Michael Schwartz, Ph.D., is director of bioengineering at Gillette Children's Specialty Healthcare since 1991 as a member of Pediatric Rehabilitation Medicine. Schwartz received his bachelor’s degree and his doctorate degree from the University of Minnesota in Minneapolis. Schwartz has a special interest in assessing outcomes in three key areas:

- Orthopaedic and Rhizotomy: Patients had orthopaedic and rhizotomy surgery.
- Rhizotomy: Patients had rhizotomy surgery only.
- Orthopaedic: Patients underwent orthopaedic surgery only, including bony procedures (correcting lever-arm dysfunction) and soft tissue procedures (lengthening short musculotendinous units and transferring spastic rectus femoris muscles).

Each subject of Gillette’s study has been diagnosed with the spastic diplegia subtype of cerebral palsy. We separated the study subjects into three treatment groups, we ignored any surgery or gait analysis performed before the study period. In each case, the answer is yes, according to a new retrospective study of 154 ambulatory children with cerebral palsy treated at Gillette’s Center for Gait and Motion Analysis. Of those, we reviewed 669 potential participants from the patient database spanning the past decade, the evolution of computerized motion analysis technology also guides treatment decisions regarding dorsal rhizotomy surgery to reduce muscle spasticity.

Nevertheless, the field has needed more objective data assessing outcomes in three key areas:

- Does surgical intervention significantly improve gait and function in children with spastic diplegic cerebral palsy?
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In each case, the answer is yes, according to a new retrospective study of 154 ambulatory children with cerebral palsy treated at Gillette’s Center for Gait and Motion Analysis. The study was published in an upcoming issue of Pediatric Orthopaedics, indicates that surgical intervention — guided by prospective (pre-op) gait analysis — is effective and safe for the vast majority of children with cerebral palsy.

Numerous other studies have reported outcomes of specific orthopaedic procedures. The Gillette study, however, assessed general trends in outcomes resulting from Gillette’s multidisciplinary treatment philosophy — which includes performing single-event multidisciplinary surgery to improve gait. Gillette surgeons use comprehensive pre-op gait analysis to plan treatments, followed by post-operative (pos-op) gait analysis to assess outcomes.

During the past decade, the evolution of computerized motion analysis has markedly altered treatment for cerebral palsy. For example, surgeons who use motion analysis to plan treatments for gait issues are significantly more likely to perform single-event multidisciplinary procedures simultaneously. These simultaneous procedures — known as single-event multilevel surgery — reduce a patient’s need for multiple surgeries and periods of rehabilitation. Increasingly, motion analysis technology also guides treatment decisions regarding dorsal rhizotomy surgery to reduce muscle spasticity.

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Oxygen Measures
The study used several measurement tools to bridge the gap between technical and functional outcome assessment.

- Normacy: Normacy (NI) to assess global gait pathology as compared to gait in people without disabilities. NI is a single number that measures how much an individual's movement pattern deviates from that of typically developing children. Up to 10 key measurements taken during a computerized gait analysis.

Community Function
On Gillette's Functional Assessment Questionnaire, the entire sample showed a modest, but not statistically significant, improvement of +0.4 levels. Within the Orthopaedic subgroup, however, an improvement of +0.5 levels reached statistical significance.

Clear Benefits
The benefits of treatment are clear in all three groups.

Orthopaedic + Rhizotomy
The Orthopaedic + Rhizotomy group showed the greatest overall improvement—a 36-percent improvement in NI, a 25-percent decrease in O2 consumption and a one-level improvement in walking function. The group also added or improved on 45 percent of higher functional skills.

Conclusions
For those patients who didn't show clinically significant improvement with any type of treatment, the study indicates that this subgroup benefited from all treatments. Second, some of the subjects in this group were not surgery candidates because they had poor post-op. A patient's treatment group proved to be a statistically significant factor in determining the percentage of post-op technical outcomes (rather than group averages) when assessing the skills that were added, lost or unchanged (Figure 3). The results indicate that this subgroup benefited from all components of Gillette's treatment philosophy for patients with spastic-diplegic cerebral palsy, including pre-op gait analysis and pre-op plans, surgical multilevel bone deformity correction, surgical spasticity reduction, functional outcome measures, and the consistent assessment of comprehensive gait analysis in making post-op technical assessments.

