Early Human Development 151 (2020) 105197

Contents lists available at ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Early intervention and its short-term effect on the temporal organization of fidgety movements

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ARTICLE INFO

Keywords:
Early intervention
Fidgety movements
General movements
Postural asymmetry
Tone

ABSTRACT

Background: The Prechtl General Movement Assessment (GMA) predicts various neurological and developmental disorders while also documenting therapeutic effects.
Aims: To describe the temporal organization of fidgety general movements in infants with mild to moderate postural asymmetries and/or tonus regulation problems, and to analyze to what extent the temporal organization of fidgety movements will change after physiotherapy.
Study design: Repeated measure design.
Participants: Twelve infants (five females) with mild to moderate postural asymmetries and/or tonus regulation problems were admitted for an early intervention program. The gestational age ranged from 27 to 40 weeks (Median, 36 weeks; nine infants born preterm) with birth weights ranging from 740 g to 3500 g (Median, 2590 g).
Measures: Fidgety movements and their temporal organization were measured using the Prechtl GMA at 9 to 19 weeks post term age (Median, 14 weeks) before and after an early motor training procedure. The movements of one of the infants were analysed using a computer-based approach, measuring the mean and standard deviation of quantity of motion, height of motion and width of motion.
Results: Seven infants had sporadic fidgety movements, and five had intermittent fidgety movements. None had continual fidgety movements before the intervention was initiated. After intervention, the temporal organization of fidgety movements increased in all infants. The observations of these movements were supported by computer-based analysis.
Conclusion: The study indicates that early intervention increases the temporal organization of fidgety movements in infants with postural asymmetries and/or tonus regulation problems. The clinical significance of this finding needs to be further evaluated.

1. Introduction

Spontaneous motor activities are one of the first ways in which young infants experience and interact with the environment. Impaired spontaneous movements are an early indicator of significant developmental difficulties. They can predict more severe conditions like cerebral palsy [1] and neuromuscular or genetic disorders, but can also be related to more benign conditions such as mild developmental delay [2] or developmental coordination disorders (DCD) [3]. It is crucial to differentiate between high-risk and typically developing infants early on. However, it is possibly easier to identify infants with severe impairments than those displaying subtler signs because early symptoms might be more obvious. For infants with less severe impairments, a decision on early intervention often depends on the experience of the examiner and requires a detailed assessment and careful observation.

Early intervention programs are useful due to the growing rate of preterm births and the annual 15% rate of children born with a low birth weight, in addition to occurrences of cerebral palsy and raising

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https://doi.org/10.1016/j.earlhumdev.2020.105197
Received 3 July 2020; Received in revised form 15 September 2020; Accepted 17 September 2020
Available online 19 September 2020

awareness of DCD [1–6]. Numerous studies also provide evidence that early stimulation and an enriched environment can positively impact a developing nervous system, improving outcomes for high-risk infants and their families [5,7–15]. There are a number of reactions and behaviours, which, if displayed during examination, suggest the need for narrowing observations to a cluster of symptoms which can guide a targeted age-specific intervention. These include poor postural control, impaired visual function, atypical tongue movements associated with feeding difficulties, asymmetries in posture and movements, a lack of antigravity movements, or a dysfunction in sensory processing [16–19].

In cases where a young infant receives early intervention, there a dependable tools available to assess immediate effects on movement and whether a proposed procedure has improved his/her motor activity. The Prechtl General Movement Assessment (GMA) [20], applied from birth until the 5th month after term is both a non-intrusive and highly reliable tool. The GMA is a well-documented approach that evaluates the integrity of the nervous system. Not only does it predict various neurological and developmental disorders, particularly cerebral palsy [e.g., [1,20,21]], but it also documents and assesses short-term effects of early intervention programs [22,23]. Specifically, fidgety movements (FMs) are of interest [20,21]. FMs are movements in all directions of an awake infant, including its neck, trunk and limbs, except for when fussing and crying. They are characterized by small amplitude, moderate speed and variable acceleration [24,25]. FMs emerge around 6–9 weeks and are present until approximately 20 weeks at which point intentional and antigravity movements start to dominate [26]. The temporal organization of FMs varies with age: initially, they occur as isolated events; then gradually become more frequent before decreasing at around 16–20 weeks [27]. Infants that meet a typical development milestone at 12–16 weeks display continual (score: F++) or intermittent FMs (score: F+) [25,27–29]. Sporadic FMs (score: F+/−) or their absence (score: F−) would be considered as aberrant and age-inadequate [20,25,30]. Prechtl considered FMs as an age-specific fine-tuning of the proprioceptive system [20].

