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Reliability and validity of the fine motor scale of the Peabody Developmental Motor Scales–2

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ABSTRACT: This study examined the test–retest reliability, inter-rater reliability, convergent validity and discriminant validity of the Fine Motor Scale of the Peabody Developmental Motor Scales–second edition (PDMS-FM-2). Participants included two groups of 18 children between the ages of 4 and 5 years with and without mild fine motor problems. The PDMS-FM-2 was administered twice to 12 children and rated by two occupational therapists. The PDMS-FM-2 results were compared with scores on the Movement Assessment Battery for Children (M-ABC). In addition, the scores of the children with and without fine motor problems were compared. For the test–retest reliability and the inter-rater reliability, correlation coefficients varied from $r = 0.84$ to $r = 0.99$. These results suggest that PDMS-FM-2 has excellent test–retest and inter-rater reliability. Convergent validity with the fine motor section of the M-ABC and discriminant validity have been confirmed. Only 39% of the children in the group with problems in fine motor activities had fine motor problems according to the PDMS-FM-2. This finding seems to indicate that the PDMS-FM-2 may not be sensitive enough for this population.

Key words: fine motor assessment, paediatric occupational therapy, Peabody Developmental Motor Scales–Fine Motor–2 (PDMS-FM-2), Movement ABC

Introduction

In paediatric occupational therapy, activities during play, self-care and school occupations are of prime importance (Law et al., 2001) and fine motor skills are essential for the performance of children’s occupations. Exner (2001)
defines fine motor skills as those skills accomplished with hands to attain and manipulate objects. Through the use of a dextrous grasp, the manipulation of objects and the enabling of multiple tool functions, the child can engage in play, self-care and school occupations (Henderson and Pehoski, 1995). Marr et al. (2003) found that children in kindergarten spend nearly one half (46%) of their in-class time in some type of fine motor activity.

The delayed development of fine motor skills in young children is frequently a cause for referral to school-based occupational therapists (Oliver, 1990). Most children in kindergarten do not experience difficulties in pre-school activities. However, a subgroup of children struggles with the acquisition of these activities. Currently the term developmental coordination disorder (DCD) is used when referring to children who exhibit mild motor problems not due to a medical condition, such as a neurological disorder. By definition, children with DCD demonstrate difficulties in motor co-ordination that negatively impact school performance and/or daily living (American Psychiatric Association, 1994).

The occupational therapist serves as the specialist for the child when delays in the development of hand skills interfere with the ability to do pre-school activities, such as drawing, printing, fastening, constructing with blocks and toys, or manipulating small objects (Case-Smith, 1996, 2000; Case-Smith et al., 1998). The goal of school-based occupational therapy is to improve a child’s performance of tasks and activities important for functioning in school (Case-Smith et al., 2001). The delayed development of fine motor skills in young children is frequently a cause for referral to school-based occupational therapists (Oliver, 1990).

School-based occupational therapists in The Netherlands, who work with pre-school children with mild fine motor problems, lack a reliable and valid measure to assess fine motor skills. There are measures for pre-school children with major fine motor problems, such as the Quality of Upper Extremities Test (DeMatteo et al., 1992) and the Melbourne Assessment (Randall et al., 1999), which are used in The Netherlands. Both are developed for children with cerebral palsy. For children with DCD who experience motor problems, there is the Dutch version of the Movement Assessment Battery for Children (M-ABC; Henderson and Sugden, 1992; Smits-Engelsman, 1998). This measure is frequently administered by physical therapists and occupational therapists in The Netherlands. Unfortunately, the fine motor section of this test consists of only three items. The authors of the M-ABC state that care must be taken when drawing a conclusion about only the fine motor section.

