

# Fidgety movements in infants born very preterm: predictive value for cerebral palsy in a clinical multicentre setting

ALEXANDRE N DATTA<sup>1,2</sup> | MARK A FURRER<sup>3</sup> | IRIS BERNHARDT<sup>4</sup> | PETRA S HÜPPI<sup>2</sup> |  
CRISTINA BORRADORI-TOLSA<sup>2</sup> | HANS ULRICH BUCHER<sup>5</sup> | BEATRICE LATAL<sup>6</sup> | SEBASTIAN GRUNT<sup>3\*</sup> |  
GIANCARLO NATALUCCI<sup>5,6\*</sup> | THE GM GROUP<sup>†</sup>

**1** Division of Neuropediatrics and Developmental Medicine, University of Basel Children's Hospital, Basel; **2** Department of Development and Growth, University Children's Hospital Geneva, Geneva; **3** Division of Neuropediatrics, Development and Rehabilitation, University Children's Hospital Bern, Inselspital, Bern University Hospital, Bern; **4** Institute for Physical Therapy, Inselspital, Bern University Hospital, Bern; **5** Division of Neonatology, University Hospital Zurich, Zurich; **6** Child Development Centre, University Children's Hospital Zurich, Zurich, Switzerland.

Correspondence to Alexandre N Datta at University of Basel Children's Hospital (UKBB), Division of Neuropediatrics and Developmental Medicine, Spitalstrasse 33,4031 Basel, Switzerland. E-mail: alexandre.datta@ukbb.ch

\*These authors contributed equally to this work.

†Names and affiliations of the GM Group are included in Appendix S1.

## PUBLICATION DATA

Accepted for publication 3rd December 2016.

Published online

## ABBREVIATIONS

BSID-II	Bayley Scales of Infant Development, 2nd edition
FMA	Fidgety movement assessment
MDI	Mental developmental index
PDI	Psychomotor developmental index

**AIM** This study assessed predictive values of fidgety movement assessment (FMA) in a large sample of infants born very preterm for developmental abnormalities, in particular for cerebral palsy (CP) at 2 years in an everyday clinical setting.

**METHOD** This is a multicentre study of infants born preterm with gestational age lower than 32.0 weeks. FMA was performed at 3 months corrected age; neurodevelopment (Bayley Scales of Infant Development, 2nd edition) and neurological abnormalities were assessed at 2 years. Predictive values of FMA for the development of CP were calculated and combined with abnormalities at cerebral ultrasound.

**RESULTS** Five hundred and thirty-five infants (gestational age 28.2wks [standard deviation 1.3wks]) were included. Eighty-one percent showed normal fidgety movements and 19% atypical (82 absent, 21 abnormal) fidgety movements. Absent fidgety movements predicted CP at 2 years with an odds ratio (OR) of 8.9 (95% confidence interval [CI] 4.1–17.0), a combination of atypical fidgety movements and major brain lesion on cerebral ultrasound predicted it with an OR of 17.8 (95% CI 5.2–61.6). Mean mental developmental index of infants with absent fidgety movements was significantly lower ( $p=0.012$ ) than with normal fidgety movements.

**INTERPRETATION** Detection of infants at risk for later CP through FMA was good, but less robust when performed in a routine clinical setting; prediction improved when combined with neonatal cerebral ultrasound.

Children born very preterm are at risk for impaired motor and cognitive development. Around 50% suffer from a broad range of neurodevelopmental impairment,<sup>1</sup> and 10% to 20% have the characteristics of cerebral palsy (CP).<sup>2</sup> At early age, standard neurological assessment has a low predictive value for neurological outcome.<sup>3</sup> Different neurodevelopmental assessments have been described that assess neuromotor function in early life in children at risk for later neurological problems.<sup>3</sup> In a systematic review summarizing the clinical properties of these assessment methods, Prechtl's assessment of general movements showed the best predictive properties at an early age.<sup>3</sup>

