Literature Review

Measuring Quality of Movement in Cerebral Palsy: A Review of Instruments

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There is a lack of appropriate evaluation instruments in the area of quality of movement in cerebral palsy. Ten measures of quality of movement, or gross motor performance, published between 1965 and 1990, were reviewed according to established criteria. These criteria include the purpose of the measure, validity, reliability, responsiveness, range of items, and description of qualitative components. These measures provide a foundation for further instrument development in the area of quality of movement. [Boyce WF, Gowland C, Rosenbaum PL, et al. Measuring quality of movement in cerebral palsy: a review of instruments. Phys Ther. 1991;71:813–819.]

Key Words: *Cerebral palsy, Child development, Motor skills, Movement disorders, Psychomotor disorders.*

The need for sensitive evaluative measures in the rehabilitation of chronic disabilities has been documented by many authors.[1–3] Change in clinical status in these conditions is often of small magnitude over prolonged periods of time. Repeated application of traditional measures designed for diagnostic or discriminative purposes usually will not detect these small changes in status.

Children with cerebral palsy, or other "nonprogressive" neurological disorders, may demonstrate changes in gross motor behaviors that have two primary dimensions: function and performance.[4,5] Gross motor *function* refers to the ability to accomplish particular motor activities, such as rolling, sitting, and walking. Gross motor *performance* refers to the quality of performing an activity, for example, coordination while walking.

It is important to evaluate performance of motor activities in children who have cerebral palsy, because, in addition to delayed development of motor skills, disordered quality of movement is characteristic of the condition.[6] Previous reviews of research in cerebral palsy have noted that lack of a sensitive measure of movement perfor-

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This work was made possible by a research grant from The Easter Seal Research Institute of Ontario.

This article was submitted December 31, 1990, and was accepted July 10, 1991.

mance has contributed to the failure to demonstrate treatment effectiveness.[7,8]

The Gross Motor Measures Group (a group of researchers and therapists in Hamilton, Toronto, and Kingston, Ontario, Canada) has been addressing measurement issues for several years. Initially, we developed the Gross Motor Function Measure (GMFM), an evaluative measure of motor function for children with cerebral palsy. This instrument has been shown to produce reliable and valid scores that can be used to detect clinically important change.[9] In the early stages of the development of the GMFM, we recognized that it was not feasible to have a single measure that was capable of evaluating all of the changes characteristically seen in children who have cerebral palsy. The GMFM assesses only gross motor function, and it does not address essential motor performance features such as alignment, stability, and weight shift.

Subsequently, we began the development of the Gross Motor Performance Measure (GMPM). Issues in the conceptual, methodological, and practical development of this instrument are reported in our accompanying article in this issue. The GMPM is currently undergoing studies to determine the validity, reliability, and responsiveness of the obtained scores.

There have been a number of reviews of instruments that measure gross motor function.[3,8,10] These reviews examine the relevance, standardization, and properties (validity, reliability, and responsiveness) of measurements obtained with a number of function instruments currently in use. There has not yet been a review, however, of instruments that are claimed to assess quality of movement in children. The purposes of this article are to outline criteria for reviewing performance instruments and to apply the criteria to available measures. This article is not intended to present an exhaustive review of all studies relevant to the measures. Rather, we illustrate the strengths of these measures for their stated purposes and the difficulties in using any one of them alone to comprehensively evaluate gross motor performance in individuals who have cerebral palsy.

Numerous measures of gross motor behavior have been created for use with children. The vast majority of these measures, however, assess only gross motor function and how much the child can do (eg, Bayley Motor Scale, Denver Developmental Screening Test, GMFM) and do not include items assessing motor performance. We have restricted this review to measures that include, or claim to include, items assessing motor performance, or quality of movement.