This study focused on FMs and their temporal organization before and after a session of physiotherapy, which was built upon task-specific exercises and facilitation of child-initiated movements. Infants participating in the study were referred to therapy because of various milder conditions which caused concern to their caregivers. The study aims were (i) to describe the temporal organization of FMs in infants with mild to moderate postural asymmetries and/or tonus regulation problems, and (ii) to analyze to what extent the temporal organization of FMs will change after physiotherapy.

2. Methods

2.1. Participants

The sample comprised twelve infants, seven males and five females, aged 9 to 19 weeks (Median, 14 weeks) post term, who were admitted to the Centre of Early Intervention in Gdańsk, Poland. The infants' gestational age ranged from 27 weeks to 40 weeks (Median, 36 weeks) with birth weights ranging from 740 g to 3500 g (Median, 2590 g). Among the preterm infants, two were born with extremely low birth weight (< 1000 g) and three infants with low birth weight (< 1500 g). Besides the preterm birth of nine infants, there were also other reasons for admission, summarized in Table 1. For all infants, physiotherapy had been recommended by their physician. Of the infants that underwent an ultrasound examination (all but one), none had any signs of brain lesions.

All parents gave written informed consent for the intervention, the video recordings of the general movements and the publication of results. The study received ethical approval from the Ethical Review Board of the Medical Committee in Gdańsk, Poland (KB 23/19).

2.2. Targeted motor training

The aim of the intervention was to improve postural patterns by altering the control of the trunk (adding more stability) and the extremities (building mobility on stable trunk). All actions including visual contact and visual pursuit, guided reaching for an object and arm support were planned in a functional context appropriate for the age of the individual infant. Achieving postural symmetry was of particular importance.

The intervention followed an up-to-date paradigm of motor developmental milestone achievements. The aim was to lessen asymmetry and enhance midline and/or antigravity activities, using the principles of ‘core’ stabilization and its effect on motor actions [31–33]. As a result, an improved postural performance would improve the temporal organization of fidgety movements.

The physiotherapeutic intervention session lasted up to 30 min (for the duration of each session see Table 1) and was carried out by an experienced pediatric physiotherapist. The session consisted of task-specific exercises and facilitation of child-initiated movements [13,34]. First, the most age-adequate and preferred position for the infant was determined. In most cases the initial positions were on the physiotherapist's legs – starting in supine position followed by supported sitting. Thereafter, the infant was guided into the following sequence: prone position followed by supine and then a return to prone position on a mattress. All additional tasks focused on facilitating child-initiated movements and were adapted to the infant's response with respect to repetitions, speed and degree of therapeutic hand support. The therapist used a proprioceptive technique also known as pressure tapping, which consists of a combination of weight bearing and compression through the joint. Its purpose is to build up co-activation of agonists and antagonists to provide a strong sensory input and facilitate the maintenance of postural control and symmetry [35]. Establishing eye contact, talking to the infant with pauses to give him/her time to respond, motivating the infant through toy presentation and tactile stimulation all formed part of a careful interplay between therapists and infant. These actions were undertaken in order to build a safe basis for the infant to co-operate and keep it in a calm, playful mood. Throughout the therapy session, the infant was cued into different activities by maintaining a comfortable position and establishing a connection with its surroundings.

The degree to which infants responded to proprioceptive stimulation differed, with some infants responding immediately and needing less support. As a result, the length of exposure of proprioceptive stimulation and contact with therapist varied. Usually, one proprioceptive stimulation lasted 5 to 12 s and was provided in 6 to 10 sets. Infants also displayed varied reactions to a presented toy. Some needed tactile stimulation of their hand to draw attention to the toy.

