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Effect of Single Event Multilevel Soft Tissue Surgery on Gait Parameters in Spastic Diplegia

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Abstract

Locomotion in subjects with Cerebral Palsy is complicated by a variety of deformities and their respective compensatory mechanisms. Children presenting with cerebral diplegia have reduced range of motion in their joints, short stride length, and increase in the energy requirement during standing and walking. In this study instrumented gait analysis data of 14 subjects with cerebral diplegia, prior to intervention was compared with data from similar analysis after multilevel soft tissue surgery and rehabilitation. Following intervention there was an increase in the range of motion in the hip and knee joints; stride length, single limb support and reduction in the energy cost of ambulation. Statistically significant differences were noted only for the stride length data (p=0.004). Overall the gait was improved by multilevel soft tissue surgery, as there was an increase in the degrees of freedom of movement in the kinetic chain.

Key words: **Spastic Diplegia, instrumented gait analysis, gait parameters, single event multiple soft tissue surgery**

Introduction

Cerebral palsy is a condition characterized by aberrant control of skeletal muscles leading to deviations in posture and gait patterns.

As the body moves along in space, the theoretical center of gravity which is normally just anterior to the second sacral vertebral body, moves along a sinusoidal curve with minimum displacement in both the vertical and the horizontal planes. When the determinants of normal human gait are abnormal, compensatory mechanisms come into play. The greater the compensation required, greater is the energy cost of ambulation.

The walking cycle is used to describe the events in ambulation.[1] Evaluation of children with cerebral palsy requires recording of events at the hip, knee, and ankle joints in the saggital plane. Excessive femoral anteversion can cause malrotation at the hip [2] (pseudo-adduction) leading to compensatory changes in the proximal and the distal joints.

Three theories proposed for this are: The persistent fetal alignment [3] caused by the lax ligament of Bigelow which fails to derotate the progressive ante-version as the child starts weight bearing. Spasticity of the hip flexors and adductors, restricting the femoral head from extending fully against the ligament of Bigelow, and the domination of the internal rotators of the femur, adductors of the hip and the medial hamstrings over their antagonistic muscles causes a torsional stress which leads to a torsional deformity over time. [4] Excessive anteversion of femoral head leads to external tibial torsion and pes-valgus in the foot. Since stability in a valgus foot is reduced the patient is unable to generate adequate extensor moment for extension of the knee in the latter part of stance leading to a crouch.[5]

The quadriceps works to stabilize the knee mainly in the first 20% of the stance phase. The plantar flexor- knee extensor couple produced by the powerful gastrosoleus muscle achieves subsequent stability.

Excessive knee flexion during stance phase leads to displacement of the ground reaction force (GRF) posterior to the knee joint generating a flexor moment rather than an extensor moment. To resist this moment, an internal muscle moment needs to be generated by the contraction of the quadriceps throughout stance. Other compensations that keep the centre of mass over the base of support are flexion at the hip, which displaces the GRF in front of the hip joint balanced by the generation of a large internal muscle moment by the hip extensors. In normal subjects walking with a self selected speed, much of the power is generated by the gastrosoleus muscle in the terminal stance phase of their gait.[6] In persons with central motor dysfunction there is poor distal voluntary control and thus much of the force

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for limb advancement is usually contributed by the "pull off" by the hip flexors, and limb stability is achieved by power generation by the hip extensors.

In a normal person, walking and movement provides all the stretch that is needed to add sarcomeres at the musculotendinous unit. [7] Chronic spastic paralysis of a muscle leads to shortening of the musculotendinous units. These processes contribute to deformities and the internal muscle moment generation as a compensatory mechanism increases the energy requirement as well as the excessive loading of the hip and knee joints during standing and walking.

Single event multilevel soft tissue surgery for spasticity control [8] is one of the options for reducing the deformities. Following surgery, muscle strengthening exercises and orthotic devices are used to improve ambulation.

Objectives

To determine the changes in the gait parameters of persons with Spastic Diplegia, after single event multilevel soft tissue surgical intervention and progressive training for ambulation.

Materials and Methods

Design: Retrospective data from instrumented (Selspot & Phase Space Motion Capturing Systems, Motion Lab EMG System and Kistler force plate) gait analysis of children with spastic diplegia prior to, and following intervention.

