**Article Title:**

Burke–Fahn–Marsden dystonia severity, Gross Motor, Manual Ability, and Communication Function Classification scales in childhood hyperkinetic movement disorders including cerebral palsy: a Rosetta Stone study

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**Running Title**: Linking impairment & function in childhood HMDs

**ABSTRACT**

**Aim**

Hyperkinetic movement disorders (HMD) can be assessed using impairment-based scales or functional classifications. The Burke-Fahn-Marsden Dystonia Rating Scale-Movement (BFM-M) evaluates dystonia impairment, but may not reflect functional ability. The Gross Motor Function Classification System (GMFCS), Manual Ability Classification System (MACS) and Communication Function Classification System (CFCS) are widely used in the cerebral palsy literature to classify functional ability.

We explore the concordance of these three functional scales in a large sample of paediatric HMDs and the impact of dystonia severity on these scales.

**Method**

Children with HMDs (n=161, median age 10y3mo, range 2y6mo-21y) were assessed using BFM-M, GMFCS, MACS and CFCS in 2007-2013. This cross-sectional study contrasts the information provided by these scales.

**Results**

All four scales were strongly associated (all rs>0.72, p<0.00001), with worse dystonia severity implying worse function. Secondary dystonias had worse dystonia and less function than primary dystonias (p<0.00001). A longer proportion of life lived before the onset of initial dystonia symptoms is associated with less severe dystonia (rs=0.42, p<0.00001).

**Interpretation**

BFM-M is strongly linked with GMFCS, MACS and CFCS, irrespective of aetiology. Each scale offers interrelated, but complementary information and was applicable to all aetiologies. Movement disorders including CP can be effectively evaluated using these scales.

**WHAT THIS PAPER ADDS**

* GMFCS, MACS and CFCS strongly associated in hyperkinetic movement disorders.
* Dystonia impairment shows strong association with all 3 functional scales.
* The scales relationships are consistent for CP and non-CP aetiologies.
* All aetiological groups share common patterns of impairment and function.
* Secondary dystonias have greater impairment and lower functional ability.

Hyperkinetic movement disorders (HMD) are defined by the Taskforce in Childhood Movement Disorders as any unwanted excess movement. They are characterised by excessive involuntary movements including dystonia, chorea, athetosis, and myoclonus arising from many aetiologies including congenital, acquired, neurodegenerative and genetic disorders**1**. The most common cause of HMDs in children is dyskinetic cerebral palsy (CP) and the impact of dystonia on the lives of children is often very disabling. Worsening symptoms of dystonic-choreoathetosis were reported by primary physicians or patients in two thirds and remained severe in the remaining third of 279 children referred to the Complex Motor Disorders Service (CMDS), irrespective of the cause or management at the time of referral**2**. Dyskinetic CP is further divided into dystonia and/or choreoathetoid according to the Surveillance of Cerebral Palsy in Europe (SCPE)**3**. Both classifications are often used in the literature and for the purposes of this paper, the term hyperkinetic movement disorders will be used globally to refer to children and young people with dystonia, chorea, athetosis or any other unwanted excess movement independent of aetiology. It is important to have reliable means of measuring the severity of the hyperkinetic impairment and functional disability that can be used across all aetiologies for epidemiological, radiological, neurophysiological and therapeutic evaluation.

Dystonia has often been classified on the basis of aetiology. Primary dystonias are those in which dystonia is the only neurological feature, with normal neuroimaging. "Primary-Plus" dystonia describes primary dystonias with additional movement disorders (e.g Myoclonus-dystonia=. Secondary dystonias are symptomatic disorders, arising due to a structural or metabolic perturbation of the brain. We further sub-divide these into those due to a static injury to the brain and those due to an underlying progressive condition (e.g. neuronal degeneration with brain iron accumulation).

HMDs present with varying impairment severity, functional capacity, participation, independence, care provision, and Quality of Life. Clinical presentations may evolve over time and differentiation of the different movement disorders poses clinical challenges**4**. The use of aetiological categories to describe cohorts of children with HMDs provides little information on functional limitations**5**.