2.3. Video recording and assessment of fidgety movements

The spontaneous motility of all twelve infants was videoed for 2 to 3 min before and after their first therapy session. The infants were recorded between feedings during periods of active wakefulness, lying in supine position with wrists and ankles visible [24]. All 24 video recordings were assessed in a random order by three certified evaluators (M.S., L.K., C.E.) using the Prechtl GMA. Two of the evaluators (L.K., C.E.) were not familiar with the participants' clinical histories nor with the sequence of recordings (before vs. after therapy). The temporal organization of FMs was scored as (i) continual (score F++; FMs occur frequently but are interspersed with very short pauses; they involve the whole body, particularly, the neck, shoulders, wrists, hips and ankles); (ii) intermittent (score F+; FMs occur in all body parts, but the temporal organization differs from F++; here, the pauses are prolonged, which creates an impression that FMs are only present during half of the observation time); (iii) sporadic (score F+/−; FMs are interspersed by long pauses; they occur in a few body parts and are never longer

Table 1
Reason for intervention, recording age and temporal organization of fidgety movements (FMs) in twelve 9- to 19-week-old infants with mild to moderate postural asymmetries and/or tonus regulation problems before and after physiotherapy.

Case	Reason for intervention; recording age in completed weeks after term age (corrected for preterm birth)	FMs before intervention	FMs after intervention	Duration of intervention in minutes
A	Preterm birth, asymmetry; 18 weeks	+	+ +	25
B	Extremely preterm birth, postural hyperextension, asymmetry; 14 weeks	+/−	+	21
C	Preterm birth, asymmetry; 9 weeks	+/−	+ +	26
D	Preterm birth, postural hyperextension, distal hypertonia; 14 weeks	+/−	+	30
E	Preterm birth, proximal hypotonia; 13 weeks	+	+ +	29
F	Asymmetry, proximal hypotonia; 18 weeks	+	+ +	30
G	Very preterm birth, proximal hypotonia; 15 weeks	+/−	+	30
H	Preterm birth, asymmetry; 19 weeks	+	+ +	30
I	Preterm birth, postural hyperextension; 10 weeks	+/−	+/+ + [a]	30
J	Preterm birth, proximal hypotonia; 9 weeks	+/−	+	30
K	Asymmetry; 9 weeks	+	+ +	28
L	Postural hyperextension, proximal and distal hypotonia; 10 weeks	+/−	+	30

Temporal organization of fidgety movements is given as +/− = sporadic, + = intermittent, or + + = continual.
[a] No full agreement between evaluators.

than 3 s); or (iv) absent (score F-; FMs not observed) [24,25,28–30]. Where evaluators disagreed, they would re-assess the recordings until consensus on a final score was reached. The evaluators agreed on all but one infant's recordings, (case I, Table 1), though they were of the same view that the infant's FMs' temporal organization had increased.

2.4. Computer-based analysis of spontaneous movements

A recent study has shown that a computer-based approach can be used to identify infants with an absence of FMs [36]. As it was not planned to use this technology at the start of the study, the infants were not recorded using the required standard video set-up for this computer-based approach [37]. Only infant C (two video recordings; C1 and C2) was recorded using the adapted standard video set-up, making it possible to use the computer-based approach to potentially support the findings by visual Gestalt perception.

The video analysis software was described in previous research [37,38]. The video contains 25 frames (video images) per second with a resolution of 1280 × 720 pixels. The computer-based video analysis software uses frame differencing (subtracting pixels in subsequent frames of the video stream) and uses the changes in pixels between frames to create a "motion image". The motion image represents the motion happening between two consecutive video frames in the video stream and can be used to extract quantitative data features and to export qualitative displays. A motion image which contains a matrix of zero changes in pixel values indicates no movement between frames, whereas a matrix of positive values in pixel changes represents movement. The videos allow for quantitative analysis of all types of movements, both FMs and superimposed movements in young infants [26]. The quantitative variables used in this study – Quantity of motion (Q), Height of Motion (HoM), and Width of Motion (WoM) – have been previously used to detect differences between infants with present and absent FMs [37].

Quantity of motion (Q) is calculated for each frame as the sum of all pixels in the motion image with positive values (active pixels indicating movement), divided by the total number of pixels in the image. Therefore, a motion value of 0.50 represents a 50% change of all pixels between frames. The Qmean reflects the mean movement quantity in the video and the Qsd reflects the variability of movement quantity.

Height of motion (HoM) reflects the movement space in a vertical direction from the upper to the lower active pixels. The HoMmean reflects the mean movement space of vertical directions in the video and the HoMsd the variability of movement space. As an example, this can measure vertical limb movements and how they vary within the video. A HoM of 1.0 would mean the infant has fully extended arms and legs in a vertical direction.