Inclusion criteria: Fourteen subjects diagnosed to have spastic diplegia who underwent gait analysis at self selected walking speed prior to, and following intervention.

Intervention: (i) Single event multilevel selective spasticity control surgery: psoas and adductor longus tenotomy and gracillis myotomy at the hip; fractional lengthening of the medial and lateral hamstrings and tenotomy of the semitendinosus muscle at the knee and Hoke's lengthening for the Tendo Achilles at the ankle as indicated by clinical evaluation, Gait Analysis and examination under anaesthesia. (ii) Comprehensive rehabilitation with occupational therapy, physiotherapy and specific tone inhibiting orthoses as indicated for each patient

Repeat gait analysis was done once independent ambulation was achieved.

Outcome measures: Stride length, single limb support, range of movement at the Hip, range of movement at the knee and physiological cost index

Statistical analysis: Paired t test was used for continuous normally distributed data and Wilcoxon's signed rank test was used for the skewed data.

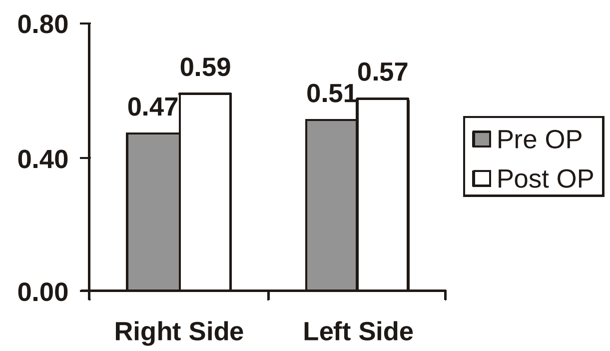
Results

Fourteen patients fulfilled the inclusion criteria (11 males, 3 females). The details are presented in Table 1.The mean age at the time of intervention was 8 years. The mean time to gait analysis following surgery was 2 years. The mean difference in the outcome measures is depicted from Figures 1 to 4. There was an increase in the range of motion in the hip and knee joints, stride length, single limb support and reduction in the physiological cost index. Statistically significant differences were noted only for the stride length data (p=0.004).

Table 1 : Patient Details

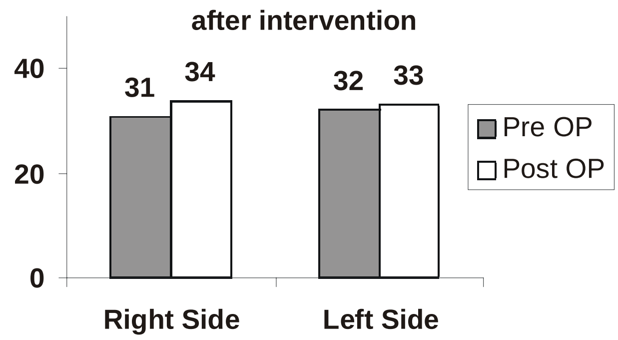
Patient No	Age at Intervention (years)	Gender	Diagnosis	Gait Analysis - Pre Intervention	Intervention Date	Gait Analysis - Post Intervention
1	13	Male	Diplegia	09-08-1999	13-10-1999	05-06-2002
2	6	Male	Diplegia	17-09-1999	12-10-1999	05-06-2001
3	3	Male	Diplegia	22-12-1999	19-01-2000	10-10-2000
4	3	Male	Diplegia	17-03-2000	22-03-2000	16-07-2002
5	7	Male	Diplegia	22-03-2000	29-03-2000	30-10-2001
6	4	Male	Diplegia	18-12-2000	13-06-2001	16-03-2004
7	6	Female	Diplegia	20-04-2001	08-05-2002	06-03-2006
8	8	Male	Diplegia	10-05-2001	15-05-2002	01-04-2003
9	6	Male	Diplegia	31-05-2001	21-06-2001	27-05-2002
10	8	Female	Diplegia	19-08-2002	21-08-2002	15-09-2004
11	8	Male	Diplegia	13-09-2002	18-09-2002	11-03-2004
12	11	Female	Tetraplegia	28-11-2002	04-12-2002	17-11-2003
13	11	Male	Diplegia	19-05-2003	11-06-2003	06-05-2004
14	7	Male	Diplegia	12-06-2004	16-06-2004	22-05-2006