Interventions for children with HMDs are frequently evaluated using impairment scales developed for adults. The Burke-Fahn-Marsden Dystonia Rating Scale-Movement (BFM-M) has been used as the primary outcome measure in many studies evaluating the role of DBS for paediatric dystonia**4,6-13**, but has been reported as having limited sensitivity when applied to children**16**. Such scales rate the presence and severity of involuntary movements, but confuse symptoms with disabilities while ignoring the contribution of other co-existing impairments to functional difficulties**1,5**. The BFM-M score might be equal for two children, but may represent severe manual and cervical dystonia in one child and severe truncal and lower limb dystonia in another with very different functional consequences. The total BFM-M scores quoted in all the literature do not allow more detailed understanding of how the individual subject is actually affected, partly because it was an aim of the BFM-M to establish some sort of equivalence between dystonia severity in one part of the body and another for the purposes of group analysis. The BFM-M ranges from 0-120 and is scored by the rater from standardised video clips, whilst the disability scale (BFM-D) ranges from 1-30 and measures patient/carer reported disability score. Higher values indicate more severe dystonia in both cases.

Despite the many limitations of a scale developed for primary dystonias and with limited reliability testing available, use of the BFM-M is a practice guideline requirement for interventional studies in dystonia (UK national commissioning) and is often the main primary outcome measure in dystonia studies**17**. In dystonia research, the BFM-M is a gold standard against all measures of dystonia change must be compared. Additional measures to the BFM-M have also captured meaningful clinical change over time following important interventions, such as deep brain stimulation, despite little or no changes in the BFM-M**14,15,17**.

Hidecker *et al*.**18** have advocated the need for functional profiling of children with CP and we believe this is also a priority for children with HMDs. Two functional classification systems have been widely adopted in paediatric CP research and are increasingly incorporated into CP registry data sets to describe the severity of motor disability: the Gross Motor Function Classification System**19** (GMFCS) and the Manual Ability Classification System**20** (MACS). A third classification system, the Communication Function Classification System (CFCS), has been more recently developed**21**. The reliability and utility of each classification system; clinical applicability as tools for research, and their uptake has recently been reviewed**22**.

These classification systems have been increasingly adopted in descriptive and interventional studies involving children with CP, though the dystonic/choreathetoid CP sub-group is not always well-described in terms of movement disorder characteristics or distribution of involvement and remains probably under-reported**23,24**, making it difficult to ascertain trends specifically related to the dystonic/choreathetoid CP sub-group.

Recently, these classification systems have been used in studies of children with dystonic movement disorders of non-CP aetiologies**2,5,14,15**. These classifications may offer useful and internationally recognised ways of describing functional ability in children with HMDs.

Although to date two studies have applied the three classification systems, in one study dyskinetic CP cases are not differentiated**18** and the other involves only one child with dystonic CP in a sample of 20 children**25** posing difficulties in applying these results to dystonic/choreathetoid CP.

A number of studies that include children with dyskinetic (dystonia and/or choreoathetoid) CP have evaluated concordance between gross motor ability and manual function**20,25-30**. The studies presenting GMFCS and MACS levels for different CP phenotypes suggest that children with dyskinetic CP typically have severe functional impairment, with 68-75% cases classified as GMFCS and MACS levels IV and V**27,29,30**. Although these scales demonstrate a strong positive relationship, particularly in dyskinetic CP, the use of both scales has been advocated since each scale offers information about different domains of function and the strength of concordance reduces in cases with less severe functional limitation.

Majnemer *et al*.**26** point out that the association between manual ability and gross motor ability remains unclear in specific subtypes of CP, including dyskinetic CP. More focused research on the dyskinetic CP phenotypes is needed to ascertain which existing and emerging CP research evidence can be meaningfully applied to this patient population.

Although the GMFCS and MACS have not been validated for children with movement disorders other than CP, we believe the use of “equivalent” scale scores could provide clinicians with a meaningful taxonomy for describing the motor severity and functional ability of children and young people with dystonia and other HMDs.

This is the first study specifically describing the functional profile of children with HMDs of varying aetiology, including dystonic-choreoathetoid CP, using these three internationally recognised functional scales and their relationship with the Burke-Fahn-Marsden dystonia impairment rating scale (BFM-M).

We present a ‘Rosetta Stone’ of scales allowing the cross-interpretation of these interdependent scales and the BFM-M. The ‘Rosetta’ Stone dating back to 196 BC, was re-discovered in 1799 by Pierre-Francois Bouchard near the town of Rashid during the Napoleonic expedition. It contained a text chiselled out of the stone in three main languages: Ancient Egyptian Hieroglyphs, Demotic Script (the Egyptian used for documents) and Ancient Greek. This allowed researchers to decipher Egyptian hieroglyphs. Similar to that historical precedent, we aim to link motor scales in different branches of clinical neuroscience to allow a comparative interpretation of the meaning of these scales to each other and between different movement disorders and CP aetiologies.