Width of motion (WoM) reflects the horizontal movement from the left to the right active pixels. The WoMmean reflects the mean movement of horizontal directions in the video. The WoMsd accounts for variability of movement space, including extension and centering of lateral limb movements. A WoM of 1.0 would mean the infant has fully extended arms in a horizontal direction.

The study uses motiongrams to visualize an entire movement sequence in a video recording and present an overview of spatial and temporal movement information [37].

2.5. Statistical analysis

Statistical analysis was carried out using the SPSS package for Windows, version 22.0 (SPSS Inc., Chicago, IL). The dependent variable "temporal organization of FMs" was measured on an ordinal level (absent, sporadic, intermittent, continual). The paired-sample sign test was used to determine whether there was a median difference between recordings 1 and 2. Quantitative data from the computer-based analysis were exported as Ascii files using a non-real time mode of the software [37]. The estimated mean values and standard deviations for QHoM, and WoM were calculated. The spatial and temporal movement information was presented on vertical and horizontal motiongrams (Figs. 1 and 2).

3. Results

3.1. Assessment of fidgety movements according to standard GMA

The assessments before the intervention showed that five infants had intermittent FMs (F+), and seven infants had sporadic FMs (F +/−). None of them had continual FMs. The temporal organization of FMs increased in all infants after the intervention; the paired sample sign test revealed positive differences in all infants ($p < 0.001$; Table 1). The temporal organization in the "after therapy" video of infant I was assessed as intermittent (+) by one evaluator and continual by the other two (+ +; Table 1). However, all three evaluators agreed that the temporal organization of FMs had increased as it was sporadic before.

3.2. Computer-based assessment of spontaneous movements in infant C

The mean quantity of motion and variability of movements in infant C increased from the first (C1) to the second recording (C2). The mean and variability (sd) of HoM and WoM also increased, which indicate more extended and variable extremity movements (Table 2). The motiongrams show a more continual structure of vertical movements in

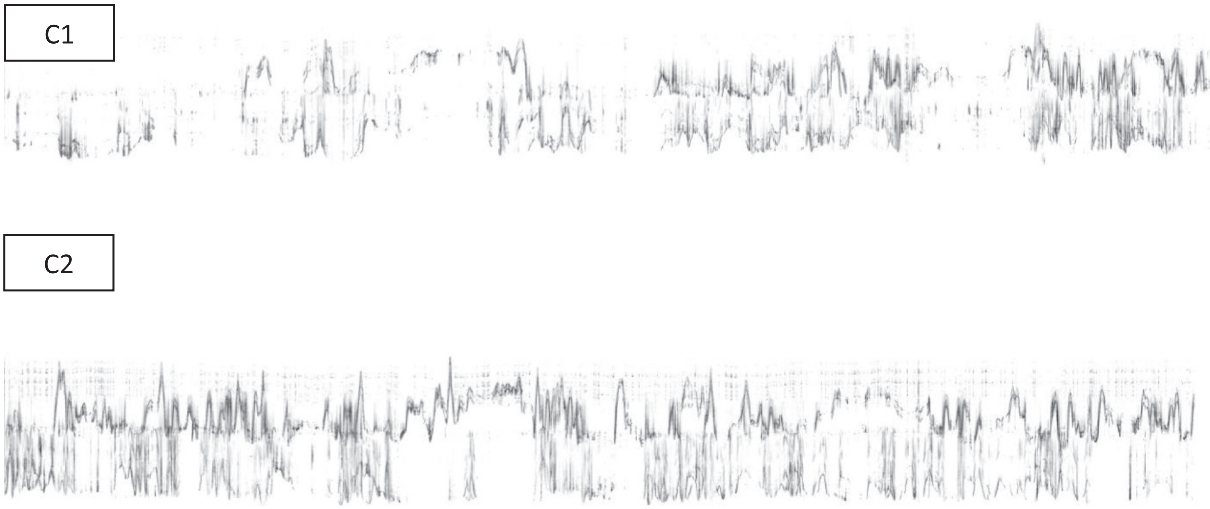

Fig. 1. Motiongrams of vertical movements of infant C before (C1) and after (C2) intervention with time running from left to right. Each motiongram depicts the upper extremities (upper line) and the lower extremities (lower line).

both upper and lower extremities in recording C2 than recording C1 (Fig. 1). Recording C2 shows only one obvious pause in the motion of lower extremities after around a third of the duration of the video. Recording C2 also demonstrates a more continual and intense structure of horizontal movements in upper and lower extremities on both sides of the body compared to recording C1. Recording C1 shows several pauses suggesting less intense motion. Recording C2 reveals a slightly more active motion pattern in the right arm/leg in the first half period of the video (Fig. 2).