A literature review was conducted, searching for assessment tools that evaluate fine motor skills in pre-school children, between the ages of 4 and 6 years, with mild fine motor problems not caused by a neurological disorder. The assessment tools found during the literature search were evaluated on their test qualities as well as on the criteria for the assessment of the fine motor construct. The clinimetric qualities that were evaluated were: standardization,
reliability, validity, norm referencing and whether a valid fine motor score was
given. The criteria for the fine motor construct required that the test evaluated
items requiring grasp, release, in-hand manipulation, bilateral hand use, tool
use and dexterity. The Fine Motor Scale of the Peabody Developmental Motor
Scales – second edition (PDMS-FM-2; Folio and Fewell, 2000) appeared to be
the only assessment tool that fulfilled both the clinimetric criteria and the
criteria for the fine motor construct. The only aspect of the fine motor
construct that is not assessed in the PDMS-FM-2 is in-hand manipulation.

The purpose of the study was to examine reliability and construct validity
of the PDMS-FM-2 in pre-school children between the ages of 4 and 5 years
with problems in fine motor skills. Construct validity is defined as the
evidence that the measurement tool actually measures what it purports to
measure (Feinstein, 1987). Folio and Fewell (2000) state that a test’s validity
must be investigated repeatedly until a conclusive body of data has accumu-
lated. Construct validity was determined by assessing the convergent and the
discriminant validity between two groups (Feinstein, 1987; Streiner and
Norman, 1996).

The guiding questions for this study were as follows:

1. What is the test–retest reliability of the PDMS-FM-2?
2. What is the inter-rater reliability of the PDMS-FM-2?
3. What is the convergent validity in terms of a correlation between the
   PDMS-FM-2 and the fine motor section of the M-ABC?
4. What is the discriminant validity of the PDMS-FM-2, when comparing the
test scores of children with problems in fine motor skills and children
   without problems in fine motor skills?

Methods

Study design

A quantitative study was conducted to research the test qualities of the
PDMS-FM-2.

Participants

For this study 18 children between the ages of 4 and 5 years were selected after
meeting the following criteria: (1) They had mild fine motor problems as
indicated by the school teacher, and (2) the mild fine motor problems were
not caused by a neurological disorder, such as cerebral palsy. The fine motor
problems were determined by the Checklist of Fine Motor Skills, which was
specially composed for this research on the basis of Part I of the Checklist
Movement ABC (Henderson and Sugden, 1992; Smits-Engelsman, 1998).

Most of the children with fine motor problems (n = 13) came from the
Pedological School, a special school for children with pedagogical problems and/or learning problems. Children from this school were chosen because there is a greater prevalence of children with developmental motor delays in special education as compared to children in regular education (Kalverboer, 1996). By choosing this school to recruit participants, the chance of obtaining a large enough sample size for this research project was expected. In The Netherlands, pre-school children reach the age of 6 years in the last pre-school year. Due to the fact that the maximum age for the PDMS-FM-2 is 71 months, there were not enough eligible pre-school children in the Pedological School. Therefore, the study group was supplemented with five children from regular schools who were referred by their teacher to occupational therapy for an assessment because of problems with fine motor activities.

This group of children with fine motor problems consisted of 16 boys and 2 girls aged 52 to 71 months (mean 61.9 months). Thirteen children were right-handed and five were left-handed. From this group, 12 children from the Pedological School took part in the reliability study. This group of children consisted of 11 boys and one girl aged 52 to 72 months (mean 61 months). Eight children were right-handed and four were left-handed. The control group included 18 children from a regular school without fine motor problems, according to their teachers. These children were matched for both age and gender to the group of children with fine motor problems. Table 1 provides details on age and gender of both groups. There were no significant differences between groups on age (p > 0.73) or gender. The parents of all children had given written informed consent for their children to participate in this study.

Instruments

PDMS-FM-2

The PDMS-2 is a standardized test, designed to evaluate both fine and gross motor skills in children from birth to 71 months of age. It is a reliable and valid assessment tool. This study focuses on the PDMS-FM-2, which consists of two subtests: Grasping, and Visual-Motor Integration (standard score range: 1–20). The Fine Motor Quotient (FMQ) is derived by adding the subtest standard
scores and converting the sum to a quotient (range: 25–165). Standard scores and quotients can be transposed to percentile scores. The PDMS-FM-2 is a standardized test; for each item the instructions are described in full text. For this study, the text of the items and the examiner record booklet have been translated into Dutch. The standardized PDMS-2 test kit was used for the administration of the fine motor scales. The items not included in the kit were provided by the primary investigator.