Safety Assessment
In order to determine the safety of oxygen consumption measurements, we compared the ratio of the subject's O2 consumption to average consumption of at least 18 children at the same velocity. As with NI, pre- and post-treatment changes in normalized O2 consumption were statistically significant for the entire sample. The study showed a 25-percent overall improvement (measured as a decrease) in O2 consumption, with improvements in individual groups as noted in Figure 2.

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The vast majority of patients (77 percent) showed clinically significant improvement on more measures than not (number of measures improved-number of measures worsened > 1). For those patients who didn't show clinically significant improvement, the level of worsening was low. Only two patients lapsed on three measures, and none lapsed on all four measures. This indicates that treatments not only were effective, but had a high level of safety.

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Oxygen Measures

This study used several measurement tools to bridge the gap between technical and functional outcomes. The Normalcy Index (NI) assesses gait pathology as compared to gait in people without disabilities. NI is a single number that measures how much an individual’s movement pattern deviates from that of typically developing children. A score of 0 (i.e., no deviations) is considered normal gait. Oxygen consumption (O2) measures normalcy for walking speed, to assess a subject’s energy expenditure and gait efficiency (see Figure 2).

Study Groups

Study groups were defined as follows:

- Orthopaedic
- Orthopaedic + Rhizotomy
- Rhizotomy

The efficacy of the study was reported as follows:

- Average improvement of 27 percent (Figure 1).
- 82 percent of patients showed an improved NI, with an average improvement of +0.4 levels. Within the Orthopaedic subgroup, however, an improvement of ≤5 levels reached statistical significance.
- The highest levels assessment was 50 percent improvement in Orthopaedic + Rhizotomy group. This represented a modest, but not statistically significant, improvement of +0.4 levels. Within the Orthopaedic subgroup, however, an improvement of ≤5 levels reached statistical significance.

Community Function

Group Functional Assessment Questionnaire showed the entire sample showed a modest, but not statistically significant, improvement of +0.4 levels. The Orthopaedic subgroup, however, an improvement of ≤5 levels reached statistical significance.

Conclusion

To our knowledge, this study is the largest of its kind to date. It focused only on pediatric outcomes in ambulatory children with spastic-diplegic cerebral palsy. Nevertheless, it often significant evidence that intervention with gait analysis has a favorable risk-benefit ratio, with a low rate of functional decline. The improvement seen in both groups and across each measure demonstrates the value of Gillette’s comprehensive approach to technical and functional assessments of outcomes.

Safety Assessment

Safety assessment was also conducted. In the Orthopaedic subgroup, some patients had orthopaedic surgery. Others might have had orthopaedic surgery, but they haven’t completed their rehabilitation to be seen for post-op gait analysis. This group is therefore viewed as an intermediate group for the purposes of this study. Nevertheless, the group showed measurable improvements in all three outcome measures, including the highest percentage of additional higher-level functional skills.

Study Limitations

Because subjects varied in age and functional walking abilities, it’s difficult to extrapolate the study’s findings to all patient groups with spastic-diplegia cerebral palsy. Nevertheless, the results show that the vast majority of patients (77 percent) showed clinically significant improvement on more measures than not (number of measures improved - number of measures worsened ≠ 0). For those patients who didn’t show clinically significant improvement, the level of worsening was low. Only two patients lagged on three or more measures, and none lagged on all four measures. This indicates that treatments not only were effective, but also had a high level of safety.

Clear Benefits

The benefits of treatment are clear in all three groups. Orthopaedic + Rhizotomy offers the highest benefit, with statistically significant changes in gait pathology for children with spastic-diplegic cerebral palsy, including:

- Surgical spasticity reduction
- Surgical multilevel bone deformity correction
- Surgical spasticity reduction

The third, based on patient reports, is functional. Gillette’s Functional Assessment Questionnaire, which the entire sample showed a modest, but not statistically significant, improvement of +0.4 levels. Within the Orthopaedic subgroup, however, an improvement of ≤5 levels reached statistical significance.

