General Movement Assessment (GMA)

홍 보 영

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성빈센트병원 재활의학과

Contents

- Introduction of General Movements
- Why GMs?
- Diagnostic Value
- Fetal behavior
- General movement
  - Characteristics
  - Normal vs. Abnormal

Heinz F. R. Prechtl (1927 - 2014)

- Medicine, zoology, anthropology
- Konrad Lorenz
- Professor of experimental neurology

On July 3rd 2014, just three days before his 87th birthday Heinz Prechtl passed away peacefully but what he left us and developmental neuroscience, he will be forever.

General movements

- Human fetus and young infant
  - A repertoire of distinct movement patterns which are carried out spontaneously
- One set of these movement patterns are the so called General Movements(GMs)

General movements

- Complex
- Frequent
- Sufficient length

- Changes in the normal quality of GMs are a reliable indicator of brain dysfunction

Prechtl's Assessment of General Movements: A Diagnostic Tool for the Functional Assessment of the Young Nervous System

Christa Einspieler* **and Heinz F. R. Prechtl**

Institute of Physiology, Center for Physiological Medicine, Medical University of Graz, Graz, Austria

- Early recognition → intervention and treatment
- A quick, non-invasive, non-intrusive, cost-effective

MENTAL RETARDATION AND DEVELOPMENTAL DISABILITIES RESEARCH REVIEWS *11: 61–67 (2005)*

Sensitivity and Specificity

- Sensitivity: average 94.5%
- Specificity: age-dependent (spontaneous recovery)
  - 3 months postterm : 82-100%

J, Ped 1997; 130:704-7 1 1., Early Hum Dev, Special Issue 1997.

GM and Brain US

- 3rd month
- Application of both techniques → increase the possibility of right prediction

	Sensitivity	Specificity
Assessment of GMs	95	96
Brain US	80	83

J. Ped 1997; 130: 704-7 11, Lancet 1997; 349: 1361-1363.

A systematic review of tests to predict cerebral palsy in young children

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RESULTS Nineteen out of 351 studies met the full inclusion criteria, including studies of general movements assessment (GMA), cranial ultrasound, brain magnetic resonance imaging (MRI), and neurological examination. All studies assessed high-risk populations including preterm (gestational range 23–41wks) and low-birthweight infants (range 500–4350g). Summary estimates of sensitivity and specificity of GMA were 98% (95% confidence interval [CI] 74–100%) and 91% (95% CI 83–93%) respectively; of cranial ultrasound 74% (95% CI 63–83%) and 92% (95% CI 81–96%) respectively; and of neurological examination 88% (95% CI 55–97%) and 87% (95% CI 57–97%) respectively. MRI performed at term corrected age (in preterm infants) appeared to be a strong predictor of CP, with sensitivity ranging in individual studies from 86 to 100% and specificity ranging from 89 to 97% There was inadequate evidence for the use of other predictive tools.

SUMMARY This review found that the assessment with the best evidence and strength for predictive accuracy is the GMA. MRI has a good predictive value when performed at term-corrected age. Cranial ultrasound is as specific as MRI and has the advantage of being readily available at the bedside. Studies to date have focused on high-risk infants. The accuracy of these tests in low-risk infants remains unclear and requires further research.

JAMA Pediatrics | Review

Early, Accurate Diagnosis and Early Intervention in Cerebral Palsy

Advances in Diagnosis and Treatment

Iona Novak, PhD; Cathy Morgan, PhD; Lars Adde, PhD; James Blackman, PhD; Roslyn N. Boyd, PhD; Janice Brunstrom-Hernandez, MD; Giovanni Cioni, MD; Diane Damiano, PhD; Johanna Darrah, PhD; Ann-Christin Eliasson, PhD; Linda S. de Vries, PhD; Christa Einspieler, PhD; Michael Fahey, PhD; Darcy Fehlings, PhD; Donna M. Ferriero, MD; Linda Fetters, PhD; Simona Fiori, PhD; Hans Forssberg, PhD; Andrew M. Gordon, PhD; Susan Greaves, PhD; Andrea Guzzetta, PhD; Mijna Hadders-Algra, PhD; Regina Harbourne, PhD; Angelina Kakooza-Mwesige, PhD; Petra Karlsson, PhD; Lena Krumlinde-Sundholm, PhD; Beatrice Latal, MD; Alison Loughran-Fowlds, PhD; Nathalie Maitre, PhD; Sarah McIntyre, PhD; Garey Noritz, MD; Lindsay Pennington, PhD; Domenico M. Romeo, PhD; Roberta Shepherd, PhD; Alicia J. Spittle, PhD; Marelle Thornton, DipEd; Jane Valentine, MRCP; Karen Walker, PhD; Robert White, MBA; Nadia Badawi, PhD

IMPORTANCE Cerebral palsy describes the most common physical disability in childhood and occurs in 1 in 500 live births. Historically, the diagnosis has been made between age 12 and 24 months but now can be made before 6 months' corrected age.

Early Detection and Diagnosis Recommendations From Best Available Evidence

Early Detection of CP Before 5 mo CA	
3.0 Option A: The most accurate method for early detection of CP in infants with newborn-detectable risks and younger than 5 mo (CA) is to use a combination of a standardized motor assessment and neuroimaging and history taking about risk factors	Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations
Standardized motor assessment 3.1 Test: GMs to identify motor dysfunction (95%-98% predictive of CP), combined with neuroimaging	Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations
Neuroimaging 3.2 Test: MRI (before sedation is required for neuroimaging) to detect abnormal neuroanatomy in the motor areas of the brain (80%-90% predictive of CP). Note that normal neuroimaging does not automatically preclude the diagnosis of risk of CP	Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations
4.0 Option B: In contexts where the GMs assessment is not available or MRI is not safe or affordable (eg, in countries of low to middle income), early detection of CP in infants with newborn-detectable risks and younger than 5 mo (CA) is still possible and should be carried out to enable access to early intervention	Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations
Standardized neurological assessment 4.1 Test: HINE (scores <57 at 3 mo are 96% predictive of CP)	Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations
Standardized motor assessment 4.2 Test: TIMP	Conditional recommendation based on low-quality evidence of test psychometrics in at-risk populations

Clinical tools used in young infants born very preterm to predict motor and cognitive delay (not cerebral palsy): a systematic review

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RESULTS Six assessments were identified in 10 studies of 992 in motor delay was 13.8% and cognitive delay was 11.7%. Methodo for patient selection, reference standard, flow, and timing. All st for the index test. General Movement Assessment (GMA) predicted motor and cognitive outcomes with good accuracy for mild, moderate, and severe delays (fidgety age: pooled diagnostic odds ratio=12.3 [5.9–29.8]; hierarchical summary receiver operating characteristics curve=0.733). The Hammersmith Infant Neurological Examination (HINE) demonstrated excellent predictive accuracy for severe motor delay (3mo and 6mo; sensitivity 93% [68–100%], specificity 100% [96–100%]) but showed limited ability to predict milder delays.