Prechtl developed this tool for evaluating the quality of spontaneous motility for the fetus and the young infant during the end of pregnancy and the first 4 months of life.<sup>4</sup> The method is based on observation of spontaneous motor

activity during different maturational stages and provides information about the integrity of the nervous system at that age. Writhing movements are general movements that are observed already at preterm age, but are best visible between term and 9 weeks; fidgety movements can be seen from the 7th week, once writhing movements begin to disappear, and persist to 16 weeks after term. Fidgety movement assessment (FMA) is a widely used method to assess spontaneous motor activity in young infants in order to predict developmental abnormalities at an early age. While fidgety movement abnormalities provide a more accurate prediction of later cerebral palsy than writhing movements, the longitudinal evolution from writhing to fidgety periods seems to be the best predictor for infants born term and preterm. Atypical writhing movements are associated with worse motor outcomes, whereas atypical fidgety

movements associate worse motor outcome with poor cognitive and language performance at 2 years and 4 years of age.<sup>5,9</sup> However, this method largely depends on professional experience and shows considerable intra- and inter-observer variability.<sup>6</sup> Few reports have been published on the practicability and predictive value for a large sample of infants born preterm in a general clinical setting.<sup>5,7-9</sup>

The first aim of this prospective multicentre study was to determine the predictive values of fidgety movements at 3 months corrected age for the presence of CP in a large cohort of children born very preterm at 2 years corrected age. A second aim was to verify whether this method would also be applicable to, and robust in, an everyday clinical setting. A third aim was to look at predictive values of FMA when combined with cerebral ultrasound.

## METHOD

### Study participants

This multicentre study includes children born preterm between 24.0 and 31.9 weeks' gestation from 2004 to 2011 who participated in a national follow-up programme.<sup>10</sup> The three participating centres (Zurich, Bern, and Geneva) performed general movement assessment in infants born preterm at 3 months corrected age, according to the method of Prechtl.<sup>5,11</sup> Routine follow-up of infants born very preterm at 2 years corrected age has been recommended and performed by the Swiss Neonatal Network and Follow-up Group, and follow-up data are prospectively collected and housed in the network database. Neonatal and follow-up data for this study were extracted from this prospective national database.

Data of general movement assessment are not part of this prospective national database. Routine follow-ups of all three centres (to the present day) did not perform an examination on all infants born very preterm before 32 weeks' gestation at 3 months corrected age. The inclusion for FMA for infants born very preterm, at corrected 3 months, was requested of parents, but was not mandatory. The incidence of infants with a gestational age below 32 weeks in the three participating centres was as follows. In centre 1, infants were recruited between 2004 and 2011: 1166 infants born very preterm were born before 32 weeks' gestation, 50 of whom had malformations and 272 died; 295 of the remaining infants could be included in the study. In centre 2, infants were recruited over the same time period: 1005 infants were born very preterm, of whom 56 had malformations and 143 died; in 184, FMA was done at the requested age to allow inclusion. In centre 3, recruitment took place between 2005 and 2007: 264 infants were born before 32 weeks' gestation, eight with malformations and 31 died; 57 could be included in the study.

Data collection and evaluation for this study were approved by the institutional ethical review boards of Zurich, Bern, and Geneva and by the Swiss Federal Commission for Privacy Protection in Medical Research. Participating centres were obliged to inform parents about the scientific use of anonymised data.

### What this paper adds

- Fidgety movement assessment (FMA) in infants born very preterm is practicable in a clinical setting.
- Clinical results of FMA are less robust than when performed in academic settings.
- A combination of FMA and cerebral ultrasound appears to improve prognostic information.
- FMA at 3 months can help to identify infants at risk for cognitive dysfunction.

### Definition of neonatal variables

Birthweight z-scores were calculated based on the growth curves.<sup>12</sup> Major brain lesion was defined by cerebral ultrasound examination between birth and term as intraventricular haemorrhage greater than grade 2, according to the classification of Papile et al.<sup>13</sup> and/or cystic periventricular leukomalacia.<sup>14</sup> Bronchopulmonary dysplasia was defined as additional oxygen requirements at 36.0 weeks postmenstrual age.<sup>15</sup> Retinopathy of prematurity was defined using the International Committee criteria.<sup>16</sup> Necrotizing enterocolitis was defined as pneumatosis intestinalis or pneumatosis vena portae (Bell's stage II) or higher.<sup>17</sup> The presence or absence of infection was classified as uninfected, suspected (clinical and laboratory signs of sepsis but absence of positive blood or cerebrospinal fluid culture), and proven sepsis (positive blood or cerebrospinal fluid culture).<sup>18</sup>

Socioeconomic status was estimated using a validated 12-point socioeconomic score based on maternal education and paternal occupation and was classified into higher class (score 2–5), middle class (6–8), and lower class (9–12).<sup>19</sup>

