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The Infant Motor Profile:
a standardized and qualitative method to assess motor behaviour in infancy

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ABSTRACT

Background: A reliable and valid instrument to assess neuromotor condition in infancy is a prerequisite for early detection of developmental motor disorders. We developed a video-based assessment of motor behaviour, the Infant Motor Profile (IMP), on motor abilities, movement variability, ability to select motor strategies, movement symmetry and fluency. The IMP consists of 80 items and is applicable from 3 to 18 months. The present study aims at teasting intra and interobserver reliability and concurrent validity of the IMP with the Alberta Infant Motor Scale and Touwen neurological examination.

Methods: The study group consisted of 40 low-risk at term born (median gestational age (GA) 40 weeks, range 38-42) and 40 high-risk preterm born infants (median GA 29.6, range 26-33) with corrected ages 4 to 18 months (31 girls, 49 boys).

Results: Intra and interobserver agreement of the IMP were satisfactory (Spearman ρ=0.9). Concurrent validity of IMP and AIMS was good (Spearman ρ=0.8, $p<0.0005$) . The IMP was able to differentiate between infants with normal neurological condition, simple minor neurological dysfunction (MND), complex MND and abnormal neurological condition ($p<0.0005$).

Conclusion: The IMP may be a promising tool to evaluate neurological integrity during infancy −a suggestion which needs confirmation by means of assessment of larger groups of infants with heterogeneous neurological conditions.

INTRODUCTION

Assessment of motor dysfunction in young children is still in its infancy. This is regrettable because a sensitive, reliable and valid instrument is a prerequisite for early detection of infants with developmental motor disorders, such as cerebral palsy (CP) and developmental co-ordination disorder (DCD). Early detection is needed to warrant the provision of intervention at young ages, *i.e.* at ages when brain development is characterized by high degrees of plasticity[1-3]. Adequate assessment techniques are also indispensable for the evaluation of the effectiveness of intervention strategies.

Recently, we reviewed fifteen instruments to assess neuromotor condition in infancy with respect to their characteristics and psychometric properties (unpublished data). It was concluded that the traditional forms of neurological examination showed good predictive validity for major developmental disorders such as CP. However, instruments that assess quality of motor behaviour (TIMP[4], General Movement method[5,6]) turned out to be most promising in terms of predictive validity, as they have good predictive value for both major and minor (minor neurological dysfunction (MND), DCD) developmental disorders.

The finding that quality of motor behaviour and variation in particular is an essential parameter to assess the condition of the young nervous system, fits well to the concepts of the Neuronal Group Selection Theory (NGST)[7-10]. According to NGST, normal motor development is characterized by two phases of variability. During the phase of primary variability variation in motor behaviour is not geared to external conditions. Next, at function-specific ages, the phase of secondary variability takes over. The child learns to select the best motor strategy for each situation on the basis of afferent information resulting from self-generated motor activity, from active trial and error. In other words, the child develops the capacity to adapt motor performance to environmental constraints. Children with pre or perinatally acquired lesions of the brain, such as children with CP and some children with DCD, exhibit stereotyped motor behaviour. This might be related to a reduction of the repertoire of primary cortical-subcortical neuronal networks. Motor behaviour of these children is not only affected by the reduced size of the repertoire of motor strategies, but also by problems in the process of selection of the most efficient strategy for each situation. The latter problems may be attributed to the absence of specific strategies which forces the child to choose in certain conditions amongst non-optimal strategies and the presence of deficits in the processing of sensory information[9-11].

Having noticed that application of motor variability as a means to evaluate neuromotor condition functions so well in early infancy, we embarked on the development of a similar assessment instrument for neuromotor condition at ages between 3 and 18 months. This resulted in the development of the Infant Motor Profile (IMP).

