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Review
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Early markers for cerebral palsy: insights from the assessment of general movements

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Overt clinical symptoms of cerebral palsy do not emerge before a child is at least half a year old. Among the most reliable early markers for cerebral palsy are abnormal 'general movements' (GMs). Two specific abnormal GM patterns predict cerebral palsy: cramped-synchronized GMs (during preterm and term age), which lack the usual smoothness and fluent character; and limb and trunk muscles contract almost simultaneously and relax almost simultaneously. In addition, the absence of so-called fidgety movements at 3–5 months post-term age. Fidgety movements are small movements of the neck, trunk and limbs in all directions and of variable acceleration. Beside a high sensitivity (>91%) and specificity (>81%), the assessment of GMs is quick, nonintrusive and easy to acquire.

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Learning objectives

Upon completion of this activity, participants should be able to:

- Describe how GMs can help predict spastic CP, based on a review
- Describe how GMs can help predict unilateral CP, based on a review
- Describe how GMs can help predict dyskinetic CP, based on a review

Keywords

■ bilateral ■ cerebral palsy ■ dyskinetic ■ fidgety movements ■ general movements ■ infant ■ neonate ■ spastic ■ unilateral ■ video analysis

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Cerebral palsy (CP) is a well-recognized neurodevelopmental condition that starts to manifest early in childhood, usually before 18 months of age [1]. The prevalence of CP increases with decreasing gestational age from 0.1% in children born at term to 14.6% in children born below 28 weeks gestational age [2,3]. Spastic CP is the most common form of CP in children born preterm, whereas in children born at term, nonspastic forms predominate [2]. Bilateral spastic CP is more widespread than unilateral spastic CP both in children born preterm (73 vs 21%) and born at term (48.5 vs 36.5%) [2].

One of the most challenging tasks for medical practitioners is to identify specific risk factors in early infancy and predict severe impairment that manifests later in development. The parents, on their part, are all the more anxious to learn about the developmental perspectives of their infant, especially if the infant has an adverse perinatal history. At the same time, one should consider that overt clinical symptoms of CP usually do not emerge before the child is at least half a year old [1,4].

In addition to the low gestational age and low birth weight, perinatal asphyxia and neonatal encephalopathy, white matter disease, severe intraventricular hemorrhage, cerebral infarction, deep gray matter lesions, infections and multiple genetic factors have been identified as risk factors for CP [5–7]. Among the most reliable markers for CP are abnormal 'general movements' (GMs) [8–13]. The assessment of spontaneous GMs is based on visual gestalt perception in preterm and term infants aged up to 5 months post-term. Normally, GMs involve the entire body and manifest themselves in variable sequences of arm, leg, neck and trunk movements. They come and go gradually, varying in intensity and speed. Rotations and frequent slight variations of the direction of motion make them look complex, though smooth [14]. GMs occur in age-specific patterns. During the post-term age of 3–5 months, they are described as 'fidgety movements', that is, small movements of the neck, trunk and limbs in all directions and of variable acceleration [8,15].

A systematic search was conducted to identify empirical studies that involved the use of Prechtl's method of qualitative assessment of GMs, which focused on CP as an outcome variable [8,10,15]. PubMed and Science Direct were searched using the following free-text terms "general movements" and "cerebral palsy"; the search was not limited to language but to peer-reviewed journals. The search occurred in March 2012 and was updated in July 2012.

The absence of fidgety movements precedes CP

In 1997, Heinz Prechtl and associates proved the assessment of GMs, particularly during 3–5 month of age, to be a reliable and valid tool for distinguishing between infants who are at significant risk of developing CP and infants who are not [8]. The findings were based on a longitudinal study on 130 infants who represented the whole spectrum of perinatal brain ultrasound findings. Central to the study were the age-specific fidgety

movements. It was found that 96% of infants with normal fidgety movements (n = 70) had a normal neurological outcome. Abnormal quality or total absence of fidgety movements was followed by neurological abnormalities (most of them CP) in 95% of the 60 infants. Specificity and sensitivity of the assessment of fidgety movements (96 and 95%, respectively) were higher than of cranial ultrasound (83 and 80%, respectively) [8].