INTERPRETATION In the population of infants born very preterm, few assessment tools used at 6 months or younger corrected age have proven predictive accuracy for cognitive and motor delay at 24 months' corrected age. Only the GMA and HINE demonstrated useful predictive validity.

and cognitive delays at 24 months' corrected age. While the HINE assessment has excellent predictive ability for severe motor delay, it is non-discriminative for milder deficits. The GMA has the best predictive ability for mild and moderate motor and cognitive delay. Further research is

Fetal Behavior

Fetal behavior

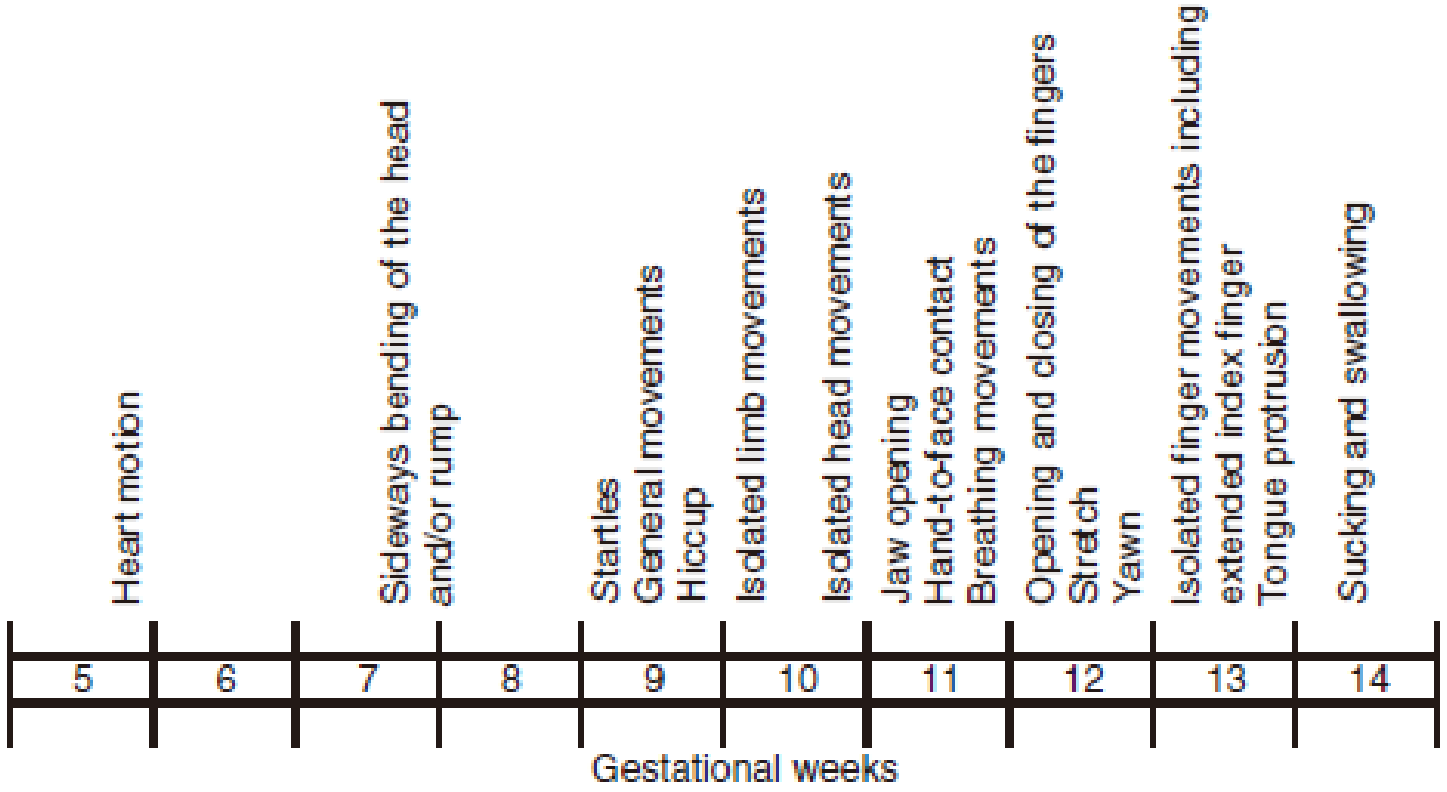
- Patterned from the beginning : 8 weeks of postmenstrual age

- First movements at 7.5-8 weeks PMA : sideward bending of the head
- Startles and complex general movements(GMs) → Isolated limb movements

PMA 10 weeks

- 3cm sized
- Startles
- General movements (GMs)
- Hiccup : diaphragm→ respiration
- Isolated limb movements
- Isolated head movements
- Jaw opening

The first occurrence of human embryonic/fetal movement patterns during the first trimester.



PMA 12 weeks

- Rich repertoire of sponataneous endogenously generated movements
- Startles
- GMs
- Hiccup
- Breathing movements
- Isolated arm and leg movements
- Side-to-side movements of the head
- Ante- and retroflexion of the head
- Opening and closing of the fingers
- Jaw movements
- Yawning

PMA 14 weeks

- Sucking and swallowing

PMA 20 weeks

- Eye movements → retinal cell diversity

Fetal eye movement

- 16주 : slow eye movement
- 20주 : rapid eye movement
- 23주 : fetal blinks

- Fetal eye movement : important for amacrine cell development → rods, cons

Fetal limb movement patterns recorded by means of dynamic magnetic resonance imaging

(a) Grasping the umbilical cord (27wks' gestation)

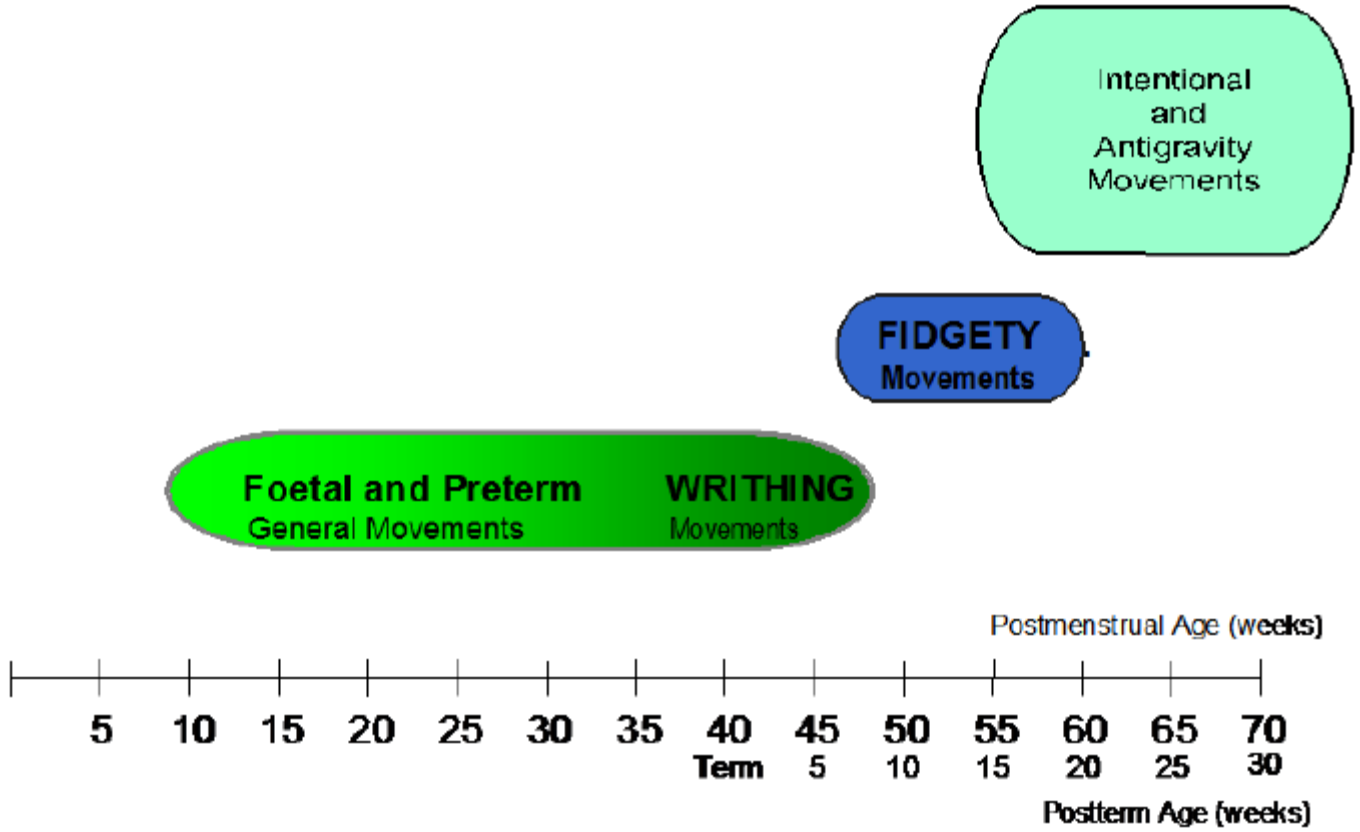
(b) Extended index finger (27wks' gestation)