M-ABC

The M-ABC consists of four age-related item sets. Each set is composed of eight items that measure different aspects of motor ability: three items measure manual dexterity, two measure ball manipulation skills and three measure static and dynamic equilibrium. In this study, only the items evaluating manual dexterity were used. Scores range from 0 to 5 on each item, so the total score for manual dexterity can vary from 0 to 15. The manual dexterity score can be converted to percentile scores. The 15th percentile score is used as cut-off point. The test has acceptable reliability and validity. Henderson and Sugden (1992) found a 62–100% agreement in classification (scores) between two measurements at a two-week interval. Smits-Engelsman (1998) found 90–96% agreement of classification of motor performance between two measurements at a two-week interval. Smits-Engelsman et al. (1998) studied the relationship between the M-ABC test and the Körper Koordination Test für Kinder (Kiphard and Shilling, 1974) in 202 children. A correlation of 0.62 and a Cramer’s V of 0.56 was found for classification of motor performance (Smits-Engelsman et al., 2001).

Procedure

To determine test–retest reliability, rater 1 administered the PDMS-FM-2 twice to 12 children with fine motor problems with an interval of 1 week. To determine inter-rater reliability, 12 children were videotaped during the administration of the PDMS-FM-2 by rater 1. Rater 2 viewed and scored the videotapes separately from rater 1 in random order. The subjects’ test papers, obtained during the assessment for the drawing and cutting test items were available for rater 2. Basal and ceiling levels, as described in the manual, were not used because they could give rater 2 cues about how rater 1 scored the child. In order to decrease cueing that a ceiling level had been reached, rater 1 tested at random, 1, 2 or 3 items above ceiling level. For the basal level, rater 1 tested at random, 1, 2 or 3 items below basal level. The random order was established by picking up a card off a pile.

To determine convergent validity, the PDMS-FM-2 and the manual dexterity items of the M-ABC were administered to all 18 children with fine motor problems. To determine discriminant validity, the PDMS-FM-2 was also
administered to the 18 children without fine motor problems. The scores of the children with problems in fine motor activities (n = 18) were compared to the scores of the children without problems (n = 18). The manual dexterity items of the M-ABC were also administered to the children without fine motor problems in order to compare the fine motor capabilities of both groups.

The test administrators were two occupational therapists with 18 and 14 years’ experience in paediatric occupational therapy, respectively. The raters prepared for the data collection independently by following the training procedure as described in the test manual (Folio and Fewell, 2000).

Data analysis
To define the sample size, the Correlation Coefficient Power Calculator from the UCLA Department of Statistics (www.statpages.net) was used. For a correlation coefficient of 0.8, an \( \alpha = 0.05 \) and a power of 0.80, nine children had to participate. For the PDMS-FM-2, standard scores per subtest were calculated by rater 1. From the total standard score for the fine motor scales, the Fine Motor Quotient (FMQ) and percentiles scores were calculated.

From the M-ABC, raw test scores were computed in weighted scores allowing for the determination of a score for manual dexterity. This final cluster score was then used to examine whether or not the percentile score was below the 15th percentile. Data were analysed using the SPSS/PC+ Statistics Version 10.0 (SPSS Inc. Illinois, USA).

For test–retest reliability and inter-rater reliability, the data were analysed based on the standard scores of the subtests and the FMQ of the PDMS-FM-2. Spearman’s rho correlation coefficient was used. The Wilcoxon signed-ranks test was used to determine if there was an equal partition of the variables. To demonstrate test–retest reliability it was expected, on the basis of the outcomes of the study of Folio and Fewell (2000), that there would be an almost perfect agreement with a correlation coefficient between 0.81 and 1.0. For an evaluation of the expected agreement, the classification of Landis and Koch (1997) was used: 0.01–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; 0.81–1.0 = almost perfect.