Since then, various groups have emphasized the significance of fidgety movements for an early prediction of CP [10–13,16]. Burger and Louw reviewed 15 studies on the predictive value of fidgety movements and reported a sensitivity >91% and a specificity >81% [11]. The most comprehensive study so far, in which 903 children participated, yielded a sensitivity of 98% and a specificity of 94% [17]. An interscorer agreement of 89 to 93% and an average κ of 0.88 obtained in 15 studies documented the high objectivity of the GM assessment [10,15,18]. Such high values can be achieved after a few days of extensive training [19]. A high interindividual consistency of GM quality was demonstrated by κ-values from 0.90 to 0.96 [20].

Assistance in identifying fidgety GMs or their absence has been recently provided by Adde and coworkers [21]. With a software called General Movement Toolbox, the identification rate of infants who later developed CP has been notably high (sensitivity: 85%, specificity: 88%), which suggested that it was actually possible to detect the characteristic features of fidgety GMs with the help of computer-based analysis systems [22].

The mere absence of fidgety movements, however, cannot predict the subtype or the severity of the CP. The motor repertoire of infants aged 3–5 months consists not only of fidgety movements but also of other motor patterns, for example, kicking, swiping and wiggling–oscillating arm movements, movements towards the midline, legs lift, arching and axial rolling [23]. Bruggink and colleagues [24] have shown that a detailed analysis of the whole repertoire can provide a number of markers that are associated with poor self-mobility (assessed by means of the Gross Motor Function Classification System [25]) in 6–12-year-old children with CP:

- A cramped movement character;
- A reduced motor repertoire depending on the age of the infant, for example, lack of movements towards the midline from 12 weeks onwards; lack of leg lift from 15 weeks onwards;
- Monotonous kicking;
- The absence of fidgety movements [24].

There are, however, also a small number of infants with some fidgety activity who nonetheless developed CP, albeit in its mildest form [8,24,26].

The absence of fidgety movements was never specific for a particular subtype of CP (Table 1). This fact indicates that intact corticospinal fibers and a normal output of the basal ganglia and cerebellum are necessary to generate normal fidgety movements [27]. Magnetic resonance studies have demonstrated that in very preterm infants, white matter lesions [28] and a reduced cerebellar diameter [29] were associated with absent fidgety movements. In infants born at term, the severity of the injury to the central gray matter correlated with a lack of fidgety movements [30].

Interestingly, fidgety movements were also absent in infants with genetic disorders like Rett syndrome and its preserved speech variant [31–33], Smith–Magenis syndrome [34], as well as in infants with autistic spectrum disorders [35].

After discovering fidgety movements as an age-specific, distinct form of GMs, Prechtl contemplated the potential biological function of this transient movement pattern [36]. He hypothesized that one of the ontogenetic adaptive functions of these small movements is optimal calibration of the proprioceptive system. This assumption is supported by the fact that fidgety movements emerge during the transformation of neural functions at 3 months of age [37] and therefore precede the onset of intentional reaching or visually controlled manipulation of objects [23,36]. Since in many respects adaptation to the extrauterine condition is not completed before the third month post-term [38], the proprioceptive system is still matched to the intrauterine environment. A recalibration of this sensory system is required in order for fine motor skills to develop properly [36]. As a matter of fact, adolescents with a dysfunction of fine manipulation showed poorly expressed or even abnormal fidgety movements during infancy [39]. Infants with a total loss of sight due to retinopathy of prematurity but with no brain lesion showed fidgety-like movements with a very high amplitude and a pace too slow. Lasting much longer than usual (i.e., until the age of 10 months old), such movements might represent an attempt to compensate for the poor integration of vision and proprioception [40].

Cramped synchronized GMs at preterm & term age: an early predictor of spastic CP

By the late 1980s, Prechtl and his associates had demonstrated that fetuses and preterm infants moved differently if their nervous system was

Table 1. Developmental trajectories with a high predictive power for normal development and the development of cerebral palsy.

GMs during preterm age	Writhing GMs (at term until 8 weeks post-term)	Fidgety GMs (3–5 months)	Neurological outcome	Ref.
Poor repertoire or normal GMs	Poor repertoire or normal GMs	Normal fidgety movements	Normal	[8–10,14,15,27,36,42,50,51]
Poor repertoire or cramped-synchronized GMs	Cramped-synchronized GMs	Absence of fidgety movements; abnormal findings in neurological examination	Bilateral spastic CP	[4,8–10,15,17,22,24,27–30, 36,42,44,50–55,58–64]
Poor repertoire or cramped-synchronized GMs	Poor repertoire or cramped-synchronized GMs	Absence of fidgety movements and asymmetrical segmental movements; normal or abnormal findings in neurological examination	Unilateral spastic CP	[15,17,45–47]
Poor repertoire GMs	Poor repertoire GMs; circular arm movements and finger spreading	Absence of fidgety movements; absence of foot-to-foot contact; circular arm movements and finger spreading	Dyskinetic CP	[15,48]