On Gillette’s Functional Assessment Questionnaire, the entire sample showed a modest, but not statistically significant, improvement of +0.4 levels. Within the Orthopaedic subgroup, however, an improvement of ≤5 levels reached statistical significance.

In reviewing the data, it’s important to look at individual improvements — a gain or loss of one walking level, and a decrease in O2 consumption, with improvements in many measures noted as in Figure 2. Further study is needed to determine whether the short-term benefits found in the study were lasting.

In addition, distracting study subjects into treatment subgroup didn’t show that the patients received only one type of treatment. Ethical considerations make it difficult to deny treatments that might benefit any individual patient — notwithstanding the study’s objectives.

Study Results

The study showed improvements in each treatment subgroup and across all measures. We found statistically significant improvements in a predominance of measures, thus providing evidence that surgery — following the diagnostic use of gait analysis — produces improvements in both technical and functional outcomes.

NI

When comparing pre- and post-treatment results, the NI showed statistically significant changes in gait pathology for the entire sample and for each treatment group. Overall, 113 patients (42 percent) showed an improved NI, with an average improvement of 27 percent (Figure 1).
Orthopaedic + Rhizotomy

Oxygen Measures
The study used several measurement tools to bridge the gap between technical and functional outcome assessments.

- Normacy of NI (NI) to assess global gait pathology as compared to gait in people without disabilities. NI is a single number that measures how much an individual’s movement pattern deviates from that of typically developing children. It’s based on 16 key measurements taken during the gait cycle of the subject to avoid any bias related to the developmental age at which children normally acquire the skills.

The first two measurements, taken during comprehensive gait analyses in the motion analysis centers at Gillette, are important: technical and functional outcomes. The third, based on patient reports, is functional.

Safety Assessment
In reviewing the data, it’s important to look at individual outcomes (rather than group averages) when assessing the safety of treatment. To assess the safety of treatment, we focused only on pediatric outcomes in ambulatory children with spastic-diplegic cerebral palsy. Nevertheless, it often significant evidence that treatment guided by pre-op gait analysis has a favorable risk-to-benefit ratio, with a low rate of functional decline. The improvement shown in each group and across each measure demonstrates the value of Gillette’s comprehensive approach to technical and functional assessments of outcomes.

Treatment for cerebral palsy isn’t a cure. Regardless of the success of surgical interventions, patients continue to have residual pathology, and there is still room to optimize treatment and control. Consumption of O2 decreased significantly after correcting lever-arm dysfunction alone.

Two factors may explain the lower level of improvement in the Orthopaedic subgroup. First, some of the subjects in this group aren’t good candidates for rhizotomy surgery because of tone problems. Those who question the value of gait analysis point to the variability of data generated and treatments recommended at motion-analysis labs. Resulting data varied from center to center, as did resulting treatment recommendations.

At Gillette’s Center for Gait and Motion Analysis, we have developed a method for dynamically calibrating each patient’s gait data, greatly reducing variability in the available data.

Community Function
This group's Functional Assessment Questionnaire, consisting of 67 items designed to evaluate walking ability, was used to assess a subject's energy expenditure and gait efficiency (see Figure 2). The higher-levels skills assessment measured 18 skills that assess a subject's energy expenditure and gait efficiency. The results indicate that this subgroup benefited from all components of Gillette’s treatment philosophy. Consumption of O2 decreased significantly after correcting lever-arm dysfunction alone.
Michael Schwartz, Ph.D. is director of bioengineering. Tom Novacheck, M.D. is a pediatric orthopaedic surgeon who has practiced at Gillette Children's Specialty Healthcare since 1991 as a member of Pediatric Orthopaedic Associates, P.A. Novacheck graduated from the University of Wisconsin-Madison Medical School. He completed his orthopaedic residency at Pennsylvania State University and his pediatric orthopaedic fellowship at Newington Children's Hospital in Newington, Conn. He is director of Gillette's Center for Gait and Motion Analysis. Novacheck treats children who have central palsy and scoliosis or other complex orthopedic conditions.