For convergent validity the standard score of the FMQ of the PDMS-FM-2 was compared with the cluster score of manual dexterity of the M-ABC. Spearman’s rho correlation coefficient was used. A strong agreement between the outcomes on the two tests was expected, with a correlation coefficient between 0.61 and 0.80. For discriminative validity, the standard scores of the subtests and the FMQ of the PDMS-FM-2 were used as well as the cluster scores of manual dexterity of the M-ABC. The Mann-Whitney test for two independent samples was used to test whether there was a significant difference between the two groups. This test was also used to determine the difference in the two groups. Both the PDMS-FM-2 and the M-ABC have a cut-off point for children who are considered to have fine motor problems. The
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The cut-off point of the PDMS-FM-2 is the 16th percentile and the cut-off point of the M-ABC is the 15th percentile. Significance level was set at the $\alpha = 0.05$ level for all analyses.

**Results**

Test–retest reliability varied from $r = 0.84 \ (p < 0.001)$ to $r = 0.98 \ (p < 0.000)$. There is an equal partition ($0.33 < p > 0.48$) of the comparing variables. The inter-rater reliability varied from $r = 0.94 \ (p < 0.000)$ to $r = 0.99 \ (p < 0.000)$. There is also an equal partition ($0.20 < p > 1.00$) of the compared variables. See Table 2 for the outcomes of test–retest and inter-rater reliability.

For the convergent validity the correlation coefficient was $r = 0.69 \ (p < 0.002)$. The discriminant validity is determined with the M-ABC and the PDMS-FM-2. For the M-ABC the mean rank of the fine motor section of the study group was 26 and the mean rank of the control group was 11. The Z-value of the statistic test on the M-ABC was 4.24 ($p < 0.000$). The difference in fine motor abilities between the two groups on the PDMS-FM-2 ranged from $Z= -4.59 \ (p < 0.000)$ to $Z= -2.80 \ (p < 0.005)$ (see Table 3).

### Table 2. Correlation coefficients test–retest and inter-rater reliability (Spearman’s rho) with the significance for equal partition (Wilcoxon signed rank test) with $p$-values ($n = 12$)

<table>
<thead>
<tr>
<th>Scores PDMS-FM-2</th>
<th>Test-retest</th>
<th>p-value</th>
<th>Equal partition</th>
<th>Inter-rater</th>
<th>p-value</th>
<th>Equal partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Motor Quotient</td>
<td>0.98</td>
<td>0.000</td>
<td>$p &gt; 0.39$</td>
<td>0.98</td>
<td>0.000</td>
<td>$p &gt; 0.38$</td>
</tr>
<tr>
<td>Standard score Grasping</td>
<td>0.96</td>
<td>0.000</td>
<td>$p &gt; 0.48$</td>
<td>0.94</td>
<td>0.000</td>
<td>$p &gt; 0.20$</td>
</tr>
<tr>
<td>Standard score Visual-Motor</td>
<td>0.84</td>
<td>0.001</td>
<td>$p &gt; 0.33$</td>
<td>0.99</td>
<td>0.000</td>
<td>$p &gt; 1.0$</td>
</tr>
</tbody>
</table>

### Table 3. Outcomes of PDMS-FM-2 on the Mann-Whitney test for two independent samples of the group with (presumed) fine motor problems ($n = 18$) and the group without fine motor problems ($n = 18$)

<table>
<thead>
<tr>
<th>Scores</th>
<th>Group</th>
<th>Mean rank</th>
<th>Sum of ranks</th>
<th>Z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Motor Quotient</td>
<td>With problems</td>
<td>10.75</td>
<td>193.50</td>
<td>-4.43</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Without problems</td>
<td>26.25</td>
<td>472.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard score Grasping</td>
<td>With problems</td>
<td>13.69</td>
<td>246.50</td>
<td>-2.80</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Without problems</td>
<td>23.31</td>
<td>419.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard score Visual-Motor</td>
<td>With problems</td>
<td>10.50</td>
<td>189.00</td>
<td>-4.59</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Without problems</td>
<td>26.50</td>
<td>477.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on the percentile score of the PDMS-FM-2, a nominal outcome is established delineating having or not having fine motor problems. Of the group children with fine motor problems according to their teachers, 39% had fine motor problems as compared to 0% of the children in the group without fine motor problems. Based on the percentile score of the M-ABC, of the group of children with fine motor problems according to their teachers, 78% had fine motor problems according to the Dutch M-ABC norm data. When using the American M-ABC norm data 50% had fine motor problems. In the group of children without fine motor problems there were, according to the Dutch and American M-ABC norm data, 0% children with fine motor problems. Table 4 provides the nominal outcomes on both tests.