4. Discussion

A small sample of infants with mild to moderate postural asymmetries and/or tonus regulation problems were studied, and seven out of the twelve infants observed displayed sporadic FMs. This was an unexpected result as none of the infants had a pathological cranial ultrasound finding. Sporadic FMs are considered to be aberrant [24,25,39] and are usually observed in infants later diagnosed with cognitive, language and/or motor delays [39–42] including cerebral palsy [21,30,41]. It is possible that four of those seven recorded infants with sporadic FMs were too young (i.e., 9 or 10 weeks after term; Table 1), as the best age to score FMs is 12 to 16 weeks [27]. Regardless, targeted motor training resulted in an immediate beneficial effect: the temporal organization of fidgety movements increased in all infants whether they had sporadic or intermittent FMs beforehand. The results of the computer-based analysis applied to one of the infants confirmed the observations' outcomes. In addition, the findings show that the Prechtl GMA can be used to evaluate short-term physiotherapeutic effects.

Studies covering the effects of intervention on general movements are still scarce [10,15,22,23,43]. The study by Fjørtoft et al. [10] of 130 preterm infants (of whom 59 were in the control group) is one of them. The therapy was performed by the parents of infants staying in the NICU. The intervention consisted of handling techniques according to each infant's needs in different positions with respect to their behavioral state, for 10 min, twice a day. The study reported no significant alteration of FMs [10]. Two other research groups demonstrated different results. Although very small in number of infants, Soloveichick and colleagues reported an improvement of general movements at 3 months due to imitating normal general movements at late preterm, term and early post-term ages [23]. Similar results are shown by a Chinese study on a considerably larger number of preterm born infants receiving various interventions, first by a hospital nurse and after discharge by trained parents [43].

To date, this study is the only one to focus on immediate alterations of FMs, demonstrating a significant improvement on the temporal organization of FMs in all participants. Seven infants particularly benefitted, as their FMs changed from sporadically present to intermittently or continuously present after the intervention. These changes in the temporal organization of FMs coincided with an improvement in postural patterns. Improved temporal organization of FMs results in better head control and a symmetric body posture enables the infant to better interact with his/her environment, which might create a better basis for both psycho-motor development and the infant's positive engagement during interactions with the care-giver [44].

The extent to which an intervention can lead to change in FMs varies depending on its duration, the type of intervention and the professional background of the provider [10,23,43]. In addition, the length of time between intervention and assessment of its benefits might play a role. In this study the intervention lasted up to 30 min, and it was supported with proprioceptive stimulations in various positions, focusing on age-specific motor function and was carried out by an experienced physiotherapist. The infants were filmed immediately before and after the physiotherapy session if the infant's behavior allowed it. None of the infants were fussy or crying. The sustainability of the changes in the temporal organization of FMs was also not part of the scope of the research. Certainly, future studies should repeat the use of the GMA to assess potential longer lasting effects.

It is very important to underline that the infants in our study were not considered to be at high risk for neurological or developmental disorders and their brain images did not show any pathologies. It appears unlikely that an infant with a brain lesion and showing no FMs would respond similarly to such an intervention.

4.1. Limitations

There are several limitations to this study, one of which is the considerably small sample size. Second, with this study design it is unclear whether temporal organization would also be altered after 30 min without any intervention. However, as Mutlu et al. [45] have shown that the intra-individual consistency of FMs is almost perfect (Fleiss Kappa 0.92), we are assuming a stable appearance of FMs over time in a non-intervention group. This should be accounted for in a larger scale study. Originally, there was no plan to use the computer-based tool which is why there are only results for one infant. In a replication study this tool should be used with all participants. The approach used here dates back to 2010 [38], however new assessment methods are now available for research, including, multi-sensor-based