The Infant Motor Profile (IMP)

The IMP evaluates spontaneous motor behaviour of infants aged 3 to 18 months, or rather until the age at which the child has a couple of months experience with walking independently. This means that the IMP can be applied in infants with a more or less typical development until approximately the age of 18 months. In children with moderate to severe developmental motor disorders the IMP can be used beyond the age of 18 months. The IMP is a video based assessment. Motor behaviour is evaluated in the following conditions: supine, prone, sitting, standing and walking. In addition, reaching, grasping and manipulation of objects are evaluated in supine and in supported sitting conditions, i.e. while sitting on the parent's lap. The child's motor activity may be entirely spontaneous or may be elicited by the presentation of interesting objects. The order in which the various conditions are evaluated depends on the child's age, functional capacities, mood and interest. In the youngest infants, assessment in general starts with an observation of behaviour in supine condition for 5 minutes. In older children, it is more common to start with a sitting condition, either on the parent's lap or in a freely sitting condition.

The IMP consists of 80 items classified into five subscales (for details see Appendix). The first subscale addresses movement variability; it assesses the size of the movement repertoire. The 25 items of this subscale are scored as 'insufficiently variable' denoting the presence of a limited repertoire of ways in which the child is able to perform the task, or as 'sufficiently variable' denoting the presence of a variable repertoire of motor solutions. The second subscale also addresses movement variability and comprises 15 items; it evaluates the child's ability to select adaptive motor strategies from his or her movement repertoire, an ability which develops during the phase of secondary variability. The items of this subscale are scored as 'no selection' or as 'adaptive selection'. 'No selection' means that the child does not select from his or her repertoire the movement strategy which fits the situation best, but uses various motor strategies. If the child chooses for most of the time the most suitable motor strategy from his or her motor repertoire for a specific situation 'adaptive selection' is scored. The other subscales of the IMP are movement symmetry, fluency, and performance. The subscale symmetry contains 10 items which address the presence or absence of stereotyped asymmetries. In fact, movement symmetry may be regarded as a specific form of movement variability, but we decided for a separate subscale on presence and absence of symmetry as it might have specific diagnostic value[12]. Movement fluency reflects the ability of the infant to fine-tune motor output. The subscale consists of 7 items, including two items on the presence of tremors. Loss of movement fluency is one of the first signs of a non-optimal neurological condition[6,13]. The subscale performance of 23 items is a more or less traditional one on achieved motor milestones. This means that the IMP does not only address quality of motor behaviour but also evaluates what the child is able to achieve.

Aim of the study

The aim of the present study is to assess psychometric properties of the IMP. First, inter and

intraobserver reliability of the IMP are addressed. Second, relations between IMP scores and age, gestational age at birth and ultrasound scans of the brain made during the neonatal period are evaluated. These relations might shed light on the construct validity of the IMP. We hypothesize that total IMP scores and scores on the subscales variability-ability to select and performance are positively correlated with corrected age as these capacities develop with increasing age, whereas such relationships between corrected age and the subscores variability-size of repertoire, symmetry and fluency are absent. In addition, we assume that low gestational age leads to lower IMP scores, especially on the subscales variability-size of repertoire, symmetry and fluency. Infants born preterm have a higher risk for brain lesions which can lead to a reduced, less variable movement repertoire, including stereotyped asymmetries. As loss of fluency is one of the first signs of a non-optimal neuromotor condition, we expect preterm infants to have lower fluency scores. We expect that infants with serious brain lesions on ultrasound scans show lower IMP scores.

Third, concurrent validity of the IMP with the AIMS[14] and the neurological examination according to Touwen[15] is assessed. To this end, a group of 80 infants with corrected ages from 4 to 18 months was evaluated by means of the IMP, the AIMS and the neurological examination according to Touwen. We expect a significant positive correlation between AIMS and total IMP score and IMP performance score, and weakly to moderately positive correlations between AIMS and other subscale scores of the IMP. In addition, we hypothesize that the degree of neurological dysfunction shows a clear inverse relationship with the total IMP score and IMP subscores.

METHODS

Participants

The study group consisted of 80 infants (31 girls and 49 boys). Forty infants were born at term (gestational age at birth 40 weeks (median value; range 38 to 42 weeks) without pre or perinatal complications with a median birth weight of 3550 grams (range 2730 to 4220 grams). Forty infants were born preterm with a gestational age at birth of 26-33 weeks (median value 29.6 weeks) and a median birth weight of 1180 grams (range 585 to 2120 grams). The preterm infants had been admitted to the neonatal intensive care unit (NICU) of the Beatrix Children's Hospital of the University Medical Center (UMC) in Groningen during the years 2003 and 2004.

