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

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ABBREVIATIONS

GMA	General movement assessment
GMOS	General movement optimality score

AIM To explore the appropriateness of applying a detailed assessment of general movements and characterize the relationship between global and detailed assessment.

METHOD The analysis was based on 783 video recordings of 233 infants (154 males, 79 females) who had been videoed from 27 to 45 weeks postmenstrual age. Apart from assessing the global general movement categories (normal, poor repertoire, cramped-synchronized, or chaotic general movements), we scored the amplitude, speed, spatial range, proximal and distal rotations, onset and offset, tremulous and cramped components of the upper and lower extremities. Applying the optimality concept, the maximum general movement optimality score of 42 indicates the optimal performance.

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).

INTERPRETATION Further research might demonstrate that the GMOS provides a solid base for the prediction of improvement versus deterioration within an individual general movement trajectory.

Abnormal general movements are among the most reliable early markers for neurodevelopmental disorders.[1,2] Recently, Bosanquet et al.[3] reviewed various structural and functional assessment techniques for which the accuracy of predicting cerebral palsy was reported. Compared to cranial ultrasound, magnetic resonance imaging and neurological examination, the general movement assessment (GMA) provided best evidence, with a sensitivity of 98% (95% confidence interval [CI] 74–100) and a specificity of 91% (95% CI 83–93).[3] Apart from the first promising attempts to analyse general movements with the aid of computer-based tools,[4,5] GMA is based on visual Gestalt perception. General movements are considered to be normal if the sequence, amplitude, speed, and intensity are variable. Abnormal general movements are characterized by a lack of variability, especially in the movement sequence.[1,6] Gestalt perception is a powerful tool when it comes to the analysis of complex phenomena. Experienced observers consistently achieved high interscorer agreements, ranging from 89% to 93%.[6]

In addition to the global assessment of general movement patterns, it can also be worthwhile to look at different aspects and components of general movements, particularly if they are abnormal. By applying the Prechtl optimality concept,[7] we are able to achieve a semi-quantification of the quality of general movements.[8] For every movement criterion such as amplitude, speed, range in space, onset and offset of general movements, a score is given whereby a higher score expresses a more optimal performance (see Appendix S1, online supporting information). The higher the total optimality score the better the quality of general movements.[7,8] With such a detailed, semi-quantitative approach we can document associations between small changes in the quality of general movements and other clinical parameters, e.g. polygraphical findings.[9,10] Another potential of such a detailed GMA lies in the evaluation of therapeutic interventions.[11]

A detailed assessment of general movements at preterm and term age was introduced by Ferrari et al.[12] The first applications were done in infants with brain malformation,[13] and in infants with Down syndrome[14] – the latter demonstrating that a reduced motor optimality score was associated with more severe motor impairments a few years later.[14] Recently, Hitzert et al.[11] reported an association between low-dose dexamethasone in preterm infants at risk for bronchopulmonary dysplasia and higher general movement optimality score (GMOS). The same research group used the detailed GMA to evaluate the neonatal neurological condition after placental lesions but did not find any association.[15] The mode of delivery in healthy infants born at term did not have an impact on the detailed GMA.[16] Another group of infants born around term, who were prenatally exposed to selective serotonin reuptake inhibitors, had lower motor optimality scores compared to non-exposed infants.[17]

Some 10 years ago we tried to differentiate between infants whose poor repertoire general movements (for definition, see Method) will have normalized and those whose poor repertoire general movements will have deteriorated, but such a differentiation was not possible.[18] During this analysis we got the impression that some infants had, for example: (1) more rotations in the lower than in the upper extremities; or (2) cramped components occurred predominantly in the legs but hardly in the arms. We therefore adapted the original score sheet for detailed GMA at preterm and term age,[12] and scored upper and lower extremities, neck, and trunk separately (see Appendix S1). In order to evaluate its soundness, we (re)assessed in a multi-centre study several hundreds of video recordings of general movements with the aim of comparing global with detailed GMA. We specifically focused on the following questions: (1) does the GMOS (obtained by detailed GMA) differentiate between the global general movement categories?; (2) how does the detailed assessment contribute to descriptions of the general movement categories?; and (3) are the results related to the infant's age?

