General movement optimality score and general movements trajectories following early parent-administrated physiotherapy in the neonatal intensive care unit

Tordis Ustad, PT, PhD[a,b], Toril Fjørtoft, PT, PhD[a,b] , Gunn Kristin Øberg, PT, PhD[c,d]

Affiliations: [a]Clinic of Clinical services, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway; [b]Department of Clinical and Molecular Medicine, Faculty of Medicine and Health sciences, Norwegian University of Science and Technology, Trondheim, Norway; [c]Department of Health and Care Sciences, University of Tromsø, The Arctic University of Norway, Tromsø, Norway; [d]Section of physiotherapy, University Hospital North Norway, Tromsø, Norway

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Corresponding author: Tordis Ustad, Clinic of Clinical services, St. Olavs Hospital, Trondheim University Hospital, Postboks 3250 Torgarden, Trondheim, Norway

tordis.ustad@ntnu.no

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Highlights

- Parent-administrated physiotherapy in the NICU had no noticeable effect on the global GMs of preterm-born infants participating in an RCT.
- A detailed analysis of GMs during preterm age revealed no subtle, early-intervention-related changes in movements.

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Abstract

Background: The Prechtl General Movement Assessment (GMA) is a reliable tool for the functional assessment of the young nervous system. It is based on a global assessment of the quality of infants' movements. In addition, detailed steps of assessment have been developed – one for preterm and term age, and one for use between 3 and 5 months. One potential benefit of such a detailed analysis is the documentation of subtle changes in the infants' spontaneous movements caused by early intervention.

Aim: To present detailed scores of the infants' general movements (GMs) at preterm age, and of the infants' motor repertoire at 3 months' postterm age (PTA), for infants having participated in a randomized controlled trial (RCT) of early intervention, and to examine possible group differences. In addition, the aim is also to present the GMA from preterm to 3 months' PTA, comparing the intervention and the control group.

Study design: A retrospective study on infants who had participated in an RCT of parent-administered early intervention.

Subjects: 141 infants born very preterm.

Outcome measures: GMA, "Detailed Assessment of General Movements During Preterm and Term Age" and "Assessment of Motor Repertoire at 3 to 5 months".

Results: The GMA and the detailed assessments of GMs conducted at 36 weeks' post menstrual age (PMA) showed the same distribution of normal and abnormal movements in both the intervention and in the control group, as did the assessment of motor repertoire at 3 months' PTA.

Conclusion: Neither the GMA nor the detailed assessments of GMs at 36 weeks' PMA and of the motor repertoire at 13 weeks' PTA suggest that early intervention, performed before term, changes the GMs of very preterm-born infants.

Keywords

Early intervention, preterm-born infants, general movements, motor repertoire.

Abbreviations:
AMR: Assessment of Motor Repertoire, GMA: General movement assessment, GMs: General movements, GMOS: general movement optimality score, MOS: Motor Optimality Score, NOPPI: NN physiotherapy study for preterm infants, OS: optimality score, PMA: post menstrual age, PTA: postterm age, RCT: randomized controlled trial

Introduction

In recent decades the survival rate of infants born very preterm has increased due to advances in neonatal medicine. However, the risk of long-term adverse neurodevelopment, including various motor difficulties, continues to be high [1, 2]. This risk increases with decreasing gestational age [2]. Brain development in terms of synaptic pruning, dendritic outgrowth, the development of the corticospinal tract and its connections with spinal motor neurons is influenced by the infants' activities and experiences [3, 4]. Therefore, the preterm period and the first year of life are considered to be especially sensitive periods in an infant's motor development. If an infant is identified with atypical development, early intervention is recommended [5, 6].

Unfortunately, a systematic review of early intervention could not document positive long-term effect on motor outcomes [7]. Since this review in 2015, other studies on long-term effect of early intervention have been published. Kara et al. conducted a randomized controlled trial of early intervention including 42 infants born preterm [8]. The intervention lasted from 3 months postterm

age (PTA)[1] until 12 months PTA and consisted of a family-based program or routine infant physiotherapy. At 24 months PTA there was no statistical differences between the two groups in fine or in gross motor development as measured by Bayley III. Another study including four very preterm infants with intraventricular haemorrhage and cramped-synchronised general movements (GMs), showed that the infants, after a period of parent oriented therapy during late preterm until 5 weeks' PTA, were classified with normal neurodevelopment at 4 – 5 years [9]. But, to confirm such a finding, studies with larger numbers of participants are needed

We conducted the NN physiotherapy study for preterm infants (NOPPI), a multi-centre randomized controlled trial (RCT) of early parent-administered physiotherapy aiming to optimize motor function [10]. According to protocol, parents had to perform interventions twice a day for 10 minutes for a period of 3 weeks from 34 to 37 weeks' postmenstrual age (PMA). The primary outcome of NOPPI was the infants' motor function measured by the Peabody Developmental Motor Scale -2 at 2 years' PTA. At 37 weeks' PMA, the intervention group showed a more substantial change in motor function than the control group [11]. At 3 months PTA, the difference between the two groups was only visible in infants who had received intervention according to protocol [12]. As part of NOPPI, the infants' spontaneous movements were recorded at 34 and 36 weeks' PMA and at 3 months' PTA for later assessment of GMs.

