The Gross Motor Function Classification System for Cerebral Palsy: a study of reliability and stability over time

Ellen Wood* MD MSc FRCP(C), Assistant Professor, Department of Pediatrics, Dalhousie University, Halifax, Nova Scotia;
Peter Rosenbaum MD FRCP(C), Professor, Department of Pediatrics, McMaster University, Hamilton, Ontario, Canada.

**Correspondence to first author at* IWK Grace Health Centre, 5850/5980 University Avenue, PO Box 3070, Halifax, Nova Scotia, Canada B3J 3G9.
E-mail: ewood@is.dal.ca

Children with cerebral palsy (CP) experience a change in motor function with age and development. It is important to consider this expected change in offering a prognosis, or in assessing differences in motor function after an intervention. The Gross Motor Function Classification System for CP (GMFCS) has been developed for these purposes. This study was based on a retrospective chart review of 85 children with CP followed from ≤2 to ≥12 years of age. The GMFCS was applied to clinical notes by two blinded raters four times throughout the study. Interrater reliability was high (G=0.93). Test–retest reliability was high (G=0.79). The positive predictive value of the GMFCS at 1 to 2 years of age to predict walking by age 12 years was 0.74. The negative predictive value was 0.90. The GMFCS can validly predict motor function for children with CP. The results are discussed in terms of their implications for clinical practice and future research.

Cerebral palsy (CP) refers to a group of non-progressive disorders of the development of motor function affecting movement and posture (Bax 1964). CP is caused either by a developmental abnormality of, or an injury to, the immature brain. The incidence of CP is 1.5 to 2.5 per 1000 live births (Aicardi 1992). Although this is a chronic disorder, little is known about the patterns of motor development in children with CP. Many interventions are recommended to the child and their family by many different health professionals, yet there is an absence of objective data to demonstrate that ultimate motor function is improved by these interventions. Without a clear understanding of the natural history of motor development in CP, it is difficult to assess the impact of interventions beyond that improvement in motor function which would have occurred due to normal growth and development; however, the amount of 'natural' change is not well understood.

Many authors have suggested prognostication systems based on a constellation of clinical features to predict eventual motor function, especially independent ambulation. Bleck (1975) and Capute (1979) looked at the presence or absence of seven primitive reflexes to diagnose CP, predict independent walking, and plan interventions. However, neither of these authors reported any reliability or validity data for their criteria. Other authors have examined whether independent sitting by age 2 years would predict later walking ability. Molnar and Gordon (1974) found it was a poor predictor, whereas Watt et al. (1989) reported that independent floor sitting by age 2 years predicted walking by age 8 years for 46 out of 47 children with CP. Based on the lack of clear prognostic information in the literature, it is currently not possible to predict reliably the expected functional motor outcome.

Attempts have also been made to classify the severity of CP using systems based on the quality of the tone and/or movement disorder (e.g. spastic, hypotonic, athetoid), the pattern of involvement (e.g. diplegia, hemiplegia), or the child's current function with regard to head and/or trunk control, independent sitting, ambulation, etc. Yokochi et al. (1993) used a three-level system of mild, moderate, and severe. Parrot et al. (1992) reported a five-point scale. Neither of these groups has reported any reliability data on their scales. Without a reliable, consistent system to classify severity it is difficult to compare research on interventions. It is impossible to be certain that the control and experimental groups are similar, and to ensure that the children in one study can be compared with those in another.

To address these challenges the Gross Motor Function Classification System (GMFCS) (Palisano et al. 1997) was developed to provide an objective classification of the patterns of motor disability in children with CP. The GMFCS was first conceptualised using data collected by the Gross Motor Function Measure (GMFM) (Russell et al. 1989), and was later consensually validated by Palisano et al. (1997) using Delphi Survey methodology. The GMFCS objectively classifies a child's current gross motor function. The focus is on the child's self-initiated movement, with particular emphasis on function in sitting and walking. Function is divided into five levels: children in Level I have the most independent motor function and children in Level V have the least. Distinctions between the levels are thought to be clinically meaningful, and are based on functional abilities and limitations. Each level of the GMFCS provides functional descriptions for four

age bands: 1 to 2, 2 to 4, 4 to 6, and 6 to 12 years. Table I shows the level of gross motor function that a child is expected to achieve between age 6 and 12 years for each of the five levels. Evidence amassed during the creation and field-testing of the GMFCS (Palisano et al. 1997) led us to believe the scale would be useful as both a prognostic and stratification system.