Infants were assessed cross-sectionally at the corrected ages of 4, 6, 10, 12 and 18 months (Table I). All parents of the infants signed an informed consent form. The project was approved by the Ethics Committee of the UMC in Groningen.

Procedures

Each assessment started with a video recording of spontaneous motor behaviour in the following conditions: supine, prone, sitting with or without support, standing with or without support, walking with or without support and sitting on the parent's lap. In the supine position and when seated

Table I: Number and age distribution of infants included in the validity study

Age (months)	4	6	10	12	18	Total
Term	7	7	7	8	11	40
Preterm	7	7	7	8	11	40
Total	14	14	14	16	22	80

on the parent's lap small attractive objects were presented to assess the infant's ability to reach, grasp and manipulate objects. Toys were also used to elicit rolling, crawling, standing up behaviour and trunk rotation during sitting and standing. In the youngest children recording always started with the infant lying in supine for 5 minutes. The order of the conditions was not fixed but was adapted to the child's interest. In general, video recording lasted about 15 minutes. On basis of the video recording both the Infant Motor Profile scores and AIMS[14] were determined. Total AIMS scores, instead of percentiles, were used in the data processing, as Canadian reference values are currently inappropriate for Dutch children[16]. Off-line scoring of the IMP took approximately 10 minutes per video recording. Calculation of IMP scores will be explained in the next paragraph.

After the video recording of motor behaviour, a neurological examination according to Touwen[15] was carried out. The neurological condition of the child was classified as normal, as the simple or complex form of minor neurological dysfunction (MND) or as definitely abnormal. A child was classified as definitely abnormal, when he or she exhibited a clear neurological syndrome such as a clear hemisyndrome, a marked hypertonia or hypotonia in combination with clearly abnormal reflexes or a hyperexcitability syndrome. MND denoted the presence of one or more clusters of mild signs of neurological dysfunction, such as mild abnormalities in muscle tone regulation, mildly abnormal reflexes, mild visuomotor dysfunction or mild dysfunction in gross motor or fine motor performance[11]. Simple MND indicates the presence of one cluster of mild signs of neurological dysfunction and can be regarded as a normal, but non-optimal condition of the nervous system. Complex MND denotes the presence of two or more clusters of dysfunction and is related to early brain damage[17].

Data analyses
IMP scores were separately calculated for each subscale according to the following formula:

$$Score = \frac{Sum\ of\ item\ scores}{(no.\ of\ items\ of\ scale\ or\ subscale - no.\ of\ items\ NA) * max\ score\ of\ items} * 100\%$$

'No' stands for number and 'NA' means not applicable (for instance the item 'variability of arm movements during walking' when a child is not able to walk) and 'max score of items' is the maximum

score amongst the items of the subscale. For the subscales variability-size of repertoire, variability-ability to select and fluency the maximum score for each item is two and for the subscale symmetry, three. Because the performance subscale contains items with different numbers of maximum scores (see Appendix I), the scores are weighed before computing the performance subscale score. If a child scores 3 points on the item 'reaching and grasping of an object in supine position' where the maximum score is 7 points, the child is given 3/7 = 0.43 points. For an item with a 4-point scale, the score would be 3/4 = 0.75 points. This means that all performance items contribute to a similar extent to the performance subscore and the total IMP score (see Appendix I). The total IMP score is computed by summing the scores on the five subscales and dividing this number by five. All scores on subscales and the total IMP score are expressed as a percentage with a maximum score of 100%.

