

operations performed at one time, which we have described as "Single Event, Multilevel Surgery". Although there is much published information as to the conduct and outcome of parts of this type of programme, there is a lack of practical information as to how to approach integrated management of this important and complex event in the life of a child with Cerebral Palsy. Furthermore, it is incumbent on the proponents of expensive technology and surgical programmes to demonstrate their quality, cost effectiveness and value to society. We believe that these aims are addressed to varying degrees by our Clinical Framework.

REFERENCES

- 1) Gage JR, 1991. Gait Analysis in Cerebral Palsy. Clinics in Developmental Medicine No 121. Mac Keith press, Oxford, New York.
- 2) Nene AV, Evans GA and Patrick JH. Simultaneous Multiple Operations for Spastic Diplegia. Outcome and Functional Assessment of Walking in 18 patients. *J Bone Joint Surg* 1993;75-B: 488-494.
- 3) Rang M, Silver R, and de la Garza, J. Cerebral Palsy in Lovell WW, Winter RB eds. Pediatric Orthopaedics 2nd edition. Philadelphia etc, JB Lippincott 1986.

A Comprehensive Evaluation of Treatment Outcomes in Ambulatory Cerebral Palsy

Jean L. Stout, MS, PT; Paulo Selber, M.D., & James R. Gage, MD
(Gillette Children's Hospital, 200 East University Avenue, St. Paul, MN 55101 USA)

Objective: To evaluate the results of surgical treatment of children with ambulatory cerebral palsy by using a comprehensive functional outcome model. Parameters included: 1) technical results 2) functional outcome, 3) parent satisfaction, and 4) cost.

Design: A retrospective study of patients with spastic cerebral palsy who underwent surgical treatment to improve ambulation. None of the children had had previous surgical intervention.

Patients: Fifty-four patients with spastic cerebral palsy (17 children with hemiplegia; 22 with di or triplegia and 13 with quadriplegia). Thirty seven had orthopaedic intervention only and 17 had both selective dorsal rhizotomy and orthopaedic surgery. Mean age at treatment was 7.5 years. All had their entire course of treatment at Gillette Children's Hospital.

Materials and Methods: The method of assessment was different for each area of outcome measured. Technical outcome was assessed by computerized gait analysis prior to and following surgical intervention. A normalcy index based on 22 variables (kinematic and kinetic) was used to analyze results. Functional outcome was measured by oxygen consumption pre and post intervention and a functional ability questionnaire. Satisfaction was assessed by a retrospective parent questionnaire. Cost of treatment was determined from hospital and physician treatment records.

Measurements and Main Results: 1) **Technical Outcome:** The normalcy index showed improvement in 50 of 54 patients. 2) **Functional Assessment:** Of the children who had only orthopaedic surgery, there was an overall reduction in energy expenditure of 35%. Of those who had a combination of rhizotomy and reduction in energy expenditure was 23%. Thirty of 54 children had follow-up questionnaire information. Strength, endurance, and ability to keep up with peers were rated as improved in 70, 67, and 63% respectively. 3) **Parent Satisfaction:** Questionnaire return rate was seventy-one percent. All of the families whose children had rhizotomy (9 of 17 responded) were satisfied and said that they would undergo the procedure again. Eighty percent of the families whose children had orthopaedics (28 of 37 responded) said they would undergo the procedures again. The greatest hardship for families of patients with rhizotomy was the length of the stay in the hospital. The greatest hardships for families of patients who underwent orthopaedic procedures were post-operative pain and scarring. 4) **Cost of Treatment:** The average number of admissions for patients who had the combination of rhizotomy and orthopaedics was 3.2 with an average combined length of stay of 40.5 days. Total cost in 1995 dollars was \$94,125.00. The average number of admissions for patients who had orthopaedic treatment only was 1.7 with an averaged combined length of stay of 7.7 days and a total cost of \$39,000.00.

Conclusions: Based on technical outcome more than 90% of patients were improved. However, functional assessment indicated improvement in only about 67%. Nevertheless, 84% of families were sufficiently satisfied with the outcome that they would have the procedures done again. The cost of the procedures in today's dollars is very high and long term benefits are difficult to assess, particularly since there are no other in-depth studies of this type in the literature. If the results stand up over time and, as a consequence of the interventions, these children are able to be more functional adults, then the long term benefit will certainly be worth the cost since these children have a long lifetime ahead of them.

Crouch gait in spastic diplegia after heel cord lengthening

R. Berghof, E. B. Zwick, L. Döderlein
Dept. of Orthopedic Surgery, University of Heidelberg, Germany

Introduction:

Crouch gait is defined by a knee flexion of more than 30 degrees maintained throughout stance phase (Sutherland and Cooper 1978). The reported incidence of crouch gait after heel cord lengthening in spastic diplegia is 1-12%. In a study with gait analysis, 30% of diplegic children after heel cord lengthening displayed a calcaneal gait (Scgal et al. 1989). Thus crouch gait might be a more widespread complication than is generally assumed. By observational gait analysis and clinical examination, two different subtypes of crouch gait could be identified: calcaneal gait and pes valgus with abduction of the midfoot. The purpose of this study was to differentiate subtypes of iatrogenic crouch gait by gait analysis and to draw conclusions for the therapeutic management.

Methodology:

We retrospectively identified 4 spastic diplegic patients with crouch gait (knee flexion $\geq 30^\circ$ during stance phase) after bilateral heel cord lengthening. All patients underwent gait analysis including video documentation, kinematic and kinetic 3-D measurements.

