Stability of the Gross Motor Function Classification System in children and adolescents with cerebral palsy: a retrospective cohort registry study

ANN ALRIKSSON-SCHMIDT[1,2] | EVA NORDMARK[3] | TOMASZ CZUBA[4] | LENA WESTBOM[2,5]

1 Department of Clinical Sciences, Orthopedics, Lund University, Lund; **2** Skåne University Hospital, Lund; **3** Department of Health Sciences, Lund University, Lund; **4** Epidemiology and Register Center South, Lund; **5** Department of Clinical Sciences, Paediatrics, Lund University, Lund, Sweden.

Correspondence to Ann Alriksson-Schmidt at Department of Clinical Sciences, Orthopedics, Lund University, Paradisgatan 5C, 221 85 Lund, Sweden. E-mail: ann.alriksson-schmidt@med.lu.se

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ABBREVIATIONS

CPUP	Cerebral Palsy Follow-Up Programme
GMFCS - E&R	Gross Motor Function Classification System - Expanded & Revised
USCP	Unilateral spastic cerebral palsy

AIM To investigate the stability and to determine factors that affect change in the Gross Motor Function Classification System (GMFCS) in a sample from the total population with cerebral palsy (CP) in two regions of Sweden.
METHOD Retrospective cohort registry study based on the follow-up programme for CP. Children with CP and a minimum of two GMFCS ratings were included. Subtype, sex, ages at GMFCS ratings, time between ratings, number of ratings, assessor change, and birth cohort were analysed in relation to initial GMFCS levels, with descriptive statistics and logistic regression models.
RESULTS Ninety-three per cent (n=736) of children with CP born between 1990 and 2007 were included, resulting in 7922 assessments between 1995 and 2014. Fifty-six per cent of the children received the same GMFCS rating at all assessments, with a median of 11 individual GMFCS ratings (range 2–21) and a median of three different assessors (range 1–10). Changes were often transient; downward change (higher performance) was more likely in GMFCS levels II and III than in the other levels. The probability of upward change (lower performance) was lowest in unilateral spastic CP.
INTERPRETATION The results support the stability of the GMFCS shown previously and add new information on the properties of the classification.

Cerebral palsy (CP) describes a heterogeneous permanent condition caused by non-progressive brain damage that occurs in utero or in early childhood.[1] Although CP manifests differently across individuals, the development of gross motor function and posture are affected and may result in activity limitations. Subtype classification is inadequate for prediction of functional development in CP, and of little use in studies on the natural development and treatment results in terms of functional changes.[2]

The Gross Motor Function Classification System (GMFCS) has facilitated research on functional changes, and provides objective classification of current gross motor function, but it should not be used as an outcome measure.[2–5] Distinctions among the five mutually exclusive levels are based on everyday functional performance, use of assistive technology, including hand-held mobility devices or wheeled mobility, and, to a lesser degree, the quality of movement.[4] The GMFCS Expanded & Revised (GMFCS - E&R) became available in 2007 and extended the age range to include 12- to 18-year-olds.[6] A high level of absolute agreement (96.8%) between the original and updated versions of the GMFCS has been shown.[7] Overall, the evidence supports that GMFCS levels remain stable over time,[4,8–12] although the stability of the GMFCS in infants younger than 2 years is lower than at older ages.[13]

For more than 20 years, children and adolescents with CP living in Sweden have participated in the Cerebral Palsy Follow-Up Programme (CPUP). In CPUP, well-established body structure indicators (e.g. Reimer's migration index, passive range of motion) are used to monitor progress over time; interventions are initiated if indicated.[14] The GMFCS was included in CPUP in 1995, and in 2009 it was replaced by the GMFCS - E&R. Because individuals are followed prospectively, a large longitudinal population-based data set with numerous GMFCS assessments per individual is available and was used in the current study.

The objectives were to: (1) investigate the stability of GMFCS (and GMFCS - E&R) ratings over time in a total population of children and adolescents with CP; (2) assess factors associated with the first change in GMFCS level; and (3) assess factors associated with the direction of change in GMFCS, meaning factors associated with a change in GMFCS level indicating higher or lower gross motor function.

METHODS

This was a retrospective cohort registry study based on data collected at clinical assessments in a population of children and adolescents with CP living in Sweden.

Study population

The eligible population comprised all children and young adults with CP born between 1990 and 2007, who lived in Skåne and Blekinge, Sweden, at some period between 1994 and January 1, 2014. Inclusion criteria were a confirmed diagnosis of CP by age 4 years, and a minimum of two GMFCS ratings recorded in CPUP from age 2 years. Ninety-three per cent of the total population with CP was included in the analyses. The inclusion flow chart is presented in Figure S1 (online supporting information).