We hypothesised:

1. A positive association between the three functional scales (GMFCS/MACS/CFCS) indicating that worse function on one scale is associated with worse function on the others.
2. A positive association between dystonia severity (higher BFM–M score) and more severe functional disability (higher GMFCS/MACS/CFCS score).
3. Worse dystonia severity and functional impairment for secondary dystonias compared to primary dystonias and for those patients with longer proportion of life lived with dystonia.

**METHOD**

**Participants**

The participants were a convenience sample of 161 children and young adults (median age 10y3mo, range 2y6mo-21y) referred to the Complex Motor Disorders Service (CMDS) at Evelina London Children’s Hospital for assessment and management of their movement disorder (Table S1). All patients with data available were included from 2007 to 2013. Insufficient information meant 3 children could not be categorised with the CFCS.

**Measures**

**Functional classification**

The three functional classification systems, GMFCS**19**, MACS**20** and CFCS**21**, are all ordinal rating scales comprised of five levels (I-V). Higher levels reflect more severe functional disability (Table S2). Emphasis is on usual performance at home, school, and in community settings.

The GMFCS describes self-initiated gross motor function of children and young people with CP. Distinctions between levels are based on differences in functional abilities for independent sitting and walking and the need for assistive technology or wheeled mobility.

The MACS classifies how children with CP handle objects in everyday life. Differences between levels are based on the child’s self-initiated ability to handle objects and their need for assistance or adaptations to perform manual activities.

The CFCS classifies how easily and effectively children with CP communicate in everyday life. Differences between levels are based on the child’s ability to adopt ‘sender’ and ‘receiver’ roles, the pace of communication and the familiarity of communication partners. All methods of communication are considered.

This cross-sectional study compares and contrasts the patient’s status at the time of initial multidisciplinary team assessment. Patients were classified using GMFCS and MACS by an occupational therapist (HG) and/or a physical therapist (KT) at the time of initial assessment. CFCS levels were retrospectively classified by the team’s occupational therapist (HG), speech and language therapist (LB) and neurology consultant (JPL) using comprehensive reports and a standard questionnaire completed at time of assessment. All assessors have several years of experience with paediatric HMDs.

**Dystonia severity rating**

The BFM-M was used to evaluate dystonia severity following the published protocol**31**. The scale rates dystonia severity both at rest and with action, the most severe state being dystonia at rest. Scores are obtained from individual assessment scores of each of nine body regions in terms of severity and also provoking factors such as speaking, writing, and walking. Both severity and provoking factors are rated from 0-4 with higher scores denoting more severe dystonia. The individual region results for provoking and severity factors are multiplied to give a score for that particular region. The total BFM-M raw score ranges from 0 to 120, a higher score denoting more severe dystonia.

The BFM-M was administered and subsequently scored from video by CMDS therapists with reference to the original guidelines**31**. Assessors were not blinded. The baseline scores for some of the participants in this sample have been previously reported in interventional studies by our group**5,11,15**.

**Aetiological classification**

Children were categorised by a paediatric neurologist (JPL) into four main groups: (i)primary dystonia, (ii)primary-plus dystonia, (iii)secondary HMD-static and (iv)secondary HMD-progressive. This is reported more fully in our previous publications**2,5,15**. The typical level of functional ability varied between the different aetiological classifications, but both lesser and greater functional abilities are represented for all aetiological classifications (Table S1).

**Proportion of life lived with dystonia**

The proportion of life lived with dystonia (PLD) is the duration of dystonia divided by the age of the child at the time of assessment. The PLD ranges from 0 to 1 with values close to 0 indicating a very recent onset of dystonia while values close to 1 indicate the child has lived with dystonia for almost all of his/her life.

**Ethics and informed consent**

This study was registered as an audit with Guy’s and St Thomas’ NHS Trust. Consultation with the chair of the local Research Ethics Committee determined ethics approval was not required given data fall into the category of “research involving previously collected, non-identifiable information”. Since data were permanently anonymised, consent was neither required nor obtained.