Before the GMFCS can be used for either clinical or research purposes, it must be shown that a child with CP tracks at the same GMFCS level throughout childhood (i.e. that the classification level is stable, and that there is good interrater reliability during use of the measure). The purposes of this study were: (1) to measure the interrater reliability of the GMFCS, (2) to assess the stability over time of a child's GMFCS level, and (3) to determine the predictive validity and likelihood ratios of the GMFCS in predicting walking in children with CP.

Method

This study was carried out as a retrospective chart review. All charts of children with CP attending a southern Ontario regional children's rehabilitation centre, who were at least 12 years old at the time of the study, were reviewed by a senior pediatric physiotherapist. To be included in the study, children had to have been diagnosed with CP by a developmental pediatrician and assessed at the rehabilitation centre by a physician or therapist between the ages of 2 to 4 (Time 2), 4 to 6 (Time 3), and 6 to 12 (Time 4) years of age. Information from assessments at age 1 to 2 (Time 1) years was included if available. Children were to be excluded if they had undergone neurosurgical interventions (selective dorsal rhizotomy, intrathecal baclofen pump) or botulinum toxin A injections, as the impact of these procedures on the natural history of motor development is unknown.

A computer search of the treatment centre caseload identified 244 children over 12 years of age with CP. Eighty-five charts met the inclusion criteria, of these 78 also had Time 1 data. The distribution of these children by GMFCS levels for the Time 4 classification (age 6 to 12 years) by each rater is shown in Table II. Table III shows the mean age and age range of children for each time period, divided into two groups based on whether the raters agreed or disagreed on the GMFCS level for that time period.

The most detailed clinical reports of gross motor function from age 1 to 2 (Time 1, if available), 2 to 4 (Time 2), 4 to 6 (Time 3), and 6 to 12 years (Time 4) were selected by one of the authors (EW). A clinical record was selected as close to age 12 years as possible for the Time 4 status. All identifying data on each report, apart from the child's age, were removed. Each clinical report was classified on the GMFCS by a developmental pediatrician (PR) and a senior pediatric physiotherapist. The raters were blinded to the identity of the child, as well as the GMFCS level assigned by either of them to each child at other time points. A table of results was constructed with six to eight scores per child, one from each rater for each time period available.

Interrater reliability was calculated as a generalisability (G) coefficient (Cronbach et al. 1972, Streiner and Norman 1995). Stability of the GMFCS level over time was considered analogous to test–retest reliability and was also calculated as a G coefficient. Positive and negative predictive values were

Table I: Description of gross motor function for children aged 6 to 12 years by GMFCS level (Palisano et al. 1997)

Level	*Expected gross motor function between age 6 and 12 y*
I	Children walk indoors and outdoors, and climb stairs without limitations. Children perform gross motor skills including running and jumping, but speed, balance, and coordination are reduced.
II	Children walk indoors and outdoors, and climb stairs holding onto a rail, but experience limitations walking on uneven surfaces and inclines, and walking in crowds or confined spaces. Children have at best only minimal ability to perform gross motor skills such as running and jumping.
III	Children walk indoors or outdoors on a level surface with an assistive mobility device. Children may climb stairs holding onto a rail. Depending on upper-limb function, children propel a wheelchair manually or are transported (pushed by another person) when travelling for long distances or outdoors on uneven terrain.
IV	Children may maintain levels of function achieved before age 6 years or rely more on wheeled mobility at home, school, and in the community. Children may achieve self-mobility using a powered wheelchair.
V	Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. Children have no means of independent mobility and are transported (pushed by another person). Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

Table II: Time 4 GMFCS level for each rater

Rater	*GMFCS levels*				
	I	*II*	*III*	*IV*	*V*
1	15	9	23	20	18
2	14	15	18	23	15

Table III: Mean age and age range of children for each time period according to rater agreement on the GMFCS level

	Time period			
	1	*2*	*3*	*4*
Agreed[a] (*n*)	55	69	68	67
Mean	17.6 mo	3.2 y	5.2 y	10.4 y
Median	17 mo	3.2 y	5.2 y	11.0 y
Range	(12–23 mo)	(2.2–3.9 y)	(4.3–5.9 y)	(6.3–12.0 y)
Disagreed[a] (*n*)	23	16	17	18
Mean	16.3 mo	3.0 y	5.1 y	10.3 y
Median	15 mo	2.9 y	5.0 y	11.0 y
Range	(12–23 mo)	(2.2–3.9 y)	(4.6–5.8 y)	(6.8–12.0 y)

[a] No significant difference in age distributions between 'agreed' and 'disagreed' groups.

calculated by collapsing the data into multiple 2 × 2 tables and using the levels from earlier time periods to predict ambulation at 6 to 12 years of age. As described below, varying definitions of ambulation were used to explore the predictive validity of the GMFCS.

