Changes in Energy Use Following Multilevel Surgery for Children with CP

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Introduction: The gait patterns of patients with cerebral palsy (CP) are typically characterized by 1) crouch and/or stiffness in the sagittal plane 2) bony torsional deformity in the transverse plane and 3) foot related problems. Orthopaedic surgery is expected to increase the energy efficiency of walking in this population. Dahlback et al [1] evaluated the effect of corrective surgery on energy expenditure during ambulation on a treadmill in six children with CP. A 5% reduction in oxygen consumption/kg was reported at 4-6 months status post soft tissue elongations or transpositions. Nene et al [2] evaluated 18 children with spastic diplegia who underwent multiple operations for crouched gait. Fourteen of eighteen patients had a reduction of their physiologic cost index (PCI), which has been shown to correlate with oxygen consumption [3]. Those with high preoperative PCI had the greatest reduction. The purpose of this study is to evaluate whether there are significant changes in oxygen consumption (VO_2) and energy cost of walking (EO_2) following multiple simultaneous surgical interventions on patients with CP.

Statement of Clinical Significance: Improved energy efficiency is a significant goal of orthopaedic treatment of children with CP. Predicting those patients who can be expected to increase or decrease energy efficiency following multilevel surgery could improve the treatment decision-making process.

Methodology: We evaluated twenty-two subjects (13 male, 9 female) with spastic CP (12 diplegia, 9 hemiplegia, 1 triplegia) an average of 5.2±3.7 months before and 12.3±5.7 months after multiple soft tissue and/or bony procedures. Severity of involvement was rated using the Gross Motor Function Classification System for Cerebral Palsy [4]. Average age at surgery was 12.0±3.1 years. VO_2 was evaluated using a standardized protocol with a metabolic cart (Vmax 29, Sensormedics, Yorba Linda, CA) using dilution mode testing on a 28m track. Time per lap was recorded to calculate average walking speed. Patients were asked to sit at rest for 3-5 minutes, walk for up to 10 minutes until a 3-minute steady state VO_2 could be determined, and then sit at rest for 3-5 minutes for recovery. Mean VO_2 (ml/kg/min) was recorded during the initial resting phase and during steady state walking. EO_2 (ml/kg/m) was calculated using the average walking speed. Each patient additionally had a complete gait analysis including examination of passive range of motion and measurement of kinematics and kinetics using a motion capture system (Vicon 370, Oxford Metrics, Oxford, UK). A standard lower extremity marker set was applied and kinematics and kinetics were calculated using biomechanics software (Vicon Clinical Manager v. 1.37, Oxford Metrics, Oxford, UK). Paired student's t-tests were used to compare selected clinical examination, anthropometric, energy use, spatial temporal, and kinematic data recorded for the patients before and after surgery. Pearson product moment ratio was used to evaluate correlation of factors to change in VO_2 and EO_2. $P<0.05$ was considered a significant finding for all statistical tests.

Results: Results are shown in Table 1. Magnitude of change in VO_2 was poorly correlated to change in speed ($r = -0.11$), cadence ($r = -0.03$), age at time of surgery ($r = 0.06$), number of procedures performed ($r=0.07$), or change in mean knee flexion in stance ($r = -0.20$) following surgery. We were unable to demonstrate differences between groups due to GMFCS level for VO_2 (ANOVA, p=0.65) or EO_2 (ANOVA, p=0.42). EO_2 decreased in 12 subjects and increased in 9 subjects following surgery. These groups could be differentiated by changes in speed and foot progresssion angle, but not by GMFCS level (p=0.55), age at time of surgery (p=0.87), number of procedures performed (p=0.13) or mean knee flexion in stance (p=0.54). The number of joints involved in surgical correction tended to be higher for those who had increased EO_2. 71% of those with surgery at 3 joints increased EO_2, while 73% of those with surgery on only 1 joint decreased EO_2. 78% of those who increased their EO_2 also had bony derotations, while only 17% of those who decreased their EO_2 had derotations.

Table 1: Changes in select parameters following surgery

	Preop	Postop
Height (cm)	139±18.7	145.3±17.3*
Weight (kg)	35.6±15.2	41.1±14.4*
Oxygen consumption – resting (ml/kg/min)	5.8±1.2	5.1±1.5*
Oxygen consumption – walking (ml/kg/min)	17.7±4.5	14.0±3.9*
Energy cost of walking (ml/kg/m)	.411±.155	.380±.170
Walking speed (m/min)	45.9±9.8	39.5±9.6*
Cadence (steps/min)	119.3±24.0	109.8±20.1*
Swing range of knee motion (degrees)	32.7±16.1	41.6±15.8*

* significant difference pre to post, p<0.05, mean ± standard deviation shown

Discussion: In typically developing children, VO_2 and EO_2 of walking at a given speed decrease as the child ages [5,6]. Children with CP typically increase their rate of energy expense with age [7]. In this study we found that 19 of 22 children with CP (86%) decreased their VO_2 by an average of 19% in the year following surgery. Thus, most children improved their energy use following surgery, meeting one of the goals of surgical intervention. We were not able to identify specific factors that predicted the magnitude of improvement in energy use. The number of joint levels involved in surgical correction and the inclusion of concomitant femoral or tibial derotation along with multilevel soft tissue surgery were characteristics that occurred more frequently in those who increased their EO_2, although these differences were not statistically significant. This does not necessarily represent causality but does highlight areas to investigate more thoroughly. This suggests that it may be more difficult for patients to improve their preoperative status following surgical correction at multiple levels including bony derotation than from single level surgery.

References

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