Construct Validity of the Observable Movement Quality Scale in Pediatrics: Hypothesis Testing of a Formative Measurement Model

Lieke M.A. Dekkers, Anjo J.W.M. Janssen, A. Rogier T. Donders, Maria W.G. Nijhuis-van der Sanden, Bert J.M. de Swart

Background. The Observable Movement Quality (OMQ) Scale measures generic movement quality. Each item of the OMQ Scale focuses on a different element; together, the 15 items assess the whole construct of movement quality.

Objective. The aim of this study was to determine the construct validity of the OMQ Scale using 7 hypotheses defined to conform to the Consensus-Based Standards for the Selection of Health Measurement Instruments.

Design. This was an exploratory validation study.

Methods. A pediatric physical therapist assessed motor performance in 101 children using an age-specific motor test and the OMQ Scale. The direction, magnitude, and rationale for 7 hypotheses, which concerned relationships (n = 2), probability of low scores (n = 4), and difference between diagnosis subgroups (n = 1), were defined.

Results. The results confirmed 6 of the 7 hypotheses, indicating sufficient construct validity. Significant positive relationships were found between OMQ Scale total scores and the severity of motor disabilities (r = 0.72) and z scores on motor tests (r = 0.60). Probabilities for low scores on OMQ Scale items—exceeding the chi-square critical value—were confirmed for children diagnosed with spasticity, psychomotor retardation, mitochondrial diseases, and ataxia; however, probabilities for low OMQ Scale item scores on strength regulation in children with ataxia were not confirmed. OMQ Scale total scores for children who were not ambulatory because of neurological conditions were significantly different from those for children who were not ambulatory because of fatigue (r = 0.66).

Limitations. The sample of children was based on theoretical assumptions about relevant variations in clinical representations; on the basis of the results, it appears that children with low strength regulation were underrepresented.

Conclusion. The confirmation of nearly all hypotheses supported the validity of the OMQ Scale for measuring movement quality in clinical practice in addition to standardized age-adequate motor performance tests.
Construct Validity of the OMQ Scale

The assessment of movement quality is relevant for recognizing motor problems, evaluating interventions, and predicting recovery. Movement quality is represented by an interaction of personal characteristics and experiences with the task difficulty and environmental condition and gives an impression on how movements are controlled and coordinated. Furthermore, movement quality gives insights into the potential of the movement system to react or adapt to changing conditions.

During motor development and motor learning, new movements and skills are mastered, showing both quantitative and qualitative changes. Quantitative changes can be seen in the acquisition of new and more complex skills, whereas changes in the quality of movements are demonstrated by more subtle characteristics (e.g., accuracy, fluency, and automatization of movements). Available and commonly used discriminative motor tests in pediatric physical therapy specifically assess quantitative aspects by comparison with peers. These motor tests are validated and norm referenced. For movement quality, however, available and commonly used measurement instruments were designed for particular diagnostic groups, for children in a specific age frame, or to assess the functioning of extremities. Despite the frequently used descriptions of movement quality—a standardized, generic instrument was not available to assess movement quality in children over time and for all age categories. This hinders both comparability and longitudinal evaluation in clinical practice and the education of observational skills for students in pediatric physical therapy.

The Observable Movement Quality (OMQ) Scale was designed to assess movement quality in children, over time, for all age categories and diagnostic groups as a generic evaluative measurement instrument. The OMQ Scale includes 15 items on aspects of movement quality, which can be completed by a pediatric physical therapist after the assessment with an age-specific discriminative motor test or disease-specific test. The development of the OMQ Scale was based on a 3-phase study involving pediatric physical therapists. The study started with semistructured interviews, followed by a structured meeting—using a nominal group technique—to explore existing perspectives on the complex phenomenon of quality of movement and to identify all relevant conceptual aspects to be included in the OMQ Scale. During the following Delphi rounds, the final selection of items was made and their definitions set, resulting in a 15-item scale.

The selection of OMQ Scale items was based on a conceptual construct. Each item of the OMQ Scale focuses on a different element of observable movement quality; together, the items form the whole construct—quality of movement—creating what is defined as a formative measurement model. The challenge for such a formative measurement model is to identify all items contributing to the construct, ensuring a comprehensive measurement of the construct. The individual items in such a measurement model do not necessarily correlate with each other and, thus, are not interchangeable.

This is in contrast to a reflective measurement model, in which items are manifestations of the construct—implying correlations of the items—and the possibility that they may replace each other.

During development of the OMQ Scale, content validity was established that showed that the content of the OMQ Scale is an adequate reflection of the construct movement quality. Recently, a first study was published on the interrater reliability of the OMQ Scale for children between 6 months and 6 years of age, showing a moderate interrater reliability when being used by pediatric physical therapists unfamiliar with the scale. The next step of the validation of the OMQ Scale is to provide evidence of validity. Considering the lack of a gold standard, construct validation—or hypotheses testing—is the most adequate method to provide this evidence.