(c) Alternating leg movements (19wks' gestation)

Dev Med Child Neurol. 2021 Oct;63(10):1142-1148

General Movements

Developmental course of GMs



General movements

- Involve whole body in a variable sequence of arm, leg, neck and trunk movements
- Wax and wane in intensity, force, and speed
- Gradual beginning and end
- Rotations along the axis of the limbs
- Slight changes in the direction of movement

→ fluent, elegant, and complexity&variability

General movements 특징

- **Fluency**
- **Variability** : sequencing, speed
- **Complexity** : spatial variation of movement, frequent changes in movement direction
- Unpredictable

General movements

- **Writhing movements**

- Fullterm- first two months postterm
- Small to moderate amplitude and by slow to moderate speed
- Ellipsoid form
- Rotation of hands : sign of complexity
- Gradual beginning

General movements

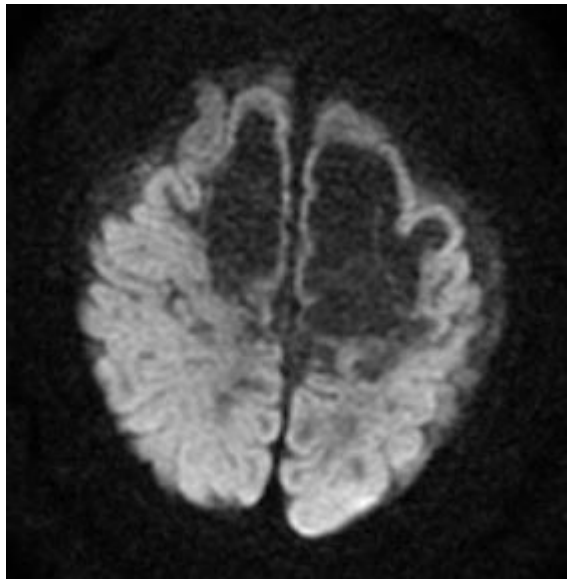
- **Preterm**

- Flat posture
- Fast, wide movement
- Larger amplitude
- Lifting of the pelvis
- Trunk movements, shoulder and hips rotate to the trunk
- Less complex movement (adaptation, not because of brain injury)

Abnormal GMs during prenatal~ first two months postterm age

- **Impairment of nervous system** → GMs lose complexity, variability

- Poor repertoire (PR)
- Cramped-synchronised (CS)
- Chaotic (Ch)



Poor repertoire GMs

- Preterm, term, early postterm age
- Sequence of the successive movement components is monotonous
- Movements of the different body parts do not occur in the complex way

- Predictive value : low
- Normal/Abnormal/Absent fidgety movement

Cramped-Synchronised GMs

- Preterm age onwards
- Rigid movement, lack the normal smooth and fluent character
- All limb and trunk muscles contract and relax almost simultaneously

- High predictive value of spastic cerebral palsy

Chaotic GMs

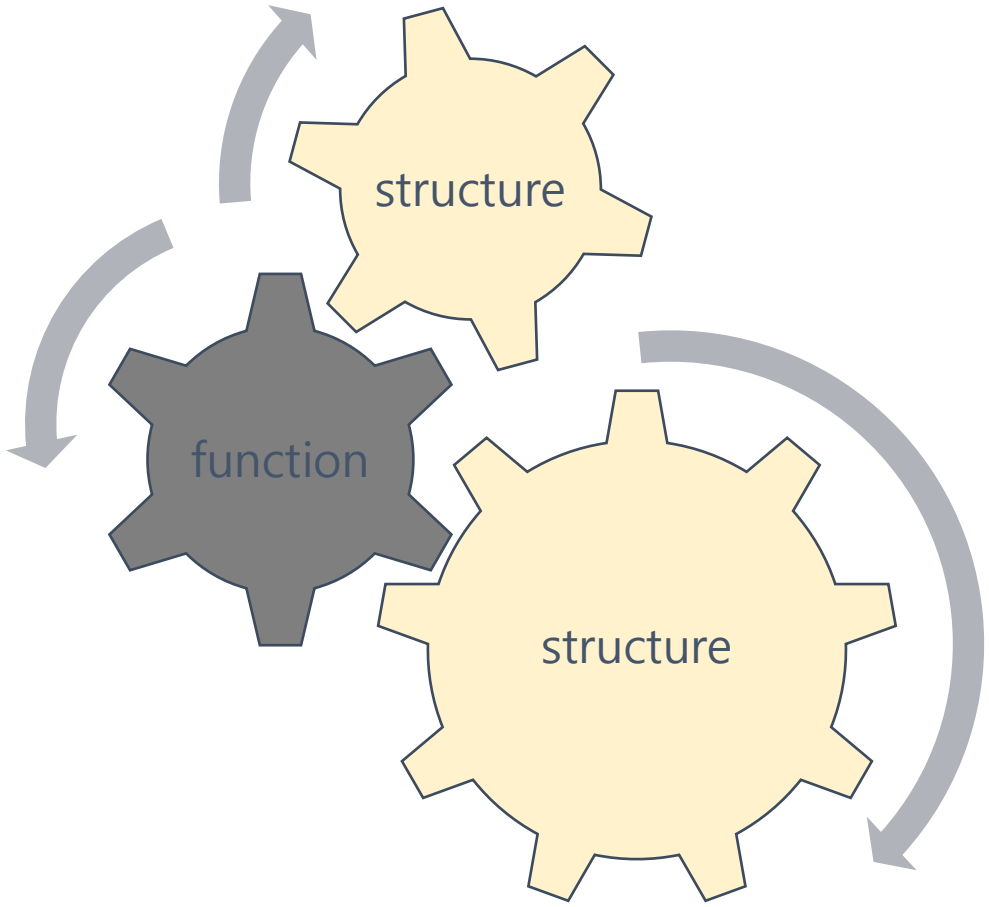
- Movements of all limbs are of large amplitude and occur in a chaotic order without any fluency or smoothness
- Abrupt