Procedure

Following consent, CPUP participants were assessed at regular intervals by their occupational and/or physiotherapists (PTs) at their habilitation clinics as part of their regular clinical care. All children were recommended to be assessed twice a year before turning 7 years, and annually thereafter. In 2011, the assessment schedule changed such that those 7 years of age or older at GMFCS level I and Manual Ability Classification System level I were recommended to be assessed biannually. This study included all GMFCS assessments recorded from 1995 and onwards in children born in the area, as well as those children who moved into the catchment area during the study period, some as adolescents, and who received their first GMFCS rating then.

Variables

The following variables were recorded as continuous variables: age at each GMFCS rating (years); time between ratings (months); total number of ratings; and total number of assessor changes. Sex and change in assessor since previous rating ('yes' or 'no') were recorded dichotomously. Only data collected after the second birthday were included. CP and subtype of CP were classified according to the Surveillance of Cerebral Palsy in Europe network.[15] Syndromes associated with non-progressive brain anomalies and brain injuries before the child's second birthday were included if the child had motor disabilities fulfilling the CP-criteria. The gross motor function was determined using the GMFCS[2] or the GMFCS - E&R[5] (level I=the highest level of function, level V=the lowest level of function). GMFCS and GMFCS - E&R were collapsed into the term 'GMFCS', as they can be used interchangeably.[6] Because knowledge has increased and health care practices and treatments have changed over time, four different birth cohorts were coded (born 1990–1993, 1994–1997, 1998–2002, and 2003–2007).

Statistical methods

Descriptive statistics were analysed to characterize the study population and course of events during the follow-up period from 2 years of age to the last assessment before January 1, 2014. Stata (IC) version 13.1 (www.stata.com; StataCorp, College Station, TX, USA) was used for all statistical analyses and a significance level of 0.05 was used. For all analyses, random-effects logistic regression models were used (procedure 'xtlogit'), with the participant ID defining panels, and visit date defining the time structure in the model.[16–18]

What this paper adds

- Further evidence of the stability of the Gross Motor Function Classification System (GMFCS) in children with cerebral palsy.
- More than half of the children received the same GMFCS rating at all assessments.

Aims 1 and 2

To investigate the stability of GMFCS ratings over time, the outcome variable was defined as 0 if the rating was identical to the rating at the previous assessment (stable) and defined as 1 if the rating changed from the previous assessment (not stable; regardless of whether it changed to a higher or lower level). The analyses included the participants' assessments up to the visit when the first change in GMFCS level was recorded. After a change in GMFCS level occurred, the participant was considered 'not stable' irrespective of how the GMFCS ratings might have changed at future GMFCS measurements for that particular participant. Hence, the outcome variable could change only once for each participant. If a change in GMFCS rating did not occur (stable), all available GMFCS recordings were included in the analyses. Because of how the model was structured, with age at the assessment as a factor, the analyses also include the time interval from the first to the last assessment, which allowed us to assess what variables were associated with the stability of the GMFCS rating (stable vs not stable).

Aim 3

In aim 3, we were interested in investigating what specific factors were associated with the direction of change in GMFCS level (higher or lower gross motor function). To accomplish this, a new outcome variable was created, and the subsequent analysis was divided into two parts: (1) for the improved motor function (downward change), and (2) for decreased motor function (upward change). In the first part (downward change), the outcome variable was coded as 1 if the motor function improved (changed to a lower GMFCS rating) and 0 if it stayed the same or deteriorated (changed to a higher GMFCS rating). In the second part, the outcome variable was coded as 1 if the motor function decreased (changed to a higher GMFCS rating) and 0 if it stayed the same or improved (changed to a lower GMFCS rating). We included all available data points per participant and consequently the outcome variable could change multiple times for each participant. Using a random-effects logistic regression model enabled the identification of what specific factors were associated with change (increased versus decreased respectively) of the motor function on a

visit-to-visit basis. This procedure would not have been possible in a single logistic model because the outcome variable would have had to have three possible values (increased, the same, or decreased), which is not allowed in the model specification. All observations (*n*=7922) were included when assessing factors related to directional change – that is, whether GMFCS changed 'upwards' or 'downwards' between two assessments. It should be noted that the odds ratio for initial GMFCS levels I and V (for improved and decreased motor function respectively) are, in fact, the odds of changing back to level I or V. For example, a participant with an initial GMFCS level I must first change upward to GMFCS level II (or possibly higher) to be able to change back to GMFCS level I again, and the given odds in this example represent the odds of changing from GMFCS level II back to GMFCS level I in the next assessment.

