

Reliability and validity of a qualitative and quantitative motor test for 5- to 6-year-old children

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ORIGINAL ARTICLE

Reliability and validity of a qualitative and quantitative motor test for 5- to 6-year-old children

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Summary Clumsiness in preschool children may be a precursor to impaired academic performance and psychological and developmental problems. It is assumed that in this age group especially the qualitative aspects (= pattern) of a movement reflect variations in motor development. Currently available motor tests for this age group, however, mostly objectify quantitative aspects of a movement alone and do not objectify qualitative aspects. The aim of this study was to develop a new, valid, and reliable tool (Maastricht's Motor Test (MMT)) to objectify qualitative and quantitative aspects of movement in 5- to 6-year-old children. The test covers Static Balance (14 items), Dynamic Balance (20 items), Ball Skills (eight items), and Diadochokinesis and Manual Dexterity (28 items). About 50% of the items measure qualitative aspects and 50% quantitative aspects of movements. In total 487 subjects were recruited from the first year of primary school. To validate the test, one school doctor's global judgment was used as a form of expert validity. Sensitivity and specificity were calculated for different cut-off points. Intra-class correlation coefficients (ICC) of inter-rater ($N = 42$), intra-rater ($N = 24$), and test-retest ($N = 43$) agreement were determined. ICCs of the qualitative total score ranged from 0.61 to 0.95 and were comparable with those of the total quantitative score. The MMT can be used to objectify both qualitative and quantitative aspects of movements. The additional value of the qualitative observations has to be determined in children with various developmental problems.

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The knowledge that clumsiness in early school years may be related to subsequent academic difficulties and psychological problems makes it imperative to screen children early and to implement intervention strategies.^{1,2} This is why evaluation of the motor performance of 5 to 6 year-old children is an important element of the child general health examination of the Youth Health Care organisation. This organisation provides periodic systemic health examinations for all children of this age. Although integrative brain activity and maturation are poorly understood,³ it is assumed that especially qualitative aspects of a movement reflect the maturity and integrity of the brain⁴⁻⁷ and may therefore be more relevant than quantitative aspects in predicting developmental problems.

Most of the motor tests developed to date only measure quantitative aspects of a movement.⁸⁻¹⁰ For example, they measure the number of hops on one leg, the number times the child catches a ball, etc. Qualitative aspects (pattern of movement) are mostly subjective and based on the experience of the physician.¹¹ Although this subjective judgement is valuable, an objective score is preferable because it would allow inter-physician and inter-study comparisons to be made. While some of the currently used tests do focus on qualitative aspects,^{5,6,12} these tests were not specifically developed for kindergarten children. Moreover, their reliability and validity are often not sufficient.^{13,14}

In order to objectify the quality of movements, we developed a new test to measure, quantitative and qualitative aspects of motor performance in 5- to 6- year- old children. The aim of the present study is to evaluate the validity, reliability, and normative values of this new test. In a preliminary study of 390 children, the sensitivity and specificity of this test were 80%, with an inter-rater reliability (kappa) of >0.6 for all different items.¹⁵ These results were used to adapt the test and this adapted test, the Maastricht's Motor Test (MMT), was evaluated in the current study.

Methods

Subjects and procedure

Subjects were recruited from the second year (age 5-6) of normal primary schools in Maastricht (capital of Limburg, province of the Netherlands) and surrounding villages. Some subjects were selected at random and some were originally selected for the Study of Attention disorders in

Maastricht (SAM study) (see^{16,17}). The SAM study used a two-stage design and selected children on the basis of the Child Behaviour Checklist results.¹⁸ Parents gave consent for their children to participate in the study, which was approved by the Medical Ethics Committee of the University Hospital in Maastricht. A total of 487 children (284 boys (mean age = 6.2; SD = 0.4), 203 girls (mean age = 6.0; SD = 0.4)) were enrolled in the study. Their age showed a Gaussian distribution and ranged from 5.1 to 7.0 years. Two children were excluded because of spasticity. The motor performance of the children was tested during school times at school. The school doctor assessed each child during routine screening (see below). He was unaware of the MMT results. The time between test and examination by the school doctor was maximally 3 months.

To minimise sources of variance three precautions were taken: (1) care was taken to ensure that the testing environment, a quiet room of at least 15 m², was similar as possible in all schools. (2) The examiners were two skilled research assistants trained to use the MMT. (3) Only one experienced school doctor (>20 years of experience) evaluated the children for their motor performance.