- Preterm, term, early postterm age
- Rare
- Often develop cramped-synchronised GMs

Neurons

- Proliferation, migration and programmed cell death
- 출생 후 8배 증가

Early development



Activity Dependent

- Variable movements in moderate speed are essential for programmed cell death and for synapse elimination

- Reduced activity : delays synapse elimination
- Increased activity : accelerate synapse elimination

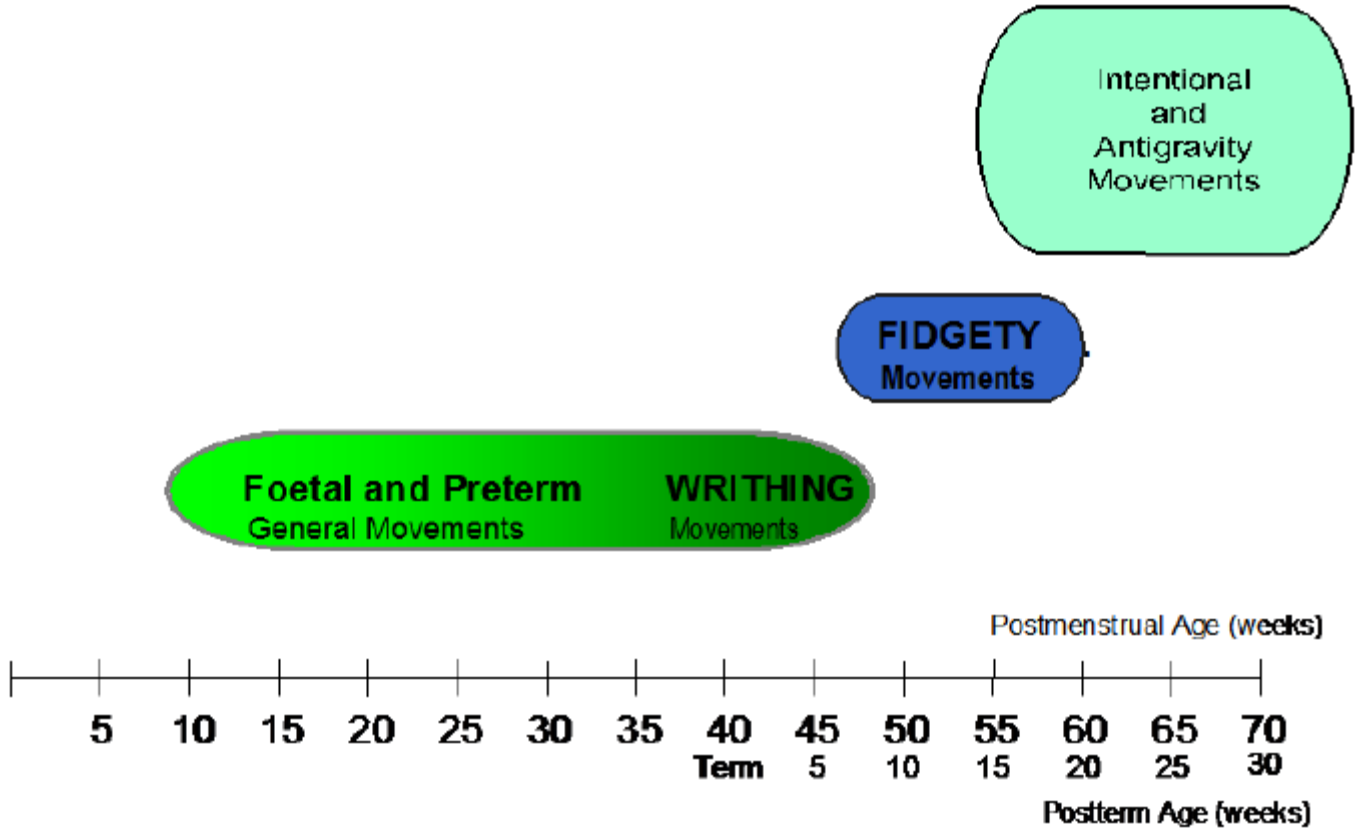
PTA 3-4개월

Period of major transformations

Visual and auditory orientation, antigravity postures, visual tracking and following in different directions of the space, interactive smile, vocalization and social interaction, change from writhing to fidgety GMs

ONTOGENETIC ADAPTATION TO THE NEW ENVIRONMENT

Developmental course of GMs



Fidgety Movements

- small movements of moderate speed and variable acceleration, of neck, trunk and limbs, in all directions
- continual in the awake infant, except during fussing and crying
- 6 weeks postterm but usually occur around 9 weeks and are present until 20 weeks(corrected age for preterm infants)

Fidgety Movements

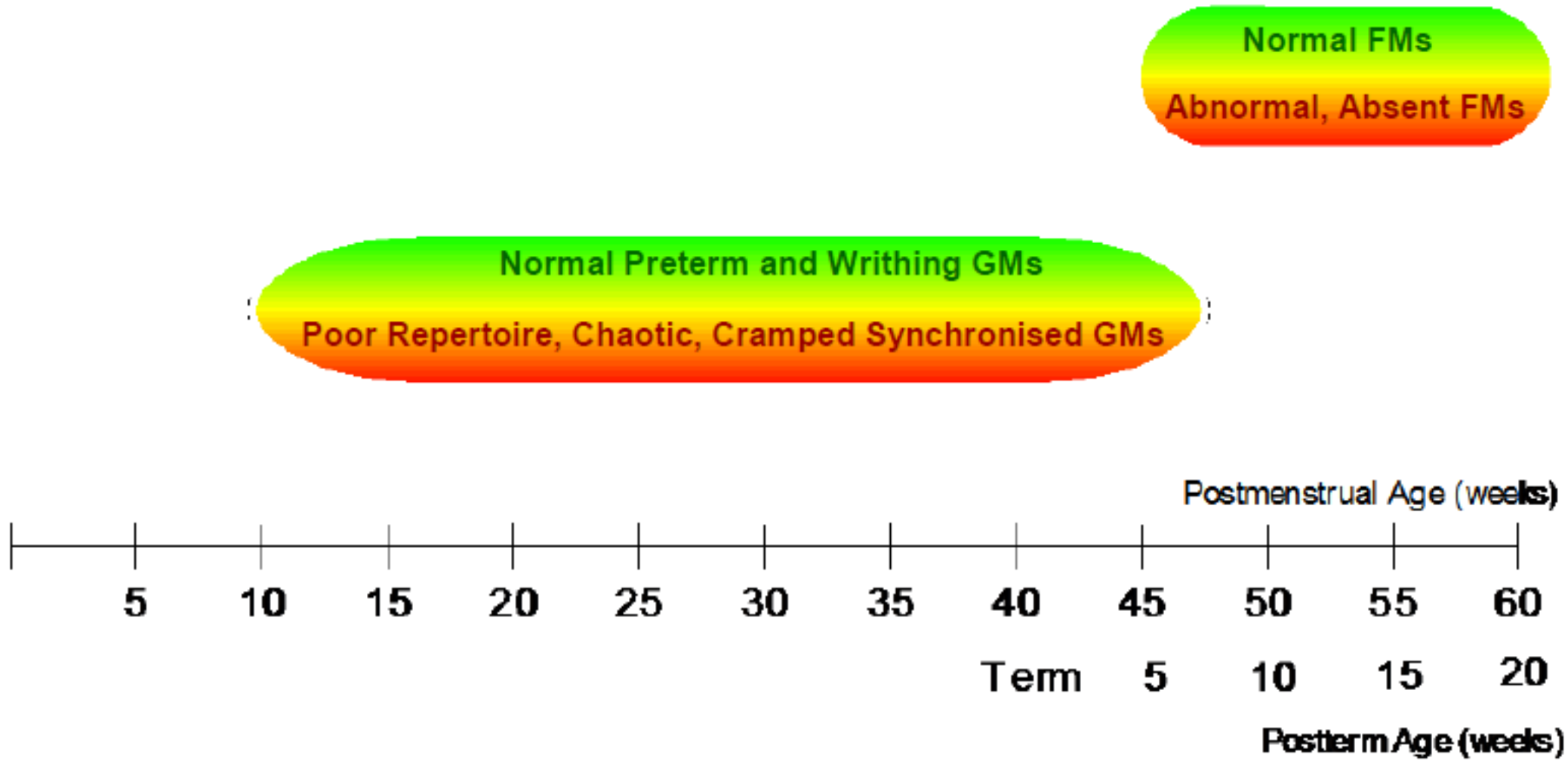
- Initially, isolated events (score: + or +/-)
- Gradually increase in frequency (score: ++)
- And then decrease once again (score: + or +/-)