At the start of our research, and before examining the data, we formulated hypotheses using the Consensus-Based Standards for the Selection of Health Measurement Instruments (COSMIN) guidelines. Two independent pediatric physical therapists, not involved in this research, contributed to hypothesis formation during a meeting. Based on this meeting, 3 authors (L.M.A.D., A.J.W.M.d.J., and M.W.G.N.)—all with adequate clinical and research expertise in pediatric physical therapy—came to a consensus on 7 independent hypotheses. The hypotheses, which were specific and clearly defined, indicated the direction, magnitude, and rationale (Tab. 1). Therefore, the aim of this research was to determine the construct validity of the OMQ Scale by investigating the degree to which the scores of the OMQ Scale are consistent with hypotheses.

Methods

In an explorative validation study, the construct validity of the OMQ Scale for children is determined. The study used anonymized data sampled in daily clinical practice from 2013 until 2017. The regional medical ethics committee of the Radboud University Medical Center (Radboudumc) agreed that the study conformed to the Declaration of Helsinki and that approval was not required. This committee waived the requirement to obtain informed consent (registration no. 2018–4842).

The data from a convenience sample of 101 children were available for analyses. All data were retrospectively extracted from patient files—by the pediatric physical therapist who performed the assessments—and anonymously sampled in a database. No repeated measurements of children were included. Data collection
### Construct Validity of the OMQ Scale

**Table 1. Hypotheses for Testing the Construct Validity of the OMQ Scale**

| Hypothesis | Rationale | Expected Value |
|------------|-----------|----------------|
| 1. Will be a positive relationship between severity of motor disabilities—as classified by pediatric physical therapists—and OMQ Scale total scores | Pediatric physical therapists classify motor impairments based on child's performance; relationship between severity of motor impairments and quality of movements has been described | Correlation strength: $0.50 < r < 0.75$ |
| 2. Will be at least a fair significant positive correlation with $z$ scores on motor tests (BSID-III-NL or MABC-2-NL) and OMQ Scale total scores | Results on quantitative motor tests related to quality of movement in children with known pathologies or developmental delays; however, some children show normal quantitative development but simultaneously show deviant quality of movements or vice versa | Correlation strength: $0.40 < r < 0.70$ |
| 3. Probability of low OMQ Scale item scores will exceed critical value in children diagnosed with spasticity in both increased muscle tone (item 5) and variation in movements (item 12) | Increased muscle tone and reduced variations in movements have been identified in literature as signs or symptoms of spasticity | Critical value: $\geq 3.84$ for $P = .05$ |
| 4. Probability of low OMQ Scale item scores will exceed critical value in children diagnosed with psychomotor retardation in stereotyped movements (item 15) | Stereotyped movements, defined as both aimless and repetitive, have been identified in literature as signs related to psychomotor retardation | Critical value: $\geq 3.84$ for $P = .05$ |
| 5. Probability of low OMQ Scale item scores will exceed critical value in children diagnosed with mitochondrial disease (confirmed by mitochondrial DNA) in strength regulation (item 11) | Strength regulation identified in literature as problematic for children with predominantly muscular mitochondrial disease | Critical value: $\geq 3.84$ for $P = .05$ |
| 6. Probability of low OMQ Scale item scores will exceed critical value in children diagnosed with ataxia in tremors (item 6), accuracy (item 10), and strength regulation (item 11) | Presence of tremors and reduced accuracy of movements and strength regulation have been identified in literature as signs or symptoms of ataxia | Critical value: $\geq 3.84$ for $P = .05$ |
| 7. Will be a statistically significant difference between OMQ Scale scores for children not ambulatory because of neurological condition and OMQ Scale scores for children not ambulatory because of fatigue caused by, eg, a mitochondrial disease | Reason for wheelchair use in children with neurological conditions (ie, cannot walk) differs from that in children with fatigue (ie, they lack endurance). Wheelchair users with neurological conditions are expected to show poorer movement quality than those affected by fatigue | Correlation strength: $0.50 < r < 0.75$ |

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primarily took place as part of a multidisciplinary assessment during diagnostic trajectories for children with suspected mitochondrial dysfunction or disease. This trajectory was chosen because these children are known to show both a wide range of motor problems—with additional signs and symptoms—or an almost normal development. To ensure even sample sizes per age group, for sex, and for a diversity in diagnosis, we added data of cases of outpatient multidisciplinary evaluations from other trajectories (eg, children preterm born or diagnosed with ataxia telangiectasia). All data were collected at the Radboudumc, Nijmegen, the Netherlands.

