# An early marker for neurological deficits after perinatal brain lesions

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## Summary

**Background** In normal awake infants, fidgety movements are seen from the age of 6 weeks to 20 weeks. The aim of the study was to test the predictive value of absent or abnormal spontaneous movements in young infants for the later development of neurological deficits.

**Methods** In a collaborative study involving five hospitals we collected data on the normal and abnormal quality of fidgety movements of 130 infants and compared it with assessments of neurological development done longitudinally until the age of 2 years. On the basis of ultrasound scans infants were classified as at low-risk or at high-risk of neurological deficits. Infants were videoed for 1 h every week from birth to discharge and then for 15 min every 3 to 4 weeks; quality of general movements was assessed. Repeated neurological assessments were also done until 24 months of corrected age.

**Findings** 67 (96%) of 70 infants with normal fidgety movements had a normal neurological outcome. Abnormal quality or total absence of fidgety movements was followed by neurological abnormalities in 57 (95%) of the 60 infants (49 had cerebral palsy and eight had developmental retardation or minor neurological signs). Specificity and sensitivity of fidgety movement assessment were higher (96% and 95%, respectively) than of ultrasound imaging of the infants' brain (83% and 80%, respectively).

**Interpretation** Our technique of assessing spontaneous motor activity can identify and distinguish between those infants who require early intervention for neurological abnormalities and those who do not. Our technique is simple, non-intrusive, reliable, quick, and can be done on very young infants.

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## Introduction

The human fetus and young infant have a repertoire of distinct movement patterns that are spontaneous.[1] One set of these movement patterns are known as general movements.[2] These movements can be observed in fetuses as young as 10 weeks postmenstrual age.[3] Postmenstrual age, age of the fetus or infant calculated from the date of the mother's last period, is used as a way of compensating for premature birth. In infants at low-risk of neurological damage general movements continue in a similar pattern until about the end of the second month post term.[4]

After birth, general movements are commonly referred to as writhing movements.[4] At the age of 6 to 9 weeks post term the form and character of general movements of normal infants changes from the writhing type into a fidgety pattern.[4,5] Fidgety movements are defined as an ongoing stream of small, circular, and elegant movements of neck, trunk, and limbs. They differ qualitatively from involuntary dyskinesias that appear to be forced. Fidgety movements of a healthy infant are a transient phenomenon; they emerge gradually at 6 weeks, come to full expression between 9 and 13 weeks post term and taper off again between the ages of 14 to 20 weeks post term.[6] This is true for low-risk term as well as preterm infants whose age has been corrected.[7,8] Fidgety movements can best be observed when the infant is awake, alert, and either lying supine or sitting reclined in a baby seat. Under these conditions, normal infants aged 3 months can sustain continual fidgety movements for as long as an hour at a time. Fidgety movements will stop when the baby cries or fusses or when it is distracted by its immediate surroundings.

In previous studies[9,10] absent or abnormal quality of fidgety movements seemed to have clinical significance for predicting the later outcome of neurological impairment. To clarify this issue we did a collaborative study, using the same method of assessment and follow-up but on a large scale. We aimed to answer three questions: which abnormal writhing general movements lead to absent or abnormal fidgety movements; what is the long-term neurological outcome of infants with abnormal quality of writhing movements whose general movements normalise at an early age and who develop normal fidgety movements; and what is the long-term neurological outcome of infants who show abnormal or a total lack of fidgety movements?

## Methods

We enrolled preterm and term newborn babies from the University Hospitals of Graz, Groningen, Heidelberg, Modena, and Pisa. We included infants for whom: mother's last menstrual dates were known, brain ultrasound scans were available, general movements at various ages had been observed, at least one assessment during the period with fidgety movements (46–60 weeks postmenstrual age) had been done, and standardised repeated neurological follow-up until 2-years corrected age had been done.

On the basis of the results of repeated ultrasound scans we graded the ultrasound findings from normal to severely abnormal and we avoided selection of only extreme cases, which could have biased the results. We then classified the infants into two groups, low-risk and high-risk, according to risk of neurological deficits. Examples of abnormal findings judged to be mild enough to allow classification into the low-risk group were short-lasting increased echogenicity or grade I intraventricular haemorrhage. High-risk infants were found to have definite abnormalities of their brains on ultrasound examination (periventricular leucomalacia grade II–IV[11] or grade II–IV intraperiventricular haemorrhage[12]). Some of the infants had participated in previous studies.[9,10] All parents gave informed consent for their children to participate in our study.