Many of the measures discussed in this review were not developed primarily for the assessment of motor quality. Originally, most of the measures were intended for discriminating, predicting, and evaluating gross motor behavior, including functional activities, reflexes, and postural reactions. Their measurement properties for these purposes are often quite adequate. All of the measures also include some items relating to motor performance, or how well functional behaviors are performed. Measurement properties for these few items were either incomplete, not reported, or not able to be clearly distinguished from other parts of the test. Since their original development, the measures have come to be used to assess quality of movement without adequate documentation of their particular ability to do so. We assert that this change in use of the measures merits a review of the instruments for a new purpose—assessing motor performance.

Criteria for Review of Measures

Purpose of Measure

The purpose of a measure should be identified at the outset of its development, because crucial methodological decisions in measurement construction depend on the purpose for which it will ultimately be used. Methods for validation of the measure will also depend on whether the measure is to be used for discriminating among subjects (discriminative measure), predicting subject outcomes (predictive measure), or evaluating change over time (evaluative measure).[11]

A *discriminative* measure is used to distinguish among individuals at a single point in time on some feature of interest. The Bayley Motor Scale is an example of such a measure used to distinguish among children of a common age who have different motor function levels.[12]

A *predictive* measure is used to classify individuals according to a set of predefined categories and is used when an accepted criterion exists to determine whether an individual has been classified correctly. The criterion can be measured concurrently or in the future. The Bleck Scale of Locomotor Prognosis is an example of such a measure used to predict future ambulation status based on the presence of certain postural and tonic reflexes.[13]

An *evaluative* measure is used to document change within subjects over time to determine the effectiveness of treatment or to monitor the natural development of a condition. The GMFM is an example of an instrument that can be used to evaluate change in gross motor function in children who have cerebral palsy.[9]

Measurement instruments are often designed and validated for one purpose (eg, to discriminate) and later used for another purpose (eg, to evaluate) without proper revalidation. Although it is possible for a measure to satisfy more than one purpose, evidence should be available to support these uses. We contend that a measure validated for evaluative purposes is necessary to assess change in gross motor performance as an outcome of treatment in children who have cerebral palsy.

Measurement Properties

To be useful, an evaluative measure must have validity, reliability, and responsiveness.[11] These terms will be briefly reviewed with respect to mea-

sures of motor performance for children who have cerebral palsy.

Validity. *Validity* has been defined as the extent to which an instrument measures what it is intended to measure.[14] Validity of a measure of motor performance is based on the measure's ability to be applied for its intended purpose. For example, an evaluative measure should demonstrate a change in score when a true change in motor performance has taken place.

Reliability. *Reliability* has been defined as the ability of a measure to give consistent responses on repeated assessments in the absence of change in the characteristic being studied.[15] Reliability of a measure of motor performance should be established by interrater consistency (single assessment, multiple raters), intrarater consistency (single assessment on videotape, rated twice by single rater), and test-retest consistency (repeated assessments over a short period of time, single rater). Test-retest stability is a crucial property for evaluative instruments; otherwise, a change in scores cannot be attributed to a real change in behavior.

Responsiveness. Responsiveness to change has been identified as the key feature an instrument should possess to determine whether it will be useful as an evaluative measure.[11] Responsiveness is judged by the ability of the measure to detect a minimal clinically important change in subjects. Responsiveness of a measure of motor performance would be evident if the measure is able to detect clinically relevant change in quality of movement, regardless of whether the change is large or small and positive or negative in direction.

Item Range and Description

The usefulness of a measure can also be determined by examining the clarity, completeness, and suitability of its items. Items in an evaluative measure should be judged on the basis of both clinical relevance and potential responsiveness to change.[3] Activities in a measure of gross motor performance must be clearly defined and relevant to important aspects of disordered movement common to cerebral palsy, and they must utilize a scoring system that allows quantification and detection of small changes in performance.

Review of Motor Performance Measures

Selection of measures for review was based on an extensive search of published and unpublished sources. We decided to include only published measures in this review, because measurement properties are not available for unpublished measures and unpublished measures are not easily available for readers to investigate on their own.