- Superimposed on other movements, or other movements may occur during the pauses between FMs, or both.

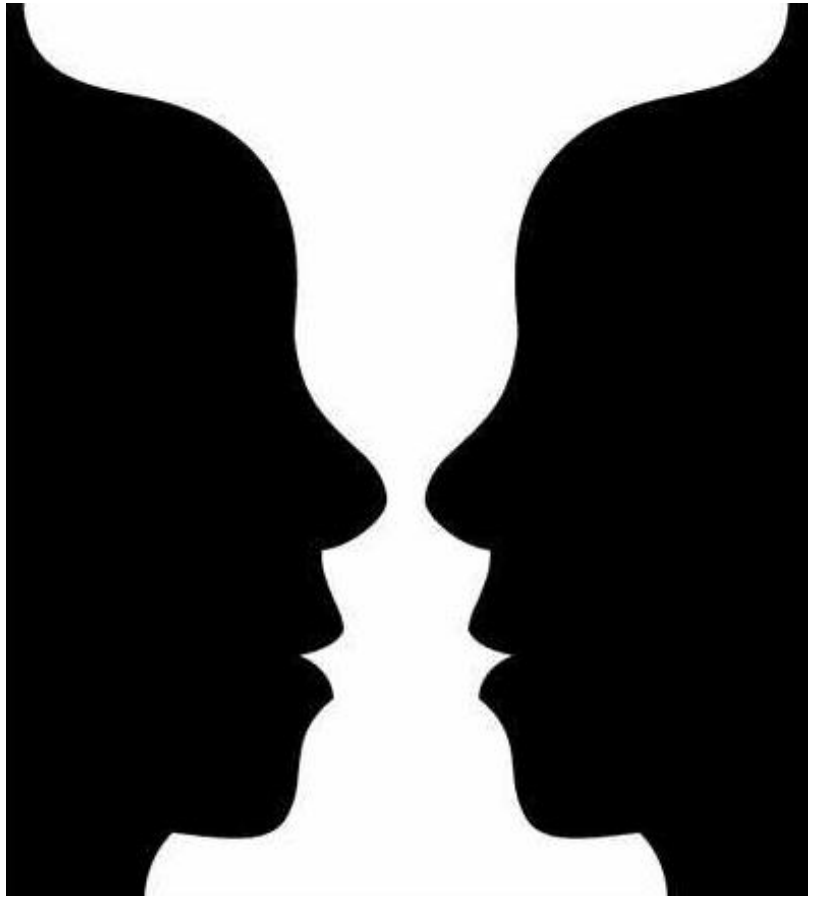
Fidgety movements judged as abnormal

- **Absent (F-)**
  - FMs are never observed from 9 to 20 weeks postterm

- **Abnormal (AF)**
  - look like normal FMs but their amplitude, speed and jerkiness are moderately or greatly exaggerated.


Normal FMs
Abnormal, Absent FMs
Normal Preterm and Writhing GMs
Poor Repertoire, Chaotic, Cramped Synchronised GMs
Postmenstrual Age (weeks)
5
10
15
20
25
30
35
40
45
50
55
60
Term
5
10
15
20
Postterm Age (weeks)

Pattern recognition
Gestalt perception



- Inter-scorer agreement : 93%
- Kappa = 0.88

When to observe ?

Active sleep (REM)

Awake calm

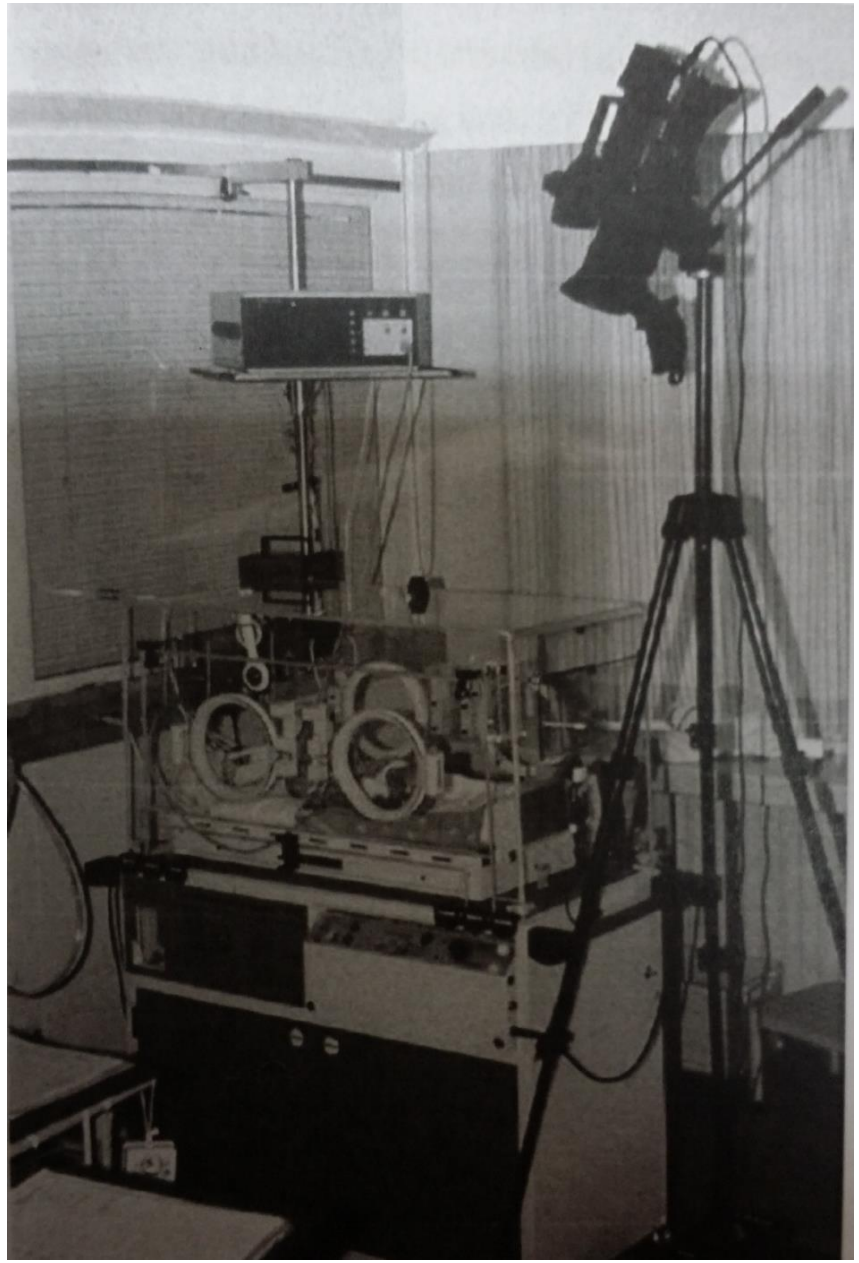
Active awake, some crying

Deep sleep 및 crying
→ 부적절

- Older than 36weeks
  : open eyes, irregular respiration, present movements, absent crying (active wakefulness)
- Younger preterm infants
  : bouts of activity