What this paper adds

- General movement optimality score (GMOS) differentiates between normal, poor repertoire, and cramped-sychronized general movements.
- Short-lasting tremulous movements occurred from very preterm age to post-term age.
- This was the case across all categories including normal general movements.
- GMOS post-term was lower compared to the scores at preterm/term age.
- This held true for both normal and poor repertoire general movements.

METHOD

Material

We analysed 783 video recordings of 233 infants (154 males, 79 females; median gestational age 34wks [25–75th centile 32–39]; range 26–42wks) who had been videoed up to 13 times (median 1 [1–6]) from 27 to 45 weeks postmenstrual age (median 35wks [33–41]). One hundred and ten recordings (14%) were performed at the very preterm period (<32wks); 166 recordings (21%) at the moderate preterm period (32^{+0} to 33^{+6}wks); 230 recordings (30%) at late preterm period (34^{+0} to 36^{+6}wks); 102 recordings (13%) at term (37^{+0} to 41^{+6}wks); and 175 recordings (22%) at the post-term period (42^{+0} to 45wks) (Table I). The infants were recorded for the following reasons: high risk for neurodevelopmental disorders due to preterm birth or perinatal asphyxia at term; abnormal findings at paediatric examinations; parental concerns; or assignment to a healthy control group. The recordings were conducted at the Medical University of Graz, the Children's Hospital of Fudan University (Shanghai), the Medical University of Warsaw, the Carmel Medical Center Haifa, the University Hospital, Modena, the Stella Maris Foundation and the Pisa University Hospital, and the Medical University Hospital Groningen. Most of the children had participated in previous studies.[1,12,19–26] All infants were recorded following the standards of the Prechtl's GMA (i.e. infant in supine position, avoiding episodes of crying or fussing, no use of pacifier)[8] either during active sleep (400 recordings; 51%) or during active wakefulness (383 recordings; 49%). The video clips used for this analysis lasted 1 to 2.5 minutes and contained at least three general movement sequences; 298 recordings (38%) were videoed in one sequence; and the remaining 485 recordings (62%) were edited from a longer recording.[8]

All parents gave written informed consent. The ethical boards of all centres involved approved recording and assessment of spontaneous movements for various studies.

Score sheet

The first part of the score sheet (Appendix S1) refers to the global categories: (1) 'normal', i.e. the movement sequence, amplitude, speed, and intensity are variable; (2) 'poor repertoire', i.e. the sequence of movement components is monotonous, and the amplitude, speed, and

Table I: Distribution of normal and abnormal general movement patterns according to the different age groups

	Normal GM	PR GM	CS GM	Chaotic GM	Total
Very preterm period	14	93	0	0	110
Moderate preterm period	19	118	31	1	166
Late preterm period	65	105	49	11	230
Term period	20	42	39	1	102
Post-term period	51	83	41	0	175
Total	169	441	160	13	783

GM, general movements; PR, poor repertoire; CS, cramped-synchronized.

intensity lack the normal variability; (3) 'cramped-synchronized', i.e. general movements lack the usual smoothness and appear rigid as the limb and trunk muscles contract almost simultaneously and relax almost simultaneously; and (4) 'chaotic', i.e. the amplitude is large and the speed is fast; movements consistently appear to be abrupt.[6,8,12] 'Hypokinetic' indicates that general movements cannot be observed during the whole recording, but isolated (usually upper) limb movements are present.[8] In this case, a detailed assessment cannot be carried out. The movement sequence is related to the global general movement category: 'variable' for normal general movements; 'monotonous and/or broken' for poor repertoire general movements; 'synchronized' for cramped-synchronized general movements; and 'disorganised' for chaotic general movements.

The detailed scoring focuses separately on neck and trunk, upper and lower extremities (see Appendix S1). For each item a description of optimal performance is given and scored with '2' (e.g. cramped components are absent). Less optimal performance is scored with '1' (e.g. cramped components are occasionally present), and non-optimal performance is scored with '0' (e.g. cramped components are predominately present). The following three items are only scored with '2' or '1': (1) the involvement of the neck – we only differentiate if the neck is involved or hardly/not involved in the sequence; (2) the amplitude of upper and lower limb movements; and (3) the speed of upper and lower limb movements – there is neither an 'absence of amplitude' nor an 'absence of speed' as long as the infant shows general movements.