Measurement criteria have been applied to 10 measures of gross motor behavior reported in the literature during the period 1965 to 1990. Measures were selected on the basis of an *Index Medicus* search using the Medical Subject Heading's key words "cerebral palsy," "child development," "motor skills," "movement disorders," and "psychomotor disorders." The selected measures were originally developed to assess general gross motor behavior, but also had to incorporate some measure of performance. A summary of the 10 instruments reviewed is presented in the Table.

Test of Motor Impairment

Stott and colleagues[16] reported on a validation study of the Test of Motor Impairment (TOMI) for discrimination of clumsiness in children. Clumsiness has often been conceptualized as demonstrating impairments in quality of movement. Clumsiness is usually assessed, however, by measuring the inability to perform functional activities, rather than measuring the quality of the activity itself. Stott and colleagues revised the original Oseretsky Test of Motor Ability and tested it on a sample of 949 5- to 16-year-old nondisabled children in Great Britain and in North America. Discriminative validity was demonstrated in a sample of 48 boys divided into groups with normal and abnormal motor ability ($\chi^2=12.55$, $P<.001$). Interrater reliability coefficients were satisfactory (Pearson $r=.79$-$.93$). Responsiveness to change was not addressed in the report. Many of the items involve high-level coordinated movements, such as jumping rope, which may be suitable for use with clumsy children, but are not appropriate for the majority of children with cerebral palsy. Scoring is undertaken on a pass/fail basis, which is unlikely to detect small changes in performance accurately. This test was one of the first instruments to identify the importance of motor performance in addition to motor function.

Milani-Comparetti Test

Milani-Comparetti and Gidoni[17] reported on a measurement tool developed in Italy for the purpose of screening children who have developmental delay. Information on numbers and ages of children was not reported. The test is based on a theoretical link between the evolution of reflexes and the emergence of spontaneous behaviour. Reliability, validity, and responsiveness data were also not reported. A scoring system was not originally developed; thus, the test results required interpretation and could not be objectively quantified. Subsequently, Ellison and colleagues[18] developed a five-point scale for the Milani-Comparetti Test and tested 999 high-risk infants at ages 6 and 16 months. Pearson Product-Moment Correlation Coefficients were calculated between item scores and the three categories of normality, transient abnormality, and abnormality. Statistically significant correlations ($P<.001$) were found for all items. The Milani-Comparetti Test describes test procedures well and gives useful definitions of terminology relating to qualitative components of movement, such as spontaneity and coordination. The range of items is limited to those applicable to very young children. The Milani-Comparetti Test provides a solid basis for further instrument development in quality of movement.

Table. *Review of Instruments for Assessing Gross Motor Performance*

Test	Purpose	Criteria[a]			Items	
		Validity	Reliability	Responsiveness	R[b]	D[c]
TOMI[d]	Discriminative	+	+	–	–	–
Milani-Comparetti[e]	Discriminative	+	–	–	–	+
Wolanski[f]	Discriminative	–	–	–	+	+
Bruininks-Oseretsky[g]	Discriminative	+	+	–	–	+
MAI[h]	Discriminative, predictive	+	–	?	–	+
MAP[i]	Discriminative	–	–	–	+	–
TMNF[j]	Discriminative, predictive	?	+	–	+	–
PDMS[k]	Discriminative, evaluative	+	+	?	–	–
TOMI-H[l]	Discriminative	+	+	–	–	+
OBMSAI[m]	Discriminative, evaluative	–	+	–	–	+

[a]Plus sign (+) indicates instrument meets criteria; minus sign (–) indicates instrument does not meet criteria or information is missing; question mark (?) indicates evidence is questionable.

[b]Range of gross motor activities assessed.

[c]Description of qualitative components of movement.

[d]Test of Motor Impairment.

[e]Milani-Comparetti and Gidoni Test.

[f]Wolanski Gross Motor Evaluation.

[g]Bruininks-Oseretsky Test of Motor Proficiency.