Video Recording
: Camera position

- Mid-sagitally or laterally from above
- See the infant's face



Infant’s position

- Supine position

- Incubator> filmed naked or wearing a nappy only
- Postterm> dressed lightly and comfortably

Duration of the recording

- Depends on the age of the infant
- Sufficient number of GMs for reliable judgement

- Preterm and term infants: ~ 1 hour
- Older infants: ~10 minutes

What should be avoided?

RECORDING

- Fussing, crying, drowsiness
- Sucking posture
- Prolonged hiccuping
- Distracting objects or persons (parents, examiner)
  : colourful blanket, mirror

What should be avoided?

OBSERVER

- Tiredness (< 45 min)
- No reference
- Poor visual Gestalt perception

Selection of GMs

- Replay at high speed
- Identify 3 sufficiently long examples of GM

- Several recordings of the preterm period

(abnormal GMs are consistently abnormal over one recording)

Trajectories

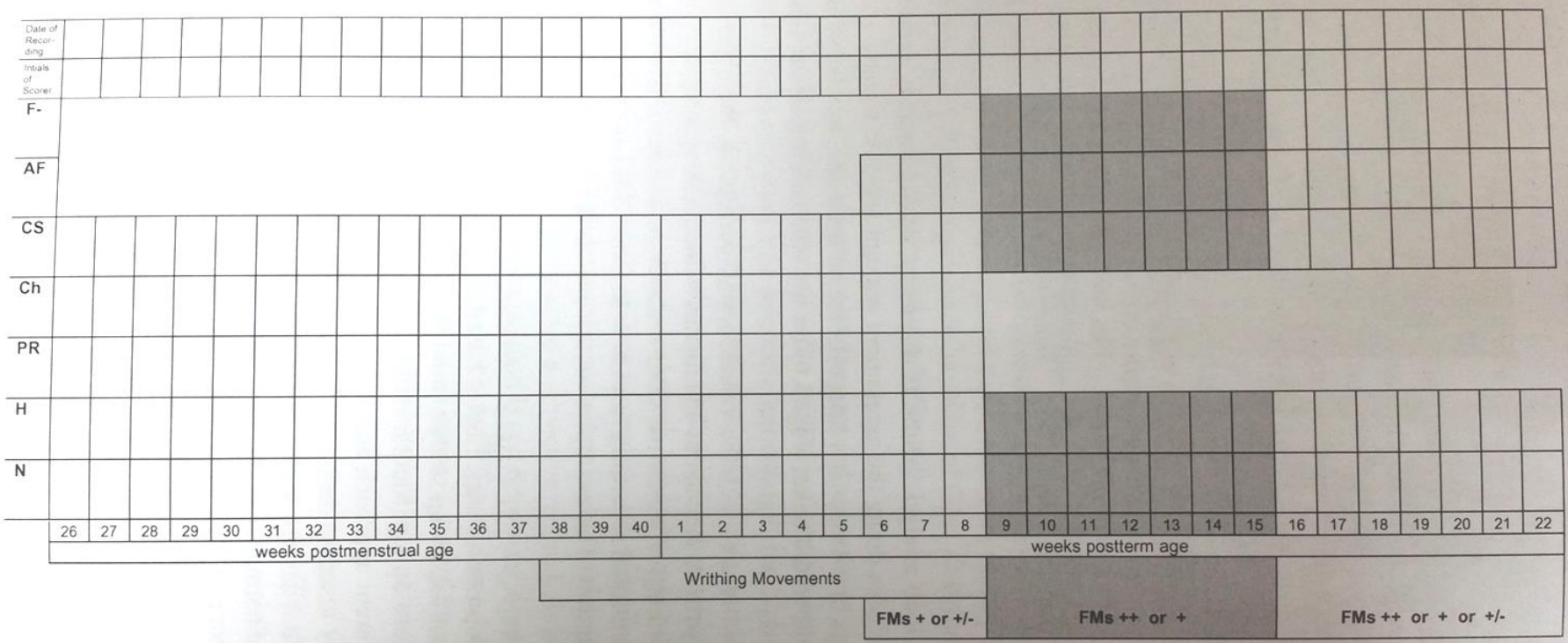
- Longitudinal recordings : Repeatedly assessed until 20 weeks
- **No** snapshot assessment **!**
- Consistency or inconsistency of normal or abnormal findings

- 2-3 recordings of preterm period
- 1 recording at term or early postterm age
- At least 1 recording between 9-15 weeks postterm : FM (-) → once more

Prechtl's Method on General Movement Assessment – Individual Developmental Trajectory

Name: _____

Date of birth: _____ Gestational age at birth: _____ weeks postmenstrual age.



N, normal age-specific GMs; FMs, fidgety movements; **H**, hypokinesis (no GMs during the recording); **PR**, poor repertoire of GMs; **Ch**, chaotic GMs; **CS**, cramped-synchronised GMs; **AF**, abnormal fidgety movements; **F-**, absence of fidgety movements. The shaded area indicates the age period during which fidgety movements usually occur.

