The ontogeny of fidgety movements from 4 to 20 weeks post-term age in healthy full-term infants

Fabrizio Ferrari a,⁎, Rossella Frassoldati a, Alberto Berardi a, Francesca Di Palma b, Luca Ori a, Laura Lucaccioni a, Natasca Bertoncelli a, Christa Einspieler c

a Neonatal Intensive Care Unit, Department of Medical and Surgical Sciences of the Mother, Children and Adults, University of Modena and Reggio Emilia, Modena, Italy
b Division of Pediatrics, Department of Health Sciences, University of Pernumonte Orientale "Amedeo Avogadro", Novara, Italy
c Research Unit iDN – Interdisciplinary Developmental Neuroscience, Institute of Physiology, Center for Physiological Medicine, Medical University of Graz, Graz, Austria

ARTICLE INFO

Article history:
Received 9 August 2016
Received in revised form 4 October 2016
Accepted 11 October 2016

Keywords:
Ontogeny
Fidgety movements
General movements
Full-term newborn

ABSTRACT

Background: Fidgety movements (FMs) are an early accurate marker for normal development.

Aim: The study assessed the ontogeny of normal FMs from 4 to 20 weeks post-term age (PTA).

Study design: Longitudinal prospective study of healthy full-term infants video recorded every second week from birth to 20 weeks PTA.

Subjects: 21 full-term newborns were enrolled.

Outcome measures: Temporal organization, amplitude, character, predominance in proximal and/or distal parts of the body and the presence of FMs in fingers and wrists were independently scored by three observers.

Results: From 4 to 10 weeks PTA, FMs were sporadic, becoming intermittent in 1–2 weeks; they occurred in the proximal parts, with larger and jerky movements in the following period. From 11 to 16 weeks PTA FMs became smaller in amplitude and slower in speed, they were present in all body parts and were more continual than before. Rotational movements in wrists and ankles and finger movements with open hands appeared. From 17 to 20 weeks PTA, FMs became more discontinuous and disappeared at 18–20 weeks PTA.

Conclusions: Developmental course of FMs was seen between 4 and 20 weeks PTA with changes in temporal organization, amplitude, speed and body parts involved. The best time for scoring FMs is between 12 and 16 weeks PTA.

© 2016 Published by Elsevier Ireland Ltd.

1. Introduction

Thirty years ago, Prechtl and Hopkins described the changes in the quality of general movements during the first months after term age [1,2]. General Movements (GMs) emerge in foetal life at 9 to 12 weeks postmenstrual age [3], and maintain their characteristics for several weeks after birth. At term age and during the first two months post-term, GMs are commonly described as having a writhing character in view of their elliptical form [4,5]. At 6 to 9 weeks post-term age (PTA) writhing movements disappear while so-called “fidgety movements” (FMs) gradually emerge [6,7]. FMs, according to their classical description, are small movements of moderate speed and variable acceleration involving the neck, trunk and limbs; they occur in all directions, and are continual in the awake infant except during fussing and crying [8]. It has been assumed that different central pattern generators (CPGs) generate GMs of a writhing versus fidgety character. Both are likely to be modulated by corticospinal or reticulospinal pathways and therefore can be affected by an impairment of these structures. A normal quality of GMs, and of FMs in particular, is lost in the case of brain lesions. Disruption of the corticospinal projection due to periventricular leukomalacia or intraparenchymal infarcts typical of preterm infants, as well as disruption of the corticothalamic and thalamocortical projections due to hypoxic-ischaemic insult found in severe asphyxia in full-term infants, lead to abnormal GMs [9]. In the last few decades, FMs have demonstrated to be a particularly accurate marker for the neurological outcome of the high-risk infants. Recent systematic reviews and meta-analyses have recognized the qualitative analysis of GMs, according to Prechtl’s method, to be equally powerful or even more powerful than classical neurological examination and neuroimaging findings [10]. Among the various GMs abnormalities, Einspieler C et al. defined an abnormal quality of fidgety movements is highly predictive, particularly of cerebral palsy [9,11,12] and minor neurological dysfunctions at school age [13,14] and consist on absent fidgety (F−) when FMs are never observed in the period from 9 to 20 weeks, abnormal fidgety (AF) when their amplitude, speed and jerkiness are exaggerated and sporadic

Abbreviations: FMs, fidgety movements; PTA, post-term age; GMs, general movements; CPGs, central pattern generators; F, absent fidgety; AF, abnormal fidgety; P, proximal; D, distal.