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By Tom Novacheck, M.D., and Michael Schwartz, Ph.D.

During the past decade, the evolution of computerized motion analysis has markedly affected treatment for cerebral palsy. For example, surgeons who use motion analysis to plan treatments for gait issues are significantly more willing to perform single-event multilevel surgery — reduce a patient’s need for multiple surgeries and periods of rehabilitation. Increasingly, motion analysis technology also guides treatment decisions regarding selective dorsal rhizotomy surgery to reduce muscle spasticity.

Nevertheless, the field has needed more objective data assessing outcomes in three key areas:

• Does surgical intervention significantly improve gait and function in children with spastic diplegic cerebral palsy?

• Does evidence support the use of pre-surgical gait analysis to guide treatment planning?

• Does evidence support the use of post-surgical gait analysis to accurately assess the technical outcomes of treatment?

In each case, the answer is yes, according to a new retrospective study of 152 ambulatory children with cerebral palsy treated at Gillette Children's Specialty Healthcare in St. Paul, Minn. The study was to be published in an upcoming issue of Pediatric Orthopaedics, indicates that surgical intervention — guided by preoperative (pre-op) gait analysis — is effective and safe for the vast majority of children with cerebral palsy.

Numerous other studies have reported outcomes of specific orthopaedic procedures. The Gillette study, however, assessed general trends in outcomes resulting from Gillette's multidisciplinary treatment philosophy — which includes performing single-event multilevel surgery to improve gait.

Gait surgeons use comprehensive pre-op gait analysis to plan treatments, followed by postoperative (post-op) gait analysis to assess outcomes.

Methodology

Each subject of Gillette's study has been diagnosed with the spastic diplegia subtype of cerebral palsy. We initially reviewed 671 potential participants from the patient database of Gillette's Center for Gait and Motion Analysis. Of those, we chose 155 based on the following criteria:

• The subject had undergone comprehensive pre-op and post-op clinical three-dimensional gait analysis at Gillette between January 1994 and January 2002. Limiting the time period ensured the use of consistent technological procedures, the existence of consistent underlying biomechanical models, and the availability of functional questionnaires for assessing outcomes.

• The subject's pre-op gait analysis had taken place no more than 18 months before surgery, and post-op gait analysis had occurred eight to 24 months following the subject's final surgery.

Because of their transient nature, localized spasticity-reduction treatments (such as botulinum toxin injections) weren't factors for inclusion in or exclusion from the study.

We separated the study subjects into three treatment groups, reflecting the type(s) of surgery they had between their pre-op and post-op gait analyses.

Orthopaedic: Patients underwent orthopaedic surgery only, including bony procedures (correcting lever-arm dysfunctions) and soft tissue procedures (lengthening short musculotendinous units and transferring spastic rectus femoris muscles).

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Referral Information

Gillette accepts referrals from physicians, community professionals and outside agencies. Contact the admitting manager at the number listed below. Physicians who are on staff may admit patients through our Admitting department from 7 a.m. to 4:30 p.m. Physicians who aren't on staff should contact the admitting manager.

Admitting Manager
651-225-6341
Infant and Toddler Program
651-225-3917

Admitting
651-225-3914
Orthopaedic Program
651-225-3915
Brain and Spinal-Cord Injury Program
651-225-3951
Neuromuscular Program
651-225-3916

Adolescent Program
651-225-3914
Orthopaedic Program
651-225-3878
Orthopaedic Program
651-225-3915
Spina Bifida Program
651-225-3978

Central Palsy
651-225-3914
Spina Bifida Program/ Spina Bifida/ Upper Extremities Program
651-225-3978

Genitourinary Program
651-225-3914
Orthopaedic Program
651-225-3916
Cerebral Palsy
651-225-3914

A conference registration brochure will be mailed in January. For more information, visit our Web site at www.gillettechildrens.org or call Susan Ellerbusch, program manager of Gillette's Center for Pediatric Rehabilitation, at 651-229-3915 or 800-719-4040.

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Children With Cerebral Palsy
Motion Analysis Guides Multidisciplinary Treatment

by Tom Novacheck, M.D., and Michael Schwartz, Ph.D.

Methodology

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