**Statistical analysis**

Data analysis was performed using the R language for statistical computing, version 3.01. Differences in BFM-M between two levels of a categorical variable were assessed using the Mann–Whitney–Wilcoxon test. Overall relationships between BFM-M and categorical variables were evaluated with the Kruskal-Wallis rank sum test and proportion variation explained (R²). Relationships between two categorical variables were assessed using Pearson's chi-squared test and Pearson residuals. Spearman correlations (rs) were also provided as an estimate of the strength of the association between variables.

Due to the number of statistical tests performed, multiple testing correction was deemed appropriate. Our 3 key hypotheses as outlined in the Introduction translate to 10 statistical tests: 6 tests of the pairwise association between the four scales and 4 tests linking BFM-M to aetiology, CP status and proportion of life lived with dystonia (PLD). To achieve an overall family-wise error rate of 0.05 for these 10 tests, the Holm–Bonferroni methodwas applied. Corrected p-values are given once in the Results section; uncorrected p-values are used elsewhere to facilitate comparisons with other publications. Sensitivity analyses were performed for all conclusions presented here to ensure that individual observations did not have an undue impact. To detect potential sources of bias, regression by sequential patient ID and year was done.

**RESULTS**

Of the 161 children included, 26 (16%) young people were classified as primary and 9 (6%) as primary-plus dystonias. The 125 secondary HMDs (78%) consisted of 99 static (61%), including 75 dyskinetic CP (47%), and 26 progressive (16%) subtypes. Demographic characteristics are shown in Table S1.

**Relationship between paediatric functional profile scales**

There were significant positive associations between all three scales: GMFCS and MACS (rs=0.896), GMFCS and CFCS (rs=0.724), MACS and CFCS (rs=0.725) (Table 1, all p<0.00001, Holm–Bonferroni corrected: all p<0.00001). These relationships persisted when looking at individual patient subgroups including patients with a diagnosis of CP only or other specific disease aetiologies (Tables S3-S6), but did not reach significance for all subgroups due to the reduced numbers of patients.

Equivalent GMFCS and MACS levels were found in 71% of participants (Table S7). Stronger concordance was seen in patients with more severe functional disability (GMFCS & MACS both level V n=83, 52%; both level IV n=15, 9%), while there was greater variation in GMFCS and MACS levels I-III.

Only 20% of patients had identical GMFCS, MACS and CFCS levels. While a positive relationship was noted between CFCS and other scales, CFCS ratings tend to be somewhat lower (i.e. higher functional ability) than both GMFCS and MACS – 60% of patients had lower CFCS scores than GMFCS scores and 69% had lower CFCS scores than MACS scores.

**Linking impairment and functional profile scales**

BFM-M scores were strongly associated with the GMFCS (rs=0.843), MACS (rs=0.839) and CFCS (rs=0.745) scales (Fig. 1a-c, Table 2, all p<0.00001, Holm–Bonferroni corrected: all p<0.00001). The relationship between BFM-M and GMFCS was roughly linear, with median BFM-M values for each GMFCS level of 24, 48, 62, 82, and 102, respectively. Both MACS and CFCS displayed non-linear relationships with BFM-M: the association between BFM-M and MACS followed a super-linear relationship with little difference between the lower MACS levels giving medians for levels I-V of 12, 38, 41, 76, and 102, respectively. The CFCS scale had a sub-linear relationship with the BFM-M giving medians of 34, 50, 89, 100, and 106 for levels I-V respectively. Again, these relationships persisted when looking at individual subgroups of patients, such as CP, or particular disease aetiologies (Fig. S1), but were not always significant for all subgroups due to the reduced number of patients.

**Impact of aetiology on disease severity**

BFM-M scores were strongly associated with disease aetiology (p<0.00001, Holm–Bonferroni corrected: p<0.00001, Fig. 1d-e). Primary/primary-plus patients showed significantly lower BFM-M scores (median 38, interquartile range (IQR) 18-58) than patients with secondary HMDs (median 97, IQR 80-107). No significant differences in BFM-M scores were found between the primary and primary-plus subgroups (p=0.637) or between the secondary-static and secondary-progressive subgroups (p=0.496). In the secondary-static subgroup, there was no significant difference in BFM-M between patients with or without CP (p=0.288, Fig. 1f). More data is ideally required to fully confirm equality of distribution of primary dystonia severity against the GMFCS.