Likelihood ratios were calculated to express the odds that a child would ambulate at age 6 to 12 years of age for any given level of the GMFCS at each of the earlier time periods. There are two advantages to using likelihood ratios: firstly, likelihood ratios can be calculated for all five levels of the GMFCS without having to combine them into only two levels; and secondly, the likelihood ratio does not change with the prevalence of the condition in the population.

Results

Seven children did not have Time 1 data. To calculate a G coefficient, all subjects must have complete data. As the children with missing data were distributed across levels at Time 4, the missing data were assigned the mean classification value for that child at the other three time periods. The interrater reliability was 0.93. Test–retest reliability over all time periods was 0.79. Test–retest reliability from Time 1 to Time 4 was 0.68, Time 2 to Time 4 was 0.82, and Time 3 to Time 4 was 0.87.

Table IV: Time 1 versus Time 4 GMFCS level

GMFCS at	*GMFCS at Time 4*				
Time 1	*I*	*II*	*III*	*IV*	*V*
I	4	1	1	1	–
II	5	7	9	2	–
III	2	1	5	7	2
IV	2	–	4	9	9
V	–	–	1	1	5

Table V: Time 2 versus Time 4 GMFCS level

GMFCS at	*GMFCS at Time 4*				
Time 2	*I*	*II*	*III*	*IV*	*V*
I	9	3	1	1	–
II	5	3	9	1	–
III	1	3	11	4	1
IV	–	–	2	13	5
V	–	–	–	1	12

Table VI: Time 3 versus Time 4 GMFCS level

GMFCS at	*GMFCS at Time 4*				
Time 3	*I*	*II*	*III*	*IV*	*V*
I	11	4	1	1	–
II	4	1	3	–	–
III	–	4	15	3	–
IV	–	–	4	14	6
V	–	–	–	2	12

Predictive values for ambulation were calculated by comparing the GMFCS level from earlier time periods to the GMFCS level at Time 4. As interrater reliability was high (G=0.93), this was done using scores from only one rater. Table IV shows the GMFCS levels for Time 1 versus Time 4, Table V for Time 2 versus Time 4, and Table VI for Time 3 versus Time 4.

To calculate predictive values the data must be collapsed into a 2×2 table. By age 12 years, children in Level I and II are community walkers, children in Level III walk indoors but use wheeled mobility in the community, and children in Levels IV and V are unable to walk functionally (Table I). The children in Level III can therefore be added either to children in Levels I and II (walking at least indoors) or to children in Levels IV and V (wheeled mobility at least in the community). When Level III is added to Levels I/II at Time 1 the positive predictive value of any ability to walk is 0.74. That is, a child whose function is classified at Levels I, II, or III at age 1 to 2 years, will be able to walk, at least indoors, by age 6 to 12 years with a predictive value of 0.74. The negative predictive value is 0.77. If Level III is added to Levels IV/V at Time 1 the positive predictive value is 0.57. The negative predictive value (requiring wheeled mobility at any time) is 0.90. That is, a child whose function is classified at Level III, IV, or V at age 1 to 2 years, will have a 90% probability of requiring wheeled mobility, at least in the community, at age 6 to 12 years (Table VII).

Positive and negative predictive values were calculated for Times 2 and 3 to Time 4 in a similar manner (Table VII).