General movements are spontaneous movements performed from the foetal stage until 18 weeks' PTA. They involve the whole body, neck, trunk, and upper and lower extremities [13]. The general movement assessment (GMA) is an indicator of the young nervous system functioning [14, 15]. General movements are age-specific and subdivided into three periods: the preterm period (< 37 weeks' PMA), the period of writhing GMs (term to 2 months' PTA), and the period of fidgety

[1] **Abbreviations:** AMR: Assessment of Motor Repertoire, GMA: General movement assessment, GMs: General movements, GMOS: general movement optimality score, MOS: Motor Optimality Score, NOPPI: NN study for preterm infants, OS: optimality score, PMA: post menstrual age, PTA: postterm age, RCT: randomized controlled trial

movements (9 to 18 weeks' PTA) [13]. The GMA is based on gestalt perception; GMs can be normal, poor-repertoire, cramped-synchronized or chaotic at preterm and at term age, and present, absent or abnormal during the period of fidgety movements. In many infants, GMs are classified as poor-repertoire at preterm age but normalize with age [16, 17]. Therefore, preterm assessments of GMs have not proven to be predictive of later adverse neurodevelopment [18]. An absence of fidgety movements, however, is highly predictive of cerebral palsy [5, 19, 20]. In addition to a global assessment of GMs, detailed steps of assessment have been developed – one for preterm and term age, and one for use between 3 and 5 months [13, 21]. This detailed analysis may help to document subtle changes in the quality of movements caused by early intervention [21]. At 3 – 5 months detailed analyses of the motor repertoire are not only predictive of cerebral palsy but can also be predictive of other neurodevelopmental problems [22-25].

Secondary outcomes of NOPPI based on analyses of the infants' GMs and of their movement character at 3 months' PTA have been published [26]. There were no differences between the intervention and the control groups in respect of fidgety movements or overall movement character [26]. Although there were no significant differences between the two groups in respect of their GMs at 3 months' PTA, we wanted, through a detailed analysis of movements, to examine to what extent early intervention could have led to subtle changes of the infants' spontaneous movements either at 36 weeks' PMA or at 3 months' PTA. Our research questions were (a) does the detailed assessment (GMOS) bring new insights to the already known lack of improvement of GMs due to NOPPI at 36 weeks? (b) does the addition of subcategories II to IV (movements and postures) of the AMR and the resulting MOS add to the already known lack of effect of NOPPI on fidgety movements and movement character? Furthermore, we wanted to examine if there were any differences between the two groups in terms of normalization of GMs by 3 months' PTA.

The aim of this study was to present detailed scores of the infants' GMs at preterm age, and of the infants' motor repertoire at 3 months' PTA, for participants of the NOPPI, and to examine possible

group differences. In addition, the aim was also to present the GMA from preterm age to 3 months' PTA comparing the intervention and the control group.

Methods

The present study reports secondary outcomes from of a multicentre RCT of early parent-administered physiotherapy (NOPPI) aiming to optimize motor function [10-12, 26]. Randomization was performed by a web-based, computer-generated system developed and administered by the Unit for Applied Clinical Research, Faculty of Medicine, NN University of Science and Technology (NTNU). The infants were stratified according to gestational age at birth (< 28 weeks and ≥ 28 weeks), with twins assigned to the same group. Sample size for NOPPI was based on scores on the Peabody Developmental Motor Scales-2 at 2 years PTA, and we considered a difference in total motor function of 0.5 SD between the intervention and control group, to be clinically significant. Sixty -three infants in each group were required to achieve a statistical power of 80 % at 0.05 (α) significance level on two-sided tests. We aimed to recruit 75 children in each group to account for potential dropouts. The study protocol of the NOPPI, the infants motor function at term age, and a paper reporting fidgety movements and movement character of the MOS at 3 months PTA, have been published [10, 11, 26].

Participants

The participants were recruited from three university hospitals in North, Central and East Norway, all of which belong to the national health service. The recruitment period lasted from March 2010 to October 2014. Inclusion criteria were gestational age at or before week 32 PMA, the infant had to be medical stable at week 33 PMA, and the parents had to understand and speak Norwegian. Exclusion criteria were triplets, infants with malformations, with syndromes or infants requiring major surgery.

To be part of the present study, the infants had to have two or three video recordings of their GMs,

once or twice during preterm age and once at 3 months' PTA. These criteria were met by 141 of 151 infants who had participated in NOPPI (65 in the intervention group and 76 in the control group).

Ethical approval

The study was approved by the Regional Committee for Medical and Health Research Ethics North in Norway (REC North: 2009/916-7). The full study is registered at ClinicalTrials.gov NCT01089296.