To assess the interobserver agreement of the IMP, 38 video recordings were scored independently by two assessors. The sample was created by randomly selecting from each of the age groups recordings of three preterm and three full-term infants. Both assessors evaluated eight videos from the 12-month age group (four full term and four preterm infants) and twelve videos from the 18-month group (six full term and six preterm infants) in order to obtain sufficient data on standing and walking items to determine reliability. One of the assessors (KRH) knew whether an infant was born preterm or at term, but she was not aware of the details of the infant's clinical history. The other observer (MHA) was blind with respect to the clinical status of the infants. In order to establish intraobserver agreement of the IMP scores, KRH evaluated the same 38 video recordings twice with an interval of one month. Inter and intraobserver reliability at subscale level were analysed by means of the Spearman correlation coefficient (ρ). Interpretation of correlation coefficients was as follows: $\rho < 0.49$: weak relationship, $0.50 < \rho < 0.75$: moderate relationship and $\rho > 0.75$: strong relationship[18].

The relationships between IMP scores, AIMS scores and corrected age were evaluated with Spearman rank correlation and associated confidence intervals. The relation between IMP and neurological classification and status at birth (preterm or full-term) was assessed with help of the non-parametric Kruskal-Wallis and Mann Whitney U test, respectively. Mann Whitney U test was also used to determine differences in IMP scores between infants with and without serious brain lesions. Throughout the analyses differences and correlations with a p-value < 0.05 were considered to be statistically significant (two-tailed testing).

RESULTS

Reliability

Intra and interobserver reliability of total IMP score were strong (Table II). Intraobserver agreement was strong for subscales variability-repertoire, variability-ability to select and performance and was moderate for subscales fluency and symmetry. Interobserver reliability of the subscales variability-ability to select and performance was strong. Interobserver reliability was moderate for subscales variability-repertoire and fluency and weak for subscale symmetry.

Table II: Intra and interobserver reliability of IMP: Spearman correlation coefficients

IMP-subscale	Spearman ρ (95% confidence interval)	
	Intraobserver reliability	*Interobserver reliability*
Total IMP score	0.9 (0.8-0.9)	0.9 (0.8-1.0)
IMP-subscale:		
Variability-repertoire	0.8 (0.6-0.9)	0.7 (0.4-0.8)
Variability-ability to select	0.8 (0.7-0.9)	0.8 (0.6-0.9)
Fluency	0.6 (0.3-0.8)	0.7 (0.4-0.8)
Symmetry	0.6 (0.4-0.8)	0.4 (0.0-0.6)
Performance	1.0 (0.9-1.0)	0.9 (0.8-1.0)

Validity

The IMP total score varied between 66 and 97 (median value 88). No significant differences in total IMP scores and all subscales were found between girls and boys. The IMP total score was significantly related to corrected age ($\rho = 0.68$ (95% CI 0.54-0.78), $p < 0.0005$). The two subscales variability-ability to select and performance, which on theoretical assumptions were expected to correlate with age, were significantly related to corrected age (variability-ability to select: $\rho = 0.68$ (95% CI 0.54-0.78), $p < 0.0005$; performance: $\rho = 0.91$ (95% CI 0.86-0.94), $p < 0.0005$). Also, a positive correlation between age and symmetry score was found, indicating that the infants showed less asymmetric behaviour with increasing age ($\rho = 0.40$ (95% CI 0.20-0.57), $p < 0.0005$). The subscales variability-size of repertoire and fluency were not related to corrected age ($\rho = 0.19$ and $\rho = 0.07$ resp.).

Preterm infants had significantly lower total IMP scores than infants born at term (median IMP score FT 89 vs. PT 82; Mann-Whitney: $p < 0.0005$). The difference was particularly present in the subscales variability-size of repertoire ($p < 0.0005$), fluency ($p < 0.0005$) and symmetry ($p = 0.021$). No statistically significant difference between the two groups was found for the other two subscales variability-ability to select (Mann-Whitney: $p = 0.064$) and performance ($p = 0.126$). Also, preterm infants had significantly lower AIMS scores than full term infants ($p = 0.046$).