[h]Movement Assessment of Infants (Volitional Movement section).

[i]Miller Assessment of Preschoolers (Quality of Movement Supplemental Measure).

[j]Test of Motor and Neurological Functions (Qualitative Movement Subtest).

[k]Peabody Developmental Motor Scales.

[l]Test of Motor Impairment-Henderson Revision.

[m]Objectives-Based Motor Skill Assessment Instrument.

Wolanski Gross Motor Evaluation

Wolanski and Zdanska-Brincken[19] developed a screening, or discriminative, test for gross motor delay. Two hundred twelve apparently nondisabled children from 3 to 13 months of age in Poland composed the test sample. Standardization features were not reported, and a later review indicated a lack of satisfactory reliability and validity data.[20] The Wolanski Gross Motor Evaluation used percentile grids for achievement of motor milestones in children on four dimensions: head and trunk movements, sitting, standing, and locomotor development. The test's original use was for quick screening of developmentally delayed children's movement patterns, rather than for assessing the disordered movement characteristic of children who have cerebral palsy. The instrument provides detailed descriptions of body parts during movement and uses a scoring system that allows summary scores to be calculated in the four dimensions. The primary strengths of this test are the range of items assessing movement quality and the items' relationship to functional activities.

Bruininks-Oseretsky Test of Motor Proficiency

Bruininks[21] published a further version of the Oseretsky Test of Motor Proficiency, which was standardized on a sample of 765 nondisabled North American children between the ages of 5 and 14 years. The test has satisfactory reliability coefficients. Test-retest reliability scores averaged .87 (unspecified statistic) for the complete battery. Interrater reliability varied between .90 and .98 (unspecified statistics). Content, construct, and criterion validity are claimed for a nondisabled population. Responsiveness to clinically important change has not been reported, because the purpose of the test is discriminative. Terminology about motor quality is well defined, and a scoring system is available. The main limitation of the instrument for assessing performance concerns the range of items suitable for children who have cerebral palsy. Items test mainly high-level motor abilities, such as simultaneous upper- and lower-limb coordination. We believe these items are not usually relevant for the majority of children with cerebral palsy. The Bruininks-Oseretsky Test of Motor Proficiency, however, does have wide application

and value in the assessment of developmental delay and clumsiness.

Movement Assessment of Infants

Chandler and colleagues[22] developed the Movement Assessment of Infants (MAI) for use in discriminating among children with motor disorders in a high-risk population. The instrument can be used to assess muscle tone (or "readiness to respond to gravity"[22(p25)]), primitive reflexes, automatic reactions, and volitional movement. For the purposes of this review, it is useful to focus on the Volitional Movement section of the MAI, because this section describes both functional and qualitative components of gross motor behavior. Harris and colleagues[23,24] have reported only fair reliability for the overall MAI when used with 53 full-term and preterm 4-month-old infants. Pearson Product-Moment Correlation Coefficients were .72 for total-score interrater reliability and .76 for test-retest reliability. Reliability coefficients for the Volitional Movement section were generally poor to fair. Interrater reliability was .65 and test-retest reliability was .16 for the Volitional Movement items. The MAI was initially tested for validity in the United States on a sample of 35 high-risk children, aged newborn to 1 year. Investigations of predictive validity have yielded values varying from poor (Pearson r=.09–.37) to good (correct identification of 74% of children with cerebral palsy), depending on the study design, sample, and outcome standard used.[25–28] Of interest for this review is the common finding of three of these studies that the Volitional Movement section was the best predictor of outcome.[29] This finding indicates the importance of items that assess function and performance in the prediction of a diagnosis of cerebral palsy.