**Motor Performance Assessment**

As part of a multidisciplinary assessment during diagnostic trajectories or outpatient's evaluations, 1 certified pediatric physical therapist (A.J.W.M.J.), with over 30 years of clinical experience who was involved in the development and education of the OMQ Scale, assessed motor performance. Motor performance was assessed by an age-appropriate motor test: the motor scales of the Bayley Scales of Infant and Toddler Development, 3rd Edition, Dutch version (BSID-III-NL),20–30 for infants and children between 0 and 3 years old, and the Movement Assessment Battery for children, 2nd edition, Dutch version (MABC-2-NL), for children between 3 and 16 years old.31,32 The Gross Motor Function Measure and the Gross Motor Function Classification System33,34 were used to measure and classify the subgroup of children with spasticity in both age groups. Furthermore, the Gross Motor Function Measure was used in children diagnosed with psychomotor retardation when assessment with
BSID-III-NL or MABC-2-NL was not possible because of cognitive disabilities. The Scale for the Assessment and Rating of Ataxia was used for children diagnosed with ataxia telangiectasia. The Motor Function Measure was used to assess a child with suspected neuromuscular disease, and the Pediatric Balance Scale was used in a child with mild ataxia.

Movement Quality
Movement quality was assessed by 1 pediatric physical therapist (A.J.W.M.J.) using the OMQ Scale, which was designed for children from 3 months to 16 years of age. The 15-item scale needs to be completed after the assessment of an age-specific discriminative motor test or disease-specific test. The OMQ Scale scores movement quality relative to what is expected for a child’s age. The 15 items are scored on a 5-point Likert scale (Appendix).

Data Methods
The descriptive data are presented as numbers and percentages for categorical variables and as median and interquartile range (IQR) for ordinal variables. For continuous data, means and SDs are reported.

Based on the clinical presentation and results of motor performance assessments, children were classified for motor disabilities by the pediatric physical therapist into severe motor disabilities, mild motor disabilities, and no motor disabilities. Criteria for severe motor disabilities and mild motor disabilities are provided in the Supplementary Table (available at: https://academic.oup.com/ptj). To make the outcomes of BSID-III-NL and MABC-2-NL comparable, the scores of motor tests were converted to z scores using an algorithm derived from the literature. Z scores of ≤ −2 indicated significantly delayed performance, scores of ≤ −1 but > −2 indicated mildly delayed performance, and scores of > −1 indicated normal performance within normal limits.

Nonparametric tests were used to test hypotheses for comparisons without normality or variance assumptions (Tab. 1). For group comparisons, the Jonckheere-Terpstra test for ordered alternatives was used when 3 independent groups were compared (hypothesis 1), and the Mann-Whitney U test was used when 2 independent groups were compared (hypothesis 7). In addition, the effect size estimate, r, as described by Rosenthal, was calculated to increase possibilities for interpretation. Spearman rank correlation coefficients were used to test correlation between z scores for motor tests and OMQ Scale total scores (hypothesis 2). Correlations were considered as follows: 0.00 to 0.25 = little or no relationship, 0.25 to 0.50 = fair relationship, 0.50 to 0.75 = moderate to good relationship, and > 0.75 = good to excellent relationship. Furthermore, cross-tabulations and Pearson chi-square tests were used to test relationships within hypotheses for diagnoses and OMQ Scale item scores (hypotheses 3–6). Statistical analyses were performed with the IBM Statistical Package for the Social Sciences (IBM SPSS Statistics), version 25 (IBM Corp, Armonk, NY, USA). All statistical tests were 2-tailed, and a P value of < .05 was considered significant.

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Results
This study reviewed data of 101 children, including 51 boys (50.5%), with a mean age of 8 years and 6 months (SD = 5 years 4 months) (Tab. 2). For all but 2 children, a classification for motor disabilities by the pediatric physical therapist based on clinical presentations was possible. The 2 missing classifications were due to difficulties in interpretation because of severe cognitive disabilities (eg, low test scores but able to walk independently and to climb stairs). Fifty-six children (55.4%) were classified as having severe motor disabilities, 17 children (16.8%) were classified as having mild motor disabilities, and 26 children (25.7%) were classified as having no motor disabilities.

Motor performance was successfully assessed in 82 children (81.2%) with the BSID-III-NL, MABC-2-NL, or Gross Motor Function Measure. In 10 children (9.9%), only partial assessment with MABC-2-NL was possible because of the severity of their disabilities. Nine children (8.9%) were assessed with disease-specific tests (eg, Scale for the Assessment and Rating of Ataxia). Outcomes on the BSID-III-NL (n = 21) showed a mean z score of −0.7 (SD = 1.6), and outcomes on the MABC-2-NL (n = 42) showed a mean z score of −1.6 (SD = 1.5). Data from the OMQ Scale were available for all 101 children; outcomes on the OMQ Scale showed a mean total score of 61.7 (SD = 11.0). Frequencies and percentages, means and SDs, and medians and IQRs for each item are presented in Table 3.