### General movement assessment at 3 months corrected age

General movement assessment was performed as described previously by paediatric physical therapists, child neurologists, or developmental paediatricians who have successfully completed formal training in Prechtl's method, depending on centre preferences. The child had to lie in the supine position, although he or she was allowed to turn on one side. Spontaneous movements were only assessed in Prechtl's behavioural state 4 (eyes open, not crying, irregular respiration, movements present).<sup>11</sup>

General movements were classified based on visual Gestalt perception intended to capture the integrity of the movement with its complexity, variation, and fluency, providing information on the integrity of the nervous system. For the present study, only assessments during the fidgety period were included. Fidgety movements were classified as either normal, as described, or atypical defined as follows: abnormal (i.e. fidgety movements whose amplitude, speed, and jerkiness were moderately or greatly exaggerated), or absent (i.e. fidgety movements were not observed).<sup>11</sup>

### Outcome assessment at 2 years corrected age

Neurodevelopmental examination was routinely performed by experienced developmental paediatricians or neuropaediatricians at 18 to 24 months corrected age at each of the three neonatal follow-up centres. The assessment consisted of a clinical examination, a structured neurological

assessment, and a developmental assessment using the Bayley Scales of Infant Development, 2nd edition (BSID-II).<sup>20</sup> Infants who were severely impaired and in whom a structured test with the BSID-II could not be performed were assigned a mental development index (MDI) and psychomotor development index (PDI) of 49. Cerebral palsy was diagnosed and classified according to the guidelines of the Surveillance Group of CP in Europe.<sup>21</sup> Functional performance was defined according to the Gross Motor Function Classification System (GMFCS).<sup>22</sup>

### Statistical analysis

We first used the  $\chi^2$  test, independent Student's *t*-test, and Mann-Whitney *U* test to compare baseline characteristics (perinatal characteristics, neonatal morbidities, socioeconomic status, and corrected age at fidgety period) between infants with normal and absent fidgety movements, and between infants with normal and atypical fidgety movements. We then used regression models to compare dichotomous and continuous outcome measures (CP, MDI, PDI, and MDI or PDI value less than 2 standard deviations [SDs] from the norm) between infants with normal and absent fidgety movements, and between infants with normal and atypical fidgety movements. We then went on to estimate the association between fidgety movements at 3 months and neonatal cerebral ultrasound findings – that is, (a) absent fidgety movements, (b) absent or abnormal fidgety movements, (c) major brain lesion, and (d) major brain lesion and absent or abnormal fidgety movements – with the development of CP at 2 years using uni- and multivariable logistic regression models. Models were adjusted for the following variables: lower socioeconomic status (i.e. score >8), gestational age below 28 weeks, male sex, bronchopulmonary dysplasia, sepsis/necrotizing enterocolitis, retinopathy of prematurity, and major brain lesion, based on their association with neurodevelopmental outcome;<sup>18</sup> and 'study centre', because of the known centre-to-centre differences in neonatal outcomes in the Swiss perinatal population.<sup>23</sup>

Associations were given as OR with 95% CI. Finally, sensitivity, specificity, positive and negative predictive values, and their 95% CI were calculated for (1) absent fidgety movements; (2) atypical, that is absent or abnormal fidgety movements; (3) major brain lesion in the neonatal cerebral ultrasound; and (4) the combined observation of atypical fidgety movements and major brain lesion for the development of CP at 2 years of age. Analyses were performed using SPSS v.21.0 (IBM Corp., Armonk, NY, USA); the significance threshold was defined as  $p < 0.05$ , and testing was two-sided.

## RESULTS

### Study population

Data on 535 study infants were available from the three participating centres: 55% female; mean gestational age 28.2 (range 23.9–31.9) weeks; mean birthweight 1023 (range 380–1600) grams. Among them, 432 (81%) showed

normal fidgety movements at a mean corrected age of 13.0 (SD 3.1) weeks, 81 (15%) infants showed no fidgety movements, and 21 (4%) infants showed abnormal fidgety movements (Table SI, online supporting information). The average corrected age at fidgety movement evaluation was similar between groups: normal fidgety movements at 13.1 (range 12.0–20.0) weeks; abnormal fidgety movements at 12.1 (range 12.0–16.0) weeks; absent fidgety movements at 12.8 (12.0–20.0) weeks.