Measures

Maastricht's Motor Test

As recommended by Streiner and Norman, a panel of experts co-operated closely in the development of the MMT.¹⁹ This panel (two child physiotherapists and a child neurologist) generated motor items that are of relevance in the examination of 5-to 6-year-old children on the basis of their clinical experience, using the available items of existing motor tests as frame of reference. All items were given a qualitative and a quantitative score. This version of the MMT was then adapted on the basis of the results of a preliminary study to form the MMT used in this study (see introduction). The MMT is organised into four sections: 14 items deal with Static Balance, 20 deal with Dynamic Balance, eight with Ball Skills, and 28 with Diadochokinesis and Manual Dexterity. Of these 70 items, 36 items deal with qualitative and 34 with quantitative aspects of movement. Items concerning quantity are those that can be counted or measured, e.g. a distance a child can walk on his heels, the velocity of tapping the hand on the table, the number of times a child can hop on one leg. Items concerning quality reflect the pattern of a movement and the ability of the child to perform isolated movements.²⁰ Because associated movements are the most

frequently assessed parameters of movement quality,¹² the qualitative items focus on associated movements, but also included co-ordination and stability items. The 70 items were scored on a three-point scale from 0 to 2 (See Appendix A for examples; the complete tests are available through a Dutch publishing company (ask the author for information)). The test takes 20–25 min. The examiners were blind to the judgement of the school doctor.

School doctor

In the Netherlands, it is customary for the school doctor to assess the motor behaviour of children as part of health screening programme by the municipal health service. This 'routine motor function assessment' is used to evaluate the motor performance of these children. The doctor evaluates both the quantitative and qualitative aspects of several movements according to his experience, largely based on 'Gestalt perception'. In this study the same school doctor assessed all children to determine the final motor score (normal versus abnormal).

Validity

To validate the MMT, the school doctor's judgement was used as expert validity. The aim was to determine whether qualitative aspects of motor behaviour could help distinguish between children with and without normal motor performance as judged by the school doctor. Furthermore, the results were compared with the sensitivity and specificity values of the quantitative score. In this study, the validity of the MMT was calculated with the 'sampling weight option' in STATA²¹ for the 487 children (see statistics).

Reliability

To investigate the reliability of the MMT, the inter-rater, the intra-rater, and test-retest reliability were determined. For inter-rater reliability two raters scored 42 children, independently, at the same time. To investigate intra-rater reliability videotapes were made of 24 children while they were being tested. With an interval of one month, these videotapes were scored twice by the same examiner. To obtain test-retest reliability, 43 children were tested twice by the same examiner, with an interval of one month.

Statistics

Because the study population was partly selected at random and partly from participants in the SAM study, the group as a whole cannot be considered as a random sample of the entire population. For this

reason, it was necessary to weight the analyses using the 'sampling weight option' of STATA²¹, which permits adjustment for design characteristics such as two-stage sampling. The weights were consistent with the inverse of the probability of selection.

To determine whether there was a difference between girls and boys, median scores and ranges were calculated by sex for each of the test categories. The significance of differences between boys and girls was calculated by using the Mann-Whitney *U* Test. Results were considered significant at $P < 0.05$ (two-tailed). Weighted median motor scores were calculated for the group with and without normal motor performance as determined by the school doctor. In addition, percentile scales were calculated for boys and girls separately.

The validity of the MMT was calculated by using a Receiver Operating Characteristic Curve (ROC), with the school doctor's judgement being used as final outcome. A ROC curve is a graph of pairs of true-positive results (sensitivity) and of false-positive results (1-specificity) corresponding to each possible cut-off point of the diagnostic test result.^{22,23} The sensitivity and specificity of the test change, depending on the chosen cut-off-point chosen. ROC-curves were made for the qualitative, quantitative and total scores of the MMT. The curve with the largest area underneath represents the most accurate test. Comparison of the areas below the ROC curves made it possible to compare the discriminative ability of the quantitative and qualitative aspects of the MMT.²⁴

To determine inter-rater, intra-rater and, test-retest reliability, Intra-class correlation coefficient (ICC) were used according to Shrout and Fleiss' formula.²⁵ Reliability coefficients were computed for each single category, the sum of all qualitative items, all quantitative items and the total score.

Results

Descriptive statistics

Weighted descriptive statistics for each of the test categories for boys and girls separately, and for children with and without motor problems are given in Table 1. Boys had significantly better ball skills than girls. For all other categories, girls scored significantly better than boys. According to the school doctor's judgement, 30 of the 487 participants had a motor performance, which deviated from the norm, and these children would benefit from an extra training or exercise programme.