The relationship between the severity of motor disabilities and OMQ Scale total scores, hypothesis 1 (n = 99), was tested by a Jonckheere-Terpstra test, which showed a significant trend in the data: the more severe the motor disabilities, the lower the OMQ Scale total scores (Z = 2474.00; z = 7.13; P < .001; r = 0.72). Children classified with severe motor disabilities (n = 56) showed a median OMQ Scale total score of 56.5 (IQR = 15), children classified with mild motor disabilities (n = 17) had a median OMQ Scale total score of 68 (IQR = 9), and children classified with no motor disabilities (n = 26) had a median OMQ Scale total score of 73 (IQR = 6.3). A box-plot for the relationship between severity of motor
### Table 2.
Characteristics of Included Children (n = 101)\(^a\)

| Characteristic                                                                 | No. of Children | Mean       | SD         |
|-------------------------------------------------------------------------------|-----------------|------------|------------|
| Boys                                                                          | 51              |            |            |
| Girls                                                                         | 50              |            |            |
| Age                                                                           | 101             | 8 y 6 mo   | 5 y 4 mo   |
| Mitochondrial dysfunction                                                     |                 |            |            |
| Mitochondrial disease confirmed by mitochondrial DNA                          | 41              |            |            |
| Suspected mitochondrial dysfunction                                           | 39              |            |            |
| Psychomotor retardation                                                       | 30              |            |            |
| Ataxia                                                                        | 23              |            |            |
| Spasticity                                                                    | 11              |            |            |
| Reason for wheelchair use                                                      |                 |            |            |
| Neurological disorder                                                         | 25              |            |            |
| Fatigue                                                                       | 20              |            |            |
| Reason for diagnostic trajectory or outpatient hospital visit                 |                 |            |            |
| Mitochondrial dysfunction                                                     | 80              |            |            |
| Born preterm (≤30 wk of GA)                                                   | 7               |            |            |
| Ataxia telangiectasia                                                         | 7               |            |            |
| Perinatal asphyxia treated with hypothermia                                    | 4               |            |            |
| MAS or CHD needing ECMO                                                        | 3               |            |            |
| Motor disabilities classification by pediatric physical therapist              |                 |            |            |
| No motor disabilities                                                         | 26              |            |            |
| Mild motor disabilities                                                       | 17              |            |            |
| Severe motor disabilities                                                     | 56              |            |            |
| Discriminative motor test (z score) or disease-specific test result           |                 |            |            |
| BSID-III-NL                                                                   | 21              | -0.73      | 1.60       |
| MABC-2-NL                                                                     | 42              | -1.64      | 1.31       |
| GMFM\(^b\)                                                                    | 19              |            |            |
| MFM                                                                            | 1               |            |            |
| PBS                                                                            | 1               |            |            |
| SARA                                                                           | 7               |            |            |
| Categorization of children with spasticity (GMFCS level)                      |                 |            |            |
| I                                                                             | 1               |            |            |
| III                                                                            | 1               |            |            |
| IV                                                                             | 4               |            |            |
| V                                                                              | 5               |            |            |
| OMQ Scale total score                                                          | 101             | 61.7       | 10.99      |

\(^a\)BSID-III-NL = Bayley Scales of Infant and Toddler Development, 3rd edition, Dutch version; CHD = congenital hernia diaphragmatic syndrome; ECMO = extracorporeal membrane oxygenation; GA = gestational age; GMFCS = Gross Motor Function Classification System; GMFM = Gross Motor Function Measure; MABC-2-NL = Movement Assessment Battery, 2nd edition, Dutch version; MAS = meconium aspiration syndrome; MFM = Motor Function Measure; OMQ = Observable Movement Quality; PBS = Pediatric Balance Scale; SARA = Scale for Assessment and Rating of Ataxia.  
\(^b\)Used to assess children with spasticity and psychomotor retardation.
Construct Validity of the OMQ Scale

Table 3.
Frequencies (Percentages) of Individual OMQ Scale Item Scores and Mean (SD) and Median (IQR) for Each Item (n = 101)*