Adding the scores of each item within a category ('neck and trunk', 'upper extremity' and 'lower extremity') plus the score for 'sequence' gives the GMOS with a maximum value of 42, indicating optimal performance. The minimum score (worst performance) is '5'.

Procedure

The scoring approach consisted of two steps. First, based on visual Gestalt perception, we re-analysed general movements globally and differentiated between normal and the three abnormal categories, poor repertoire, cramped-synchronized, or chaotic general movements. The item 'sequence' refers to the four global categories and constitutes 4.76% of the total GMOS. In a second step, all details (see Appendix S1) were scored by watching the video as often as necessary. In the majority of cases, it took six reviews to finalize the detailed scoring: (1) neck and trunk; (2) amplitude and speed; (3) range in space; (4) rotations; (5) onset and offset; and (6) tremulous and cramped components. Each video was scored by CE, and independently by at least a second scorer certified for GMA (PBM, JP, AS, HY, MS) with substantial interscorer agreement for the detailed assessment (Cohen's kappa=0.69–0.82). In case of disagreements, the video was discussed among at least three scorers until agreement on a final score was reached.

Statistics

Statistical analysis was performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). The Pearson's chi square test was used to evaluate associations between nominal data, and the McNemar–Bowker test was used on paired nominal data (i.e. comparison between upper and lower extremities). Non-parametric tests were applied because the data were not normally distributed. The Mann–Whitney *U* test and Kruskal–Wallis test were used to compare the GMOS between groups. The Wilcoxon signed-rank test was used to compare the subscores of upper and lower extremities within a sample. Spearman's rank order correlations (ρ) were applied to analyse the association between ordinal variables with a monotonic relationship between the two. Throughout the analyses, $p<0.05$ (two-tailed) was considered to be statistically significant.

RESULTS

Global GMA

We assessed 169 video recordings (21.6%) as normal general movements; 441 recordings (56.3%) as poor repertoire; 160 recordings (20.4%) as cramped-synchronized; and the remaining 13 recordings (1.7%) as chaotic. Table I provides the distribution of normal and abnormal general movements for the different age groups. Chaotic general movements occurred predominantly during the late preterm period (11/13).

The association between global and detailed GMA

Table II provides the GMOS (median, 10, 25, 75, and 90th centile rank, minimum and maximum) for each global general movement category. The distributions of the GMOS did not differ across cramped-synchronized and chaotic general movements. All other distributions of the optimality scores were significantly different (Table II). Table III provides the age-related GMOS. Again, the distribution of the optimality scores across cramped-synchronized and chaotic general movements did not differ at the late preterm period (p=0.09), whereas all other scores of

Table II: General movement optimality scores (GMOS) according to the different categories of general movements quality

GMOS	Normal GM (n=169)	PR GM (n=441)	CS GM (n=160)	Chaotic GM (n=13)
Maximum	42	39	19	25
P90	42	33	17	17
P75	41	29	14	17
Median	39	25	12	14
P25	37	22	10	12
P10	35	19	7	8
Minimum	30	13	5	8
p-values	$p<0.01$[a]			
		$p<0.01$[a]		
			p=0.09[a]	
		$p<0.01$[a]		

[a]Independent-samples Mann–Whitney *U* test. P, centile rank; GM, general movements; PR, poor repertoire; CS, cramped-synchronized.

Table III: Age-specific general movement optimality scores according to the different categories of general movements quality

	Very preterm period		Moderate preterm period			Late preterm period				Term period			Post-term period		
	N	PR	N	PR	CS	N	PR	CS	Ch	N	PR	CS	N	PR	CS
n	14	93	19	118	31	65	105	49	11	20	42	39	51	83	41
Max	42	37	42	39	19	42	38	18	25	42	37	18	42	33	19
P90	42	34	42	34	18	42	32	15	25	42	33	16	41	31	17
P75	41	30	41	32	15	41	28	14	16	42	29	14	40	26	15
Median	39	26	40	27	12	40	25	11	14	40	25	11	37	23	13
P25	37	23	35	23	10	37	22	9	11	39	20	9	35	21	11
P10	34	19	35	20	8	36	20	7	8	36	18	7	35	18	9
Min	31	13	30	14	5	30	15	5	8	32	13	6	32	16	6

P, centile rank; N, normal general movements; PR, poor repertoire; CS, cramped-synchronized; Ch, chaotic general movements; Max, maximum score; Min, minimum score.

the detailed GMA significantly differed between the global categories ‘normal’ versus ‘poor repertoire’ versus ‘cramped-synchronized’ ($p<0.01$).