Infants with absent fidgety movements had significantly lower gestational ages ( $p=0.022$ ) (Table SI). Out of all neonatal morbidities, infants with absent fidgety movements suffered significantly more often from intraventricular haemorrhage grade 1 ( $p=0.041$ ), albeit not for grades 2, 3, and 4 intraventricular haemorrhage. This was not so for cystic periventricular leukomalacia; however, the number of children with periventricular leukomalacia was rather small. Baseline characteristics of infants with normal and abnormal fidgety movements were similar except for the rates of intraventricular haemorrhage grade 1 and major brain lesion, which were significantly higher in infants with abnormal fidgety movements than in infants with normal fidgety movements ( $p=0.032$  and  $p=0.010$  respectively). Very surprisingly, periventricular flaring in the cerebral ultrasound at day 14 of life or later was found much more often in the group of children with normal fidgety movements compared with absent and abnormal fidgety movements ( $p=0.046$  and  $p=0.003$ ); this flaring was not at all predictive of a negative outcome, but rather presented more randomly in the population we studied (Table SI).

### Outcome at 2 years corrected age

To achieve a more complete picture, despite the very low number of infants with 'abnormal fidgety movements', we also performed analyses for normal, abnormal, absent, and 'atypical' (abnormal and absent) fidgety movement patterns. However, because of the low number of infants with abnormal fidgety movements, this group is not visible in Tables I and II, and Tables SII and SIII (online supporting information).

Outcome assessment took place at an average corrected age of 23.4 (range 18.0–38.0) months. Among all study infants, 39 (7%) infants suffered from CP at the corrected age of 2 years. Bilateral spastic CP ( $n=22$ ) was the most common of all forms of CP, followed by unilateral spastic ( $n=11$ ), ataxic ( $n=5$ ), and dyskinetic ( $n=1$ ) CP. Among the 39 infants with CP, absent fidgety movements was identified in 20, and abnormal fidgety movements was identified in three, while 16 infants had normal fidgety movements. Seven infants in GMFCS levels above 2 had absent fidgety movements, and one had normal fidgety movements. Of 535 study infants, 80 had atypical (i.e. absent or abnormal fidgety movements) and did not develop CP. Table SII details the data concerning type and grading of CP.

Infants with absent fidgety movements ( $p < 0.001$ ) and abnormal fidgety movements ( $p=0.031$ ) were significantly more likely to develop CP than infants with normal fidgety

**Table I:** Prediction of neurodevelopmental outcome at 2 years corrected age of infant with normal and absent fidgety movements; of infants with major brain lesions on neonatal brain ultrasound, and of infants of both major brain lesions and atypical fidgety movements

OR (95% CI); B coefficient of linear regression model (95% CI)	Normal fidgety movements n=432	Absent fidgety movements n=83		Major brain lesion n=35		Major brain lesions and absent or abnormal fidgety movements n=11		
	n (%) mean (range)	n (%) mean (range)	Unadjusted		Unadjusted		Unadjusted	
			Adjusted <sup>a</sup>	Adjusted <sup>b</sup>	Adjusted <sup>b</sup>	Adjusted <sup>b</sup>		
CP, n (%)	16 (4%)	20 (24%)	8.9 <sup>c</sup> (4.1 to 17.1)	12 (34%)	8.4 <sup>c</sup> (3.8 to 18.5)	6 (54%)	17.8 <sup>c</sup> (5.2 to 61.6)	
MDI ≤70, n (%)	34 (8%)	13 (16%)	10.9 <sup>c</sup> (4.2 to 28.0)	7 (20%)	8.4 <sup>c</sup> (3.3 to 21.8)	1 (9%)	31.1 <sup>c</sup> (4.4 to 222.0)	
PDI ≤70, n (%)	56 (13%)	9 (11%)	2.4 <sup>e</sup> (1.2 to 4.9)	6 (17%)	3.2 <sup>e</sup> (1.3 to 7.9)		1.6 (0.2 to 13.4)	
MDI, mean (SD)	92.4 (16.6)	86.6 (18.5)	2.9 (1.1 to 7.2)	6 (17%)	4.0 <sup>d</sup> (1.4 to 11.1)	3 (27%)	NA	
PDI, mean (SD)	88.1 (14.9)	86.3 (16.0)	1.0 (0.4 to 2.5)	63.0 (18.2)	2.2 (0.8 to 6.2)	80.6 (18.3)	23.9 <sup>d</sup> (2.4 to 234.1)	
			1.7 (0.6 to 5.1)		2.2 (0.8 to 6.2)		NA	
			-5.4 <sup>e</sup> (-9.6 to -1.2)		-4.8 (-11.1 to 1.4)	87.0 (19.1)	-5.0 (-17.6 to 7.6)	
			-4.8 (-9.3 to -0.3)		-4.4 (-11.1 to 2.2)		-0.6 (-15.4 to 14.2)	
			-2.2 (-6.5 to 2.2)		-7.5 <sup>e</sup> (-13.4 to -1.6)		-24.8 <sup>d</sup> (-39.7 to -10.0)	
			-4.1 (-8.7 to 0.4)		-7.5 <sup>e</sup> (-13.7 to -1.4)		-28.0 <sup>d</sup> (-45.1 to -11.1)	