**Impact of proportion of life lived with dystonia (PLD) on disease severity**

There was an overall association between PLD and BFM-M scores for 156/161 cases in whom PLD was available (rs=0.423, p<0.00001, Holm–Bonferroni corrected: p<0.00001, Fig. 2). Longer PLD was associated with worse dystonia. This relationship was weaker when looking at subgroups of primary and primary-plus (rs=0.187, p=0.283), secondary-static (rs=0.124, p=0.226) and secondary-progressive HMDs (rs=0.226, p=0.288). A similar relationship of longer PLD indicating worse functional ability was found for GMFCS, MACS, and CFCS (Fig. S2).

**DISCUSSION**

Intervention outcomes for children with dystonia and other hyperkinetic movement disorders are mostly described using impairment-based dystonia rating scales, such as the BFM-M. However, without additional information, the individual scores of such scales allow only limited inferences about an individual’s functional status.

The use of functional classification scales, such as the GMFCS, MACS, and CFCS, provides a common language to describe the motor severity and function of both patients and research participants. These scales require no formal clinician training, are quick, cost-effective and simple to apply. They help to contextualise BFM-M scores and facilitated the interpretation of research results by providing a clearer understanding of the functional capabilities of study participants. By focusing on function and reflecting on usual performance in everyday environments, these classification systems provide meaningful information that goes beyond aetiology and impairment as strongly advocated by the international classification system of functioning, disability and health.

**Relationship between functional scales**

As found in other studies**21**,**26**, GMFCS and MACS exhibited greater concordance in less functionally able children: 93% of children rated GMFCS V were also rated MACS V. A greater discordance was seen in more able children (levels I-III). Virtually all children (98%) classified GMFCS and MACS levels V were rated CFCS III-V. Of those rated GMFCS IV/V, 10% could make themselves understood to unfamiliar others, at least to some extent (CFCS I-II). This is a lower proportion than the 25% found by Hidecker**18**. Only 32 (20%) of the 158 children for whom all scales were available had the same classification level for all 3 scales. This is similar to other studies**18**, though as previous studies do not differentiate dyskinetic CP cases, it is difficult to make direct comparisons with our results.

We found a very strong relationship between GMFCS and MACS (rs=0.896) and strong associations between GMFCS and CFCS (rs=0.724) and MACS and CFCS (rs=0.725). This suggests the three classifications offer related, complementary information. Given correlation coefficients are highly influenced by sample characteristics, the homogeneity of our study sample may explain the higher correlation seen in our study compared to studies investigating children with all types of CP, as strong correlations between GMFCS and MACS have been specifically noted in the dyskinetic CP subgroup**18,26**.

**Linking functional and disability scales**

We found a strong relationship between dystonia severity, as measured by the BFM-M, and both GMFCS (rs=0.843) and MACS (rs=0.838). The relationship was only slightly weaker for the CFCS (rs=0.745). As the CFCS considers all forms of communication including augmentative and alternative communication (AAC), this finding might reflect the impact of non-motor factors, such as cognition, on communication function. Furthermore, the ability to access assistive technology is compromised in children and young people with dystonia and has been reported as one of the key concerns**5**, which is likely to affect access to communication.

Although there seems to be a remarkable segregation of BFM-M scores by primary vs secondary aetiology, the GMFCS and MACS levels are also very informative. The BFM-M discriminated surprisingly well between GMFCS levels (Fig. 1a), with a split of the BFM-M into 5 blocks of approximately equal size corresponding to each GMFCS level. This link between impairment and gross motor function supports the discriminative validity of this impairment-based measure in all children with dystonic movement disorders. This clear discriminative pattern is not seen using the other scales: a non-linear relationship exists between MACS and BFM-M as well as between CFCS and BFM-M (Fig. 1b-c). MACS levels I-III share similar BFM-M profiles and CFCS levels III-V share similar BFM-M profiles. This is possibly due to the MACS providing additional information about how objects can be handled for the less severe cases (BFM-M less than approximately 60) and the CFCS allowing more in-depth assessments of the communication with familiar partners for more severe cases (BFM-M more than approximately 80).

A moderate association was found between PLD and dystonia severity (BFM-M) (Spearman correlation 0.423; p<0.001). This link became much weaker within aetiological subgroups. Thus, either aetiology or PLD can be used as a predictor of dystonia severity.