Normal general movements assessed in detail

The description is based on 169 assessments. Each optimal criterion is usually met by more than 70% of the general movements assessed as normal (Table IV). The following exceptions were found: 36% of very preterm infants globally assessed as normal moved their upper extremities in a limited space, and exhibited tremulous arm and leg movements. One-third of moderate preterm infants with normal general movements ended the general movement sequences with minimal fluctuations (37% for upper and 32% for lower extremities respectively). One-third of normally moving late preterm infants showed tremulous arm (29%) and/or leg movements (31%); and although globally assessed as normal during post-term age, a considerable number of infants had only ‘just a few trunk rotations’ (47%), ‘minimal fluctuations’ at the end of an upper extremity movement (41%), uni- or bilateral tremulous arm movements (53%), and/or ‘occasionally present’ cramped arm (63%) and/or leg movements (49%).

The following differences were observed between the upper and lower extremities: across all age groups, upper limbs moved more often in a limited space than lower limbs (19% vs 2%; $p<0.01$). During the post-term period, there were more often ‘just a few rotations’ in the wrists than in the ankles (27% vs 2%; $p<0.01$); also during the post-term period, both the onset and offset were more often scored as ‘minimal fluctuation’ in the upper limbs than in the lower limbs (27% vs 10%, $p<0.01$; 41% vs 14%; $p<0.1$ respectively). At term, tremulous movements occurred more often in the legs than in the arms (30% vs 15%; $p=0.02$), whereas at the post-term period, tremulous movements were more frequent in arms (53%) than in the legs (4%; $p<0.01$). At the late preterm period, cramped components were observed in the lower, but not in the upper extremities (20% vs 0%); and at the post-term period the occurrence of cramped components was high, both in the upper and lower extremities (63% vs 49%, $p=0.21$).

The subscores for upper (median 17 [15–18]; range 10–18) versus lower extremities (median 17 [16–18]; range 11–18) did not differ ($p=0.40$).

Within the global category of normal general movements a slight decrease of the GMOS could be observed with age ($\rho=-0.18$; $p=0.02$).

Poor repertoire general movements assessed in detail

The description is based on 441 assessments. During the preterm period one-third of infants with poor repertoire general movements had fluent and elegant trunk rotations, although this feature decreased with age ($\rho=-0.24$; $p<0.01$). Shoulder rotations ($\rho=-0.15$; $p<0.01$), fluctuations in the onset of upper ($\rho=-0.25$; $p<0.01$) and lower limb movements ($\rho=-0.15$; $p<0.01$), and fluctuations in the offset of upper limb movements ($\rho=-0.10$; $p<0.05$) also decreased with age (Table IV). The occurrence of tremulous arm movements increased from 35% to 70% with age ($\rho=-0.25$; $p<0.01$), whereas the occurrence of tremulous leg movements decreased from 58% at very preterm age to 11% at post-term age ($\rho=0.28$; $p<0.01$). The occurrence of cramped components increased with age in both the upper (from 10% to 78%; $\rho=-0.48$; $p<0.01$) and the lower limbs (from 29% to 70%: $\rho=-0.31$; $p<0.01$; Table IV).

The following differences were found between the upper and lower extremities: across all age groups, fluent and elegant rotations were more frequent in the shoulders than in the hips (34% vs 25%; $p<0.01$); at the moderate and late preterm periods, fluent and elegant rotations were more frequent in wrists than in ankles ($p<0.01$; Table IV); and across all age groups, cramped components were more frequent in the lower than in the upper extremities (51% vs 31%; $p<0.01$).