The group of infants with abnormal fidgety movements has been removed because of its small number. <sup>a</sup>Adjusted for study centre, low socioeconomic status, gestational age below 28 weeks, sex, bronchopulmonary dysplasia, sepsis/necrotizing enterocolitis, retinopathy of prematurity >2 grade, and major brain lesion. <sup>b</sup>Adjusted for study centre, low socioeconomic status, gestational age below 28 weeks, sex, bronchopulmonary dysplasia, sepsis/necrotizing enterocolitis, retinopathy of prematurity >2 grade. <sup>c</sup>p<0.001. <sup>d</sup>p<0.01. <sup>e</sup>p<0.05. OR, odds ratio; CI, confidence interval; MDI, mental development index; PDI, psychomotor development index; NA, not available; SD, standard deviation.

**Table II:** Predictive values for cerebral palsy at 2 years corrected age

Predictive values	Absent fidgety movements	Major brain lesion	Major brain lesion and absent or abnormal fidgety movements
Sensitivity	56%	31%	15%
95% CI	38–72%	17–46%	6–31%
Specificity	87%	95%	99%
95% CI	84–90%	93–97%	97–100%
PPV	24%	32%	54%
95% CI	16–32%	18–50%	24–82%
NPV	96%	95%	94%
95% CI	94–98%	92–96%	91–96%

Area under the receiver operating characteristic curve, p<0.001 for all four values. The group of infants with abnormal fidgety movements has been removed because of its small number. CI, confidence interval; PPV, positive predictive value, NPV, negative predictive value.

movements. Both results remained statistically significant after adjustment for confounders (p<0.001 and p=0.042 respectively). Mean MDI of infants with absent fidgety movements (86.6 [SD 18.5]) was significantly lower (p=0.009) than in infants with normal fidgety movements (92.4 [SD 16.6]). Accordingly, the rate of infants with an MDI lower than 70 (i.e. less than 2 SDs from the norm) was higher in infants with absent fidgety movements than in infants with normal fidgety movements (p=0.022). After adjustment for confounders, the level of significance for both comparisons became marginal (p=0.083 and p=0.051 respectively) (Table I).

When we excluded those infants who developed CP, the association with MDI became weaker; nevertheless, significant associations of low mean PDI with major brain lesions

(p<0.005) and with major brain lesions and absent or abnormal fidgety movements (p<0.001) were found; an effect which disappeared as soon as the value was adjusted (Table III).

Both the presence of major brain lesion in the neonatal cerebral ultrasound examination (OR 8.4, 95% CI 3.8–18.4) and the absence of fidgety movements at 3 months corrected age (OR 8.9, 95% CI 4.1–17.0) were strongly associated with the later development of CP (p<0.001). The observation of atypical (i.e. absent or abnormal fidgety movements) despite its strong association with CP (OR 7.5, 95% CI 3.8–14.8), did not increase the OR for later CP, while the combined observation of major brain lesion and atypical (i.e. absent or abnormal) showed the strongest association (OR 17.8, 95% CI 5.1–61.58) with CP.

### Predictive values of fidgety movements for the development of cerebral palsy

Table II shows details of the calculated predictive values. Absent fidgety movements provided the highest sensitivity (56%) for later CP compared with major brain lesion (31%), while the combined observation of atypical fidgety movements and major brain lesion provided the lowest value (15%). Specificity value was best provided by the combined observation of atypical fidgety movements and major brain lesion (99%), while absent fidgety movements provided the lowest value (87%). The true negative rate ranged from 94% (combined atypical fidgety movements and major brain lesion) to 96% (absent fidgety movements), while the true positive rate ranged from 24% (absent fidgety movements) to 54% (combined atypical fidgety movements and major brain lesion).