⁎ Corresponding author at: Neonatal Intensive Care Unit, Department of Medical and Surgical Sciences of the Mother, Children and Adults, University of Modena and Reggio Emilia, Via del Pozzo n. 71, 41124 Modena, Italy.
E-mail address: fabrizio.ferrari@unimore.it (F. Ferrari).
FMs (F+/−) characterized by isolated fidgety bursts of 1 to 3 s, interspersed with long pauses of up to 1 min. Sporadic FMs is considered normal only when found between 6 and 8 weeks and during the 5th month when FMs fade out [7].

Despite the great clinical impact of FMs on the diagnosis of cerebral dysfunction and outcome, only a few studies have specifically focused on the development of FMs [2, 5, 6, 15]. We need to know when FMs reach their optimal expression in order to facilitate the recognition of this movement pattern. The present study aims to evaluate the ontogeny of FMs in a group of healthy full-term infants who were monitored with video recordings performed every second week from birth to 16–20 weeks post-term age.

2. Methods

2.1. Participants

The study is a longitudinal observational study on the ontogeny of FMs. It is a two centres project involving the NICU of the University of Modena and the “Institute of Physiology” of the Medical University of Graz. The infants were born at the Department of Obstetrics and Gynaecology of the Modena and Graz University Hospitals. The selection criteria for enrollment were birth at term (38 to 41 weeks postmenstrual age – PMA), an appropriate birth weight (between 10’th and 90’th centile for gestational age according to the Italian reference growth charts [16]), no pre- or perinatal complications and a 1- and 5-min Apgar score of at least 9 and 10, respectively. All infants were found to be normal on neurological examination at birth. Twenty-one infants (10 girls and 11 boys) were recruited soon after birth in Graz and in Modena (autumn 2010). The families had given their informed consent to participate in the study according to the standards of the local research committee.

2.2. Video recording and analysis of fidgety movements

All infants were recorded during active wakefulness while lying supine in a cot. A single camera was installed high above the cot to provide an optimal (mid-sagittal) view of the infant. The infants were wearing a small nappy and a short-sleeved bodysuit and had been fed one hour before the observation session. The infants were recorded without any external stimulation for approximately 10 min to ensure that there would be enough material for analysis. The mother was asked to be present in case the infant became fussy. The first video recording was made at two weeks after birth and the recordings were repeated at two-week intervals until the 20th week of life. There was a median of 9 videos per case (range 5–10). Movements were scored for the first 2 min of each video. FF, CE and RF evaluated all recordings separately offline according to the methods described by Prechtl et al. [6], there was high interobserver agreement (Cohen’s kappa 0.92). When the evaluators disagreed on the description of an infant, the infant’s record was re-evaluated and in all cases a consensus was reached on a final score.

The infants were video recorded every second week and the analysis was based on the post-term age of the infant. Two types of analysis – global and detailed – were performed on the video recordings. Global analysis consisted in an assessment of fidgety movements according to standard methodological principles for the qualitative assessment of general movements [Prechtl’s method] and the temporal organization of FMs was scored according to Einspieler et al. [8, 17] as follows: Continued FMs (score +++) FMs occur frequently but are interspersed with short pauses; Intermittent FMs (score +) the pauses between FMs are prolonged, giving the impression that FMs are present for only half the observation time; Sporadic FMs (score +/−) FMs are interspersed with even longer pauses.