The study was approved by the Ethics Board at Lund University (Institutional Review Board [IRB] LU 443-99, revised 2009 by LU IRB).

RESULTS

Ninety-three per cent of the total population with CP met the inclusion criteria. Characteristics of the total population (*n*=791), study participants (*n*=736), and non-participants (*n*=55) are shown in Table SI (online supporting information).

A total of 7922 assessments were included. The median number of GMFCS ratings per participant was 11 assessments (range 2–21). The distribution of the first GMFCS rating after turning 24 months, and the median age at the first and at the last rating, were as follows: GMFCS level I, *n*=317 (first 4y and last 14y 5mo); level II *n*=113 (first 3y 6mo and last 14y 10mo); level III *n*=104 (first 3y 7mo and last 15y 1mo); level IV *n*=90 (first 2y 8mo and last 13y 7mo), and level V *n*=112 (first 3y 4mo and last 13y 4mo). First GMFCS and age at first assessment are provided in Table SII (online supporting information).

Eighty-five (11.6%) of the participants had the same assessor at all assessments, meaning that the same PT performed all GMFCS ratings for the particular child. In 140 participants (19.0%), the child had two PTs performing the GMFCS ratings over time; 156 (21.2%) had three PTs; 121 (16.4%) had four PTs; 105 (14.3%) had five PTs; 64 (8.7%) had six PTs, and 65 (8.8%) had 7 to 10 PTs rate GMFCS levels over time. The distributions of number of assessments and number of assessors are shown in Figures S2 and S3 (online supporting information).

Of all 736 study participants, 409 (56%) received the same GMFCS rating at all assessments. Of the remaining participants, 327 (44%) changed GMFCS level at least once; the median number of changes in this group was two times (range 1–8, interquartile 1–3 changes).

First and last GMFCS ratings

In 542 (74%) of the participants, the last GMFCS level recorded was the same as the first, meaning that 133 of the participants, who had changed GMFCS level at least once, had returned to the first recorded GMFCS level at the end of the study period. Those with initial GMFCS levels II and III had the lowest proportions returning to the same GMFCS level (56% and 49% respectively), and children with unilateral spastic cerebral palsy (USCP) had the highest proportion (81%) of all subtypes rated at the same GMFCS level at the first and last assessments (Table I).

At the end of the study, 84 (11%) children and adolescents had a lower GMFCS (higher functional level) rating and 110 (15%) a higher GMFCS (lower functional level) than the level they were classified at initially; 16 of these

Table I: Comparison between the first (after second birthday) and last (before January 1, 2014) assessment of Gross Motor Function Classification System (GMFCS) level

	Stable GMFCS level, *n* (%)	Lower GMFCS level, more function, *n* (%)	Higher GMFCS level, less function, *n* (%)
GMFCS level at first assessment[a]			
I (*n*=317)	271 (85)	–	46[a] (15)
II (*n*=113)	63 (56)	31 (27)	19[b] (17)
III (*n*=104)	51 (49)	28[c] (27)	25[c] (24)
IV (*n*=90)	62 (69)	8[d] (9)	20 (22)
V (*n*=129)	112 (85)	17 (15)	–
CP subtype			
Unilateral spastic (*n*=221)	178 (80)	22 (10)	21[e] (10)
Bilateral spastic (*n*=297)	218 (73)	33[f] (11)	46[f] (15)
Ataxic (*n*=73)	44 (60)	11 (15)	18 (25)
Dyskinetic (*n*=137)	97 (71)	17[g] (12)	23[g] (17)
Mixed (*n*=8)	5	1	2
Sex			
Female (*n*=309)	224 (72)	39[h] (13)	46[h] (15)
Male (*n*=427)	318 (74)	45[i] (11)	64[i] (15)
Birth cohort			
1990–1993 (*n*=86)	142 (76)	19 (10)	25 (14)
1994–1997 (*n*=152)	116 (76)	13 (9)	23 (15)
1998–2002 (*n*=213)	156 (73)	26 (12)	31 (15)
2003–2007 (*n*=185)	128 (69)	26 (14)	31 (17)
Number of assessments			
Median; interquartile range; total range	11; 7–14; 2–21	11; 8–14; 3–20	12; 8–15; 2–20
Number of assessors			
Median; interquartile range; total range	3; 2–5; 1–10	4; 2–5; 1–10	4; 2–5; 1–9
Total study population (*n*=736)	542 (74)	84 (11)[k]	110 (15)[k]

For participants with two GMFCS level changes: [a]One child from level I–III; [b]Six children from level II–IV; [c]Seven children from level III–I, and one child to level V; [d]One child from level IV–II; [e]Four children with unilateral spastic CP plus two levels; [f]One child with bilateral spastic CP minus two and six children plus two levels; [g]One child with dyskinetic CP minus two, and one plus two levels; [h]Two females minus two and one plus two levels; [i]Six males minus two and seven plus two levels; [k]Eight children had two levels lower (improved function) and eight two levels higher (lower function) GMFCS level in the end of the study period than at start. CP, cerebral palsy.