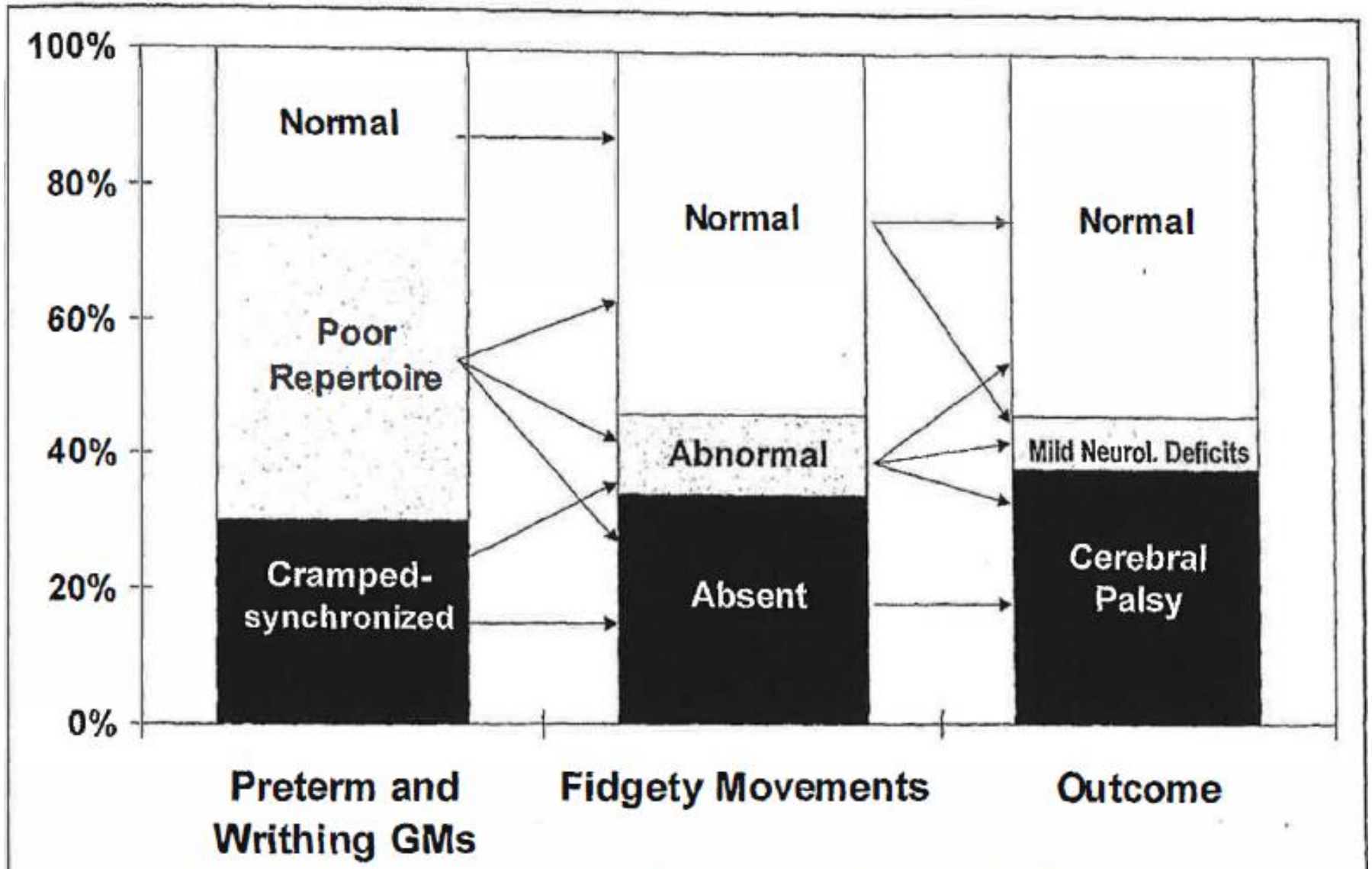


Fig. 2. A longitudinal study on 130 infants with various ultrasound findings: preterm and writhing quality (left) preceding the quality of fidgety movements (middle), which is predictive for the neurological outcome at three years [Prechtl et al., 1997a].

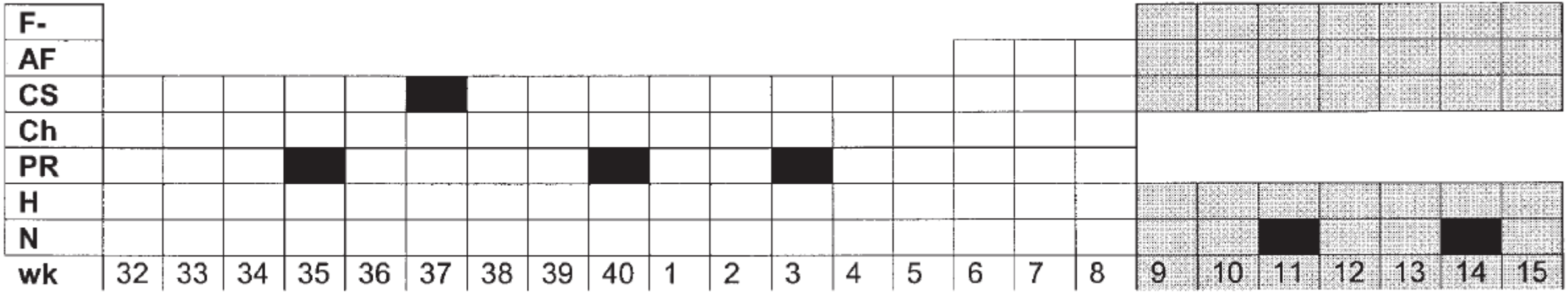


Fig. 4. Individual developmental trajectory of case B born at 32 weeks' postmenstrual age. Poor repertoire of preterm and writhing GMs but transient cramped-synchronized GMs at 37 weeks are followed by normal fidgety movements. Outcome: normal. Abbreviations as in Fig. 3.

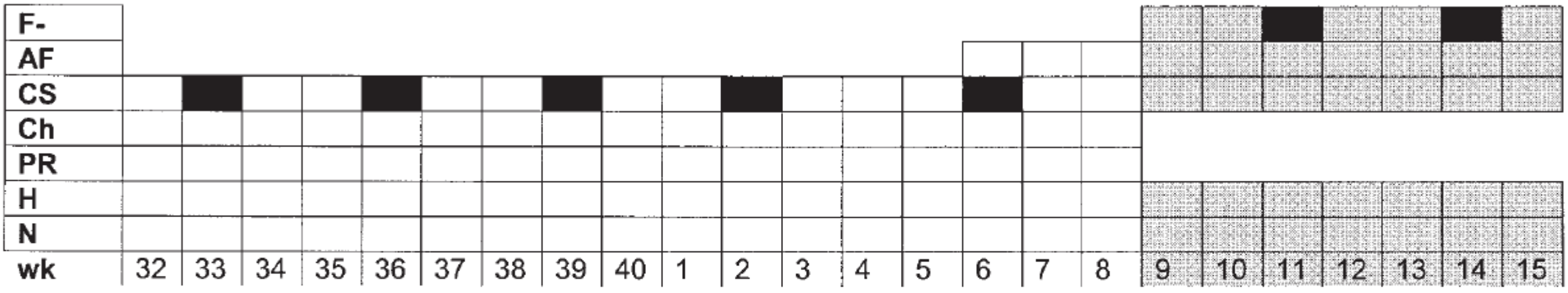


Fig. 3. Individual developmental trajectory of case A born at 31 weeks' postmenstrual age. Consistent cramped-synchronized GMs during the preterm, term, and early post-term period are followed by an absence of fidgety movements. Outcome: spastic CP. F-, absence of fidgety movements; AF, abnormal fidgety movements; CS, cramped–synchronized GMs; Ch, chaotic GMs; PR, poor repertoire GMs; H, hypokinesis; N, normal GMs; wk, weeks. The age period for obligatory fidgety movements is marked in gray.

www.general-movements-trust.info

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Prechtl´s Method on the Qualitative Assessment of General Movements

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Prechtl´s Method on the Qualitative Assessment of General Movements

LICENCED TUTORS

Licensed Tutors in alphabetical order (senior tutors are indicated with *):

Dr. Vittorio Belmonti, Child Neurologist and Psychiatrist at Stella Maris Foundation in Calambrone, Pisa

- https://www.researchgate.net/profile/Vittorio_Belmonti
- https://it.linkedin.com/in/vittorio-belmonti-822529101