### *Observation of spontaneous movements*

From birth in term and in preterm infants until the expected date of delivery, 1 h video recordings with the infant in an incubator or cot

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| Ultrasound classification | | Quality of writhing movements (birth–9 weeks) | | | Quality of fidgety movements (6–20 weeks) | Neurological outcome (2 years) | | |
|---|---|---|---|---|---|---|---|---|
| Low risk | High risk | Normal | Poor repertoire | Cramped synchronised | | Normal | Mental and/or motor retardation | Severe cerebral palsy |
| 58 (83%) | 12 (17%) | 32 (46%) | 38 (54%) | 0 | Normal (n=70) | 67 (96%) | 3 (4%) | 0 |
| 6 (38%) | 10 (62%) | 0 | 12 (75%) | 4 (25%) | Abnormal (n=16) | 3 (19%) | 7 (44%) | 6 (37%) |
| 6 (14%) | 38 (86%) | 0 | 8 (18%) | 36 (82%) | No fidgety movements (n=44) | 0 | 1 (2%) | 43 (98%) |

**Relation of ultrasound classification of risk of neurological deficits to quality of movements and outcome at 2 years**

were done each week. After discharge from the hospital the infants were recorded for 15 min every 3 to 4 weeks in the outpatient clinic or at home. All the recordings were done at least 30 min after feeding, during periods of active wakefulness with the infants partially dressed (ie, wearing a body vest and nappy) and lying supine. During the age when fidgety movements are observed usually an average of three recordings (range one to five) were made to ensure that the quality of movement (normal or abnormal) could be accurately judged.

### *Quality assessment of general movements*

During the playback of video recordings, three to four general writhing movements, each lasting about 30 s or longer, excluding those during crying, fussing, or suckling periods, were selected as typical for each particular age. During the fidgety-movements age a representative sample of fidgety movements that lasted several minutes was chosen. The collection of general movements at different ages was then stored in sequence from birth to 65 weeks postmenstrual age on a separate tape.

For all recordings the quality of general movements was assessed by the co-authors in their respective centre. In addition, one author who was unaware of the infants' clinical history reassessed the quality of all the general movements. There was a 91% agreement in judgments given. The results of the longitudinal assessments were graphically displayed on a time axis to give individual developmental trajectories.[9,13] The interobserver reliability in judgment of general movements has been assessed.[13–16] The interscorer agreement ranged from 85% to 92% in these studies. The test-retest reliability after an interval of 2 years was 1·0 for the global judgment (normal *vs* abnormal) and 0·85 for the analysis of details (ie, amplitude, speed, fluency, range of movements, etc).[17]

### *Movement definitions*

We used the following definition of normal writhing general movements: gross movements, involving the whole body. They may last from a few seconds to several minutes or longer. What is particular about them is the variable sequence of arm, leg, neck, and trunk movements. They wax and wane in intensity, force, and speed, and they have a gradual beginning and end. The majority of sequences of extension and flexion movements of arms and legs is complex, with superimposed rotations and often slight changes in direction of the movement. These additional components make the movements fluent and elegant and create the impression of complexity and variability.[13]

Types of abnormalities of writing general movements are poor repertoire and cramped-synchronised movements. Poor repertoire is when a sequence of successive movement components is monotonous and movements of the different body parts do not occur in the complex way as seen in normal general movements.[9] Cramped-synchronised general movements look rigid and lack the normal smooth and fluent character; all limb and trunk muscles contract and relax almost simultaneously.

Normal fidgety movements are circular movements of small amplitude, moderate speed, and variable acceleration of neck, trunk, and limbs in all directions. They are continual in the awake infant, except during focused attention, fussing, and crying. They may be concurrent with other movements. They may be seen as early as 6 weeks post term but usually occur around 9 weeks and are then present until 15 to 20 weeks. This age range holds true for term as well as preterm infants with corrected age. Initially they occur as isolated events, gradually increase in frequency, and then once again decrease in frequency.

Fidgety movements are judged as abnormal if they are absent: never observed from ages 6 to 20 weeks post term (other movements can be observed); or abnormal in nature: look like normal fidgety movements but their amplitude, speed, and jerkiness are moderately or greatly exaggerated.

### *Neurological follow-up examination*

Neurological assessment was done repeatedly at least until 24 months of corrected age. After the first 6 months of life the neurological status was assessed by a partly expanded and age-adequate neurological examination based on criteria outlined by Amiel-Tison and Grenier[18] and Touwen.[19] In addition, development was tested repeatedly with either the Griffiths Scales[20] or the Bayley Scales.[21] The outcome at 24 months was classified as: normal (no abnormal neurological signs, developmental scores >85); developmentally retarded (developmental scores between 84 and 50, and two cases of very mild cerebral palsy); or severe cerebral palsy.