Early intervention

The intervention has been described in detail in a previous paper [10]. It was performed by the parents after they had been instructed by a physiotherapist. It was important for the intervention that interaction between parents and infants increased and that parents were helped to "read cues" presented by their infants [27]. The intervention was individualized based on each infant's development level and movement tolerance. The main objectives were to improve the infants' postural control, head control and midline orientation to optimizing early motor development. The sessions were paused or terminated if the infants showed signs of stress. The intervention period lasted for three weeks, from week 34 until the end of week 36 PMA. Parents of infants in the control group only received general information about positioning and handling, as none of the hospitals had implemented routines of individualized physiotherapy before the age of 37 weeks' PMA.

Video recording and assessment of GMs

The infants' spontaneous movements had been video-recorded according to procedures endorsed by Einspieler et al [13]. Infants were recorded for 10 minutes in supine position, awake or about to wake up at 34, 36 weeks' PMA, and fully awake at 3 months' PTA, dressed in a body with short sleeves and legs, or wearing nothing but a nappy.

Before assessing the GMs recorded at 34 and 36 weeks' PMA, the videoclips were anonymized and edited into two-minute-clips containing two to three GMs. Then a detailed analysis was performed using the scoring sheet "Detailed Assessment of General Movements During Preterm and Term Age"

[21]. First, GMs were classified as normal (2 points), poor-repertoire (1 point), cramped-synchronized or chaotic (0 points). After this global assessment came a detailed analysis of the spontaneous movements of the neck, trunk, upper and lower limbs. The scoring sheet comprises nine movement components in the upper and lower limbs: amplitude, speed, space, proximal rotation, distal rotation, onset of movements, offset of movements, tremulous movements, and cramped components. These items were rated according to a 0-to-2-point scale, 2 being the optimal score. Optimality scores (OS) for upper and lower limbs and for the neck and trunk are calculated separately, 18 being the respective highest OS for upper and lower limbs, and 4 being the highest OS for the neck and trunk. The highest possible general movement optimality score (GMOS) is 42 points.

At 3 months' PTA we applied the "Assessment of Motor Repertoire – 3 to 5 Months" (AMR) [13]. This scoring sheet has been revised [28], but at the time of assessing the videos, the revised version was not yet available to the assessors. The AMR comprises an analysis of five subcategories of spontaneous movements in infants at 3 to 5 months' PTA. The first subcategory, "Fidgety movements" (i.e. small, elegant movements occurring all over the body) was either normal (12 points), abnormal (4 points), or absent or sporadic (1 point). Sporadic fidgety movements occurring at 12 to 14 weeks' PTA might indicate later adverse neurodevelopment [29, 30]. The second subcategory, "Repertoire of co-existent other movements" (e.g. hand-to-hand, hand-to-mouth or foot-to-foot contact), was either scored as age-adequate (4), reduced (2) or absent (1). The two subcategories "Quality of other movements" and "Posture" was scored according to the following criteria: more normal than abnormal patterns observed (4), equal number of normal and abnormal patterns (2), or more abnormal than normal patterns (1). The fifth subcategory, "Movement character", classifies the overall movement character as smooth and fluent (4), abnormal, but not cramped-synchronized (2), or cramped-synchronized (1). The total Motor Optimality Score (MOS) ranges from 5 to 28 points.

Blinded assessments were performed by three experienced paediatric physiotherapists, all of whom had completed the General Movement Advanced Course and were certified in the Prechtl General Movement Assessment (GMA). Two testers assessed each videoclip independently as described above. In case of disagreement about the global score, a third tester was asked to assess the respective videoclip to reach consensus. Inter-tester reliability between the three testers has previously been reported to be good (Cohen's kappa > 0.70) [26].

Statistical analysis

Data were analysed using the IBM SPSS Statistics software version 25. Descriptive statistics were applied to describe clinical characteristics and GMA findings of infants in the intervention and in the control group. The normality of the data was established through a Shapiro–Wilk test. Student's *t*-test, Mann-Whitney U or Chi-square tests were used to compare the clinical characteristics of participants in the intervention and control group, and to assess between-group differences at 34 and 36 weeks' PMA and at 3 months' PTA.

Chi-square tests were applied to assess if early intervention could lead to subtle changes of the infants' spontaneous movements. The scores of each item of the "Detailed Assessment of General Movements During Preterm and Term Age" including the OS for the neck and trunk and upper and lower extremity, at 34 and 36 weeks' PMA, were compared to examine possible differences between the intervention and the control group.

At 3 months' PTA Chi-square tests were applied for the subcategories of "Assessment of motor repertoire at 3 to 5 months", to assess possible differences between the two groups. We also conducted a linear mixed model analysis with the group, time, and centre (represented by the three hospitals) as fixed effects to compare GMOS between the intervention and the control group at 34 and 36 weeks' PMA.