(2.2%) had changed two levels, eight in each direction (Table I).

Change in GMFCS level over time

In total, 4933 of the 7922 GMFCS ratings were included in the analysis of a change (or no change at all) in GMFCS ratings over time. CP subtype, change in assessor since last assessment, time between assessments, sex, and birth cohort were not found to be significantly associated with change in GMFCS level. Initial GMFCS level was significantly associated with change in GMFCS rating (non-directional), as were age at first assessment, age at all GMFCS assessments, and number of assessments before first change. Odds ratios (ORs) are presented in Table SIII (online supporting information).

Direction of change in GMFCS level

All observations (n=7922) were included when assessing factors related to directional change, that is whether GMFCS changed 'upwards' (lower performance of gross motor function) or 'downwards' (higher performance of gross motor function) on the ordinal scale.

Upward change in GMFCS rating (lower performance of gross motor function)

Compared to GMFCS level III at the initial assessment, levels I and V were less likely to be associated with an upward change during the follow-up period. All other CP subtypes were more likely to be associated with upward change than USCP (specific ORs presented in Table II, mixed type was not significant). An upward change was more likely in the third and fourth birth cohorts born between 1998 and 2002, than the first cohort born between 1990 and 1993. Time between assessments was associated with an upward change. No significant associations were found for sex, change in assessor since last assessment, age at time of first GMFCS assessment, or age at all assessments (ORs presented in Table II).

Downward change in GMFCS rating (higher performance of gross motor function)

The ORs for downward change of GMFCS level were lower in children with initial GMFCS levels I, IV, and V than in GMFCS levels II and III at first assessment (ORs presented in Table II). Change in assessor since last assessment was also associated with downward change. The odds of downward change were 1.33 per assessor change. No significant associations with downward change were shown for any of the remaining variables (Table II).

Table II: Directional change in Gross Motor Function Classification System (GMFCS) levels during the entire follow-up period

	Upward change in GMFCS level			Downward change in GMFCS level		
	OR	SE	95% CI	OR	SE	95% CI
GMFCS level at first assessment[a] (III reference)						
I	0.63[b]	0.11	0.46, 0.88	0.25[d]	0.05	0.17, 0.36
II	1.23	0.20	0.90, 1.69	1.21	0.20	0.88, 1.66
IV	0.69	0.13	0.47, 1.01	0.63[c]	0.13	0.42, 0.95
V	0.24	0.06	0.14, 0.99	0.50[b]	0.11	0.32, 0.75
CP subtype (unilateral spastic CP reference)						
Bilateral spastic	1.91[d]	0.31	1.39, 2.63	0.97	0.17	0.70, 1.37
Ataxic	2.13[b]	0.46	1.39, 3.26	1.13	0.26	0.71, 1.79
Dyskinetic	2.43[d]	0.53	1.58, 3.73	0.97	0.23	0.61, 1.53
Mixed	2.28	1.26	0.77, 6.76	1.07	0.61	0.35, 3.24
Sex (female reference)						
Male	0.98	0.11	0.78, 1.21	0.91	0.11	0.72, 1.15
Birth cohort (1990–1993 reference)						
1994–1997	1.30	0.25	0.89, 1.91	1.14	0.24	0.75, 1.72
1998–2002	1.68[b]	0.32	1.16, 2.44	1.33	0.27	0.89, 1.98
2003–2007	2.11[b]	0.46	1.38, 3.24	1.43	0.33	0.91, 2.25
Change in assessor ('no' reference)						
Yes	0.96	0.12	0.75, 1.23	1.33[c]	0.17	1.05, 1.71
Time between assessments	1.34[c]	0.16	1.06, 1.69	1.18	0.16	0.91, 1.53
Age at time of first GMFCS rating[a]	1.01	0.02	0.98, 1.05	0.97	0.02	0.93, 1.00
Age at first change in GMFCS rating	0.99	0.03	0.99, 1.06	0.98	0.04	0.90, 1.05

An upward change in GMFCS rating indicates a change to a category that indicates lower performance of gross motor function, a downward change in GMFCS rating indicates a change to a category that indicates higher performance of gross motor function.
[a]After second birthday; [b]$p<0.01$; [c]$p<0.05$; [d]$p<0.001$. OR, odds ratio; SE, standard error; CI, confidence interval; CP, cerebral palsy.