**Limitations and conclusion**

It is important to acknowledge the limitations of this study. Generalisation of results is limited by the inclusion of children referred to a specialist movement disorder service rather than a random sample taken from a wider HMD population. This raises the potential for selection bias given the sample is likely comprised of patients with more severe functional difficulties for which specialist intervention is being sought. Indeed, 52% of our patients were categorised as levels V for GMFCS and MACS. However, our results are in line with the findings of other studies**18,26,30**. Other limitations include the use of functional classification scales validated only for CP, the retrospective assignment of CFCS scores based on clinical documentation and the use of the BFM-M in the heterogeneous group of secondary dystonia patients.

The consistency of results when these scales are applied to different aetiologies and when comparing CP with non-CP diagnoses suggests that GMFCS, MACS, and CFCS equivalent scores, as operationally defined disability levels, can be applied to children without CP. Even though comparisons between different aetiological groups should be interpreted with caution, certain management strategies, such as deep brain stimulation, require the same surgical technique irrespectively of aetiology. However not all cases of dystonia respond similarly to DBS because of differences in functional motor and dystonia severity, PLD and aetiology. We need to understand what children with dystonia share in common, and thus we need to use scales commonly applied to CP side-by-side with those used in non-CP movement disorders. This work broadly suggests that a drop of 20 BFM-M points are required to improve the GMFCS by 1 ordinal point.

Dystonia rating scales alone do not provide us with a clear understanding of the child’s functional ability or functional motor severity, since they measure at impairment level and they can potentially fail to capture significant improvements in quality of life or achievement of goals set by patients**5,14,15** prior to interventions such as DBS. The ability of the BFM-M scale to discriminate between GMFCS levels in this sample offers the possibility to compare samples across different studies and arguably supports the premise that higher scores on the BFM-M reflect more significant disability. However, the similarity between MACS I-III in terms of BFM-M scores indicates that non-motor components such as cognition, process skills and planning are required for functional daily life activities and cannot be explained by motor deficits alone. It is clear as the literature matures that even primary dystonias have a number of non-motor consequences**32** though this information is only now percolating into the adult literature.

This ‘Rosetta Stone’ scales study provides a descriptive report of the functional profile of a sample of children with HMDs allowing a comparative understanding of the value of each scale in relation to the other scales. The results show that children with secondary HMDs are typically more severely functionally impaired than children with primary dystonias. We support the use of these functional scales in all children with HMDs regardless of aetiology. This will allow not only descriptive reports on functional profiles for these children, but could also provide us with a common language for clinical practice and interpretation of research outcomes in children. We advocate the use of all three functional classification systems together with the BFM-M for cases of hyperkinetic movement disorders.

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**DISCLOSURES**

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Supplementary material is available online.

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| --- | --- | --- | --- |
|  |  | **GMFCS** |  |
|  |  | **I** | **II** | **III** | **IV** | **V** | **Totals** |
| **MACS** | **I** | **5(3%)** | 0(0%) | 2(1%) | 0(0%) | 0(0%) | 7(4%) |
| **II** | 8(5%) | **11(7%)** | 1(1%) | 1(1%) | 0(0%) | 21(13%) |
| **III** | 9(6%) | 6(4%) | **1(1%)** | 2(1%) | 2(1%) | 20(12%) |
| **IV** | 0(0%) | 3(2%) | 4(2%) | **15(9%)** | 4(2%) | 26(16%) |
| **V** | 0(0%) | 0(0%) | 1(1%) | 3(2%) | **83(52%)** | 87(54%) |
|   | **Totals** | 22(14%) | 20(12%) | 9(6%) | 21(13%) | 89(55%) | 161(100%) |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **GMFCS** |  |
|  |  | **I** | **II** | **III** | **IV** | **V** | **Totals** |
| **CFCS** | **I** | **12(8%)** | 8(5%) | 3(2%) | 2(1%) | 0(0%) | 25(16%) |
| **II** | 8(5%) | **6(4%)** | 3(2%) | 6(4%) | 3(2%) | 26(16%) |
| **III** | 0(0%) | 3(2%) | **2(1%)** | 8(5%) | 23(15%) | 36(23%) |
| **IV** | 1(1%) | 3(2%) | 1(1%) | **5(3%)** | 39(25%) | 49(31%) |
| **V** | 0(0%) | 0(0%) | 0(0%) | 0(0%) | **22(14%)** | 22(14%) |
|   | **Totals** | 22(14%) | 20(13%) | 9(6%) | 21(13%) | 89(56%) | 158(100%) |