Likelihood ratios can also be calculated using data from the same tables (Tables IV to VI). One advantage of likelihood ratios is that they can be calculated for varying levels of

Table VII: Positive and negative predictive value of GMFCS

Time periods	*Level III combined with*	
	I and II	*IV and V*
Time 1 to 4		
Positive predictive value	0.74	0.57
Negative predictive value	0.77	0.90
Time 2 to 4		
Positive predictive value	0.87	0.62
Negative predictive value	0.94	0.92
Time 3 to 4		
Positive predictive value	0.91	0.80
Negative predictive value	0.89	0.93

Table VIII: Likelihood of walking (GMFCS I, II, III) at age 6 to 12 years (Time 4) by GMFCS level at Times 1, 2, and 3

GMFCS level	*Time*		
	1	*2*	*3*
I	5.1	10.5	12.9
II	9.0	13.8	
III	0.8	2.4	5.1
IV	0.3	0.1	0.2
V	0.1	0	0

a diagnostic test or scale, although the outcome has to be a dichotomy, in this case walking (GMFCS Levels I, II, III) or non-walking (GMFCS Levels IV, V). The likelihood ratios for all time periods are shown in Table VIII. The likelihood that a child whose gross motor function is classified at GMFCS Level I, at less than 2 years of age (Time 1), will walk by 6 to 12 years of age, is 5.1:1. Similarly, a child less than 2 years of age with a GMFCS Level II has a likelihood of walking of 9.0:1. Children of this age at GMFCS Level III have a likelihood of walking of 0.8:1, 0.3:1 at GMFCS Level IV, and 0.1:1 at GMFCS Level V.

Discussion

The GMFCS for CP makes clinical sense as a way to describe motor activities of children with CP. That is, it has face validity. In randomised control trials for interventions in CP, the GMFCS could be used as a means of stratification to ensure that the control and experimental groups are matched, and to compare the long-term outcome of the experimental group to the expected natural improvement over time without intervention. The system could also be useful clinically to therapists and families. There is no other reliable method of prognostication for walking ability in children with CP.

The GMFCS has excellent interrater reliability (0.93). The GMFCS relies on important clinical information about children's usual (as opposed to best ever) gross motor function, which is routinely observed and documented in the assessment of children with CP. One does not have to obtain unusual or complicated information to use the system objectively to assess the severity of CP, nor is the GMFCS a 'test' or 'measure' requiring special skills or procedures. Thus, the GMFCS can be easily incorporated into routine clinical practice to assign a classification level to an individual child. The clinician can compare a child they are following with CP to other children followed by other clinicians, or reported in research trials, and be assured they are comparing children with similar functional severity of CP.

The GMFCS is relatively stable over time with an overall test–retest reliability of 0.79. This means that in general a child will stay at the same level of the GMFCS from age 1 to 2 years to age 6 to 12 years. More clinically relevant, however, is the predictive value. The positive predictive value measures the ability of the GMFCS to predict future walking in a young child.

Walking in CP is not a dichotomous outcome. When we use the GMFCS to answer a parent's question 'Will my child walk?', we must be certain what that parent considers 'walking'. Parents of young children may be more likely to consider any use of a wheelchair as 'not walking' whereas parents of an older child may consider any ability to walk, even indoors with assistive mobility aids, as 'walking'. The GMFCS will be useful clinically to predict outcome, plan rehabilitation programming, and counsel families regarding individual children. The child may be able to walk in all situations, may be a full-time wheelchair user, or may walk in certain situations and use wheeled mobility in others. Children classified at Level III are able to walk indoors, on a level surface, but use a wheelchair in the community. When children at Level III are considered as having the ability to walk, the positive predictive value of the GMFCS to predict at age 1 to 2 years walking ability at age 6 to 12 years is 0.74, at age 2 to 4 years is 0.87, and by 4 to 6 years is 0.91. If children at Level III are considered 'not able to walk', the predictive values are lower (0.57, 0.62, and 0.80 respectively).

The likelihood ratio will also be useful in predicting a child's potential ability to walk. The likelihood of a child walking at age 6 to 12 years can be calculated simply by knowing the child's GMFCS level and the age at which he/she was assessed. Another advantage of the likelihood ratio is the ability to combine it with the pretest probability of walking. If the child's probability of walking is known, or can be estimated, before the GMFCS is done (pretest probability), the likelihood ratio can be combined with the pretest probability to give the posttest probability (the pretest odds for the target disorder × the likelihood ratio for the diagnostic test result = the posttest odds for the target disorder). This calculation can be done for any pretest probability either mathematically (Sackett et al. 1991) or by using a nomogram (Fagan 1975).