The subscores for upper (median 11 [10–13]; range 4–18) versus lower extremities (median 11 [9–13]; range 3–18) did not differ ($p=0.14$).

Within the global category of poor repertoire general movements, the GMOS slightly decreased with age ($\rho=-0.21$; $p<0.01$).

Table IV: Optimal criteria (in %) met within each category of general movements (GM) according to the different age groups

	Normal GM (n=169)					PR GM (n=441)					CS GM (n=160)					Chaotic GM (n=13)				
Optimal criterion	VP	M	LP	T	PT	VP	M	LP	T	PT	VP	M	LP	T	PT	VP	M	LP	T	PT
Number of recordings	14	19	65	20	51	93	118	105	42	83	0	31	49	39	41	0	1	11	1	0
Neck involved in the sequence	79	84	89	80	76	30	30	34	31	27		7	18	10	15			9		
Fluent and elegant trunk rotations	86	74	86	75	53	33	34	21	14	5		0	0	0	0			0		
Upper extremities																				
Variable amplitude	93	90	89	80	98	40	33	33	41	37		7	18	15	3			18		
Variable speed	71	84	80	85	94	26	26	26	41	23		3	2	10	5			0		
Full space variably used	64	84	80	85	82	26	32	29	24	17		10	8	2	0			36		
Fluent and elegant proximal rotations	79	94	91	90	84	37	47	32	36	17		0	0	0	5			0		
Fluent and elegant distal rotations	86	79	85	75	73	31	39	28	36	30		0	0	0	5			9		
Smooth and fluctuating onset	71	95	91	100	73	33	27	19	17	6		0	0	0	0			0		
Smooth and fluctuating offset	79	63	80	100	59	10	10	7	7	1		0	0	0	0			0		
No tremulous movements	64	79	71	85	47	65	60	65	41	30		48	46	41	32			9		
No cramped components	93	84	100	100	37	90	82	81	45	22		0	0	0	0			18		
Lower extremities																				
Variable amplitude	93	95	100	90	99	44	40	33	31	27		0	10	0	0			18		
Variable speed	93	84	85	95	90	27	28	27	31	27		3	2	0	0			0		
Full space variably used	99	100	95	99	99	28	38	32	29	30		7	2	0	0			36		
Fluent and elegant proximal rotations	93	79	82	85	92	28	36	15	19	22		0	0	0	0			0		
Fluent and elegant distal rotations	100	74	79	85	98	20	25	11	21	30		0	0	0	2			0		
Smooth and fluctuating onset	79	100	92	100	90	26	24	16	14	6		0	0	0	0			0		
Smooth and fluctuating offset	86	68	82	100	86	1	8	2	7	1		3	0	0	0			0		
No tremulous movements	64	79	69	70	96	42	53	49	62	89		52	57	54	85			9		
No cramped components	93	84	80	90	51	71	64	30	38	30		0	0	0	0			18		

PR, poor repertoire; CS, cramped-synchronized; VP, very preterm; M, moderate preterm; LP, late preterm; T, term; PT, post-term.

Cramped-synchronized general movements assessed in detail

The description is based on 160 assessments. Cramped-synchronized general movements did not occur in the very preterm age. Table IV shows that hardly any cramped-synchronized general movements met an optimal criterion for a particular item. The following exceptions were found: across all age groups, a variable amplitude was relatively more frequent in the upper extremities than in the lower ones (11% vs 3%; $p<0.01$); and almost every second infant with cramped-synchronized general movements showed no tremulous movements (Table IV) – whereas the occurrence of tremulous arm movements was not related to age ($\rho=-0.12$; $p=0.12$), tremulous leg movements decreased with age with an occurrence of only 15% at the post-term period ($\rho=0.23$; $p<0.01$).

The subscores were relatively higher for the upper extremities (median 6 [5–8]; range 2–12) than for the lower extremities (median 4 [3–5]; range 2–10; $p<0.01$), although both were in the lower range.

Within the category of cramped-synchronized general movements, the GMOS did not significantly differ with age ($\rho=0.10$; $p=0.19$).