Results

Sample characteristics

There were no significant differences between the clinical characteristics of infants in the intervention and control groups (Table 1). The mean gestational age was 29.74 weeks (intervention group) and 29.68 weeks (control group), the mean birthweight was 1430.6 grams (intervention group) and 1376.4 grams (control group). The percentage of infants with grade 3 or 4 intraventricular haemorrhage or periventricular leukomalacia was higher in the intervention group than in the control group, but the difference was insignificant. The median number of days with ventilator treatment, CPAP ventilation and extra oxygen was similar in both groups.

(Insert Table 1 here)

General movements optimality score at 34 and 36 week's postmenstrual age

The median GMOS was approximately equal in the intervention group at 34 and 36 weeks' PMA (Table 2). There were hardly any differences between the two groups in respect of GMOS or the subcategories at either point in time, and no evidence in the data of a relationship between intervention and GMOS or its subcategories at 36 weeks' PMA. (Table 2). Only in very few infants did GMs normalize between 34 and 36 weeks' PMA.

(Insert Table 2 here)

The linear mixed model analysis revealed an insignificant difference between the groups from 34 to 36 weeks' PMA (the GMOS was approximate 3 points higher in the control group). The data also provide evidence of a centre effect, as the infants in one hospital scored 3 or 4 points lower than those in the other two centres.

"Assessment of motor repertoire at 3 to 5 months (GM trust's 2001 version)"

Motor optimality scores at 3 months' PTA were identical in the intervention and the control group (Table 3). The median MOS was 26 in both groups, with a range of 10 to 28 in the intervention group and 6 to 28 in the control group. When we compared the repertoire of other movements, the quality

of other movements, the posture and the movement character, there were no differences between the two groups.

(Insert Table 3 here)

General movement assessment from 34 weeks' PMA to 3 months' PTA

The number of participants varied slightly because not all infants had three video recordings.

When we compared the GMs at 34 and 36 weeks' PMA, both groups had had a small reduction in the number of infants with a global score of poor-repertoire (Table 4). Besides we found at 36 weeks' PMA, that 8.3 percent of infants in the intervention group showed either cramped-synchronized or chaotic movements whereas no-one in the control group. At 3 months' PTA most of the infants in both groups had normal GM score, and an equal low number had sporadic or absent fidgety movements in each group.

(Insert Table 4 here)

Discussion

Assessment of GMs observed at 36 weeks' PMA, after 2 weeks of intervention, and at 3 months' PTA showed no difference between the intervention and control groups. At 34 and 36 weeks' PMA there was no difference between the intervention and control groups with respect to general movement optimality or global GM scores. Both groups revealed a high proportion of abnormal GMs at both points in time. This is in line with Olsen et al. (2020), who found that 87 percent of 122 very preterm-born infants had abnormal GMs at 34 weeks' PMA [31]. A randomized controlled trial, including 30 infants born preterm, also found that there was no difference between the groups in respect of GMA or GMOS after a 3-weeks period of early intervention, one group receiving craniosacral therapy and one group usual care [32].

We found that, between 34 and 36 weeks' PMA, the global score changed from poor-repertoire to

cramped-synchronized or chaotic in 3 and 2 infants respectively, in the intervention group, but none in the control group. This can be explained by the fact that twice as many infants in the intervention group had a grade 3 or 4 intraventricular haemorrhage or periventricular leukomalacia. Another possible explanation could be that the intervention had influenced the infant's spontaneous movements negatively, but since an important element of the intervention was the parent infant interaction, a worsening from 34 to 36 weeks' PMA due to the intervention was less likely. The parent had learned to "read the infant's cues" and to stop the intervention if the infant showed any stress reactions.

"The assessment of motor optimality at 3 months' PTA showed that the percentage of infants with normal quality of other movements and with normal posture was insignificantly higher in the intervention group. However, a higher percentage of infants in the control group had age-adequate repertoire of other movements and a smooth and fluent movement character. The median MOS was very similar in the two groups. The motor optimality scores were quite high in general, which can be explained by the fact that the infants had to be medically stable at 32 weeks' PMA to be able to participate in the NOPPI scheme. The lack of major differences between the groups is in line with previous findings [26].

Early physiotherapy does not, from a present-day perspective, change the neurological outcome of infants born preterm. We expected to find the same neurological outcome in both groups, but standardized motor function tests at 37 weeks' PMA and 3 months' PTA suggest that motor functions had improved in the intervention group [11, 12]. Yet the detailed analysis provided no evidence for subtle changes in GMs due to early intervention.

Limitations

A major limitation of the study is that the second video recording of preterm GMs was performed after only two weeks, at 36 weeks' PMA, i.e. before the end of intervention. This interval between the two recordings, might have been too short to reveal differences between the two groups.

Furthermore, there was no recording during term age. To determine differences between the groups, the ideal moment for a second video recording would most likely have been after end of intervention, at 37 weeks' PMA, since a detailed analysis yields information about the quality of the infants' movements and the potential effect of intervention (i.e. stimulation). Another limitation of the study is the rather short intervention period, which lasted only three weeks. Besides, not all infant received intervention after protocol.