Results:

By observational gait analysis (videotape) 2 patients with calcaneal gait and neutral rotational foot position and 2 patients with pes valgus and abduction of the midfoot could be identified. Gait analysis demonstrated an increased ankle dorsiflexion during stance in calcaneal gait and an increased external rotation of the foot progression angle in pes valgus. The ankle plantarflexion moment during stance was unacceptably high in both deformities. In the patients with pes valgus, the ankle power generation during 'push-off' and the hip power generation at the beginning of swing ('pull-off') was lower compared to calcaneal gait.

Discussion:

The different foot and ankle deformities in iatrogenic crouch gait, identified by clinical examination and observational gait analysis, could be differentiated by the kinematic measurements. The kinetic measurements did show a lower power generation at ankle and hip during 'push-off' and 'pull-off' in patients with pes valgus. This implies that we have to be careful with pes surgery in these cases, because a further decrease of power generation at the hip could impair locomotion.

LENGTH OF HAMSTRINGS AND PSOAS MUSCLES DURING CROUCH GAIT

L.M. Schutte, S.W. Hayden, J.R. Gage

Gillette Children's Hospital, St. Paul, MN, USA
University of Minnesota, Minneapolis, MN, USA

INTRODUCTION

Previous studies by Hoffinger *et al.* (3) and Delp *et al.* (2) have found that in many cases of crouch gait the hamstrings are longer than normal and the psoas shorter than normal, suggesting that hip flexion contracture may be a more important and hamstrings tightness a less important cause of crouch gait than had been previously thought. In these studies, however, muscle lengths have been calculated by applying a child's joint kinematic data to a nominal lower extremity model of an adult. Children with cerebral palsy and other disorders generally do not have normal bony architecture, however, but rather have muscle attachment points and muscle paths altered by bony deformities. In this study we explore the sensitivity of hamstrings and psoas muscle lengths calculations to model assumptions.

METHOD

Using a model similar to that described by Delp *et al.* (1) lengths of the medial and lateral hamstrings and the psoas muscles were calculated for a group of subjects with no identified gait abnormalities and a group of 13 subjects who walk with a crouch gait. The crouch gait subjects all walked with minimum knee flexion greater than 20° on one or both legs, had no previous surgeries, did not use any orthosis or assistive devices for their gait analysis. Eight of the crouch gait subjects had knee flexion greater than 20° throughout the gait cycle on both the right and left side. For the remaining five subjects knee flexion was greater than 20° throughout the gait cycle for one limb but less than 20° for some portion of the gait cycle on the other limb. Modifications were made to the musculoskeletal model to represent the body proportions and bony deformities (i.e., femoral anteversion) of each of the 21 individual crouch gait limbs. Muscle lengths were recalculated with the modified model.

RESULTS

When muscle length were calculated with the generic (non-subject specific model) 14 out of 21 medial hamstrings, 11 out of 21 lateral hamstrings and 12 out of 21 psoas muscles did not reach a length within two standard

deviations of the average maximum length of these muscles during normal gait. That is, slightly less than half of the crouch gait subjects showed signs of walking with "hamstrings shift" (i.e., hamstrings of normal length despite abnormal knee flexion due to the position of the hip), and approximately half had psoas lengths shorter than normal. When the muscle lengths were recalculated with a subject specific model, 12 out of 21 medial hamstrings, 10 out of 21 lateral hamstrings, but only 2 out of 21 psoas muscles did not reach a length within two standard deviations of their average maximum length during normal gait.

DISCUSSION

Our analysis indicates that calculated psoas length is very sensitive to whether or not subject specific musculoskeletal geometry is represented. In contrast, the hamstrings muscle lengths were found to be relatively insensitive to either subject specific body proportion or femoral anteversion. Although our inclusion criteria was nearly identical to the inclusion criteria used by Delp *et al.* (2), we found fewer cases of hamstrings shift among our crouch gait patients. Despite these differences, our results support Delp's hypotheses that calculated muscle lengths can be useful in surgical planning. Specifically, the insensitivity of the hamstrings lengths to the model assumptions provides added confidence that the calculations are robust and suggests that a nominal model can be used to adequately estimate when the hamstrings are short and when they are long. Our results, however, suggest that Delp's finding of short psoas muscles in all of the crouch gait subjects may be a reflection of the model they used and not necessarily an indication that these muscles were short.

REFERENCES

- 1) Delp, S.L., et al. *IEEE Trans Biomed Eng.* 37(8): pp. 757-767, 1990
- 2) Delp, S.L., et al., *J Orthop Res.* 1996
- 3) Hoffinger, S.A., et al. *J Pediatr Orthop.* 13: pp. 722-726, 1993.

Does Rectus Femoris Contracture Affect Stance-Phase Hip Function? J.R. Linskill, S.F. Fairgrieve, The Dundee Gait Lab, Dundee, Scotland

A previous study¹ has shown correlations between clinical measures and dynamic gait variables for patients with spastic diplegia. Intersubject variability was removed, using intrasubject asymmetry to investigate the relationship between clinical measures and dynamic gait variables, with patients being sub-grouped according to their dynamic sagittal plane pelvic tilt.

Using this technique a correlation ($r=0.89$, $p<0.04$, $n=5$) was found between the following variables, for subjects with a difference in pelvic tilt at mid-stance greater than 5° :

- 1) Asymmetry in pelvic tilt at mid-stance,
- 2) Asymmetry in contracture of the rectus femoris (measured in prone lying).

A case study is presented of an individual, taken from this study group, who had significant contracture and spasticity of the rectus femoris. The patient, a ten year old spastic diplegic, was given stretching programme for the rectus femoris as part of his routine therapy.

The contracture was reduced by approximately 15° during this period of treatment. The gait data shows a significant increase in hip extension in terminal stance following the stretching programme.