| Item No. | Item Description                      | Frequency (%) of Score of: | Mean (SD) | Median (IQR) |
|----------|---------------------------------------|-----------------------------|-----------|--------------|
| 1        | Appropriate fine motor movements      | 6 (5.9) 21 (20.8) 12 (11.9) 26 (25.7) 36 (35.6) | 3.6 (1.3) | 4 (3)        |
| 2        | Appropriate gross motor movements     | 6 (5.9) 17 (16.8) 22 (21.8) 28 (27.7) 28 (27.7) | 3.5 (1.3) | 4 (2)        |
| 3        | Fluency of movements                  | 8 (7.9) 14 (13.9) 16 (15.8) 30 (29.7) 33 (32.7) | 3.7 (1.3) | 4 (2)        |
| 4        | Reduced muscle tone                   | 2 (2.0) 7 (6.9) 12 (11.9) 28 (27.7) 52 (51.2) | 4.2 (1.0) | 5 (1)        |
| 5        | Increased muscle tone                 | 3 (3.0) 3 (3.0) 8 (7.9) 18 (17.8) 69 (68.3) | 4.5 (1.0) | 5 (1)        |
| 6        | Tremors                               | 3 (3.0) 11 (10.9) 5 (5.0) 10 (9.9) 72 (71.3) | 4.4 (1.2) | 5 (1)        |
| 7        | Slow and/or delayed movements         | 2 (2.0) 13 (12.9) 22 (21.8) 15 (14.9) 49 (48.5) | 4.0 (1.2) | 4 (2)        |
| 8        | Accelerated and/or abrupt movements   | 3 (3.0) 5 (5.0) 8 (7.9) 11 (10.9) 74 (73.3) | 4.5 (1.0) | 5 (1)        |
| 9        | Asymmetry in movements                | 3 (3.0) 4 (4.0) 9 (8.9) 37 (36.6) 48 (47.5) | 4.2 (1.0) | 4 (1)        |
| 10       | Accuracy (well aimed)                 | 5 (5.0) 11 (10.9) 21 (20.8) 29 (28.7) 35 (34.7) | 3.8 (1.2) | 4 (2)        |
| 11       | Strength regulation                   | 4 (4.0) 9 (8.9) 19 (18.8) 37 (36.6) 32 (31.7) | 3.8 (1.1) | 4 (2)        |
| 12       | Variation in movements                | 2 (2.0) 4 (4.0) 12 (11.9) 25 (24.8) 58 (57.4) | 4.3 (1.0) | 5 (1)        |
| 13       | Involuntary movements                 | 1 (1.0) 3 (3.0) 2 (2.0) 16 (15.8) 79 (78.2) | 4.7 (0.8) | 5 (0)        |
| 14       | Automated movements                   | 1 (1.0) 10 (9.9) 15 (14.9) 33 (32.7) 42 (41.6) | 4.0 (1.0) | 4 (2)        |
| 15       | Stereotyped movements                 | 1 (1.0) 5 (5.0) 6 (5.9) 3 (3.0) 86 (85.1) | 4.7 (0.9) | 5 (0)        |

*IQR = interquartile range; OMQ = Observable Movement Quality.

disabilities and OMQ Scale total scores showed larger variations in OMQ Scale total scores for children with severe motor disabilities than for children in the other groups (Fig. 1).

There was a significant positive relationship between OMQ Scale total scores and z scores on motor tests, hypothesis 2 (n = 63), as shown by the Spearman rank correlation ($r_s = 0.595$; 95% bias-corrected and accelerated confidence interval = 0.381–0.750; $P < .001$). A scatterplot (Suppl. Figure, available at https://academic.oup.com/ptj) displays OMQ Scale total scores and z scores on motor tests, showing more scattering of OMQ Scale total scores in children with low z scores on motor tests than in children with high z scores.

To test the possible existence of relationships between diagnoses and OMQ Scale items, cross-tabulation and Pearson chi-square tests were performed. The probabilities for scores on OMQ Scale items in children diagnosed with spasticity, psychomotor retardation, mitochondrial diseases, and ataxia are presented in a contingency table (Tab. 4). All hypothesized relationships between diagnosis and low scores on OMQ Scale items exceeded the critical value of 6.663 and were significant ($P < .005$), except for the diagnosis ataxia and the expected low scores on item 11 in which the Pearson chi-square test showed a value of 1.91 ($P = .13$).

A Mann-Whitney test indicated a statistically significant difference ($U = 56.5$; $z = -4.42$; $P < .001$; $r = 0.66$) between OMQ Scale total scores for children who are not ambulatory because of a neurological condition and OMQ scores for children who are not ambulatory because of fatigue caused, for example, by a mitochondrial disease (Fig. 2). Thus, results for the construct validity testing were that 6 of the 7 hypotheses (85.7%) were confirmed, although hypothesis 6 was rejected for only 1 of the 3 items (item 11); these data were judged as sufficient construct validity.

Discussion
This is the first study to assess the construct validity of the OMQ Scale. According to the COSMIN criteria, the construct validity of an instrument is sufficient when 75% of the predefined hypotheses are confirmed in a sample of at least 50 patients. With an 86% rate of confirmed predefined hypotheses in this study of 101 children, the COSMIN quality criteria were met. We used the overall quality criterion for adequate sample sizes for validation studies of measurement instruments, which were set by the COSMIN group, as a guidance for this study.
Construct Validity of the OMQ Scale

Figure 1.
Box plot showing correlation between severity of motor disabilities and Observable Movement Quality (OMQ) Scale total scores (n = 99).

Furthermore, in addition to needing an appropriate sample size, even sample sizes per age group and sex were needed because the OMQ Scale was designed for children in the broad age range of 3 months to 16 years. Therefore, data from other groups, also assessed during a multidisciplinary evaluation, were added to the data from children with suspected mitochondrial dysfunction. This was done to ensure that a diversity of motor problems was included in the sample.