Because of these limitations, and quite few participants in the study, we cannot generalize our findings. Larger scales studies, with interventions lasting for longer periods, might reveal subtle changes in the infants' spontaneous movements, which we did not find in our study.

Conclusion

A detailed assessment of GMs at 36 weeks' PMA provided no evidence of subtle changes in the movements of preterm-born infants due to early intervention. Assessed at 36 weeks' PMA and 3 months' PTA, the global scores, general movement optimality scores, and motor optimality scores were identical in the intervention and control groups. Since only 141 very preterm-born infants participated, and for want of videos recorded immediately after intervention, this finding cannot be generalized.

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References

[1] Husby IM, Stray KM, Olsen A, Lydersen S, Indredavik MS, Brubakk AM, et al. Long-term follow-up of mental health, health-related quality of life and associations with motor skills in young adults born preterm with very low birth weight. Health and quality of life outcomes. 2016;14:56.

[2] Ferrari F, Gallo C, Pugliese M, Guidotti I, Gavioli S, Coccolini E, et al. Preterm birth and developmental problems in the preschool age. Part I: minor motor problems. J Matern Fetal Neonatal Med. 2012;25:2154-9.

[3] Kolb B, Harker A, Gibb R. Principles of plasticity in the developing brain. Dev Med Child Neurol. 2017.

[4] Sudhof TC. Towards an understanding of synapse formation. Neuron. 2018;100:276-93.

[5] Novak I, Morgan C, Adde L, Blackman J, Boyd RN, Brunstrom-Hernandez J, et al. Early, accurate diagnosis and early intervention in cerebral palsy: advances in diagnosis and treatment. JAMA Pediatr. 2017.

[6] Ferrari F, Plessi C, Lucaccioni L, Bertoncelli N, Bedetti L, Ori L, et al. Motor and postural patterns concomitant with general movements are associated with cerebral palsy at term and fidgety age in preterm infants. J Clin Med. 2019;8.

[7] Spittle A, Orton J, Anderson PJ, Boyd R, Doyle LW. Early developmental intervention programmes provided post hospital discharge to prevent motor and cognitive impairment in preterm infants. The Cochrane database of systematic reviews. 2015;11:CD005495.

[8] Kara OK, Sahin S, Yardimci BN, Mutlu A. The role of the family in early intervention of preterm infants with abnormal general movements. Neurosciences (Riyadh). 2019;24:101-9.

[9] Soloveichick M, Marschik PB, Gover A, Molad M, Kessel I, Einspieler C. Movement imitation therapy for preterm babies (MIT-PB): a novel approach to improve the neurodevelopmental outcome of infants at high-risk for cerebral palsy. J Dev Phys Disabil. 2020;32:587-98.

[10] Øberg GK, Campbell SK, Girolami GL, Ustad T, Jørgensen L, Kaaresen PI. Study protocol: an early intervention program to improve motor outcome in preterm infants: a randomized controlled trial

and a qualitative study of physiotherapy performance and parental experiences. BMC Pediatr. 2012;12:15.

[11] Ustad T, Evensen KA, Campbell SK, Girolami GL, Helbostad J, Jorgensen L, et al. Early parent-administered physical therapy for preterm infants: a randomized controlled trial. Pediatrics. 2016;138.

[12] Øberg GK, Girolami GL, Campbell SK, Ustad T, Heuch I, Jacobsen BK, et al. Effects of a parent-administered exercise program in the neonatal intensive care unit: dose does matter-a randomized controlled trial. Phys Ther. 2020;100:860-9.

[13] Einspieler C, Prechtl HF, Bos A, Ferrari F, Cioni G. Prechtl´s method on the qualitative assessment of general movements in preterm, term and young infants. London: Mac Keith Press; 2004.

[14] Einspieler C, Prechtl HF. Prechtl's assessment of general movements: a diagnostic tool for the functional assessment of the young nervous system. Ment Retard Dev Disabil Res Rev. 2005;11:61-7.

[15] Einspieler C, Bos AF, Libertus ME, Marschik PB. The general movement assessment helps us to identify preterm infants at risk for cognitive dysfunction. Front Psychol. 2016;7.

[16] Olsen JE, Brown NC, Eeles AL, Lee KJ, Anderson PJ, Cheong JL, et al. Trajectories of general movements from birth to term-equivalent age in infants born <30 weeks' gestation. Early Hum Dev. 2015;91:683-8.

[17] Sharp M, Coenen A, Amery N. General movement assessment and motor optimality score in extremely preterm infants. Early Hum Dev. 2018;124:38-41.

[18] Nakajima Y, Einspieler C, Marschik PB, Bos AF, Prechtl HF. Does a detailed assessment of poor repertoire general movements help to identify those infants who will develop normally? Early Hum Dev. 2006;82:53-9.

[19] Bosanquet M, Copeland L, Ware R, Boyd R. A systematic review of tests to predict cerebral palsy in young children. Dev Med Child Neurol. 2013;55:418-26.