The detailed analysis included an assessment of individual aspects of FMs such as amplitude, character, proximal or distal joint involvement and hand and finger movements. The analysis was performed when FMs appear at least intermittently over time. For the purpose of this qualitative assessment, each video was observed several times by the examiners (FF, CE, RF) whereby the last session was specifically dedicated to assessing hand and finger movements. For FMs we scored the following details: Amplitude: the predominant amplitude of FMs was evaluated. By definition, FMs are small movements but they can have a different range of motion in each joint. A score of + + + identified a larger range of motion in most of the joints; a score of + was given for fine and tiny movements with a lower range of motion in most of the joints. When both ranges were present almost equally, a score of ++ was given to indicate variability. Fidgety character: the predominant character of FMs was evaluated. A score of + + + identified a predominantly jerky character of FMs; a score of + was given for a predominantly smooth character of FMs. When both characters were present, a score of ++ was given. Proximal/distal: the predominant localization of FMs was also ascribed a score. Proximal (P) was used when FMs were predominant in the trunk and proximal joints, P/D when FMs occurred to an equal degree in the distal and proximal body parts, and Distal (D) when fidgety activity was predominant in the wrists, fingers and ankles. Finger and wrist movements (score of the best performance): a score of 0 was given in the case of fisting accompanied by few wrist movements; a score of 1 for simultaneous opening and closing of fingers, sometimes accompanied by slow wrist movements; a score of 2 for isolated finger movements accompanied by wrist movement (rotation, palmar flexion and extension and ulnar or radial flexion); a score of 3 for sequential movements of fingers accompanied by wrist movements (as in 2); and a score of 3 + for sequential and isolated finger movements (as for exploration) accompanied by wrist movements (as in score 2).

2.3. Statistical analysis

Data were analysed using Stata 13.1 (StataCorp LP). Pearson correlation was applied to check the association between the age of onset and the several components of FMs.

3. Results

The first video recording was made at 2 weeks PTA. All infants showed normal writhing movements at the time of the first recording but not yet fidgety movements.

3.1. Onset and temporal organization of FMs

FMs occurred for the first time between 4 and 8 weeks PTA (median 6 weeks). The overall length of the period when FMs were observable varied between 8 and 16 weeks (median 12 weeks). The temporal organization of FMs changed during the study period from sporadic to intermittent to continual and back to intermittent and/or sporadic.

At their onset, FMs were sporadic in 18 infants and intermittent in 3 infants (cases 2, 8 and 15). As there was a two-week interval between recordings, the latter three infants may also initially have had sporadic FMs. All babies but one (case 9) with initial sporadic FMs later showed intermittent FMs, followed by continual FMs. No 6-week recording is available for case 9. Continual FMs started between 8 and 14 weeks PTA (median 10) and were present in all infants between 12 and 14 weeks. The median duration of continual FMs was 6 weeks. The disappearance of FMs seemed faster than the emergence, as it took place over 2 to 4 weeks and showed an inverse trend: continual FMs were most often followed by intermittent and/or sporadic fidgety movements and later by the absence of FMs. Only 11 babies were video recorded at 18 weeks: at this age none had continual FMs, whereas 3 had intermittent, 6 sporadic and 2 no FMs anymore (Fig. 1).
3.2. Amplitude of FMs

At their onset, FMs showed a larger range of motion in most of the joints (++) in the majority of infants (16/21). Between 2 and 4 weeks after their onset some smaller FMs appeared and larger and smaller FMs coexisted in general for a median period of 2 weeks (range 2–6 weeks). Finally, at 10 to 14 weeks PTA (median 12) small, fine FMs were predominant. These tiny elegant movements lasted for a median of 4 weeks. This small amplitude was observed in 10 infants until the last video recording, while 7 infants returned to a more variable amplitude during the late period (Fig. 2).

3.3. Character of FMs

The character of FMs changed in all infants but one (patient 19). At their onset, FMs were jerky in 12 out of 21 infants. Over time (6 to 12 weeks), jerkiness decreased and a smooth character eventually prevailed. The period with the most fluent and smooth FMs was between 10 and 16 weeks PTA, with two infants (cases 6 and 7) showing a smooth quality of movement even at 18 weeks. The median duration of the smooth character was 4 weeks (range 2 to 6 weeks). During the late period a more variable character of FMs usually reappeared (Fig. 3).

3.4. Proximal/distal fidgety movements

At their onset, FMs were limited to the proximal parts of the body (neck, trunk and proximal joints) in all infants but 2 (cases 9 and 19). After 2 to 6 weeks (median 4 weeks) FMs also involved distal joints. At this stage (starting between 8 and 14 weeks PTA), FMs occurred in proximal and distal body parts almost equally. Around 14 weeks PTA (range 12 to 16 weeks), FMs prevailed in the distal joints during a period of 2 to 6 weeks (median 4 weeks). In the late period, FMs were
predominantly distal in 12 infants while present in both proximal and distal parts in 5 children (Fig. 4).

3.5. Finger and wrist movements

Usually, fisting of the hands and/or simultaneous opening and closing was no longer present after 10 weeks PTA; on the other hand, in all but one infant (case 14) sequential and/or isolated finger movements did not occur before 12 weeks.