Assessing the relationship between the severity of motor disabilities and OMQ Scale total scores revealed a greater range of OMQ Scale total scores in children with severe motor disabilities than in children with mild or no motor disabilities. A similar pattern was noticed when assessing the relationship between z scores on motor tests and OMQ Scale total scores. A closer examination of the data showed that 3 children with high OMQ Scale total scores were classified with severe motor disabilities—or a z score of \( \leq -2 \), indicating a significant delay for motor performances. However, these children scored more than 1 IQR above the subgroups' median for OMQ Scale total scores. These 3 children were all suspected to have mitochondrial dysfunction. This indicates that the classification of severe disabilities in these children with good quality of movement was based on their limited functioning in daily life because of other aspects, such as severe fatigue. A contrasting outcome can be noticed in children classified as having no motor disabilities—or a z score indicating motor performance within normal limits—who scored more than 1 IQR below the subgroups' median on OMQ Scale total scores. These 3 children—including the outlier shown in the box plot in Figure 1—were children born preterm. Those 3 preterm-born children were assessed at, respectively, 5, 11, and 27 months of age, and showed no delay in motor performance. However, they showed a low score for movement quality. At a young age, the spontaneous recovery of abnormal motor signs, and thereby quality of movement, was reported in the literature, indicating the potential for these children to catch up in their quality of movement. However, low scores for motor quality could also indicate that these children are at risk for future developmental delays. Both these clinical discrepancies were seen in longitudinal motor performance studies, using quantitative motor assessments, in which large variabilities in individual developmental trajectories were shown. This confirms the necessity for pediatric physical therapists to rely not only on the outcomes of the quantitative motor assessment or on the assessment of movement quality alone. Instead, physical therapists should evaluate both factors and relate the outcomes to the functional capabilities of the child before developing a personalized therapy approach. However, in future studies, we need to test whether combined use of quantitative motor tests and the assessment of movement quality can refine prediction models for individual motor developmental trajectories. This can possibly contribute to the determination of the effects on motor development after developmental interventions.

The assessment of the relationship between diagnoses and OMQ Scale item scores showed that the hypothesis of an expected probability for low scores on item 11 (strength regulation) in children with ataxia was not confirmed. Cerebellar damage that results in ataxia leads to the presence of tremors and increases the instability and poor accuracy of movements. In the literature, the role of the cerebellum is mentioned in the regulation of muscle tone and its importance for balance control and the
### Table 4.
Contingency Table Showing the Relationship Between Diagnoses and Item Scores on the OMQ Scale (n = 101) (Hypotheses 3–6)\(^a\)

| Diagnosis                        | Presence (Yes) or Absence (No) | Item | \(\chi^2\) (n = 101) | \(P\) | % of: Low Scores (Scores of 1–3) | Normal Score (Score of 4 or 5) | Confirmed? |
|---------------------------------|---------------------------------|------|----------------------|-------|---------------------------------|-------------------------------|-------------|
| Spasticity                      | Yes 5                           | 17.11| .001                 |       | 54.5                            | 45.5                          | Yes         |
|                                 | No                              |      |                       |       | 8.9                             | 91.1                          |             |
|                                 | Yes 12                          | 25.41| .001                 |       | 72.7                            | 27.3                          | Yes         |
|                                 | No                              |      |                       |       | 11.1                            | 88.9                          |             |
| Psychomotor retardation         | Yes 15                          | 25.04| .001                 |       | 36.7                            | 63.3                          | Yes         |
|                                 | No                              |      |                       |       | 1.4                             | 98.6                          |             |
| Mitochondrial disease, confirmed| Yes 11                          | 6.85 | .01                  |       | 46.3                            | 53.7                          | Yes         |
|                                 | No                              |      |                       |       | 21.7                            | 78.3                          |             |
| Ataxia                          | Yes 6                           | 50.23| .001                 |       | 69.6                            | 30.4                          | Yes         |
|                                 | No                              |      |                       |       | 3.8                             | 96.2                          |             |
|                                 | Yes 10                          | 22.23| .001                 |       | 78.3                            | 21.7                          | Yes         |
|                                 | No                              |      |                       |       | 24.4                            | 75.6                          |             |
|                                 | Yes 11                          | 1.91 | .13                  |       | 43.5                            | 56.5                          | No          |
|                                 | No                              |      |                       |       | 28.2                            | 71.8                          |             |

\(^a\)OMQ = Observable Movement Quality.

### Figure 2.
Comparison of total scores on Observable Movement Quality (OMQ) Scale for 2 groups of children who were not ambulatory (n = 45).

modulation of rhythmic agonist and antagonist muscle activity—necessary for adequate direction, timing, and amplitude of movements.\(^{55–57}\) However, clear statements about muscle strength or strength regulation were not found. Even though in this study the presence of tremors and deviant outcomes for the level of accuracy of movements were scored, no deviant outcomes on strength regulation were scored, which agrees with the literature but contradicts the predefined hypothesis. This hypothesis was possibly not formulated specifically enough.