[20] Prechtl HF, Einspieler C, Cioni G, Bos AF, Ferrari F, Sontheimer D. An early marker for neurological deficits after perinatal brain lesions. Lancet. 1997;349:1361-3.

[21] Einspieler C, Marschik PB, Pansy J, Scheuchenegger A, Krieber M, Yang H, et al. The general movement optimality score: a detailed assessment of general movements during preterm and term age. Dev Med Child Neurol. 2016;58:361-8.

[22] Fjortoft T, Grunewaldt KH, Lohaugen GC, Morkved S, Skranes J, Evensen KA. Assessment of motor behaviour in high-risk-infants at 3 months predicts motor and cognitive outcomes in 10 years old children. Early Hum Dev. 2013;89:787-93.

[23] Salavati S, Einspieler C, Vagelli G, Zhang D, Pansy J, Burgerhof JGM, et al. The association between the early motor repertoire and language development in term children born after normal pregnancy. Early Hum Dev. 2017;111:30-5.

[24] Zang FF, Yang H, Han Q, Cao JY, Tomantschger I, Krieber M, et al. Very low birth weight infants in China: the predictive value of the motor repertoire at 3 to 5months for the motor performance at 12months. Early Hum Dev. 2016;100:27-32.

[25] Bruggink JL, Einspieler C, Butcher PR, Stremmelaar EF, Prechtl HF, Bos AF. Quantitative aspects of the early motor repertoire in preterm infants: do they predict minor neurological dysfunction at school age? Early Hum Dev. 2009;85:25-36.

[26] Fjortoft T, Ustad T, Follestad T, Kaaresen PI, Oberg GK. Does a parent-administrated early motor intervention influence general movements and movement character at 3months of age in infants born preterm? Early Hum Dev. 2017;112:20-4.

[27] Kaaresen PI, Rønning JA, Ulvund SE, Dahl LB. A randomized, controlled trial of the effectiveness of an early-intervention program in reducing parenting stress after preterm birth. Pediatrics. 2006;118:e9-19.

[28] Einspieler C, Bos AF, Krieber-Tomantschger M, Alvarado E, Barbosa VM, Bertoncelli N, et al. Cerebral palsy: early markers of clinical phenotype and functional outcome. J Clin Med. 2019;8.

[29] Einspieler C, Yang H, Bartl-Pokorny KD, Chi X, Zang FF, Marschik PB, et al. Are sporadic fidgety movements as clinically relevant as is their absence? Early Hum Dev. 2015;91:247-52.

[30] Peyton C, Einspieler C. General movements: a behavioral biomarker of later motor and cognitive dysfunction in NICU graduates. Pediatr Ann. 2018;47:e159-e64.

[31] Olsen JE, Cheong JLY, Eeles AL, FitzGerald TL, Cameron KL, Albesher RA, et al. Early general movements are associated with developmental outcomes at 4.5-5 years. Early Hum Dev. 2020;148:105115.

[32] Raith W, Marschik PB, Sommer C, Maurer-Fellbaum U, Amhofer C, Avian A, et al. General movements in preterm infants undergoing craniosacral therapy: a randomised controlled pilot-trial. BMC Complement Altern Med. 2016;16:12.

Table 1. Clinical characteristics of the participants

	Intervention group		**Control group**		
	n=65		**n=76**		
Perinatal factors	**Mean**	**SD**	**Mean**	**SD**	***p*[a]**
Gestational age (weeks)	29.74	2.2	29.68	2.1	0.88
Birth weight: grams	1430.6	421.4	1376.4	357.5	0.41
	Median	IQR	Median	IQR	*P*[b]
Days of ventilation	0	0-1	0	0-1	0.97
Days of CPAP	7	1-18	8	3-27	0.37
Days with oxygen	0	0-10	2	0-12	0.30
	n	**%**	**n**	**%**	***P*[c]**
Gender (male)	33	50.8	41	53.9	0.71
Intraventricular haemorrhage					
grade 1–2	4	5.2	8	10.5	0.97
grade 3–4	2	2.6	1	1.3	
Periventricular leukomalacia	6	9.2	3	3.9	0.20
Septicaemia	6	9.2	12	15.8	0.25
Bronchopulmonary dysplasia	6	9.2	8	10.5	0.77

[a] *t*-test, [b] Mann-Whitney U, [c] Pearson Chi-square, SD = standard deviation, IQR = interquartile range, CPAP = continuous positive airway pressure

Table 2. General movement optimality scores at 34 and at 36 weeks' postmenstrual age