DISCUSSION

We studied the stability of the GMFCS during a 20-year follow-up period in a sample derived from a known total population of children with CP. The GMFCS levels were classified by each child's physiotherapist as part of CPUP. Several findings reported by the developers of the GMFCS classification[10] were replicated, providing further evidence of the stability of the GMFCS. We also found associations between GMFCS stability and other variables not described previously.

The agreement between the first and last ratings of GMFCS level was 74% in our study. In the original *CanChild* study of GMFCS stability the corresponding figures were 76% and 83% for children younger and older than 6 years respectively.[10] The results from both studies thus support the stability of the GMFCS classification levels, and there were no sex differences. Even though we excluded assessments performed earlier than 2 years of age, which are known to be associated with less stable GMFCS ratings,[13] a lower proportion (56%) of children received the same GMFCS rating at all assessments in our study than in the *CanChild* study (73%).[10] Besides a different age span (24mo–20y vs 16mo–13y), our study included more GMFCS ratings per child (median 11 vs median 4 ratings), which help to clarify why a lower proportion of the study participants in our study received the same GMFCS level over time as there were more opportunities for exposure to reclassification.

Change of assessor since last assessment did not influence the odds of non-directional change in GMFCS level.

When all assessments were included, assessor change since previous assessment was associated with downward change in GMFCS level (higher function). This might imply that a new assessor rates more positively than an assessor who has worked with the child for a long time, and this may also be reflected in the lower probability of upward change of GMFCS in the first birth cohort, which was followed for some years before the introduction of the GMFCS. The CPUP began in 1994, before the existence of the GMFCS classification. Thus children in the first cohort were older at their first GMFCS assessment than the other cohorts. In terms of training of the assessors, workshops on the GMFCS have been provided over the years and there are manuals readily available. However, we do not know how carefully the assessors rate the GMFCS level and if they assess whether there might have been a change in GMFCS level from the previous assessment. Nevertheless, the overall study results support the high intra- and inter-rater reliability shown in previous studies.

That initial GMFCS levels I and V were least likely to change was to be expected because, by default, those at the extreme ends can only change in one direction.[10] It might seem counterintuitive to report ORs of upward change for those at level V and downward change for those at level I, as in this study. However, because it is possible for an initial level I to change to, for instance, level II, and then back to level I again (and vice versa for level V), this can produce odds for changing upwards and downwards even for initial levels I and V in the analyses of up- and downwards changes.

An additional finding was that children who function at GMFCS level I had lower probabilities of an upward change (lower gross motor function) than those at levels II to IV. This may be due to less paresis, muscle hypertonia, contractures, deformities and pain, and a low frequency of interventions with transient postoperative decline of function in children with the least disability (level I). Accordingly, the high rate and severity of such musculoskeletal problems in levels IV to V may explain the lower probabilities of downward change (higher gross motor function) than in less severe initial GMFCS levels.[19–21]

The probability of upward change in GMFCS level (to lower gross motor function) at any point during the study period was lower in USCP than in the other subtypes, irrespective of the GMFCS level and the additional variables included in the analysis. This might indicate that the GMFCS level is easier to assess in USCP, or it might imply a more stable gross motor function in USCP compared to the other subtypes.

The GMFCS was constructed to classify gross motor function in children and adolescents with CP, irrespective of type of CP, into separate, stable strata of gross motor function performance levels. However, some children function at the extreme ends of each functional level, and therefore the GMFCS level will be difficult to assess, explaining some of the changes reported.

As GMFCS is a classification system, the aim was not to study if it were possible to achieve substantial improvement of gross motor function from a lower to a higher gross motor performance level as classified by the GMFCS or if such an improvement would be sustainable over time. However, it may be worthwhile to study subgroups of individuals with seemingly permanent changes in GMFCS level, in terms of associations with comorbidities and major interventions.

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SUPPORTING INFORMATION

The following additional material may be found online:

Figure S1: Inclusion flow chart.

Figure S2: Distribution of number (*x*-axis) of GMFCS assessments per child (*y*-axis) in the 736 children.

Figure S3: Distribution of number (*x*-axis) of assessors per child (*y*-axis) in the 736 children.

Table SI: Characteristics of individuals with cerebral palsy born between 1990 and 2007 residing in Skåne and Blekinge, Sweden, at some period between 1994 and January 1, 2014

Table SII: First GMFCS and age at first assessment

Table SIII: Odds ratios of changing GMFCS level over time (minimum of one change)

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