The COSMIN taxonomy of measurement properties\(^{25}\) states that all measurement properties included in their taxonomy are relevant and should be evaluated for each measurement instrument. Three quality domains are thereby distinguished: reliability, validity, and
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Responsiveness. Content validity was considered as the most important measurement property; all content (eg, items) should be relevant, comprehensible, and comprehensive with respect to the construct of interest and target population. During the developmental process of the OMQ Scale, the selection of OMQ Scale items was based on a conceptual construct of quality of movement (based on expert opinions), and content validity was established. Next, the internal structure (which includes structural validity and internal consistency and is crucial for item reduction and selection of subscales) is considered important. This is true, however, only for measurement instruments based on a reflective model. Because the OMQ Scale is a formative measurement model, an analysis evaluating the internal structure was not relevant. We continued to evaluate the measurement property of construct validity in this study, which we showed to be sufficient. A first study on reliability of the OMQ Scale, including first reports on measurement error, was published, reporting moderate interrater reliability. A future study on responsiveness of the OMQ Scale and remaining items of reliability (such as intrarater reliability) will complete the validation of the OMQ Scale and provide further evidence for the use of the OMQ Scale in clinical practice.

A limitation of our study was that the inclusion of children with mitochondrial diseases was based on the theoretical assumption. Assumed was that the children would show a relevant variation in clinical representations and that they would show deviant outcomes in all aspects of quality of movement. Based on our results, it appears that children with low strength regulation were underrepresented. Therefore, it will be beneficial for the validation of the OMQ Scale to assess the hypotheses also within other subgroups such as neuromuscular diseases or syndromes. Moreover, additional hypotheses could have been formulated regarding muscle tone, strength regulation, and the timing of movements. Another limitation of this study was that this was a single center study from 1 university hospital; a multicenter study would have been beneficial for the generalizability of the results.

Conclusion

The OMQ Scale demonstrates a sufficient construct validity in children assessed for motor performance as part of a multidisciplinary assessment. Our findings indicate that the construct of the OMQ Scale—based on expert opinion in the developmental phase—is valid and can be used in clinical practice. However, a future study for additional hypotheses testing in subgroups of children diagnosed with neuromuscular diseases or syndromes will be beneficial for increased statements on validity. Furthermore, a future study on responsiveness of the OMQ Scale and remaining items of reliability will complete the validation of the OMQ Scale and provide further evidence for the use of the OMQ Scale in clinical practice.

Author Contributions and Acknowledgments

Concept/idea/research design: L.M.A. Dekkers, A.J.W.M. Janssen, A.R.T. Donders, M.W.G. Nijhuis-van der Sanden, B.J.M. de Swart

Writing: L.M.A. Dekkers, A.J.W.M. Janssen, M.W.G. Nijhuis-van der Sanden, B.J.M. de Swart

Data collection: A.J.W.M. Janssen

Data analysis: L.M.A. Dekkers, A.J.W.M. Janssen, A.R.T. Donders, M.W.G. Nijhuis-van der Sanden, B.J.M. de Swart

Project management: M.W.G. Nijhuis-van der Sanden, B.J.M. de Swart

Providing facilities/equipment: M.W.G. Nijhuis-van der Sanden

Consultation (including review of manuscript before submitting): A.R.T. Donders, M.W.G. Nijhuis-van der Sanden, B.J.M. de Swart

Ethics Approval

The regional medical ethics committee of the Radboud University Medical Center (Radboudumc) agreed that the study conformed to the Declaration of Helsinki and that approval was not required. This committee waived the requirement to obtain informed consent (registration no. 2018-4842).

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Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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Appendix.

Observable Movement Quality (OMQ) Scale Terminology, Definitions, and 5-Point Likert Scale With Description of Aspects

1. **Appropriate fine motor movements**
The child adapts its postures and movements to the demands of the fine motor tasks and the environment.

1. Consistently inappropriate
2. Typically inappropriate; 1 or 2 instances of appropriate fine motor movements
3. Inappropriate half of the time and appropriate other half of the time
4. Typically appropriate; 1 or 2 instances of inappropriate fine motor movements
5. Consistently appropriate

2. **Appropriate gross motor movements**
The child adapts its postures and movements to the demands of the gross motor tasks and the environment.

1. Consistently inappropriate
2. Typically inappropriate; 1 or 2 instances of appropriate gross motor movements
3. Inappropriate half of the time and appropriate other half of the time
4. Typically appropriate; 1 or 2 instances of inappropriate gross motor movements
5. Consistently appropriate

3. **Fluency of movements**
The movements of the child are controlled in such a manner that they are adapted to the tasks and the environment in a fluent manner, without faltering or stumbling.

1. Consistently not fluent
2. Typically not fluent; 1 or 2 instances of fluent movements
3. Not fluent half of the time and fluent other half of the time
4. Typically fluent; 1 or 2 instances of not fluent movements
5. Consistently fluent

4. **Reduced muscle tone**
The movements and/or maintenance of posture of the child give the impression of being slack and not adapted to the tasks and environment.

1. Consistently low muscle tone: like a rag doll
2. Typically low muscle tone; 1 or 2 instances without low muscle tone
3. Low muscle tone half of the time and without low muscle tone other half of the time
4. Typically without low muscle tone; 1 or 2 instances of low muscle tone
5. Absence of low muscle tone

5. **Increased muscle tone**
The movements and/or maintenance of posture give the impression of being stiff/rigid and not adapted to the tasks and the environment.

