Can Clinical Gait Analysis Guide the Management of Ambulant Children With Bilateral Spastic Cerebral Palsy?

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Background: The role of clinical gait analysis in the management of ambulant children with bilateral spastic cerebral palsy (BSCP) is controversial. We hypothesized that gait analysis would allow us to differentiate between children with BSCP who would benefit from surgical intervention and those in whom surgery was not indicated.

Methods: We reviewed the outcome in 3 groups of children with BSCP referred for treatment recommendations based on gait analysis by looking at changes in the popliteal angle (PA), Gillette Gait Index (GGI), and minimum knee flexion in single support (MKFS) on a subsequent gait analysis. We identified 15 children in whom surgical intervention was not thought to be needed (SNR group) and 15 children who had multilevel surgery recommended but not performed (SND group). We randomly selected and reviewed 15 children referred during the study period who had multilevel surgery recommended and performed following gait analysis (OP group) for comparison.

Results: The initial PA, MKFS, and GGI were greater in the OP and SND groups compared with the SNR group. Popliteal angle did not change between analyses in the SNR and SND groups and decreased in the OP group ($P = 0.004$). Minimum knee flexion in single support remained similar between analyses in the SNR group, increased in the SND group ($P < 0.0001$), and decreased in the OP group ($P < 0.0001$). The GGI remained similar in the SNR and SND groups but decreased in the OP group ($P = 0.0002$). The number of children in the SND group showing an increase of more than 10% in the GGI between analyses (8/15) was greater than that in the OP group (0/15) ($P = 0.0022$). The PA, MKFS, and GGI contributed significantly to the treatment recommendations ($P = 0.0013$, $P = 0.0045$, $P = 0.0054$, respectively), which were not affected by age and Gross Motor Functional Classification System level.

Conclusions: Gait analysis helped us to distinguish children with BSCP who would benefit from surgery from those in whom non-operative management was appropriate, and its routine clinical use is encouraged in the management of these children.

Level of Evidence: Level III, retrospective comparative study.

Key Words: cerebral palsy, surgery, gait analysis


The role of clinical gait analysis in the management of children with cerebral palsy (CP) is controversial, with little evidence that the information provided by gait analysis leads to an improved functional outcome from surgical intervention.1 Noonan et al found marked variability in the kinematic data obtained from 11 ambulatory children with spastic CP assessed in 4 treatment centers and suggested that this variability contributed to the variation in treatment recommendations between the centers for 3 of the 11 children assessed. These concerns would not necessarily have been allayed if the data between the centers had been consistent, as variability in treatment recommendations based on the same gait data has been shown between different centers.2 Cuomo et al have recently shown improvements in motor function in ambulatory children with CP after multilevel surgery based on clinical indications: their study does not seem to use gait analysis. Do we need clinical gait analysis in the management of ambulant children with CP?

Ambulant children with CP represent a heterogeneous group with varying levels of function and a variable long-term prognosis for mobility. Ambulant children with hemiplegic CP, for example, have better gait and lower extremity function compared with children with diplegic CP within the same Gross Motor Functional Classification System (GMFCS) level.3 Children with diplegia, in particular, represent a variable group, with no clear distinction between diplegia and quadriplegia. Colver and Sethumadhavan noted that the percentage of children with bilateral spastic CP (BSCP) described as having diplegia ranges from 39% to 86% in different population studies, suggesting that children in some centers described as having diplegic CP may in other centers be described as having quadriplegic CP. Because of this, the use of the terms unilateral or bilateral CP together with a functional description such as the GMFCS level has been recommended.4-8

This variability in classification may explain the variation in surgical philosophy between different centers and the lack of clear agreement in the literature on the timing of surgery.9 The natural history of mobility of ambulant children with BSCP is one of deterioration,10,11 but this is likely to mask individual variation. The functional goal of surgical intervention is likely to depend on the level of mobility and likely prognosis of each child: for some children with BSCP, surgical intervention may be aimed at improving a near-normal gait, whereas for other children, surgical intervention may be aimed at maintaining a limited level of ambulation. The ability to define which children are likely to have a deterioration in their level of mobility with time and which children are likely to have an improvement or remain stable would be helpful in planning treatment. The GMFCS theoretically enables prediction of a child’s future functional level, but variations in the GMFCS level of a child12 and in their level of mobility within a particular GMFCS level13 have been reported in longitudinal studies, limiting its use in...
treatment planning. Clinical assessment can be helpful in predicting outcome, but the limited correlation between measures of deformity and function needs to be considered.