While FMs prevailed at the proximal joints, finger and wrist movements were usually faint and isolated. When FMs emerged and became prevalent in the distal joints, wrist movements became richer and variable, sequential finger FMs were continual or subcontinual (Fig. 5).

When FMs became continual, they were usually very small in amplitude. Such tiny FMs were statistically correlated to the appearance of predominantly distal FMs. A smooth character of FMs was significantly associated with a greater involvement of distal body parts and more variable sequential finger movements (Table 1).

4. Discussion

Despite minor interindividual variations in the timing and sequence of the various features, a clear and consistent developmental course of FMs emerged from the study. In the first period (4 to 11 weeks PTA) FMs were initially sporadic; soon afterwards, over a period of 1 to 4 weeks, they became intermittent, larger and often jerky, and occurred predominantly in the proximal parts. In the middle period (12 to 16 weeks PTA) FMs became smaller in amplitude and smoother in character. They were present in all body parts, continual and occurred predominantly in the distal parts. Rotations in the wrists and ankles and a variety of finger movements enriched the motor repertoire. The study confirmed that this is as the ‘golden age’; FMs are finer and more fluent, continual and elegant. In the last period (17 to 20 weeks PMA) FMs became less continual, more variable in amplitude and less smooth; they disappeared between 18 and 20 weeks PMA.

How neural functions change, how the different neural functions are related to one another at any specific time and when these changes occur are central issues in developmental neurology [2]. Knowledge of these changes is of key importance for understanding neural
development and helps clinicians to choose the best timing for follow-up checks. The assessment of the quality of FMs has come to play a major role in the neurological examination of high-risk infants during the first months after birth.

The high predictive value of FMs in relation to neurological outcome has been repeatedly confirmed. The emergence and full expression of FMs occur in the period from 2 to 4 months post-term [4,6]; this is also a period of major neurological transformations. The change in the pattern of GMs from writhing to fidgety coincides with a set of changes in the neurological repertoire, including an increase in muscle power, postural control (head maintained in the midline), vision (steady fixation and brisk orienting) social responsiveness (smiling and cooing), state and sleep organization (sleep-wakefulness cycles and circadian rhythms) [8].

This period is ideal for assessing the neurobehavioral repertoire and predicting outcome in high-risk infants [9–12]. A thorough knowledge of these changes and of the normal timing and development of fidgety movements in particular is therefore valuable. Three previous studies described the development of FMs, but the intervals between the video recordings were longer than in the present study [2,5,6]. Moreover, none of these studies followed the infants until 20 weeks PTA. Prechtl and Hopkins concluded that FMs were almost constantly present at the age of 8–12 weeks [2]. In the Manual on the Prechtl GM assessment, Einspieler et al. [8] stated that FMs “may be seen as early as 6 weeks but usually occur around 9 weeks and are present until 20 weeks”. At least one recording between 9 and 15 weeks post-term is recommended and in an absence of FMs a second recording at 12 and 15 weeks is also advisable. The best time for assessing FMs is considered to be either 10 or 12 weeks post-term age [11].

Bruggink et al. [13,14] are the only authors to have evaluated the quality of FMs and of the concurrent motor repertoire more than once – namely, three times – during the fidgety periods in a group of preterm infants. They distinguished an early-FM period (6 to 10 weeks), a mid-FM period (11 to 16 weeks) and a late-FM period (17 to 24 weeks) but they did not explore the developmental course of FMs, nor did they include a group of healthy full-term infants. Einspieler et al. described the temporal organization of FMs and found that they initially occur as isolated events before gradually increasing in frequency [4,8,17]. The present study, based on video recordings made of 21 healthy full-term infants every second week, is novel in that it investigates the ontogeny of FMs. Three periods of FMs were recognized and these corresponded quite closely to the three periods proposed by Bruggink et al. [14] in their study on preterm infants.

A number of clinical implications emerge from the study. First, the best time for assessing FMs is between 12 and 16 weeks PTA, slightly later than previously suggested. If the follow-up protocol of a centre provides for only one session during the age of FMs, a PTA of 13–14 weeks is ideal.