## Results

The final study sample was 130 infants: 52 girls and 78 boys. Their gestational age at birth ranged from 26 to 41 weeks (median 32 weeks, IQR: 29 to 38 weeks); 74% were born preterm. The infants' birthweight ranged from 700 to 4680 g (median 1660 g, IQR: 1245 g to 2730 g).

With ultrasound scanning 70 (54%) of the 130 infants were classified as at low risk and 60 (46%) were classified as at high risk of developing neurological deficits. Of the low-risk infants 47 had no abnormalities and 23 had mild abnormalities (table).

### *Quality of general movements*

All 32 infants who showed normal general movements during the preterm, term, and early post-term periods, also showed normal fidgety movements. 38 infants had abnormal general movements (ie, poor repertoire) but these normalised before (12 infants) or during (26 infants) the fidgety period. 70 infants showed normal fidgety movements.

In contrast, all 60 infants with abnormal (16 infants) or absent (44 infants) fidgety movements also had abnormal writhing general movements. The 12 infants with a poor repertoire of general movements and the four infants with cramped-synchronised general movements all later showed abnormal fidgety movements, whereas the 44 infants who never showed any fidgety movements previously had cramped-synchronised general movements (36 infants), and eight infants showed general movements with a very poor repertoire. None of the infants with abnormal or absent fidgety movements had ever shown normal general movements.

### *Neurological outcome at 2 years*

67 of 70 infants with normal fidgety movements had a normal long-term neurological outcome. Only three infants had an abnormal outcome. One had motor retardation while two suffered from a very mild form of cerebral palsy (one minimal monoplegia of a leg and the other a mildest form of hemiplegia).

By contrast, the long-term outcome of the 16 infants with abnormal fidgety movements was definitely abnormal in 13 of the infants. Six of these had cerebral palsy, the other

seven gave clear evidence of developmental retardation or minor neurological signs. Only three of the 16 infants were judged normal at the 2-year follow-up examination.

The prognosis was poorest for the 44 infants who had never shown fidgety movements; none of them were found to be normal at the 2-year examination. One was developmentally retarded, and 43 of 44 infants had cerebral palsy (one dyskinetic form, four hemiplegias, 18 diplegias, and 20 quadriplegias).

Of the 60 infants with abnormal and absent fidgety movements, 57 infants had an abnormal outcome, including 49 with cerebral palsy and eight with developmental retardation or minor neurological signs, and only three were diagnosed as normal at age 2 years.

### *Prediction of neurological outcome*

Prediction of neurological outcome based on ultrasound-scan findings had a lower validity than that based on fidgety-movement assessment. Of the 70 infants with normal or mildly abnormal ultrasound-scan findings, 58 had normal fidgety movements and 12 had abnormal or absent fidgety movements. 12 of the 60 infants with definite ultrasound-scan abnormalities had normal and 48 had abnormal or absent fidgety movements. Neurological outcome at 2 years in the low-risk group, as defined by ulrasound scans, was normal in 58 of 70 infants and abnormal in 12 infants; six infants had cerebral palsy. In the high-risk group 12 of 60 infants were normal and 48 abnormal; 45 infants in the latter group had cerebral palsy.

The specificity (83%) and sensitivity (80%) of predictions based on the ultrasound assessment were, therefore, clearly lower than the specificity (96%) and sensitivity (95%) of predictions based on the assessment of fidgety movements.

## Discussion

Our method of observing the quality of fidgety movements in young infants allows valid predictions about later neurological outcome to be made long before the first signs of spasticity appear. Not only are abnormal and absent fidgety movements indicative of a poor outcome but normal fidgety movements are an excellent marker for a normal neurological outcome. The qualitative assessment of general movements before the onset of fidgety movements has an equally high sensitivity but its specificity is considerably lower.[22] Many of the earlier general-movement abnormalities are transient phenomena and normalise before or at the appearance of fidgety movements, whereas infants with abnormal or absent fidgety movements do not normalise, with very few (5%) exceptions, but still have abnormal neurological signs after the age when fidgety movements normally disappear.

Our technique is non-invasive and non-intrusive; it can be done without expensive equipment and by contrast with time-consuming neurological examination an experienced observer needs no more than a few minutes to do the assessment. Our technique is an excellent method to distinguish between infants in need of close surveillance and intervention and those for whom this is unnecessary.

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