Clinical gait analysis provides data that, in combination with the history, clinical examination, and other data sources can help with the formulation of a treatment plan. We hypothesized that gait analysis would help to appropriately identify ambulant children with BSCP in whom surgery was indicated and those for whom surgery was not indicated. The ideal way to investigate this would be to consider a randomized controlled clinical trial, but this poses ethical difficulties as most young children are referred for consideration of surgical intervention because of a perceived failure of nonoperative management, and randomizing them into what may be seen, in the absence of an alternative, as treatment and nontreatment groups may not be acceptable to the families or the referring clinicians. We instead reviewed the outcome in 3 groups of 15 ambulant children with BSCP who were referred for gait analysis: a group for whom multilevel surgery was not thought to be indicated, a group for whom surgery was recommended but not performed, and a group for whom surgery was recommended and performed.

METHODS

Our unit provides treatment and assessment facilities for children with CP in close collaboration with community teams. Children are referred for gait analysis and subsequent operative or nonoperative treatment recommendations and are followed up with repeat gait analysis. A review of the children seen over the last 5 years identified a total of 15 ambulant children with BSCP in whom multilevel surgical intervention (defined as at least 2 surgical procedures on each of the lower limbs) had been recommended following gait analysis but not performed because of a decision by the family or local team (surgery recommended but not done [SND] group) and a second (coincidental) total of 15 children with BSCP in whom surgical intervention was not thought to be indicated on the basis of gait analysis (surgery not recommended [SNR] group). A third group of 15 children with BSCP in whom multilevel surgery had been recommended and performed (operation performed [OP] group) was randomly selected from the other children seen during this period. We did not have any cases for whom surgical intervention had not been recommended following gait analysis but had been performed. All of the children were under regular review by pediatric physiotherapists and pediatricians.

The children had 2 gait analyses performed by the same team following the same protocol, which included a clinical history and examination, recording of video and electromyographic data, and the collection of 3-dimensional motion and force-plate data using a Vicon optical motion capture system (Vicon, Oxford, UK). Although an interval of a year or more between gait analyses is usual, we brought 4 children from the SNR group and 4 from the SND group back earlier than a year for a repeat analysis because of clinical perception of an alteration in their gait. At each analysis, the children walked at a self-selected speed either independently or using assistive devices as preferred, and a minimum of 4 walking trials were collected for each child. All of the treatment recommendations were made by the same orthopaedic surgeon, following review of the data with a clinical engineer and pediatric physiotherapist. All of the surgical procedures were performed in our unit.

The variables reviewed included age, GMFCS level, and popliteal angle (PA). Because of the interdependency of lower limb joint movement when walking, we retrospectively calculated the Gillette Gait Index (GGI) for each child. This uses multivariate analysis to derive a single figure from 16 variables including motion data and normalized velocity, with a greater GGI value being interpreted as a greater variation from normal gait. The GGI has been used to describe the outcome of multilevel surgery in children with diplegia, with an improvement or deterioration of more than 10% of the preoperative value after intervention considered as significant, and seems to be consistent between individual gait laboratories, and has been recommended for use as a global outcome measure of gait analysis in children with CP. The values for the able-bodied and reference groups in our calculations of the GGI were similar to published values. We also looked at minimum knee flexion in stance (MKFS) because this is not explicitly included in the GGI and seems to influence the support moment in the lower limbs.20

| TABLE 1. Comparison of Groups at Initial Analysis |
|---------------------------------|-------------------|-----------------|-----------|
|                                 | SNR               | SND             | OP        | P*       |
| Females/males                   | 9:6               | 10:1            | 11:5      | 0.116†   |
| Mean age, y                     | 8.7 (7.0–10.5)‡   | 10.1 (8.8–11.5)‡| 7.5 (6.7–10.9)§| 0.264∥   |
| GMFCS level I/II/III/IV         | 4:1:1:1           | 4:2:0:0         | 0:1:3:0:0 | 0.027∥   |
| PA, degrees                     | 56 (53–60)‡       | 65 (61–70)§     | 69 (60–70)§| 0.0001∥  |
| Minimum knee flexion in stance, degrees | 5 (2–9)‡ | 24 (15–30)§ | 26 (22–31)‡ | <0.0001∥ |
| Gillette gait index             | 286 (195–377)†    | 1079 (710–1449)§ | 1353 (961–1745) | <0.0001∥ |
| No. procedures recommended      | 10 (9.7–10.8)†    | 7 (4.5–7.5)§    | 1.69 (1.44–1.94)‡ | 0.0032|| |
| Interval between analyses, y    | 1.05 (0.925–1.5)§ | 1.16 (1.00–1.32)‡ | 1.69 (1.44–1.94)‡ | 0.534#   |