Natascia Bertoncelli, Physiotherapist at the University Hospital of Modena

- https://www.researchgate.net/profile/Natascia_Bertoncelli

* **Dr. Arend F (Arie) Bos**, Professor of Neonatology at the Beatrix Children's Hospital, University Medical Center of Groningen

- http://www.umcg.nl/EN/Research/Researchers/Faculty/Paginas/BosAF.aspx
- http://www.narcis.nl/person/RecordID/PRS1295341/Language/en

* **Dr. Giovanni Gioni**, Professor of Infant Neurology and Psychiatry at the University of Pisa and Stella Maris Foundation and President of the GM Trust Tutor's Association

- https://www.researchgate.net/profile/Giovanni_Cioni

* **Dr. Christa Einspieler**, Professor of Physiology at the Medical University of Graz and Secretary to the GM Trust

- http://www.medunigraz.at/idn

* **Dr. Fabrizio Ferrari**, Professor of Neonatology at the University of Modena and Reggio Emilia

- http://www.neonatologia.unimore.it/site/home/equipe/articolo118004206.html

* **Dr. Andrea Guzzetta**, Associate Professor of Infant Neurology and Psychiatry at the University of Pisa and Stella Maris Foundation

- https://www.researchgate.net/profile/Andrea_Guzzetta

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for further information, please mail to juditgomerohidalgo[at]gmail.com

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for further information, please contact colleen.peyton1[at]northwestern.edu

- **April 4-7, 2022 - Port Elizabeth, South Africa (in English)**

for further information, please contact generalmovementassessment.sa[at]gmail.com

The general movement optimality score: a detailed assessment of general movements during preterm and term age

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RESULTS General movement optimality scores (GMOS) differentiated between normal general movements (median 39 [25–75th centile 37–41]), poor repertoire general movements (median 25 [22–29]), and cramped-synchronized general movements (median 12 [10–14]; $p<0.01$). The optimality score for chaotic general movements (mainly occurring at late preterm age) was similar to those for cramped-synchronized general movements (median 14 [12–17]). Short-lasting tremulous movements occurred from very preterm age (<32wks) to post-term age across all general movement categories, including normal general movements. The detailed score at post-term age was slightly lower compared to the scores at preterm and term age for both normal ($p=0.02$) and poor repertoire general movements ($p<0.01$).

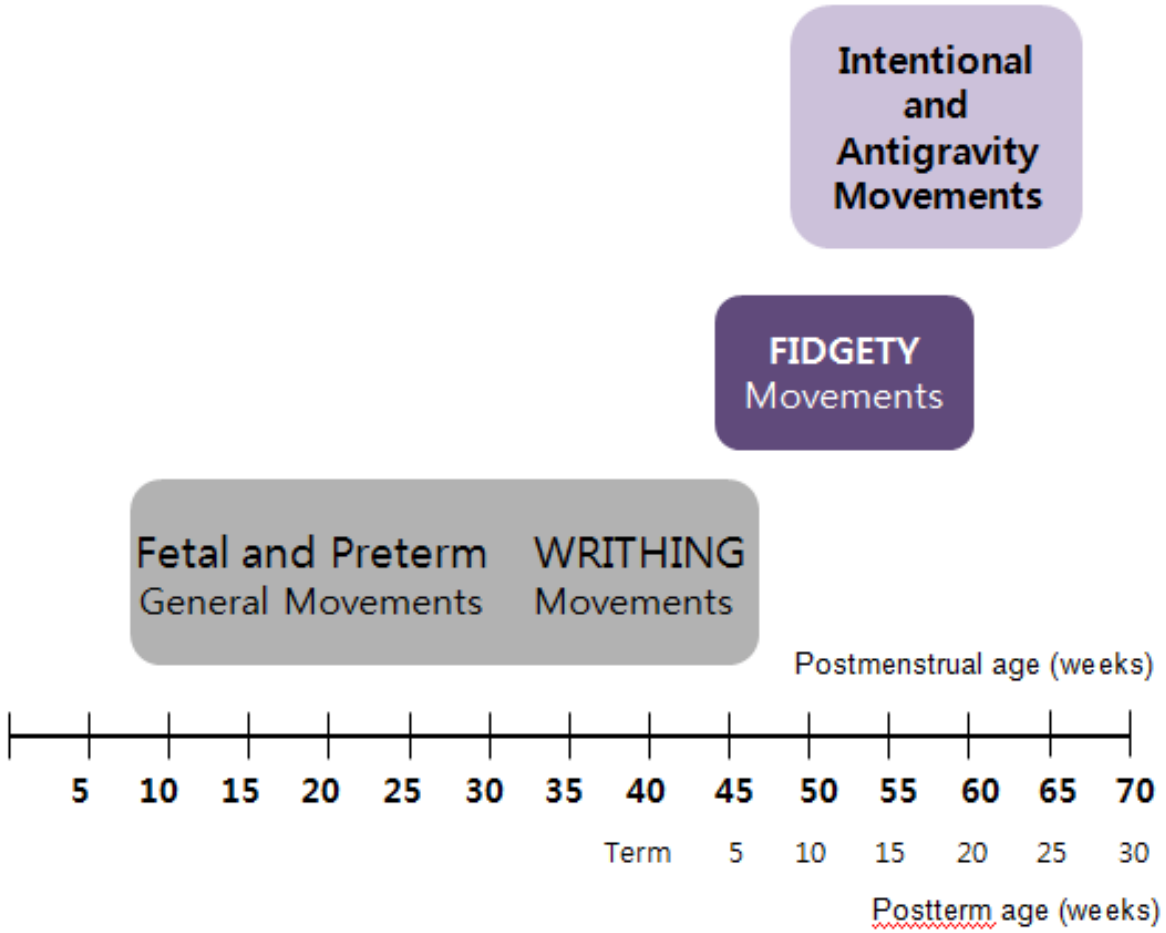
Summary

Diagnostic value of GMs

Developmental course of GMs

Pros and Cons

Developmental course of GMs



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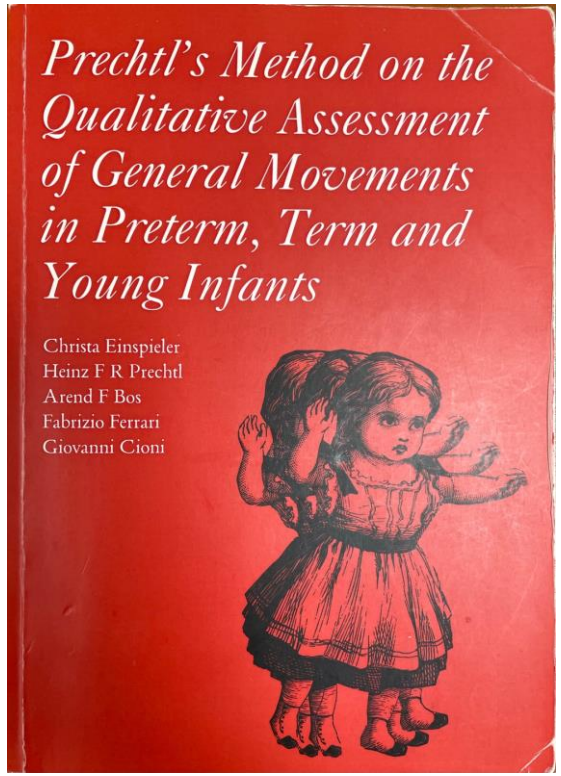

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