Chaotic general movements assessed in detail

The description is based on 13 recordings; 11 of the chaotic general movements (85%) occurred in the late preterm period (Tables I and IV). The subscores for the upper extremities (median 7 [5–8]; range 3–12) did not differ from the subscores for the lower extremities (median 6 [5–8]; range 3–11; $p=0.39$).

Although the GMOS did not significantly differ between chaotic and cramped-synchronized general movements (Table II), we found the following differences between these two categories across all age groups: whereas the amplitude of the arm movements was predominantly large in chaotic general movements (77%), it was predominantly small in cramped-synchronized general movements (70%; $p=0.02$); whereas the speed of the arm and leg movements was predominantly fast (69%) in chaotic general movements, it was predominately slow (39%) or monotonous (48%) in cramped-synchronized general movements ($p<0.01$). Within chaotic general movements, both arms and legs covered the full spatial range in 38%, while this occurred in only 5% (arms) or 2% (legs) of the cramped-synchronized general movements ($p<0.01$). While the lower limbs ended a chaotic general movement with minimal fluctuations in 69%, 90% of cramped-synchronized general movements ended abruptly ($p<0.01$); whereas 92% of chaotic general movements consisted of upper limb tremulous movements, this was only the case in 58% of cramped-synchronized general movements ($p<0.01$); and the same was true of the lower extremities – 92% tremulous leg movements in chaotic general movements versus 38% in cramped-synchronized general movements ($p<0.01$).

Focusing on the subscores for the extremities, the upper extremities scored similarly in chaotic (median 7 [5–8]) and cramped-synchronized general movements (median 6 [5–8];

p=0.89), whereas the lower extremities did not. Within chaotic general movements, the lower limbs scored slightly higher (median 6 [5–8]) than within cramped-synchronized general movements (median 4 [3–5]; p<0.01).

DISCUSSION

Prechtl and associates have established a systematic, albeit qualitative, analysis of general movements as a valid, reliable assessment of the integrity and function of the young central nervous system.[1–3,6,8,12] Quantitative analyses of general movements (i.e. counting the number of general movements per time) have failed to demonstrate significant differences between high-risk and low-risk preterm infants.[12,27] Applying the optimality concept[7] allowed us to define optimal criteria for the various movement components, and thus semi-quantify the qualitative scoring.[8,12]

Detailed GMA separated 'normal' from 'poor repertoire' and 'cramped-synchronized'

To the best of our knowledge, our study is the first to relate detailed GMA to global GMA in a considerable number of recordings. Across all age groups, GMOS differentiated between normal, poor repertoire and cramped-synchronized general movements. Despite these highly significant statistical differences we should be aware of a certain overlap within the scores, for example the maximum score within poor repertoire general movements corresponds to the median of normal general movements. Such an overlap demonstrates the basic need to interpret the detailed score within the context of a global assessment. Future research has to demonstrate whether, for example, an infant with poor repertoire general movements and a detailed score above the median (or any cut-off point) is more likely to normalize his/her general movements than an infant with a detailed score below the median.

Interestingly, the detailed GMA resulted in similar distributions of optimality scores for cramped-synchronized and chaotic general movements. However, our sample of recordings assessed as chaotic general movements was small (n=13), with the majority (11/13) occurring at late preterm age. It is well known that chaotic general movements are rather rare, and often precede the development of cramped-synchronized general movements.[6,8] Apart from the occurrence of chaotic general movements in infants with severe brain injury,[8] this general movement pattern was also reported for anencephalic neonates,[13] or was related to congenital thyrotoxicosis.[28] In the latter, chaotic general movements preceded poor repertoire general movements that normalized within the first months post-term age.[28] Recently, de Vries and Bos[29] described some chaotic features in poor repertoire general movements in preterm infants, especially during the first 10 days of life, correlating with hypocalcaemia.

Although the GMOS for chaotic general movements did not differ from cramped-synchronized general movements, the appearance of both patterns is quite different. The detailed GMA confirmed that chaotic general movements are rapid, with large amplitude, covering all spatial planes. By contrast, cramped-synchronized general movements are slow with small amplitude, especially in the upper extremities, and have a limited spatial range. Tremulous limb movements might occur in every second infant with cramped-synchronized general movements, but are present in almost all infants with chaotic general movements. In the detailed GMA, both deviant amplitude and speed are scored as '1', irrespective of large or small amplitude, high or low speed. This scoring procedure might have contributed to similar distributions of the optimality scores for chaotic and cramped-synchronized general movements.

