a bony corrective surgery. Preoperatively, the children showed internal rotation of the hip at initial contact, throughout the stance phase, and in swing. Postoperatively significant changes towards normal were observed. The hip joint showed a significant decrease in the degree of internal rotation in the first double support and during single limb support. A maximum of 9° of external rotation was possible in swing as compared to the preoperative internal rotation of 4°. Given the fact that the psoas has little influence on hip rotation, and that hamstring lengthening and distal rectus transfer were performed in all the cases in this study, we believe that the significant improvements in the hip rotations seen at follow-up was due to hamstring lengthening.

The results of this study also have to be viewed taking into account certain limitations. Studies on repeatability of gait data in normal and diplegic children have documented that repeatability of transverse plane rotations measurement is less accurate due to limitations of the model used for computing the gait data, as well as the contribution from errors due to marker placement (25). However, since our evaluation included clinical examination, observational gait analysis from slow motion video viewing and gait analysis, an improvement in the internal rotation pattern seen in all the cases in this group suggests a positive influence of hamstring lengthening on hip rotations. It has been well documented that operating on diplegic children at an earlier age necessitates less operative procedures for gait improvement. With the concept of single-session multi-level surgery, it is tempting for the treating surgeon to consider a derotation osteotomy of the femur and/or the tibia to correct the rotation deformity (11). Our results suggest that for children with spastic internal rotation gait in the absence of fixed bony rotational deformities, multi-level soft-tissue surgery effectively corrects the dynamic internal rotation gait. Long-term studies are needed to establish whether

such correction obviates the need for bony derotation at a later age.

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SAMENVATTING

G. STEINWENDER, V. SARAPH, E. B. ZWICK, C. UITZ, W. LINHART. Beoordeling van heuprotatie na gangverbeterende ingrepen bij cerebral palsy.

Zestien kinderen met een spastische diplegie en spastische endorotatiegang werden preoperatief en na een interval van gemiddeld 3 jaar geëvalueerd met ganganalyse Zij ondergingen verschillende weke-delen operaties. Significante verbetering werd vastgesteld na multi-level ingrepen, met inclusie van verlenging van de mediale hamstrings. Wanneer er geen osseuse rotatoire afwijkingen zijn, zijn deze multi-level weke-delen procedures effectief voor de correctie van de endorotatiegang.

RÉSUMÉ

G. STEINWENDER, V. SARAPH, E. B. ZWICK, C. UITZ, W. LINHART. Étude de la rotation de la hanche chez l'enfant IMC après intervention sur les tissus mous pour améliorer la marche.

Les auteurs ont réalisé une étude de la marche chez 16 enfants IMC qui présentaient une démarche de type diplégique ou en rotation interne de type spastique, avant et en moyenne 3 ans après chirurgie sur les tissus mous. Ils ont observé une correction significative de la démarche en rotation interne après une opération comportant plusieurs gestes sur les tissus mous, avec allongement des ischio-jambiers internes dans tous les cas. Ces résultats suggèrent qu'en l'absence de trouble rotationnel fixé par des déformations osseuses, une intervention à plusieurs niveaux sur les tissus mous peut effectivement corriger la démarche en rotation interne chez des enfants IMC présentant cette anomalie.