Repeated brain ultrasound scans made during the first weeks of life indicated serious brain lesions in each of three preterm infants: one infant had a unilateral periventricular haemorrhage due to a venous infarction[19], one had bilateral periventricular echodensities evolving into extensive periventricular cysts[20] and one infant had middle cerebral artery infarction on the right side. Compared to the other 37 PT infants with no or milder brain lesions such as transient periventricular echodensities, these three infants showed significant lower IMP scores (Mann-Whitney: $p = 0.006$) and AIMS scores (Mann-Whitney: $p = 0.041$).

The AIMS scores of the various assessments varied from 8 to 58 with a median value of 46. The AIMS score showed a high correlation with corrected age ($\rho = 0.91$ (95% CI 0.86-0.94), $p < 0.0005$). The total IMP score was related to the AIMS score ($\rho = 0.78$ (95% CI 0.68-0.85), $p < 0.0005$). This correlation was brought about in particular by the high correlation between the conceptually

similar AIMS score and IMP subscore on performance (ρ = 0.94 (95% CI 0.91-0.96), p < 0.0005). Also the subscales variability-size of repertoire, variability-ability to select and symmetry were related to the AIMS (variability-size of repertoire: ρ = 0.42 (95% CI 0.22-0.59), p < 0.0005; variability-ability to select: ρ = 0.69 (95% CI 0.56-0.79), p < 0.0005; symmetry: ρ = 0.46 (95% CI 0.27-0.62), p < 0.0005), but the subscale on fluency was not (ρ = 0.20, n.s.). When the effect of the confounding factor of age was partialled out, the correlations between the various IMP scores and the AIMS score remained statistically significant (ρ-values varying from 0.31 (95% CI 0.10-0.50), p = 0.006 (fluency) to 0.72 (95% CI 0.60-0.81), p < 0.0005 (performance); median ρ-value 0.338).

Twenty-seven of the 80 infants had a normal neurological condition, 19 were classified as having simple MND, 32 as having complex MND and 2 as neurologically abnormal. Neurological condition was not related to corrected age. The total IMP score showed a highly significant relation with neurological condition (Kruskal-Wallis: p < 0.0005, Figure 1). Also the various subscales of the IMP were related to neurological condition: variability-size of repertoire (Kruskal-Wallis: p < 0.0005), variability-ability to select (p = 0.013), fluency (p< 0.0005), symmetry (p = 0.023), and performance (p = 0.024; Figure 2A-E). It is interesting to note that differences in IMP total score and in scores on the subscales of variability and performance are found in particular between infants with complex MND or an abnormal neurological condition and those with a normal neurological condition or simple MND.
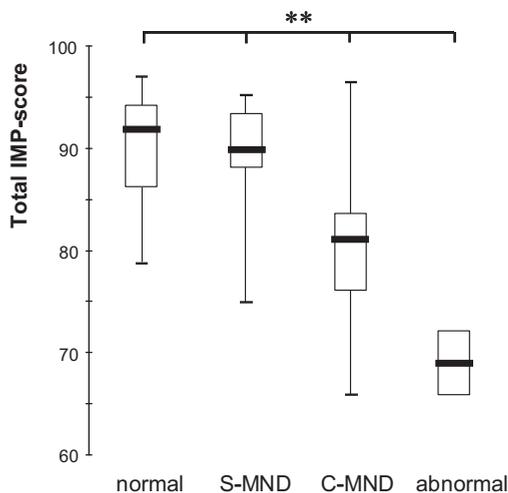