**Discussion**

Based on the literature research, the PDMS-FM-2 is the only available test that meets the accepted criteria of reliability and validity and the criteria for the fine motor construct, except for in-hand manipulation. The purpose of this study was to examine if the PDMS-FM-2 was a reliable and valid assessment tool to be used with children, between the ages of 4 and 5 years, who have problems in the execution of fine motor activities.

The test–retest reliability and the inter-rater reliability were determined via analysis of the Fine Motor Quotient (FMQ) and the standard scores of the subtests Grasping and Visual-Motor Integration. This was done in order to be consistent with the analysis of Folio and Fewell (2000) who also determined the reliability based on these scores. The results indicated that, as was expected, reliability met the criteria ($r = 0.81–1.0$). The reliability was almost perfect, the correlation coefficients varied from $r = 0.84$ to $r = 0.99$. These
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Values are comparable to the correlation coefficients of the reliability study in the manual of PDMS-FM-2 (Folio and Fewell, 2000), which vary from $r = 0.73$ to $r = 1.00$.

A factor that contributed to the high reliability of PDMS-FM-2 is the fact that most of the outcome scores were based on quantitative measures (Larkin and Cermak, 2002), such as buttoning, that must be done within 20 seconds. An additional factor that might have improved the inter-rater reliability values obtained in this study was the use of videotapes. The ability to review a child’s performance may have increased inter-rater reliability (Gebhard et al., 1994). Observers generally have greater agreement when they are aware that their observations are being assessed (Stokes et al., 1989).

To determine the convergent validity, the manual dexterity items of the M-ABC were administered in addition to PDMS-FM-2. To assess convergent validity, there must be another test administered which measures the same construct. The fine motor construct of PDMS-FM-2 is composed of items concerning grasping and visual motor integration and the fine motor construct of the M-ABC is composed of items concerning manual dexterity. Although the items on the two tests are different, convergent validity can be assessed because grasping and visual motor integration are the basic necessities for manual dexterity. The correlation that was found between PDMS-FM-2 and the M-ABC met the expected criteria ($r = 0.61–0.80$). The correlation coefficient $r = 0.69$ indicated a strong agreement between the tests. According to Streiner and Norman (1996) it is satisfying to have a strong correlation, especially because PDMS-FM-2 is ‘better’, namely, it explains more findings and allows for more accurate judgement on the tested construct.

To determine discriminative validity, PDMS-FM-2 was administered to a group of 18 children with problems in fine motor activities and to a group of 18 children without fine motor problems. The presence of problems in fine motor activities was initially based on the opinion of the teacher. Although this is not a gold standard, it is what often occurs in daily practice. The teacher worries about the fine motor abilities and refers the child to an occupational therapist. By administering the manual dexterity items of the M-ABC to both groups, the teachers’ opinion was validated by means of an objective score from the test. There was a difference in Z-value between the two groups of −4.24 ($p < 0.000$). The difference between the two groups is more than four standard deviations. Based on the percentile score of the M-ABC, a nominal outcome was established delineating having, or not having, fine motor problems. Of the group of children reported to have fine motor problems by their teachers, 78% had fine motor problems according to the Dutch M-ABC norm data. When using the American M-ABC norm data 50% had fine motor problems. In the control group of children none was found to have fine motor problems according to the Dutch and American M-ABC norm data. Upon evaluation of the M-ABC norm data, there was an obvious difference between the two groups, however the manual dexterity items of the M-ABC are not a ‘gold standard’.
Through statistical analysis of the outcomes of the PDMS-FM-2 for the two groups, the Z-value varied from –4.59 to –2.80 (a contrast of 4.5 to 3 standard deviations was present, indicating a significant difference). When the contrast was based on the nominal outcome of the percentile scores of the PDMS-FM-2, there was an evident difference: 39% of the children in the study group had fine motor problems as compared to 0% of the children in the control group. However the discriminative validity that was found did not meet the expected criteria (80%).