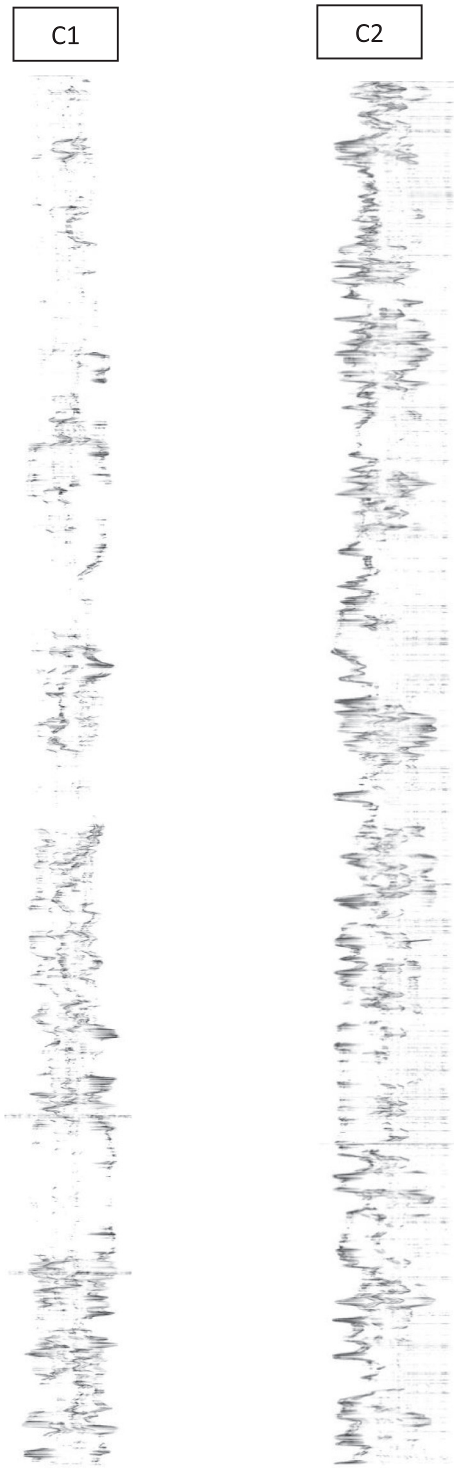

Fig. 2. Motiongrams of horizontal movements of infant C before (C1) and after (C2) intervention with time running from top to bottom. Each motiongram depicts the upper extremities (left line) and the lower extremities (right line).

[e.g., [46]] or markerless approaches [e.g., [47,48]]. The application of an up-to-date, standardized assessment for posture and motor performance (such as the Hammersmith Infant Neurologic Examination) would also be useful as the improvement of FMs might be related to postural organization. Finally, a follow-up examination would be needed to document the duration of beneficial effects. These limitations definitely raise the need for a replication study with a larger sample.

Table 2
Estimated computer-based video analysis values for case C before (C1) and after therapy (C2).

Computer-based variables	Recording C1	Recording C2
Qmean (%)	0.28	0.56
Qsd (%)	0.58	0.84
HoMmean	0.29	0.44
HOMsd	0.25	0.27
WoMmean	0.22	0.35
WoMsd	0.25	0.27

Key: Q = quantity; sd = standard deviation; HoM = height of motion; WoM = width of motion.

5. Conclusion

This study reveals a favorable short-term effect of physiotherapy on the temporal organization of FMs in infants with mild to moderate postural asymmetries and/or tonus regulation problems. The computer analysis of general movements appears to be a valuable tool for the assessment of such alterations. Due to the small sample size, these results should be interpreted with some caution and need to be verified with a larger group of infants.

CRediT authorship contribution statement

Michal Sokołów: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Resources, Writing - original draft. **Lars Adde:** Methodology, Software, Formal analysis, Investigation, Writing - review & editing. **Liliana Klimont:** Methodology, Formal analysis. **Ewa Pilarska:** Supervision, Project administration. **Christa Einspieler:** Formal analysis, Writing - review & editing, Supervision.

Declaration of competing interest

One of the authors (C.E.) is a tutor for the Prechtl General Movement Assessment. It is a tool used in our study to assess the change in infant motility. All other authors have no declaration of interest.

Acknowledgements

We are grateful to the children and parents for their compliance and cooperation; to Mrs. Malgorzata Halon-Golabek for her continuous support; to the Centre of Early Intervention in Gdańsk for kindly providing the infrastructure for this study; and to Ms. Anna Marcinkiewicz for English editing.

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