CP: Cerebral palsy; GM: General movement.
Adapted with permission from [16].

impaired [14,41,42]. It is the lack of variability, complexity and fluency of movements that indicates an impaired nervous system at such an early stage. While referring to 'fetal' or 'preterm GMs' before term, Prechtl and associates labeled them 'writhing movements' from term until about 6–8 weeks post-term age [14,15]. Writhing movements are characterized by shorter bursts than GMs during preterm age [43]; the pace of writhing movements is slower [15], and there is less involvement of the pelvis and trunk [9]. Fetal, preterm and writhing GMs display three patterns of abnormality, among them the so-called 'cramped-synchronized GMs' [15]. Cramped-synchronized GMs appear rigid as they lack the usual smoothness and fluent character. All limb and trunk muscles contract almost simultaneously and relax almost simultaneously [42]. Observing this pattern consistently over several weeks is highly predictive (98%) for the eventual development of spastic CP (Table 1) [8,42]. The sooner the cramped-synchronized GMs evolve and the longer they last, the more severe the future functional impairment will be [44].

Can we identify a high risk for unilateral CP by means of observation?

Children with unilateral spastic CP showed abnormal (usually cramped-synchronized) GMs during their first weeks of life; moreover, they had no fidgety movements at 3–5 months post-term age, a circumstance that refuted the hypothesis of a silent period of unilateral CP [45]. At the age of 2–4 months the first asymmetries could be observed: contralateral to the side of the lesion and regardless of the position of the head, the so-called 'segmental movements' (i.e., isolated finger and toe movements) were reduced or even absent [45,46]. At this age, neurological examination might still yield normal results (Table 1).

The combination of the Hammersmith Infant Neurological Examination with the assessment of GMs facilitated early identification of unilateral CP [17]. In an Italian multicenter study, 13 children out of 903 preterm infants were eventually diagnosed with unilateral CP. Eleven of them had no fidgety movements. This finding is especially remarkable since nine of the infants had had a persistent flare on the brain ultrasound with no signs of unilateral damage, meaning that their brain ultrasound had not pointed to later unilateral or any other form of CP. Surprisingly, the Hammersmith Infant Neurological Examination scores of all but one infant were within the normal range [17]. These results clearly lead to the conclusion that a 3–4-month-old infant with a normal neurological score but an absence of fidgety movements and asymmetric segmental movements is at a high risk of developing unilateral CP [47].

Are there early markers for dyskinetic CP?

Until the second month post-term, infants who later become dyskinetic showed a so-called 'poor repertoire of GMs' [48]. A monotonous sequence of movement components and a lack of complexity characterized a poor repertoire of GMs [15]. Apart from the poor repertoire, the infants moved their arms circularly and spread their fingers (Table 1) [48]. Characteristically, these abnormal circular arm movements were present at least until the age of 5 months post-term. They are uni- or bi-lateral, monotonous, slow forward rotations starting in the shoulder. From 3 to 5 months, fidgety movements and movements

towards the midline (particularly foot-to-foot contact) were absent (Table 1) [48].

Conclusion

The methodological breakthrough of the GM assessment, which is nonintrusive, easy to acquire and cost effective [15], lies in its predictive value of the development of neurological deficits, in particular of CP, at a much earlier age than before [8]. Recognition of abnormal GMs can help to improve earlier detection of CP if this technique is successfully incorporated into follow-up programs and developmental surveillance [49]. A number of studies have proposed to combine the GM assessment with neuroimaging, especially MRI, and/or a neurological assessment as such a combination is even more effective in predicting the neurological outcome than the GM assessment alone [17,28–30,47,50–55]. The great advantage of detecting an increased risk of CP at such an early stage consists of the possibility of intervention long before the emergence of obvious pathological features of CP. The consistent presence of cramped-synchronized GMs, and even more so the absence of fidgety movements, puts an infant at such a high risk of CP that physiotherapeutic intervention is justified. Furthermore, it is no less important to identify infants who, despite an increased risk based on their clinical history, have normal GMs and can thus be expected to have a normal neurological outcome.