Positive predictive value reached 54% for the combined observation of atypical fidgety movements and major brain

lesion and was below 33% for the other assessments. All assessments provided a negative predictive value above 93%. The observation of abnormal fidgety movements combined with absent fidgety movements provided no further increase of predictive values.

We observed that the positive and negative predictive values were similarly low ( $\leq 31\%$ ) and high ( $\geq 92\%$ ) respectively in all study centres, while relevant differences in the sensitivity (range 42–100%) and specificity (range 67–96%) were noted among centres.

## DISCUSSION

This multicentre study, consisting of 535 children preterm born before 32 weeks' gestation, assessed the predictive value of FMA for CP and cognitive outcome in combination with cerebral ultrasound. Circumstances of the study reflected daily practice in the routine follow-ups of children born preterm within the context of the Swiss Neonatal Network and Follow-up Group. To our knowledge, the present study has the largest sample size of infants born very preterm with FMA.

In summary, the results of the study demonstrate that infants born very preterm with absent fidgety movements or atypical (absent and abnormal merged together) fidgety movements were significantly more likely to develop CP than those with normal fidgety movements, a finding in line with previous studies.<sup>4,5,11</sup> After adjustment for several risk factors of poor neurodevelopmental outcome, the association between absent or abnormal fidgety movements and later CP remained significant and was clinically relevant. Major brain lesions were also clearly associated with CP, and when combined with atypical fidgety movements, the effect became even stronger.

Predicting CP in infants born preterm is of great importance for parental counselling and support planning. In our study population, the incidence of CP was 7%, in line with previous studies.<sup>24</sup> The sensitivity of absent fidgety movements for the development of later CP was 56%. Thus, in this sample and under the described clinical setting, only half of the children who develop CP would be detected with the help of fidgety movements assessment at 3 months corrected age. In addition to the prediction of CP later in life, the severity and distribution of later motor handicap is also relevant. In the present study, absent fidgety movements were more often associated with severe functional impairment. However, the subgroups of GMFCS were too small to calculate a predictive value of fidgety movements for the severity of motor abnormalities, and further research on larger numbers would be valuable.

The combined observation of major brain lesion observed in neonatal cerebral ultrasound and atypical fidgety movements (absent and abnormal fidgety movements merged together) at 3 months showed the strongest association with later CP. These findings underline the hypothesis that FMA improves prediction and is best used in conjunction with other methods; therefore, we strongly

recommend combining the FMA with earlier neuro-imaging for parental counselling and therapeutic plans.

We showed that absent as well as atypical fidgety movements were associated with poorer cognitive outcome. An association between general movements and later cognitive development in infants born preterm at preschool and school age has also been previously reported.<sup>5,6,8,9</sup> In addition to these previous studies, our results underline that atypical spontaneous motor activity at an early age might not only be predictive for motor, but also for cognitive development. Why absent and atypical FMA is associated with poorer cognitive outcome can only be assumed, as to date no causative explanation is reported in the literature.

In children born preterm, minor motor impairments are common.<sup>25</sup> Although minor motor impairments are not by definition compatible with the diagnosis of CP, they still have a considerable impact on quality of life, academic achievement, and participation.<sup>25</sup> Minor motor impairments in children born preterm may or may not be associated with cognitive impairments. In our detection of atypical fidgety movements at 3 months corrected age, we may have additionally identified infants with minor motor impairments. Because CP and minor motor deficits are often associated with cognitive problems, it might be possible that what we observed is of epiphenomenal nature, reflecting a common implication of brain areas involved in both cognitive and motor performance. Our study does not allow a definite conclusion on whether atypical fidgety movements at 3 months of age are an expression of motor, cognitive, or the combination of motor and developmental abnormalities later in life. However, our findings highlight that FMA may also identify infants born preterm at risk of cognitive dysfunction and that a thorough motor and cognitive follow-up is therefore important.