Stride Length Normalised by Height before and after intervention



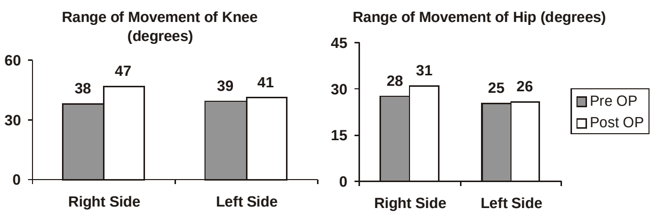
There was significant improvement (p=0.004) in the stride length normalized by height, after the intervention.

Single Limb Support (%) before and after intervention



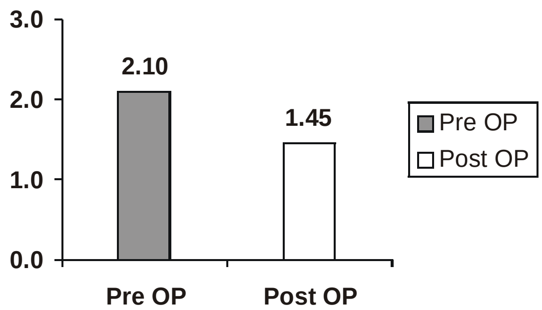
Single limb support increased on the left and right side following intervention but the changes observed were not statistically significant.

Range of movement of the hip and the knee before and after intervention



There was an increase in the range of motion in both the hip and the knee joints, however this increase was not statistically significant.

Physiological cost index before and after the intervention



The physiological cost index was calculated by measuring the difference in maximal heart rate after walking 25m from resting heart rate divided by the walking speed. There was reduction in the Physiological cost index after the intervention but the change was not statistically significant. ($p = 0.432$)

Discussion

Subjects with central motor dysfunction often demonstrate decreased walking speed, decreased stride length, and increased energy consumption. Early comprehensive rehabilitation helps to correct or prevent progression of the fixed structural deformities in the musculoskeletal system. This in turn leads to better ambulation and greater independence in carrying out activities of daily living.

Single event, multilevel selective spasticity control surgery helps in increasing the effective length of the musculotendinous unit and thereby resets the existing tone in that specific muscle which in turn causes general reduction in the irradiation of afferents in the spinal cord helping overall reduction of spasticity.

This study supports the benefit of multiple soft tissue releases in these subjects, as there was significant improvement in their stride length and marginal improvement in the other outcome measures. The possible explanation for the increase in stride length but not hip and knee range of motion is that the small, insignificant changes in the hip and knee range of motion added up to a significant change in the stride length. Another possible explanation is that in this study pelvic rotations in the saggital plane were not measured and the change in the stride length may have been largely due to pelvic compensations. (The pelvic measurements were only possible after we upgraded our equipment.) Single limb support increased on the left and right side following intervention, suggesting some improvement in balance and voluntary control in the lower limbs as also evidenced by the drop in the physiological cost index post operatively. These results were not statistically significant because of the small population studied. Though all of the subjects were diagnosed to have cerebral diplegia, they had variable degrees of spasticity, deformities, and voluntary control and therefore the group was not completely homogenous. Measurement errors [10] from inconsistencies in the placement of the LED markers over bony prominence of the subjects could have affected the reliability of joint angle measurements. This was however minimised by evaluating the range of motion at the joint instead of the peak values. The outcome in a particular patient depends not only on the surgery done but also on the effectiveness of therapy and compliance of the subjects in the use of orthoses. These interventions were not controlled in the study and so may explain the lack of significant change in some of the gait parameters.

Further studies are needed with larger, more homogenous sample sizes and with controlled rehabilitation programs to study the effectiveness of single event multilevel soft tissue surgery in children with spastic diplegia.

Conclusion

There was significant increase in stride length after single event multilevel soft tissue surgery in children with spastic diplegia. There was an increase in the individual range of motion at the hip and knee joints, single limb support and the physiological cost index of walking. However these changes were not statistically significant.

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