A second implication is that FMs should be assessed at least two times during the fidgety period in order to identify the developmental trajectory of FMs. The first assessment could be done at 10 to 12 weeks and the second one at 14 to 16 weeks. The two assessments may reduce the risk of missing a delayed appearance of FMs. If a second (or a third) video will not be possible for logistic or family reasons, the suggestion is to collect home videos recorded by the parents themselves. Considering the functions offered by smartphones and digital cameras nowadays, it would be easy to instruct parents to make video recordings of their baby.

A third implication is the similarity between FMs when they first emerge and two abnormal patterns of FMs such as exaggerated fidgety (AF) and sporadic fidgety (F+/−). AF is sometimes difficult to recognize because the exaggerated amplitude and jerkiness typical of this pattern create a similar impression than normal FMs in their first appearance (that is larger amplitude). Sporadic fidgety (F+/−) at 6 to 8 weeks after term may be normal, as FMs occur as brief and isolated events. At 12 to 16 weeks PTA however, sporadic FMs are age-inadequate and it was recently shown that they can be equally considered an early marker of CP as absent FMs [17]. At the time of onset, distinguishing normal FMs from these two abnormal FM patterns may be difficult and require a follow-up assessment: a second or third check on GMs during the mid- or late fidgety period can provide an answer to the question as to whether the quality of the FMs is normal or abnormal.

Table 1

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Continual FMs</th>
<th>Tiny FMs</th>
<th>Smooth FMs</th>
<th>Distal FMs</th>
<th>Pattern 3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continual FMs</td>
<td>/</td>
<td>0.56*</td>
<td>0.07</td>
<td>0.24</td>
<td>0.04</td>
</tr>
<tr>
<td>Tiny FMs</td>
<td>/</td>
<td>0.39</td>
<td>0.65*</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Smooth FMs</td>
<td>/</td>
<td>0.62*</td>
<td>0.01*</td>
<td>0.57*</td>
<td></td>
</tr>
<tr>
<td>Distal FMs</td>
<td>/</td>
<td>0.57*</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

Fig. 5. Finger and wrist movements. When FMs emerged and became prevalent in the distal joints, wrist movements became richer and variable, sequential finger FMs were continual or subcontinual.

Table 2

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Continual FMs</th>
<th>Tiny FMs</th>
<th>Smooth FMs</th>
<th>Distal FMs</th>
<th>Pattern 3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continual FMs</td>
<td>/</td>
<td>0.56*</td>
<td>0.07</td>
<td>0.24</td>
<td>0.04</td>
</tr>
<tr>
<td>Tiny FMs</td>
<td>/</td>
<td>0.39</td>
<td>0.65*</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Smooth FMs</td>
<td>/</td>
<td>0.62*</td>
<td>0.01*</td>
<td>0.57*</td>
<td></td>
</tr>
<tr>
<td>Distal FMs</td>
<td>/</td>
<td>0.57*</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>
The study has several limitations. The data reported in our study are not based on computer analysis but on visual pattern recognition, that is Gestalt perception. Recently, the computer-based analysis was able to demonstrate more details about FMs: not only the presence versus absence of FMs, but also differences between intermittent to continual FMs, although to date the Gestalt perception remains the most used method [18,19]. A few attempts are currently underway and this limitation may be overcome in the future. Another limitation is related to the fact that video recordings in the late FMs period are lacking for 9 infants; when the study was originally planned, it was decided to go only as far as 16 weeks PMA. After the first infants were video recorded, we realized that it was worthwhile to prolong the duration of the study and therefore 11 out of the 21 infants included in the study had recordings as far as 60 weeks PMA. We are planning to recruit new babies at 60 weeks.

We also have to be cautious with generalizing our results as the sample size is not very large. Recruitment of more healthy infants of different care-giving background might shed more light into inter-individual variations.

5. Conclusions

In conclusion, a clear and consistent developmental course of FMs was observed between 4 and 20 weeks PTA, with changes occurring in temporal organization, amplitude, character and body part involvement. The developmental course may be broken down into three distinct periods: early (4 to 10 weeks), middle (11 to 16 weeks) and late (17 to 20 weeks), each of them associated with specific features. In the early period, because of the sporadic temporal organization, large amplitude and jerkiness of fidgety movements, normal FMs may be confused with abnormal (AF) or sporadic fidgety (F+/-) FMs. Hence, the optimal time for scoring FMs is between 12 and 16 weeks PMA.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors have indicated they have no potential conflicts of interest to disclose.

Acknowledgements

We thank the children and parents who participated in the study.

References