*See text for discussion of post hoc analyses.
†Fisher exact test.
‡Mean (95% CI).
§Median (interquartile range).
¶Kruskal-Wallis test, Dunn multiple comparison test (see text for further results).
‖Analysis of variance, Tukey-Kramer post hoc test (see text for further results).
#Mann-Whitney U test.
Statistical analysis was performed using GraphPad Prism version 4.00 for Macintosh (GraphPad Software, San Diego, Calif; www.graphpad.com). The Shapiro-Wilk test was used to assess whether individual data sets were taken from a normal distribution: groups were then compared using an analysis of variance or Kruskal-Wallis test as appropriate. Paired data were compared using Student t test or the Wilcoxon matched-pairs signed rank test. Fisher exact test was used to compare categories and Spearman test to investigate correlation. The effects of variables on a dichotomous outcome (surgery recommended or not) were assessed using logistic regression. Effect sizes are given with Hedges correction for small sample sizes.21 The study was approved by the hospital research ethics committee and used retrospective anonymized data that had been collected during routine clinical management.

## RESULTS

The groups are compared in Table 1. There was no significant difference in age or sex between the groups at their initial analysis. There was a difference in GMFCS levels, which was due to differences between the SNR and OP, with higher GMFCS levels in the SNR group (P < 0.05, Dunn test). The PA differed between groups, with Dunn test showing a difference between the SNR and SND groups (P < 0.01) and between the SNR and OP groups (P < 0.001), with a greater PA measured in those children for whom surgery was recommended. The MKFS also differed between groups, with Dunn test showing a difference between the SNR and SND groups (P < 0.001) and between the SNR and OP groups (P < 0.001), as did the GGI, with the Tukey-Kramer test showing differences in the GGI between the SNR and SND groups (P < 0.01) and between the SNR and OP groups (P < 0.001). When the OP and SND groups were combined and compared with the SNR group, they were more likely to have had no operative intervention before gait analysis (P = 0.0108, Fisher exact test) and, in particular, to have had previous botulinum toxin A injections (P = 0.0008, Fisher exact test). For all of the children assessed, there was a weak correlation between GMFCS level and GGI (Spearman ρ = 0.459, P = 0.0015) and between the PA and GGI (ρ = 0.348, P = 0.0008). A similar number of operative procedures were recommended for the children in the SND and OP groups. When the SND and OP groups were combined into a single group in whom surgery had been recommended, their PA, MKFS, and GGI differed markedly from the SNR group (P < 0.00001, effect size = 1.3321; P < 0.00001, effect size = 1.77; and P < 0.00001, effect size = 1.8, respectively).

The groups differed in their interval between gait analyses, with Dunn test showing a difference between the SNR and OP groups (P < 0.05) and between the SND and OP groups (P < 0.01), with a longer interval in the OP group. Of the 8 children who had a repeat analysis after an interval of less than a year, 3 from the SNR group and 1 from the SND group showed an improvement of more than 10% in the GGI between analyses, whereas 1 child from the SNR group and 3 children from the SND group showed a deterioration of more than 10% in their GGI between analyses, suggesting that clinically relevant changes in their gait had occurred. The children in the SNR group did not have intervention in addition to their usual physiotherapy program between analyses, but 3 of the children in the SND group worked at an additional exercise program in the interval between analyses.

There was no change in GMFCS level between analyses in the SNR group. In the SND group, 12 children had the same GMFCS level, and 3 children decreased by 1 level between analyses. In the OP group, 9 children had the same GMFCS level, 2 had decreased by 1 level, and 4 had improved by 1 level between analyses. The changes in PA, MKFS, and GGI in each group are shown in Table 2. The variables measured in the SNR group did not change between analyses. The SND group showed a significant increase in PA and MKFS, whereas the OP group showed a significant improvement in PA, MKFS, and GGI. A change of 10% in GGI has been taken as clinically significant.22 On this basis, 7 children improved, 4 remained stable, and 4 deteriorated between analyses in the SNR group. In the SND group, 6 children improved, 1 remained stable, and 8 deteriorated. In the OP group, 12 children improved, and 3 remained stable between analyses. The number of children showing a deterioration of more than 10% in the SND group between analyses was greater than that in the OP group (P = 0.0022, Fisher exact test).