Figure 1: Relationship between neurological condition and total IMP score. The data are presented by median values (horizontal bars) and interquartile ranges (boxes) and ranges (vertical lines). N = neurologically normal, S-MND = simple MND, C-MND = complex MND. Kruskal Wallis: ** p < 0.0005
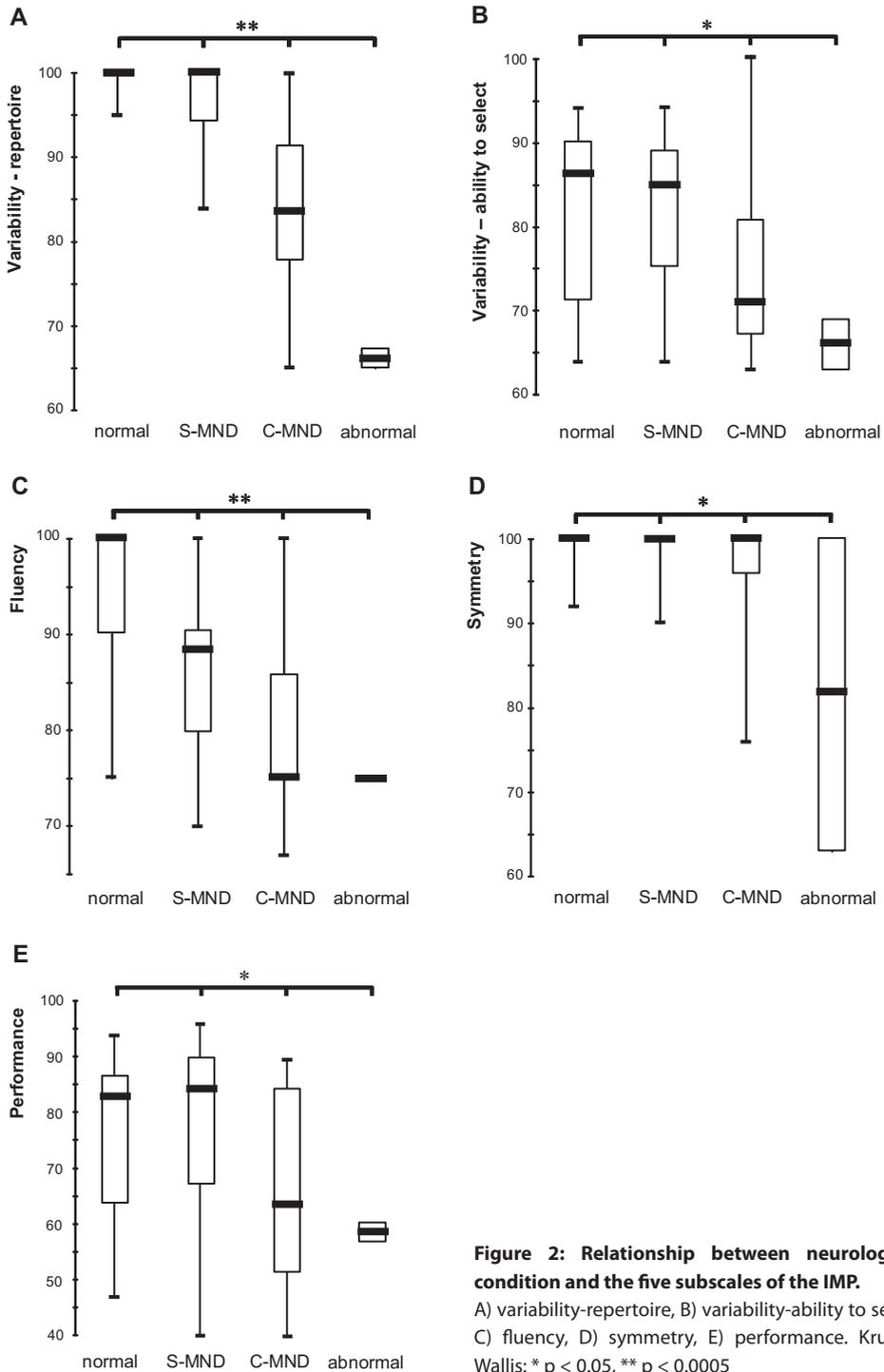
Figure 2: Relationship between neurological condition and the five subscales of the IMP.
A) variability-repertoire, B) variability-ability to select C) fluency, D) symmetry, E) performance. Kruskal Wallis: * p < 0.05, ** p < 0.0005

DISCUSSION

The present study indicates that the IMP can be performed in a reliable way. In addition, the study suggests that the IMP has a good concurrent validity with the AIMS and with the infant's neurological condition.