Table 1 Descriptive statistics of the Maastricht's Motor Test.

Category of MMT	No.	Boys		Girls		<i>p</i> -value	Abnormal		Normal		<i>p</i> -value
		Median	Range	Median	Range		Median	Range	Median	Range	
<i>Quality</i>											
Static balance	7	8	0-14	10	0-14	<0.001	5	0-11	10	0-14	<0.001
Dynamic balance	9	14	3-22	16	6-22	<0.001	11	3-15	15	4-22	<0.001
Ball skills	4	6	0-8	5	0-8	<0.001	4	0-8	5	0-8	<0.001
Diadochokinesis and manual dexterity	14	19	4-28	20	7-27	<0.001	15	4-25	20	7-28	<0.001
Total	34	46	12-67	50	22-66	<0.001	37	12-48	50	18-67	<0.001
<i>Quantity</i>											
Static balance	7	14	2-14	14	8-14	<0.001	12	2-14	14	7-14	<0.001
Dynamic balance	11	18	3-18	18	11-18	<0.001	14	3-18	18	11-18	<0.001
Ball skills	4	8	1-8	8	2-8	<0.001	8	1-8	8	2-8	0.110
Diadochokinesis and manual dexterity	14	26	12-28	27	13-28	<0.001	25	12-28	27	13-28	<0.001
Total	36	65	31-68	65	22-66	<0.001	59	31-68	65	18-67	<0.001
<i>Total score</i>	70	110	43-135	116	72-134	<0.001	97	43-112	114	72-135	<0.001
MMT = Maastricht's Motor Test, No. = number of items, <i>p</i> -value = <i>p</i> -value according to Mann-Whitney <i>U</i> test.											

MMT = Maastricht's Motor Test, No. = number of items, *p*-value = *p*-value according to Mann-Whitney *U* test.

After weighting 7% of the weighted population could be considered as having a deviant performance. Of this group 93.5% were boys and 6.5% were girls.

With the exception of quantitative ball skills, the normal group scored significantly better in all categories than did the problem group. Table 2 provides normative scores for boys and girls separately. To give some insight into the age differences, information is given for 5-to 6- and 6- to 7-year-old children.

Validity

ROC curves of the total, qualitative, and quantitative scores of the MMT are plotted in Fig. 1.

Areas under the curve (AUC) varied from 0.81 for the quantitative score, 0.86 for the qualitative

score, and 0.87 for the total score of the MMT. The AUC of the quantitative score was significantly smaller (<0.001 and <0.04) than that of the AUC for the total and qualitative scores. The AUCs for the qualitative and total scores were not significantly different.

Table 3 gives the validity parameters for different cut-off points for the categories mentioned above. Children with a score equal to or less than a cut-off point were identified as having an abnormal motor performance. For example, the specificity and sensitivity of a total MMT score of 108 points was 70 and 86%, respectively.

Intra-class correlation coefficient

ICC for inter-rater, intra-rater and retest reliability are shown in Table 4. Intra-class correlations of

Table 2 Normative scores.

Percentiles	Boys						Girls					
	≤ 6 year			> 6 year			≤ 6 year			> 6 year		
	Quality	Quantity	Total	Quality	Quantity	Total	Quality	Quantity	Total	Quality	Quantity	Total
5	26	45	64	31	57	89	33	58	93	37	58	102
10	30	55	89	36	59	97	38	60	98	41	62	104
25	37	59	96	41	63	105	45	63	110	45	64	108
50	43	63	106	49	65	113	50	65	114	51	65	117
75	50	66	113	54	67	120	56	67	121	56	68	122
90	56	67	123	59	68	125	61	68	126	59	68	126
95	61	68	126	60	68	126	64	68	130	60	68	128