In comparison with previous studies using similar techniques,<sup>26</sup> the sensitivity of FMA to detect later CP was low in the present study. Specificity, on the other hand, was high and comparable with previously reported results.<sup>7</sup> Most previous studies were conducted by experts on general movements. In the present study, fidgety movements were assessed by certified professionals who use FMA as part of their daily clinical practice. It was previously reported that interrater and intrarater agreements of FMA differ considerably depending on experience<sup>6</sup>; therefore, rater differences may explain the higher sensitivity of previous studies. The findings of the present study remind us that methods developed and applied by experts in highly skilled academic settings may be less robust when applied in a daily clinical setting.

The present study illustrates that FMA, even in a daily clinical setting, is a valuable tool to detect an increased risk of CP in infants born very preterm. However, interpretation of the results requires caution. We have shown that the predictive value can be improved in combination with cerebral ultrasound, and therefore recommend that the results of cerebral ultrasound and FMA be combined for increased accuracy.

A weakness of this study is the relatively low inclusion percentage of infants born very preterm for FMA. Routine follow-ups of all three centres (to the present day) did not perform an examination on all infants born very preterm before 32 weeks' gestation at 3 months corrected age.

Finally, results from the group with 'abnormal fidgety movements' corroborated those from previously reported studies, where this particular movement pattern (1) is much less often observed than that of absent fidgety movements, and (2) provides lower prediction than absent fidgety movements.<sup>6</sup>

The major limitation of the present study is that three different teams scored fidgety movements independently. Nevertheless, the rater trainings were comparable as all three teams used the guidelines for the general movement assessment previously published.<sup>11</sup>

Outcome testing with the BSID-II, however, were not in all cases performed by different teams or different persons within the same team, but not simultaneously. Furthermore, as motor patterns may change considerably in toddlers and young children with neurological abnormalities, the diagnosis of CP at 2 years of age is generally considered early. The classification of subtypes and GMFCS levels is particularly difficult at this early age. The guidelines of the Surveillance Group of Cerebral Palsy in Europe used to define CP in the present study, recommend that a definite diagnosis of CP should be undertaken at the age of 4 years. Minor neurological and cognitive deficits might not be visible at the age of 2 years. The BSID-II score did reveal minor deficits in patients with an absence of CP; but BSID-II does not provide a good predictive value for later cognitive outcome,<sup>5</sup> and children with normal cognitive test scores at 2 years of age might still reveal minor deficits later.

## REFERENCES

1. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to adulthood. *Lancet* 2008; **371**: 261–69.
2. Aylward GP. Neurodevelopmental outcomes of infants born prematurely. *J Dev Behav Pediatr* 2014; **35**: 394–407.
3. Spittle AJ, Doyle LW, Boyd RN. A systematic review of the clinimetric properties of neuromotor assessments for preterm infants during the first year of life. *Dev Med Child Neurol* 2008; **50**: 254–66.
4. Prechtl HF. Qualitative changes of spontaneous movements in fetus and preterm infant are a marker of neurological dysfunction. *Early Hum Dev* 1990; **23**: 151–81.
5. Spittle AJ, Spencer-Smith MM, Cheong JL, et al. General movements in very preterm children and neurodevelopment at 2 and 4 years. *Pediatrics* 2013; **132**: e452–58.
6. Bernhardt I, Marbacher M, Hilfiker R, Radlinger L. Inter- and intra-observer agreement of Prechtl's method on the qualitative assessment of general movements in preterm, term and young infants. *Early Hum Dev* 2011; **87**: 633–39.
7. Spittle AJ, Cheong J, Doyle LW, et al. Neonatal white matter abnormality predicts childhood motor impairment in very preterm children. *Dev Med Child Neurol* 2011; **53**: 1000–06.
8. Bruggink JLM, van Braeckel KN, Bos AF. The early motor repertoire of children born preterm is associated with intelligence at school age. *Pediatrics* 2010; **125**: e1356–63.
9. Einspieler C, Bos AF, Libertus ME, Matschik PB. The general movement assessment helps us to identify preterm infants at risk for cognitive dysfunction. *Front Psychol* 2016; **406**: 1–8.
10. Schlapbach LJ, Adams M, Proietti E, et al. Outcome at two years of age in a Swiss national cohort of extremely preterm infants born between 2000 and 2008. *BMC Pediatr* 2012; **12**: 198.
11. Einspieler C, Prechtl HF. Prechtl's assessment of general movements: a diagnostic tool for the functional assessment of the young nervous system. *Ment Retard Dev Disabil Res Rev* 2005; **11**: 61–67.
12. Voigt M, Fusch C, Olbertz D, et al. Analysis of the neonatal collective in the Federal Republic of Germany 12th report: presentation of detailed percentiles for the body measurements of newborns. *Geburtsb Frauenbeilk* 2006; **66**: 956–70.
13. Papile LA, Munsick-Bruno G, Schaefer A. Relationship of cerebral intraventricular hemorrhage and early childhood neurologic handicaps. *J Pediatr* 1983; **103**: 273–77.
14. de Vries LS, Eken P, Dubowitz LM. The spectrum of leukomalacia using cranial ultrasound. *Behav Brain Res* 1992; **49**: 1–6.
15. Jobe AH, Bancalari E. Bronchopulmonary dysplasia. *Am J Respir Crit Care Med* 2001; **163**: 1723–29.
16. The International Committee for the Classification of Retinopathy of Prematurity. The International Classification of Retinopathy of Prematurity revisited. *Arch Ophthalmol* 2005; **123**: 991–99.