The question is, what is the clinical relevance of the PDMS-FM-2 for children with problems in fine motor activities? It was expected that a minimum of 80% of the children in the study group would have fine motor problems according to the PDMS-FM-2. However this was not the case. Only 39% of the children with problems in fine motor activities had fine motor problems according to the PDMS-FM-2. This seems to indicate that the PDMS-FM-2 is not sensitive enough for this population. Larkin and Cermak (2002) also mentioned this limiting factor in current assessment tools for the identification of developmental co-ordination disorder. They also indicated that the lack of precision in an assessment can be a source of frustration for the practitioner. This was also experienced by the therapists administering the PDMS-FM-2 in this study. The quantitative outcomes on the test were within the norms, but during observation of the quality of performance, problems that were mentioned by the teacher could be identified. An example of this is observed during 'cutting a square'. The child might have met the quantitative norm and received the maximum score of 2, but performed the task in an uncoordinated and primitive way, with much difficulty.

As mentioned in the introduction, the only aspect of the fine motor construct that is not assessed in the PDMS-FM-2 is in-hand manipulation. In fact manipulative skills could differentiate between children with and without fine motor problems (Exner, 1992; Miles Breslin and Exner, 1999). Despite the importance of these skills, none of the standardized assessments used by occupational therapists specifically measures the quality of children's in-hand manipulation skills. There is still a need for a reliable and valid test for in-hand manipulation. Because of the fact that the PDMS-FM-2 does not seem to be sensitive enough to identify this population, one could state that if the PDMS-FM-2 indicates fine motor problems, these children most likely would benefit from occupational therapy treatment. And the other children with mild problems, according to their teacher, would benefit from occupational therapy instructions to teacher and parents.

The results of this study should be treated with caution because, as stated earlier, there were significant differences in norms between American and Dutch children in the 4–5 year age group on the manual dexterity items of the M-ABC. For all other age groups and other parts of this test there are no significant differences between Dutch and American children. According to the Dutch norms of the M-ABC more children have fine motor problems. In this
study, the norms that were used for the PDMS-FM-2 were the American norms. If Dutch norms for the PDMS-FM-2 were available the validity outcomes of this study would, perhaps, be different.

Nonetheless, due to the fact that in this study the PDMS-FM-2 was not sensitive enough to identify this population, the next question is, which reliable and valid assessment tool(s) can be used for the evaluation of Dutch pre-school children with fine motor problems? The most plausible answer is to use the manual dexterity items from the M-ABC. The M-ABC was normed for the Dutch population and on the basis of these Dutch norms, 78% of the children in the study group had fine motor problems. Unfortunately, the M-ABC has limitations. The test has only three manual dexterity items and therefore the author (Smits-Engelsman, 1998) recommends caution when interpreting and drawing conclusions based on the manual dexterity items only. With the manual dexterity items of the M-ABC only a small part of the fine motor construct is assessed. Therefore, it is important to complement the test outcomes of the M-ABC with observations of the fine motor skills. Larkin and Cermak (2002) state that reliable observations require highly trained observers with appropriate pre-planned observational strategies. In The Netherlands occupational therapists use a standardized observational tool for fine motor pre-school activities. However, the combined use of M-ABC and a standardized observational tool for fine motor pre-school activities is limited since the visual-motor integration items are missing. So, it seems a good idea to complete this assessment with the Developmental test for Visual Motor Integration (VMI; Beery, 1997). Different authors (Burgman, 1998; Exner, 2001; Richardson, 2001; Larkin and Cermak, 2002) state that an occupational therapy assessment should contain norm-referenced tests in combination with observations of functional skills. Therefore, the proposed assessment plan for Dutch pre-school children with fine motor problems would be the administration of the manual dexterity items of the M-ABC, the VMI and a standardized observational tool for fine motor pre-school activities, therefore incorporating norm referenced tests with standardized observation.

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