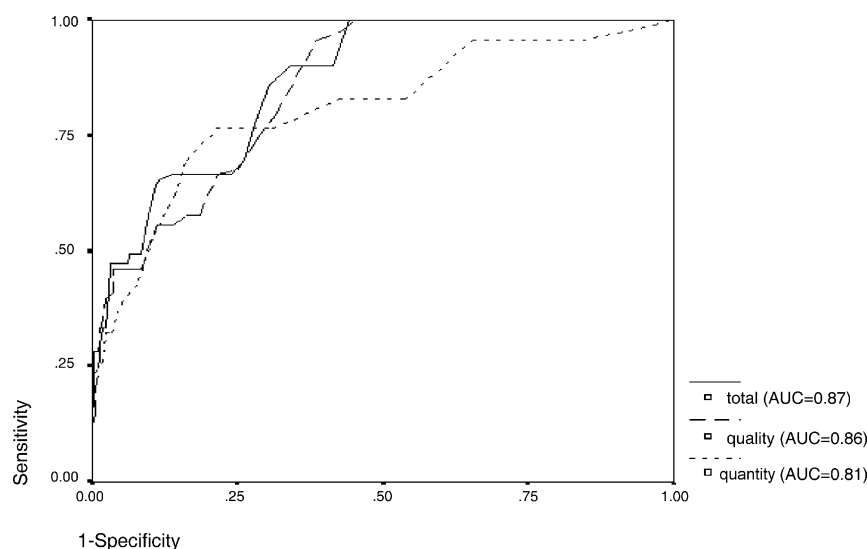


Figure 1 Roc curves, AUC = area under the curve.

the inter-rater reliability varied from 0.92 for the qualitative score, 0.97 for the quantitative score, to 0.96 for the total score. Individual attribute reliability coefficients were all >0.80 , with values varying from 0.83 to 0.97. These values are more or less comparable with those of the intra-rater reliability, except for the quantitative scores of Ball Skills and Diadochokinesis and Manual Dexterity (0.73 and 0.72, respectively). The test-retest reliability was considerably lower: the children performed slightly (but not significantly) better when tested for a second time.

Table 3 Sensitivity and specificity values for the different cut-off point.

Category Of MMT	Cut-off Point	Specificity (%)	Sensitivity (%)	False pos. (%)	False neg. (%)
<i>Quality</i>	≤ 26	99.5	20.4	0.5	79.6
	≤ 40	81.4	58.1	18.6	41.9
	≤ 43	71.9	74.2	28.1	25.8
	≤ 45	66.8	83.9	33.2	16.1
	≤ 46	61.4	95.7	38.6	4.3
<i>Quantity</i>	≤ 49	99.9	16.1	0.1	83.9
	≤ 59	89.5	53.8	10.5	46.2
	≤ 62	78.8	76.3	21.2	23.7
	≤ 64	57.6	82.8	42.4	17.2
	≤ 66	34.6	95.7	65.4	34.6
<i>Total</i>	≤ 88	97.7	33.3	0.3	66.7
	≤ 97	90.6	58.1	9.4	41.9
	≤ 107	72.2	77.4	27.8	22.6
	≤ 108	69.6	86.0	30.4	14.0
	≤ 112	55.7	100.0	44.3	0.0

MMT = Maastricht's Motor Test, False pos. % = percentage of false positives, False neg. % = percentage of false negatives.

Discussion

Evaluation of motor performance is an important element of the general health examination of children. It is suggested that especially the qualitative aspects of several movements reflect the maturity and integrity of the brain, and can probably play an important role in the early diagnosis of developmental disorders. The MMT was developed because of the lack of a qualitative motor test for this age group. Results show that the MMT is a valid and reliable tool for scoring the qualitative aspects of motor performance in children and for distinguishing between children with and without normal motor behaviour.

Table 4 Intra-class correlation coefficients.

Category of MMT	Inter-rater N = 42	Intra-rater N = 24	test-retest N = 43
<i>Quality</i>			
Static balance	0.87	0.92	0.43
Dynamic balance	0.87	0.85	0.48
Ball skills	0.88	0.82	0.62
Diadochokinesis and manual dexterity	0.83	0.89	0.93
Total	0.92	0.95	0.61
<i>Quantity</i>			
Static balance	0.95	0.98	0.48
Dynamic balance	0.97	0.90	0.77
Ball skills	0.90	0.73	0.55
Diadochokinesis and manual dexterity	0.95	0.72	0.62
Total	0.97	0.93	0.74
<i>Total score</i>	0.96	0.96	0.74

MMT = Maastricht's Motor Test.