The intra and interobserver agreement on the total IMP score was high. Agreement on the subscales variability-repertoire, variability-ability to select, performance and fluency was satisfactory. Intraobserver reliability on the subscale symmetry was moderate, but the interobserver reliability on this subscale was only poor. This was probably caused by the virtual absence of serious asymmetries in the group used for reliability testing: 34 out of the 38 infants obtained symmetry scores of 100% from both assessors. The other four infants were given somewhat lower symmetry scores, but the degree of reduction differed slightly between the assessors. This suggests that the population studied suited the purpose of assessing the reliability of the symmetry subscale only to a moderate extent.

In line with our assumptions, the IMP total score increased significantly with increasing age. This effect was brought about by the relationship between age and the subscores performance and variability. Our finding parallels those on the AIMS; the AIMS score is significantly related to age[14]. The positive correlation between age and the subscore variability-ability to select underlines the notion that infants learn to select a preferred strategy from the motor repertoire when they get older[9]. In our population, symmetry scores also correlated with age with older infants showing less asymmetries than younger infants. This is probably due to the fact that in our study group only one infant had a serious asymmetry. This girl was assessed at 10 months corrected age; later follow-up assessments revealed that she developed a unilateral spastic cerebral palsy. Young infants quite often show mild to moderate asymmetries which usually resolve spontaneously with increasing age[21]. The low prevalence of serious unilateral disorders in the present sample precludes a proper evaluation of the effect and utility of the symmetry subscale. As expected, movement fluency was not related to age.

Preterm infants showed lower total IMP scores and lower scores on the subscales variability-repertoire, symmetry and fluency, as was expected. Infants born preterm are at risk for brain lesions, which can lead to a reduction of movement repertoire and the presence of stereotyped asymmetries[10,12]. Loss of movement fluency is one of the first signs associated with non-optimal neurological condition[6,13]. Prematurity was not related to the scores on the subscales variability-ability to select and performance. Infants with serious brain lesions as seen on ultrasound, such as haemorrhage grade IV or periventricular cystic lesions, indeed showed significantly lower IMP scores than infants with no or mild brain lesions. Altogether, construct validity of the IMP, operationalized as relation of IMP scores with age, gestational age and brain lesions on ultrasound, seems satisfactory.

The IMP total score and the five subscales of the IMP correlated with the AIMS scores. Especially the performance subscale showed high correlation with the AIMS, which is not surprising, as both

assess achievements in motor behaviour. Also if correction for age is applied, these correlations still subsist, which shows that both AIMS and IMP measure the same construct, i.e. integrity of the brain. Nevertheless, it is interesting to note that the IMP is more sensitive in picking up the effect of preterm birth and serious brain lesions than the AIMS.

Differences in total IMP scores and scores on the five subscales were found between the four neurological conditions, with an inverse relationship between IMP scores and degree of neurological dysfunction. Especially the subscales variability-repertoire and fluency showed clear differences. Differences in total IMP scores, scores on variability subscales and on performance subscale were in particular found between infants with complex MND or abnormal neurological condition and those with a normal neurological condition or simple MND. Complex MND is the form of minor neurological dysfunction which – in contrast to simple MND – has clinical relevance. It probably is caused by adversities in the pre or perinatal period, and in some cases it might be considered as a borderline form of cerebral palsy[11,22]. All in all, concurrent validity of the IMP with the AIMS and with the neurological examination according to Touwen can be regarded as good.

A limitation of this pilot study is the small sample size of 80 infants of different ages and with different risk for developmental motor disorders. Present data on reliability and concurrent validity with AIMS and the Touwen neurological examination are promising, but further research on construct and predictive validity is necessary. Extrapolation of the difference in predictive power of General Movement-assessment[5,6] and the neonatal neurological assessment[22] generates the hypothesis that predictive power of the IMP surpasses that of the AIMS and the neurological examination. The next step in IMP-development will be the generation of norms and the determination of clinical applicability.

In conclusion: the Infant Motor Profile is a reliable video based assessment of motor behaviour in infancy which does not only address the child's motor abilities but also movement variation, ability to select movement strategies, symmetry and fluency. The current study suggests that the latter characteristics are promising parameters of neurological integrity – a suggestion which needs confirmation by means of assessment of larger groups of infants with a heterogeneous neurological condition.

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