	Intervention group (n=64) 34 weeks	**Control group** (n=71) 34 weeks		**Intervention group** (n=60) 36 weeks	**Control group** (n=74) 36 weeks	
	N (%)	**N (%)**	***p*[a]**	**N (%)**	**N (%)**	***p*[a]**
Neck (score)			0.30			0.65
Involved in the sequence (2)	31 (48.4)	41 (57.7)		35 (58.3)	46 (62.2)	
Hardly/not involved (1)	33 (51.6)	29 (40.8)		25 (41.7)	28 (37.8)	
Trunk rotation (score)			0.57			0.06
Fluent and elegant (2)	6 (9.4)	10 (14.1)		8 (13.3)	11 (14.9)	
Just a few rotations (1)	43 (67.2)	42 (59.2)		36 (60.0)	55 (74.3)	
Almost none (0)	15 (23.4)	19 (26.8)		16 (26.7)	8 (10.8)	
Upper extremities						
Amplitude (score)			0.89			0.40
Variable, full range (2)	22 (34.9)	24 (33.8)		23 (38.3)	29 (39.2)	
Small or large range (1)	13 (20.6)	17 (23.9)		5 (8.3)	11 (16.3)	
Monotonous (1)	28 (44.4)	30 (42.3)		32 (53.3)	33 (44.6)	
Speed (score)			0.37			0.88
Variable (2)	12 (19.0)	12 (16.9)		13 (21.7)	16 (21.6)	
Monotonous (1)	51 (81.0)	59 (83.1)		47 (78.3)	58 (78.4)	
Spatial range (score)			0.24			0.01
Full space, variable (2)	25 (39.7)	26 (36.6)		23 (38.3)	45 (60.8)	
Limited space (1)	37 (58.7)	39 (54.9)		33 (55.0)	28 (37.8)	
In one plane only (0)	1 (1.6)	6 (8.5)		4 (6.7)	1 (1.4)	
Proximal rotatory component (score)			0.43			0.06
Fluent and elegant (2)	11 (17.5)	9 (12.7)		9 (15.0)	17 (23.0)	
Just a few rotations (1)	49 (77.8)	55 (77.5)		45 (75.0)	56 (75.7)	

Almost none (0)	3 (4.8)	7 (9.9)		6 (10.0)	1 (1.4)	
Distal rotatory component (score)			0.47			0.14
Fluent and elegant (2)	10 (15.9)	8 (11.3)		10 (16.7)	13 (17.6)	
Just a few rotations (1)	44 (69.8)	51 (71.8)		37 (61.7)	54 (73.0)	
Almost none (0)	9 (14.3)	12 (16.9)		13 (21.7)	7 (9.5)	
Onset (score)			0.43			0.66
Smooth, fluctuating (2)	8 (12.7)	9 (12.7)		6 (10.0)	11 (14.9)	
Minimal fluctuations (1)	53 (84.1)	56 (78.9)		51 (85.0)	58 (78.4)	
Abrupt (0)	2 (3.2)	6 (8.5)		3 (5.0)	5 (6.8)	
Offset (score)			0.30			0.58
Smooth, fluctuating (2)	7 (11.1)	9 (12.7)		7 (11.7)	11 (14.9)	
Minimal fluctuations (1)	56 (88.9)	59 (83.1)		51 (85.0)	58 (78.4)	
Sudden release (0)	0	3 (4.2)		2 (3.3)	5 (6.8)	
Tremulous movements (score)			0.66			0.55
Absent (2)	36 (57.1)	35 (49.3)		28 (46.7)	35 (47.3)	
Unilaterally present (1)	10 (15.9)	14 (19.7)		9 (15.0)	16 (21.6)	
Bilaterally present (0)	17 (27.0)	22 (31.0)		23 (38.3)	23 (31.1)	
Cramped components (score)			1.00			0.46
Absent (2)	62 (98.64)	70 (98.6)		55 (91.7)	71 (95.9)	
Occasionally present (1)	1 (1.6)	1 (1.4)		5 (8.3)	3 (4.1)	
Predominantly present (0)	0	0		0	0	
<u>Lower extremities</u>						
Amplitude (score)			0.83			0.57
Variable, full range (2)	16 (25.4)	14 (19.7)		13 (21.7)	23 (31.1)	
Small or large range (1)	3 (4.8)	5 (7.0)		3 (5.0)	3 (4.1)	
Monotonous (1)	44 (69.8)	52 (73.2)		44 (73.3)	48 (64.9)	
Speed (score)			0.72			0.39
Variable (2)	4 (6.3)	5 (7.0)		6 (10.0)	12 (16.2)	