Responsiveness, or sensitivity to change in motor development, of the MAI has been studied in comparison with responsiveness of the Peabody Gross Motor Scale.[30] A small sample of infants with Down syndrome (N=10), aged 6 to 42 weeks, showed minor changes on the MAI (t=3.99, df=9, P<.01; two-tailed), but not on the Peabody Gross Motor Scale (t=2.23, df=9, P>.05), over a 6-week period. Responsiveness for children with a diagnosis of cerebral palsy over a longer period of time has not yet been established. The MAI has a well-constructed scoring system and clear item definitions, which encompass many features of motor dysfunction apparent in children who have cerebral palsy. As the test was developed for very young children, it does not include many gross motor items, and none are at a level higher than walking. The MAI, therefore, has limited value for assessing motor performance for a wide range of children with cerebral palsy. The MAI is a landmark test, as it was the first to apply the assessment of movement performance to children with disordered movement.

Miller Assessment of Preschoolers

Miller[32] published a screening test, the Miller Assessment of Preschoolers (MAP), to discriminate among 3- to 6-year-old children who have delays in sensory, motor, and cognitive abilities. The purpose of the MAP was to identify children who may have future problems in school performance. The main test was standardized on 616 children in the United States. Supplemental appendixes were compiled to assess qualitative aspects of language, vision, touch, movement, and drawing abilities. An interrater reliability coefficient (Pearson r=.98) was obtained for a sample of 40 preschool-aged children. Test-retest reliability (Pearson r=.81) was obtained for another sample of 90 children. Validity has been investigated by Miller in four categories: content, criterion, construct, and predictive. Thus, validity and reliability coefficients have been satisfactory for the main test, but the supplemental measures have not yet been standardized.[32,33] The Quality of Movement Supplemental Measure includes a wide range of items to assess motor dysfunction typical of children with cerebral palsy. Terms such as "stability" and "fixing," however, are not well-defined, and scoring is limited to a present/absent scale, which may have limited value in evaluating gradual change in motor behavior. The MAP also includes a measure of the child's behavior during testing, which may be of value in interpreting test results.

Test of Motor and Neurological Functions

DeGangi and colleagues[34] developed the Test of Motor and Neurological Functions (TMNF) for discriminative purposes in a high-risk population under 1 year of age. This test assesses muscle tone, primitive reflexes, and automatic postural reactions in specific subtests. It also assesses qualitative movement during functional activities of the Bayley Motor Scale. Using a sample of 56 full-term, high-risk children in the United States, construct validity was demonstrated on all sections of the test. Atypical qualitative movement findings were significantly greater for preterm infants at age 0 to 9 months, but not at age 10 to 12 months. Discriminative validity was reported for only two items on the qualitative subtest (arching of trunk, neck hyperextension). Excellent interrater reliability (intraclass reliability coefficients=.93–.97) has been reported for a mixed subsample of children (n=23).[35] Responsiveness to change was not addressed in the testing of this discriminative instrument. The section of the TMNF that tests abnormal movement qualities is comprehensive and uses a descriptive approach. Item definitions, however, are not available, and scoring is only on a present/absent basis, making it difficult to assess gradual change in children who have cerebral palsy. Nonetheless, the qualitative content of the TMNF appears to have excellent potential for further development of measures of motor performance in very young children.

Peabody Developmental Motor Scales

Folio and Dubose[36] developed the Peabody Developmental Motor Scales

(PDMS) as a test having the ability to discriminate between motor-delayed and nondisabled children. The PDMS is also claimed to be able to evaluate change over time and to aid in treatment planning. The normative sample was 617 newborn to 7-year-old children in the United States, of whom 104 had identified developmental motor problems. Good test-retest (Pearson r=.88) and interrater reliability (Pearson r=.99) coefficients have been reported.[37] Predictive validity has been reported as poor ($r \leq .60$), and concurrent criterion validity with the Bayley Motor Scale has been demonstrated (r=.63–.93).[37,38] Responsiveness to change was apparently investigated in a 12-week pilot study, but the results have not been published in the scientific literature. Functional items are well-defined, and a raw score (or scaled score for children with handicaps) can be calculated. The PDMS has become widely used in the assessment of motor delay in older children. A lack of items relating to quality of movement, however, is the main drawback of the test for its use in assessing motor performance in cerebral palsy.