Girls scored significantly better than boys in almost all MMT categories. This is consistent with the school doctor's finding of more boys than girls with an 'abnormal' motor behaviour (93.5% boys; 6.5% girls). Henderson and Sugden¹⁰ did not find significant differences between boys and girls in the normative scores of the Movement ABC. However, their findings are inconsistent with the literature, in which most studies report a difference in locomotion in favour of girls.²⁶⁻²⁸ Seven percent of the weighted population was identified as having an abnormal motor behaviour. This percentage is comparable to the prevalence of abnormal motor performance reported in the literature.^{26,27} As mentioned in Section 1, the school doctor's judgement was used as expert validity. According to Gestalt perception, his final judgement probably reflects both quantitative and qualitative aspects. Comparison of the qualitative results of the MMT with the quantitative scores showed that the AUCs of the qualitative and total scores were significantly larger than that of the quantitative score. This indicates that the qualitative and total scores were more accurate than the quantitative score. Cut-off scores can be set depending on the purpose of the study. The higher the sensitivity and specificity values are, the better. But high-sensitivity scores may lead to many false positive results and high-specificity scores are accompanied with many false negative results. A compromise between these two parameters should be made depending on the purpose of the instrument. For example, if the test is used as a screening instrument, high-sensitivity rates are important whereas high-specificity rates are of interest if the test is used as a diagnostic tool.²²

The reliability of a test provides information about the consistency and stability of measurements.²⁹ To evaluate the reliability of the test, intra-class correlations were calculated to investigate inter-rater, intra-rater, and test-retest reliability. When the ICC is high, a large proportion of the variance of observations is associated with variation between subjects rather than between raters.²⁵ Although there is not a universally accepted minimum value for reliability coefficients, Shrout and Fleiss²⁵ used a value of 0.75 or 0.80 as a minimum acceptable value. Assuming this, inter-rater and intra-rater reliability values were very good for all individual categories. Reliability scores for all categories were much lower for test-retest reliability. This may be due to practice effects and to the natural variability in a child's motor behaviour.

In conclusion, the MMT is a reliable and valid instrument to measure qualitative as well as

quantitative aspects of a movement. The validity of the qualitative MMT was higher than that of the quantitative MMT. This instrument makes it possible to translate Gestalt perception into an objective score, which may be of great relevance for research purposes. The high prevalence and possible consequences of abnormal motor performance justify the screening of developmental co-ordination disorders in children in the second grade.^{2,22} Because the MMT is non-invasive, easy to use, and has a clear protocol, we recommend that this instrument be used by school doctors to objectify findings, which will optimise communication between care givers. In addition, the MMT test is a useful instrument for research and health care purposes. However, the results of the MMT should always be interpreted in the context of further examination, the opinion of the parents, the child, and eventually the teacher.

We believe that especially the qualitative items of the MMT will be useful to identify children at risk of developmental problems such as attention deficit hyperactivity disorder and learning disorders. The MMT is the first motor test to objectify qualitative aspects of several important motor domains in a reliable and valid way. This test can make an important contribution to the evaluation of qualitative motor behaviour in groups of children with and without developmental problems.

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Appendix A. Examples of *qualitative* items of the Maastricht Motor Test

General rules

The MMT contains quantitative and qualitative items. Every task should be explained and demonstrated by the examiner.

The child may not practice; only when he/she shows by the performance of the movement that he/she did not understand what to do, the examiner explains the task again and the child will have another attempt. About the qualitative part of the test; the examiner scores what he sees the most, unless otherwise mentioned in the text.



Score 0



Score 1



Score 2

Static balance

Stand on one leg, eyes open, flex other leg backwards (extension hip, flexion knee) arms relaxed next to the body.

Score 0: co-movements:

elbow flexion (left/right)

shoulder abduction (left/right) ($>45^\circ$)

Score 1: a lot of balance/correction movements trunk/wrist and finger extension or fist

Score 2: good, no co-movements



Score 0



Score 1



Score 2

Dynamic balance

Walking on heels; 4.5 m, on a straight line

Score 0: elbow flexion (left/right)

Score 1: wrist and finger flexion/extension (left/right) or fist

Score 2: good, a few balance movements are allowed



Score 0



Score 1



Score 2

Ball skills

Ball catching: child stands with feet next to each other behind a line. Ball is thrown from a distance of 3 m, not above shoulder level or below waist of the child. Examiner throws five times and the child has to catch the ball with both hands, ball should not touch the body.

Score 0: head deviates, child leans backward, arms are held forward, no anticipation

Score 1: child catches the ball between hands and chest

Score 2: child catches the ball with both hands, ball away from the body, anticipation is good



Score 0



Score 1



Score 2

Manual dexterity

Tracking pencil between lines: see bicycle trail. Child sits on chair, picks pencil up.

The examiner instructs the child to draw a line between both lines in the picture as quick and neat as possible. Child may practice once, and may pause while drawing an uninterrupted line.

Way child holds pencil

Score 0: pencil is held in fist

Score 1: pencil is held in odd/ immature grip but not in fist

Score 2: pencil is held between thumb and index finger, middle finger may be used

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