1. Consistently high muscle tone: muscles are rigid and tight
2. Typically high muscle tone; 1 or 2 instances without high muscle tone
3. High muscle tone half of the time and without high muscle tone other half of the time
4. Typically without high muscle tone; 1 or 2 instances of high muscle tone
5. Absence of high muscle tone

6. **Tremors**
There is an involuntary, rhythmic, periodic, uncontrollable trembling of a body part or body parts during the child's movements, which can vary in amplitude from barely observable to clearly visible or in frequency from low to high.

1. Constantly
2. Frequently
3. Occasionally
4. Infrequently
5. None

7. **Slow/delayed movements**
The child moves the body or a part at a lower speed than is suitable for the task and can, despite instruction, not accelerate sufficiently.

1. Consistently slow and delayed movements
2. Typically slow and delayed; 1 or 2 instances of appropriate timing and pacing
3. Slow and delayed half of the time and appropriately timed and paced other half of the time
4. Typically appropriate timing and pacing; 1 or 2 instances of slow and delayed movements
5. Absence of slow and delayed movements

8. **Accelerated/abrupt movements**
The child moves the body or a part at a higher speed or abruptly at a higher speed than is suitable for the task and can, despite instruction, not slow down sufficiently.

1. Consistently accelerated and abrupt movements
2. Typically accelerated and abrupt; 1 or 2 instances of appropriate timing and pacing
3. Accelerated and abrupt half of the time and appropriately timed and paced other half of the time
4. Typically appropriate timing and pacing; 1 or 2 instances of accelerated and abrupt movements
5. Absence of accelerated and abrupt movements

9. Asymmetry in movements
In movements and/or maintenance of posture, a body half or part of a body half inadequately participates in the task. The difference in the use of body parts does not fit with the age of the child and with the demands of the tasks and the environment.

1. Consistently asymmetric
2. Typically asymmetric; 1 or 2 instances of symmetry
3. Asymmetric half of the time and symmetric other half of the time
4. Typically symmetric; 1 or 2 instances of asymmetry
5. Consistently symmetric

10. Accuracy (well aimed)
The child moves the body parts in such a way that the target is reached accurately and immediately.

1. Target consistently not reached
2. Target typically not reached; 1 or 2 instances of target being reached
3. Target not reached half of the time and target reached other half of the time
4. Target typically reached; 1 or 2 instances of target not being reached
5. Target consistently reached

11. Strength regulation
The movements of the child are in terms of force/strength well suited to the task and the environment.

1. Strength consistently not adapted to tasks
2. Strength typically not adapted to tasks; 1 or 2 instances of strength adapted to tasks
3. Strength not adapted to tasks half of the time and strength adapted to tasks other half of the time
4. Strength typically adapted to tasks; 1 or 2 instances of strength not adapted to tasks
5. Strength consistently adapted to tasks

12. Variation in movements
The child can move body parts relatively independently from each other in different directions, so the necessary degrees of freedom are used to match the demands of the tasks and the environment.

1. Consistently no variation in movements
2. Typically no variation in movements; 1 or 2 instances of variation in movements
3. No variation in movements half of the time; variation in movements half of the time
4. Typically variation in movements; 1 or 2 instances of no variation in movements
5. Consistently variation in movements

13. Involuntary movements
While moving, parts of the child's body and/or those parts not directly involved in the movements show unconscious movements not appropriate to the child's age.

1. Consistently involuntary movements
2. Typically involuntary movements; 1 or 2 instances of involuntary movements
3. Involuntary movements half of the time and without involuntary movements other half of the time
4. Typically without involuntary movements; 1 or 2 instances of involuntary movements
5. Absence of involuntary movements

14. Automated movements
The child has mastered the skills appropriate for the age in such a way that these are consistent and can be executed without much attention, and, if necessary, in combination with another task or tasks.

1. Movements consistently not automated
2. Typically movements not automated; 1 or 2 instances of automated movements
3. No automated movements half of the time and automated movements other half of the time
4. Typically automated movements; 1 or 2 instances of no automated movements
5. Consistently automated movements

15. Stereotyped movements
The child shows spontaneous, repetitive, purposeless movements (examples include repeatedly turning and shaking of the head and/or rocking or flutter of body parts).

1. Consistently stereotyped movements
2. Typically stereotyped movements; 1 or 2 instances of stereotyped movements
3. Stereotyped movements half of the time and without stereotyped movements other half of the time
4. Typically without stereotyped movements; 1 or 2 instances of stereotyped movements
5. Absence of stereotyped movements

a. In a previous version (2012), “normal” was used instead of “without low” (Adapted in 2015).
b. In a previous version (2012), “normal” was used instead of “without high” (adapted in 2015).
c. Deleted from the description: “has an extensive repertoire of” (adapted in 2015).
d. Deleted from the description: “that disrupt the proper execution of the task” (adapted in 2015).
e. In a previous version (2012), “normal” was used instead of “without low.” (adapted in 2015).