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| --- | --- | --- | --- |
|  |  | **MACS** |  |
|  |  | **I** | **II** | **III** | **IV** | **V** | **Totals** |
| **CFCS** | **I** | **6(4%)** | 10(6%) | 7(4%) | 2(1%) | 0(0%) | 25(16%) |
| **II** | 1(1%) | **6(4%)** | 9(6%) | 8(5%) | 2(1%) | 26(16%) |
| **III** | 0(0%) | 2(1%) | **1(1%)** | 10(6%) | 23(15%) | 36(23%) |
| **IV** | 0(0%) | 3(2%) | 2(1%) | **6(4%)** | 38(24%) | 49(31%) |
| **V** | 0(0%) | 0(0%) | 0(0%) | 0(0%) | **22(14%)** | 22(14%) |
|   | **Totals** | 7(4%) | 21(13%) | 20(13%) | 26(16%) | 87(55%) | 158(100%) |

Table 1. Cross-tabulation of GMFCS and MACS (top), GMFCS and CFCS (middle) and MACS and CFCS (bottom) for 161 patients (CFCS data was unavailable for 3 patients). Quantities are given as number of patients and percentages out of total. Light blue (red) shading indicates significantly more (fewer) patients than expected in a cell (Pearson residual ≥ 2 (≤ - 2)). Dark blue shading indicates much more patients than expected (Pearson residual ≥ 4). Green shadings in Totals are proportional to the percent out of total. To facilitate finding diagonal cells, they have been bolded.

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| --- | --- |
|  | **BFM-M median [range]** |
| **GMFCS = I** (n=22, 14%) |  24 [2-66] |
| **GMFCS = II** (n=20, 12%) |  48 [6-68] |
| **GMFCS = III** (n=9, 6%) |  62 [32-85] |
| **GMFCS = IV** (n=21, 13%) |  82 [64-104] |
| **GMFCS = V** (n=89, 55%) |  102 [60-120] |

|  |  |
| --- | --- |
|  | **BFM-M median [range]** |
| **MACS = I** (n=7, 4%) |  12 [2-60] |
| **MACS = II** (n=21, 13%) |  38 [6-80] |
| **MACS = III** (n=20, 12%) |  41 [2-86] |
| **MACS = IV** (n=26, 16%) |  76 [20-104] |
| **MACS = V** (n=87, 54%) |  102 [60-120] |

|  |  |
| --- | --- |
|  | **BFM-M median [range]** |
| **CFCS = I** (n=25, 16%) |  34 [2-80] |
| **CFCS = II** (n=26, 16%) |  50 [6-94] |
| **CFCS = III** (n=36, 23%) |  89 [45-114] |
| **CFCS = IV** (n=49, 31%) |  100 [22-120] |
| **CFCS = V** (n=22, 14%) |  106 [86-118] |

Table 2. BFM-M medians and ranges by GMFCS (top), MACS (middle) and CFCS (bottom) scores or equivalent.



Figure 1. Boxplots of BFM-M by GMFCS (a), MACS (b) and CFCS (c) levels or equivalent and grouped by aetiological classification (d-e) and cerebral palsy status (f, secondary-static patients only). The p-values for the Mann–Whitney–Wilcoxon test between two subgroups are shown at the bottom. Overall Kruskal-Wallis p-values for BFM-M versus functional scale are p<0.00001 for GMFCS, MACS, CFCS, and aetiological classification (both grouped and non-grouped) and p=0.28650 for CP. The proportion of variation in the BFM-M explained by the categorical variable (R²) is also shown below each plot. In subfigures a-c, aetiologies are indicated using symbols for Primary and Primary-plus (red square ■), Secondary-static (blue circle ●), and Secondary-progressive (green triangle ▲).

 

Figure 2. Scatterplot of proportion of life lived with dystonia (PLD) versus BFM-M. Aetiologies are indicated using symbols for Primary and Primary-plus (red square ■), Secondary-static (blue circle ●), and Secondary-progressive (green triangle ▲). LOESS curves are plotted in the respective colour for each subgroup and the overall population (black). Correlations for each subgroup are indicated at the top, overall correlation is indicated at the bottom.