Test of Motor Impairment-Henderson Revision

Stott and colleagues[39] have reported on the Henderson Revision of the Test of Motor Impairment (TOMI-H). The test was standardized on a sample of 923 children between the ages of 5 and 12 years in Canada and Great Britain. The test is intended to identify motor impairment in areas of manual dexterity, ball-handling skills, and balance and includes such high-level items as jumping over a rope and catching with one hand. This version of the TOMI includes a detailed checklist of Faults of Motor Control, which assesses movement patterns and coordination. It also measures responses to environmental demands in terms of timing and control of force during activities as well as behavioral responses. The TOMI-H has been reported to have satisfactory reliability and concurrent validity coefficients.[40,41] Test-retest reliability was calculated for 41 children, aged 4 to 7 years. A Kappa agreement statistic of .71 was obtained in the study. Concurrent validity with the Bruininks-Oseretsky Test of Motor Proficiency was demonstrated (K=.58). The three-point scoring system is suitable for a discriminative measure designed to provide a diagnosis, but may not be adequate for the evaluative purpose of assessing change. The TOMI-H identifies many important motor control dimensions in the assessment of motor quality, but does so primarily for advanced motor activities.

Objectives-Based Motor Skill Assessment Instrument

Ulrich[42] developed the Objectives-Based Motor Skill Assessment Instrument (OBMSAI) as a criterion-referenced test. The test is claimed to be useful in discriminating between handicapped and nonhandicapped students as well as in evaluating the effectiveness of motor skills programs. The test measures 12 advanced gross motor skills such as running, hopping, leaping, and kicking. Qualitative motor components such as body alignment, sequencing of movement, and weight transfer are assessed on a mastery/nonmastery basis. Reliability estimates have been satisfactory, although validity and responsiveness studies have not yet been reported. Ulrich[43] calculated test-retest reliability in a sample of 120 children, aged 3 to 10 years. Kappa agreement statistics varied from .62 to .84. The test appears to be suitable for assessing qualitative aspects of delayed development, but may be less useful for the disordered movement characteristic of cerebral palsy. The OBMSAI illustrates the approach to movement assessment taken by our colleagues in the field of adapted physical education.

Summary

This review of published measures that incorporate quality of movement, or motor performance, reveals a wide variety of instruments developed originally for discriminative and predictive purposes. Only two instruments (PDMS and OBMSAI) were developed with the stated purpose of evaluating change. Neither instrument, however, has published evidence of responsiveness in detecting clinically important change. Subsequently, there appears to be a lack of measures of motor performance appropriate for use in treatment effectiveness studies in cerebral palsy.

The qualitative movement content of the instruments reviewed is wide-ranging and creative and indicates that many authors consider motor performance to be important to assess. Most instruments were developed for use either in high-risk settings or for older children with developmental delay. Consequently, the range of qualitative items in individual tests is situated either at the low or high end of the motor activities spectrum. Qualitative item descriptions vary considerably in detail. Some descriptions are appropriate for disordered movement, whereas others are more suitable for normal and delayed development. Item scoring is usually on a dichotomous basis, because the primary purpose of most of the instruments is to discriminate between groups of children. No single instrument's item and scoring arrangements appear to be optimal for evaluating movement performance in children with cerebral palsy in whom small changes may occur over a large range of activities.

A number of issues must be addressed in the development of measures of movement performance for children who have cerebral palsy. First, evaluative measures that can reliably assess small gradations of change in quality of movement are needed. Second, measures are needed that can assess motor capabilities across a wide range of children who have cerebral palsy, from the very young or severely involved child to the older or mildly involved child. Finally, measures of movement performance must address the characteristics of disordered movement that make the motor behavior of children with cerebral palsy unique.

There are many challenges in these tasks. Previous efforts to measure quality of movement, such as those

cited in this review, have been instrumental in setting the groundwork for future measurement development in this area.

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