The contribution of the detailed GMA to the description of the global patterns

Because optimal is not synonymous with normal, we did not expect that all recordings globally assessed as normal would be distributed in the upper 10% of the scoring list. Whereas normal is defined by the absence of abnormality (often synonymous with pathology), an optimal condition is more restricted and more narrowly defined. For example, the delivery of a primigravida is certainly within the realm of normality, but is not considered to be optimal because of the increased mortality rate as compared to the second and third delivery.[7]

The most surprising result was the relatively high rate of occurrence of tremulous – albeit short-lasting – movements across all global general movement categories. By contrast, general movements classified as 'chaotic' are characterized by long-lasting and predominant tremulous movements superimposed on large-amplitude limb movements.

Although the variability of the sequence indicated normal general movements, very preterm infants had short-lasting tremulous arm and leg movements, along with small-amplitude arm movements that did not cover the full spatial range. Short, tremulous limb movements also occurred in one-third of normally-moving, late preterm infants, and even more frequently after term. Apart from tremulous movements, every second infant at post-term age had cramped and stiff arm or leg movements, although the movement sequence was variable, indicating a global score of normal general movements. Tremulous and cramped movement components, along with a reduction in the amount of wrist rotations, were the most common reason for a slightly lower optimality score (for normal general movements) during post-term age compared to term and preterm age.

Short-lasting tremulous arm movements (increasing with age) and tremulous leg movements (decreasing with age) were also a common feature of poor repertoire general movements. Apart from the dominant lack of variability in the sequence, the majority of poor repertoire general movements did not show variable amplitude or speed, did not cover the full range in space, and had no smooth and fluent beginning and ending. At least during preterm age, the absence of cramped components was similar to infants with normal general movements, and was – in addition to tremulous components – not a feature to distinguish between normal and poor repertoire general movements.

Cramped-synchronized general movements met almost no optimal criteria, apart from the absence of tremulous movements. Similar to poor repertoire or normal general movements, tremulous leg movements in cramped-synchronized general movements were rare during post-term age. The clinical impression that the abnormal features of cramped-synchronized general movements are more often expressed in the legs than in the arms was confirmed by a lower score for the lower extremities as compared to the upper extremities.

The age-dependency of the results

It was surprising to see that the optimality scores for both normal and poor repertoire general movements were lower after term compared to preterm and term age. Future research should consider the postnatal age of the infant videoed at post-term age, as previous observations revealed that preterm infants approaching term-equivalent age might have fewer rotations and more jerky movements than infants born at term.[30] But also the fading out of writhing movements at the end of the first month post-term could cause a less optimal general movement performance after term.

We could confirm the clinical impression that neither cramped-synchronized nor chaotic general movements occurred during very preterm age – chaotic general movements were predominantly observed during the late preterm period.

Limitations and a note of caution

First, our sample is not representative of the normal population, and consists of cross-sectional and longitudinally acquired data of at-risk populations. Second, detailed assessment is much more time-consuming than global GMA. Third, we would like to point out that detailed GMA interferes with the ability to globally assess general movements. Gestalt perception/pattern recognition has its limitations when the observer focuses on details. We strongly advise the scorer to chronologically separate global from detailed GMA. In this context we would like to stress that the item 'sequence' is related to the global GMA. Therefore, a possible limitation of our study could be that this item has an effect on the results, although it constitutes only 4.76% of the total GMOS.

CONCLUSION

The clinical significance of this detailed GMA lies in a better description of the global categories, which certainly has implications for less experienced general movement scorers to comprehend the underlying parameters of the general movement classification system. Another benefit might lie in documenting subtle changes caused by (early) intervention, with the potential of evaluating various therapeutic approaches. Perhaps more importantly, detailed GMA might provide a solid base for the short-term prediction of improvement versus deterioration within an individual general movement trajectory.

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SUPPORTING INFORMATION

The following additional material may be found online:

Appendix S1: Detailed Assessment of General Movements During Preterm and Term Age – Score Sheet.

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