## CONCLUSION

In a daily clinical setting, FMA at 3 months of age is easy to perform for trained staff, non-invasive, and cost-effective. However, the predictive value of fidgety movements in daily clinical practice is less robust than shown in highly skilled academic settings. When FMA is combined with cerebral ultrasound, however, its sensitivity in predicting CP increases. In conclusion, additional diagnostic tools such as cerebral ultrasound are recommended to improve the predictive power of FMA in everyday clinical settings.

## ACKNOWLEDGEMENTS

We thank all children and their parents who participated in this study. We would also like to thank Brigitte Püntener for her help with data collection, and Karine Landgren Hugentobler for proofreading the manuscript. AND was supported by the von Meissner Foundation, Geneva, Switzerland. The authors have stated that they had no interests which might be perceived as posing a conflict or bias.

## SUPPORTING INFORMATION

The following additional material may be found online:

**Appendix S1:** The GM Group.

**Table SI:** Baseline characteristics of infants with normal, absent, and abnormal fidgety movements.

**Table SII:** Neuromotor outcome at 2 years in infants with normal, abnormal, and absent fidgety movements.

**Table SIII:** Prediction of neurodevelopmental outcome at 2 years corrected age of infant without CP with normal and absent fidgety movements; of infants with major brain lesions on neonatal brain ultrasound; and of infants of both major brain lesions and pathological fidgety movements.

17. Bell MJ, Ternberg JL, Feigin RD, et al. Neonatal necrotizing enterocolitis. Therapeutic decisions based upon clinical staging. *Ann Surg* 1978; **187**: 1–7.
18. Schlapbach LJ, Aebischer M, Adams M, et al. Impact of sepsis on neurodevelopmental outcome in a Swiss National Cohort of extremely premature infants. *Pediatrics* 2011; **128**: e348–57.
19. Largo RH, Pfister D, Molinari L, et al. Significance of prenatal, perinatal and postnatal factors in the development of AGA preterm infants at five to seven years. *Dev Med Child Neurol* 1989; **31**: 440–56.
20. Bayley N. Bayley Scales of Infant Development, 2nd ed. San Antonio, Texas: The Psychological Corporation, 1993.
21. Surveillance of Cerebral Palsy in Europe. Surveillance of cerebral palsy in Europe: a collaboration of cerebral palsy surveys and registers. Surveillance of Cerebral Palsy in Europe (SCPE). *Dev Med Child Neurol* 2000; **42**: 816–24.
22. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 1997; **39**: 214–23.
23. Steurer MA, Adams M, Bacchetti P, et al. Swiss medical centres vary significantly when it comes to outcomes of neonates with a very low gestational age. *Acta Paediatr* 2015; **104**: 872–79.
24. Sellier E, Platt MJ, Andersen GL, et al. Decreasing prevalence in cerebral palsy: a multi-site European population-based study, 1980 to 2003. *Dev Med Child Neurol* 2016; **58**: 85–92.
25. Spittle AJ, Orton J. Cerebral palsy and developmental coordination disorder in children born preterm. *Semin Fetal Neonatal Med* 2014; **19**: 84–89.
26. Oberg GK, Jacobsen BK, Jorgensen L. Predictive value of general movement assessment for cerebral palsy in routine clinical practice. *Phys Ther* 2015; **95**: 1469–95.