The GMFCS will also be useful in research trials to determine if the long-term motor outcome has been altered beyond what would have been expected without the intervention, due to normal growth and development for children with that 'level' of CP. By knowing the children's expected outcome with current interventions, it will be possible to measure any change with an innovative intervention, and to determine if that change is more or less than expected. If a therapy is helpful it should improve a child's function, and over time the GMFCS level might change. For example, based on current knowledge of therapy effects, a child at Level IV at age 5 years would not be expected to walk, and at best may be able to use wheeled mobility independently by age 12 years. If an intervention is used, and the same child at age 12 years is walking independently (Level I or II), or even with assistive mobility aids (Level III), one could conclude that the intervention is beneficial as, by current predictions, that child would have had a very low likelihood of walking without the intervention. Some interventions may be harmful, and we could see a worsening of the GMFCS level over time. Others may only speed up the developmental process, so that a child reaches the same level of function at a younger age, but the final outcome is unaffected. Depending on the intervention (e.g. a new type of splint), this may be worthwhile. If the intervention has potential serious complications (e.g. neurosurgery) it may not be worthwhile.

These findings suggest that families and clinicians can now begin to predict the ultimate gross motor function of a child with CP with some reasonable degree of confidence. They can choose rationally between interventions tested on children with CP of the same age and severity as their child. Researchers can compare the results of their interventions with other interventions on children with the same level of CP. This has never before been possible, and is crucial if we are to use evidence-based medicine for children with CP.

The next step in assessing the stability of the GMFCS is a prospective cohort study, currently underway across Ontario. Applying the GMFCS systematically to a large randomly sampled population of children with CP, we are charting the gross motor progress of children in an effort to evaluate prospectively the predictive validity of the GMFCS. Data from this study will help to document further the usefulness of the classification system as a predictive instrument.

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References

Aicardi J. (1992) *Diseases of the Nervous System in Childhood. Clinics in Developmental Medicine No. 115/118.* London: Mac Keith Press.

Bax MCO. (1964) Terminology and classification of cerebral palsy. *Developmental Medicine & Child Neurology* **6:** 295–7.

Bleck EE. (1975) Locomotor prognosis in cerebral palsy. *Developmental Medicine & Child Neurology* **17:** 18–25.

Capute AJ. (1979) Identifying cerebral palsy in infancy through study of primitive-reflex profiles. *Pediatric Annals* **8:** 589–95.

Cronbach LJ, Gleser GC, Nanda H, Rajaratnam N. (1972) *The Dependability of Behavioral Measurements: Theory of Generalisability for Scores and Profiles.* New York: Wiley.

Fagan TJ. (1975) Nomogram for Bayes's Theorem. *New England Journal of Medicine* **293:** 257. (Letter.)

Molnar GE, Gordon SV. (1974) Predictive value of clinical signs for early prognostication of motor function in cerebral palsy. *Archives of Physical Medicine* **57:** 153–8.

Palisano RJ, Rosenbaum PL, Walters SD, Russell D, Wood E, Galuppi B. (1997) Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Developmental Medicine & Child Neurology* **39:** 214–23.

Parrot LC, Selley WG, Brooks WA, Lethbridge PC, Cole JJ, Flack FC, Ellis RE, Tripp JH. (1992) Dysphagia in cerebral palsy: a comparative study of the Exeter dysphagia assessment technique and a multidisciplinary assessment. *Dysphagia* **7:** 209–19.

Russell DJ, Rosenbaum PL, Cadman DT, Gowland C, Hardy S, Jarvis S. (1989) The gross motor function measure: a means to evaluate the effects of physical therapy. *Developmental Medicine & Child Neurology* **31:** 341–52.

Sackett DL, Haynes RB, Guyatt GH, Tugwell P. (1991) *Clinical Epidemiology: A Basic Science for Clinical Medicine.* Boston: Little, Brown and Company.

Streiner DL, Norman GR. (1995) *Health Measurement Scales: A Practical Guide to their Development and Use.* Oxford: Oxford University Press.

Watt JM, Robertson CM, Grace MGA. (1989) Early prognosis for ambulation of neonatal intensive care survivors with cerebral palsy. *Developmental Medicine & Child Neurology* **31:** 766–73.

Yokochi K, Shimabukuro S, Kodama M, Kodama K, Hosoe A. (1993) Motor function of infants with athetoid cerebral palsy. *Developmental Medicine & Child Neurology* **35:** 909–16.