Monotonous (1)	57 (93.7)	66 (93)		54 (90.0)	62 (83.8)	
Spatial range (score)			0.70			0.15
Full space, variable (2)	15 (23.8)	15 (21.1)		11 (18.3)	24 (32.4)	
Limited space (1)	45 (71.4)	50 (70,4)		41 (68.3)	44 (59.5)	
In one plane only (0)	3 (4.8)	6 (8.5)		8 (13.3)	6 (8.1)	
Proximal rotatory component (score)			0.87			0.19
Fluent and elegant (2)	3 (4.8)	5 (7.0)		3 (5.0)	10 (13.5)	
Just a few rotations (1)	45 (71.4)	48 (67.6)		46 (76.7)	55 (74.3)	
Almost none (0)	15 (23.8)	18 (25.4)		11 (18.3)	9 (12.2)	
Distal rotatory component (score)			0.88			0.31
Fluent and elegant (2)	7 (11.1)	7 (9.9)		3 (5.0)	8 (10.8)	
Just a few rotations (1)	39 (61.9)	47 (66.2)		39 (65.0)	50 (67.6)	
Almost none (0)	17 (27.0)	17 (23.9)		18 (30.0)	16 (21.6)	
Onset (score)			0.01			0.76
Smooth, fluctuating (2)	2 (3.2)	8 (11.3)		2 (3.3)	1 (1.4)	
Minimal fluctuations (1)	60 (95.2)	54 (76.1)		51 (85.0)	64 (86.5)	
Predominantly abrupt (0)	1 (1.6)	9 (12.7)		7 (11.7)	9 (12.2)	
Offset (score)			0.02			1.00
Smooth, fluctuating (2)	2 (3.2)	7 (9.9)		2 (3.3)	3 (4.1)	
Minimal fluctuations (1)	61 (96.8)	59 (83.1)		53 (88.3)	65 (87.8)	
Sudden release (0)	0	5 (7.0)		5 (8.3)	6 (8.1)	
Tremulous movements (score)			0.24			0.47
Absent (2)	30 (47.6)	37 (52.1)		35 (58.3)	40 (54.1)	
Unilaterally present (1)	17 (27.0)	24 (33.8)		11 (18.3)	20 (27.0)	
Bilaterally present (0)	16 (25.4)	10 (14.1)		14 (23.3)	14 (18.9)	
Cramped components (score)			0.05			0.23
Absent (2)	48 (76.2)	58 (81.7)		38 (63.3)	49 (66.2)	
Occasionally present (1)	15 (23.8)	9 (12.7)		16 (26.7)	23 (31.1)	

Predominantly present (0)	0	4 (5.6)		6 (10.0)	2 (2.7)	
	Median (IQR)	**Median (IQR)**	***p*[b]**	**Median (IQR)**	**Median (IQR)**	***p*[b]**
Neck and trunk OS	2 (2-3)	3 (1-3)	0.33	3 (1-3)	3 (2-3)	0.20
Upper extremity OS	11 (10-13)	11 (9-12)	0.40	11 (8-13)	11 (10-13.25)	0.11
Lower extremity OS	10 (9-11)	10 (9-11)	0.91	10 (8-11)	10 (8-12)	0.15
GMOS	25 (21-28)	25 (21-27)	0.78	24 (19.25-27.75)	25 (22-29)	0.11

[a] Chi-square test, [b] Mann–Whitney *U* test, OS = optimality score, GMOS = general movement optimality score

Table 3. Intervention and control groups' motor optimality scores (MOS) at 3 months' PTA

	Intervention group n=58		**Control group n=67**		
	n	**%**	**n**	**%**	***p*[a]**
Fidgety movements					0.96
Present	47	81.0	56	83.6	
Abnormal	0	0	0	0	
Absent/sporadic	11	19.0	11	16.4	
Repertoire of other movements					0.23
Age-adequate	51	87.9	61	91	
Reduced	7	12.1	4	6	
Absent	0		2	3	
Quality of other movements					0.50
N > A	58	100	65	97	
N = A	0	0	0	0	
N < A	0	0	2	3	
Posture					0.56
N > A	55	94.8	60	89.6	
N = A	2	3.4	6	9	
N < A	1	1.7	1	1.5	
Movement character					0.39
Smooth/fluent	25	43.1	34	50.7	
Abnormal, not CS	33	56.9	33	49.3	
Cramped-synchronized	0	0	0	0	
	Median (IQR)	**Min-MAX**	**Median (IQR)**	**Min-MAX**	***p*[b]**
Motor optimality score	26 (26–28)	10–28	26 (26–28)	6–28	0.46

[a] Chi-Square test, [b] Mann–Whitney *U* test, PTA = postterm age, N = normal, A = abnormal, CS = cramped-synchronized, IQR = interquartile range

Table 4. General movement assessment, intervention and control group, at 34, 36 weeks' PMA and 3 months' PTA

	Intervention group (n=64) 34 weeks	**Control group** (n=71) 34 weeks		**Intervention group** (n=60) 36 weeks	**Control group** (n=74) 36 weeks			**Intervention group** (n=58) 3 months	**Control group** (n=67) 3 months	
Preterm GMs	N (%)	N (%)	*p*[a]	N (%)	N (%)	*p*[a]	**Fidgety movements**	N (%)	N (%)	*p*[a]
Normal	7 (10.9)	5 (7)	0.43	4 (6.7)	11 (14.9)	0.03	Normal	47 (81)	56 (83.6)	0.96
Poor-repertoire	57 (89.1)	66 (93)		51 (85.0)	63 (85.1)		Sporadic	8 (13.8)	9 (13.4)	
CS	0	0		3 (5)			Abnormal	0	0	
Chaotic	0	0		2 (3.3)			Absent	3 (5.2)	2 (3)	

GMs = General Movements, [a] Chi-Square tests, PMA = postmenstrual age, PTA = postterm age, CS = cramped-synchronized