Logistic regression analysis showed that age and GMFCS level did not seem to influence the decision to recommend surgery (P = 0.451 and P = 0.116, respectively). Treatment recommendations were, however, significantly influenced by PA (P = 0.0013; odds ratio [OR], 1.36; 95% confidence interval [CI], 1.13–1.64) and MKFS (P < 0.0045; OR, 1.53; 95% CI, 1.14–2.04). The GGI was calculated retrospectively but was significantly associated with the choice of treatment (P = 0.0054; OR, 1.007; 95% CI, 1.0019–1.0112), suggesting that the gait data used to calculate the GGI also influenced the treatment recommendations.

## DISCUSSION

Clinical gait analysis seems to help distinguish between ambulant children with BSCP who have a relatively stable gait pattern and those who would benefit from surgical intervention because of an increased risk of deterioration in their gait. Would it have been possible to define these groups without gait analysis?
The decision to recommend surgery did not seem to have been influenced by age or GMFCS level, but was influenced by the PA and by the MKFS. The significant retrospective association of the GGI with the treatment recommendations on logistic regression suggests that the 16 gait variables that were used to calculate the GGI also contributed to the treatment decision at the time. The OR for MKFS was higher than that for PA, suggesting that the contribution of MKFS to the treatment decision was greater than that of PA. The ORs seem small but refer to the OR per change in unit variable: for the GGI, the large values involved would result in correspondingly large ORs. When children for whom surgery was recommended are compared with those in whom it was not recommended, the effect sizes for MKFS and GGI are larger than those calculated for PA, again suggesting that although clinical examination data contributed to the treatment recommendation, its contribution was less than that of the gait data.

There are limitations to the study such as the limited number of cases assessed. Retrospective power calculations were not performed because of the inherent limitations, but large effect sizes were noted. The OP group had a longer interval between analyses, but the shorter interval in the SND group is likely, if anything, to underestimate the deterioration noted in that time. The treatments recommended are likely to reflect the philosophy of our unit as well as the severity of involvement of the children that we see, and the degree to which the results can be generalized may be limited because of this. Our recommendations may have been biased by the referral letter for each child, which in some cases outlined a provisional treatment plan, although the results of the logistic regression analysis indicate that our recommendations were significantly influenced by the gait and clinical data available from the gait analysis session.

Two of the children in the operative group showed a deterioration in their GMFCS grade by 1 level between analyses without a clinically relevant alteration in their GGI. This is likely to reflect differences between the GGI and GMFCS. The GGI is an objective measure derived from data obtained on a specific occasion as the child walked in a well-lit unobstructed room at a self-selected speed, allowing time for rest as needed. The GMFCS level was obtained from discussion with the family and reflects the cumulative day-to-day function of the child, which may be influenced by child-specific factors such as fatigue and motivation and by environmental factors such as accessibility to buildings and the need to be mobile within the community while minimizing energy expenditure. This does not call into question the validity of the GGI as long as it is remembered that it may represent a child’s gait in an ideal setting on a specific occasion.

The GGI improved between analyses in 6 children in the SND group and deteriorated between analyses in 4 children in the SNR group, raising concern about the predictive ability of a single gait analysis or the predictive ability of the GGI. Our treatment philosophy is likely to have evolved over the course of the study in response to the increasing number of follow-up gait analyses, so there may have been differences in treatment recommendations made at the start and end of the study period on similar patterns of gait and associated data. This may explain some of the variability. In practice, however, a range of factors is likely to influence outcome including child-specific factors such as motivation, muscle strength and selective motor control, local factors such as the type and frequency of physiotherapy support in the community between analyses, and factors related to intervention such as the surgeon involved, the postoperative rehabilitation program, and the preoperative and postoperative discussions with the child and family.

The ability of serial gait analysis to provide more accurate information about the natural history of mobility of a specific child suggests that the clinical role of gait analysis should be expanded beyond that of preoperative planning and postoperative follow-up. The influence of MKFS on treatment recommendations and its potential sensitivity to change as seen in the SND group where a significant change in MKFS was noted between analyses without a significant change in the GGI raise the possibility of developing a less extensive and perhaps less expensive model of 3-dimensional gait analysis looking particularly at knee motion that could be used in a clinical setting where observational gait analysis may not have the necessary discriminative power. The findings of this study do not discount or overlook the concerns raised about the variability of gait data, which will need to be addressed. The findings, however, do support the use of clinical gait analysis to explore the variable natural history and response to treatment of ambulant children with BSCP to enable us to continue to develop our management of this challenging and vulnerable group of children.

REFERENCES