Future perspective

The global assessment of GMs allows an early identification of infants at high risk for CP. Detailed analyses of movements and postures even provided markers that are associated with the location and severity of CP. Early identification asks for early intervention; however, well-designed studies on the effectiveness of early (physio)therapeutic interventions are rare [56,57]. Future research should therefore focus on the effects of early intervention based on the quality of GMs. Even though there is actually no proof that early intervention could prevent CP, it may have a positive effect on the quality of spontaneous movements and hence, the child's functional abilities in the future [9,10,49].

Executive summary

Cerebral palsy & general movements

- Among the most reliable markers for cerebral palsy (CP) are abnormal spontaneous 'general movements' (GMs).
- GMs involve the entire body and manifest themselves in variable sequences of arm, leg, neck and trunk movements; they come and go gradually, varying in intensity and speed.
- GMs occur in age-specific patterns; during the post-term age of 3–5 months, they are described as 'fidgety movements' – that is, small movements of the neck, trunk and limbs in all directions and of variable acceleration.

The absence of fidgety movements precedes CP

- An absence of fidgety movements is followed by neurological abnormalities, most likely CP.

Cramped-synchronized GMs at preterm & term age: an early predictor of spastic CP

- Cramped-synchronized GMs appear rigid as they lack the usual smoothness and fluent character; all limb and trunk muscles contract almost simultaneously and relax almost simultaneously.
- Observing cramped-synchronized GMs over several weeks during preterm and term age is highly predictive (98%) for the eventual development of spastic CP.

Can we identify a high risk for unilateral CP by means of observation?

- Children with unilateral spastic CP show abnormal GMs during their first weeks of life; moreover, they lack fidgety movements at 3–5 months post-term age.
- At about the age of 2–4 months, the first asymmetries can be observed: contralateral to the side of the lesion and regardless of the position of the head, the so-called 'segmental movements' (i.e., isolated finger and toe movements) are reduced or even absent.
- At this age, neurological examination may still yield normal results.

Are there early markers for dyskinetic CP?

- Until the second month post-term, infants who later become dyskinetic display a so-called 'poor repertoire of GMs', that is, a monotonous sequence of movement components.
- Apart from the poor GM repertoire, the infant moves his/her arms circularly and spreads the fingers; these signs are present at least until the age of 5 months post-term.
- Fidgety movements are absent.

Conclusion

- The assessment of GMs is nonintrusive, easy to acquire and cost effective.
- Its breakthrough lies in its predictive value of the development of neurological deficits, in particular of CP, at a very early age.

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Medscape EDUCATION

Early markers for cerebral palsy: insights from the assessment of general movements

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Activity evaluation: where 1 is strongly disagree and 5 is strongly agree.	1	2	3	4	5
The activity supported the learning objectives.					
The material was organized clearly for learning to occur.					
The content learned from this activity will impact my practice.					
The activity was presented objectively and free of commercial bias.					

1. Your patient is a 3-month-old male born at 29 weeks gestation with low Apgar scores. He is brought to you for evaluation regarding concern that he might be at risk for cerebral palsy (CP). Based on the review by Dr. Einspieler and colleagues, which of the following statements about the role of "general movements" (GMs) in helping to predict spastic CP is **most likely** correct?

- ☐ **A** Normal GMs are constantly present and unchanging in intensity and speed
- ☐ **B** The presence of fidgety movements precedes CP
- ☐ **C** Cramped-synchronized GMs at preterm and term age are an early predictor of spastic CP
- ☐ **D** Assessment of GMs has a low sensitivity and specificity for diagnosis of CP

2. Based on the review by Dr. Einspieler and colleagues, which of the following statements about use of GM to help predict unilateral CP for the patient described in question 1 **most likely** correct?

- ☐ **A** Children with unilateral spastic CP have no abnormal GMs during their first weeks of life
- ☐ **B** Children with unilateral spastic CP lack fidgety movements at 3 to 5 months postterm age
- ☐ **C** Asymmetries in children who will develop unilateral spastic CP first appear at about age 6–8 months
- ☐ **D** Normal neurological exam in this patient rules out future development of unilateral spastic CP

3. Based on the review by Dr. Einspieler and colleagues, which of the following statements about how GM can help predict dyskinetic CP would **most likely** be correct?

- ☐ **A** Until the second month post term, infants who later become dyskinetic have a poor repertoire of GMs, characterized by a monotonous sequence of movement components
- ☐ **B** The infant who will later develop dyskinetic CP moves the arms up and down
- ☐ **C** The infant who will later develop dyskinetic CP clenches the fists
- ☐ **D** The infant who will later develop dyskinetic CP has fidgety movements