Load perturbation does not influence spontaneous movements in 3-month-old infants

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Abstract

Background: The assessment of the quality of general movements (GMs) in young infants is a reliable and valid diagnostic tool for detecting brain dysfunction early in life. Of special interest is a type of GMs called fidgety movements (FMs) characteristic for 3- to 5-month-old infants. GMs are part of an infant’s spontaneous motor repertoire and as such endogenously generated by the nervous system. Visual, acoustic and social stimuli hardly had any influence on FMs. Aim: Our main purpose was to find out whether FMs are sensitive to load perturbation. Study design: Spontaneous motility in supine position, with and without weighting was recorded on video and the data were semiquantitatively analysed. Weights were attached to the ankles and wrists of all four limbs; on one side of the body only; or without visual feedback of the weighted arm. Subjects: We studied 29 healthy infants with normal FMs at the age of 12 weeks. Results: Spontaneous motility remained symmetrical during all the experimental trails. Weighting had no influence on the quality or temporal organisation of FMs. Conclusion: This study demonstrated that the mechanisms responsible for FMs in 3-month-old infants are all but impervious to weight perturbation, at least not with the loads studied. FMs is the stable and predominant motor pattern of this age.

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Keywords: Fidgety movements; Proprioceptive system; Sensory stimulation; Neurology; Weight perturbation

1. Introduction

Overwhelming evidence, based on animal studies, is presently available to prove that rhythmic spontaneous movements are endogenously generated by so-called...
Central Pattern Generators (CPG) [1–3]. Most CPGs consist in part of bistable neurons which generate self-sustained oscillations of membrane potentials and act as pacemaker-like structures [4]. Well-known examples of CPGs in the developing human organism are the central mechanisms for rhythmic motor patterns such as sucking, chewing, breathing movements and locomotion. The human fetus and young infant, however, also display a number of nonrhythmical movement patterns that have all the characteristics of being endogenously generated, i.e. there is no recognisable external stimulus. Prechtl [4] suggested that in these cases the generating neural mechanisms should also be called CPGs because these nonrhythmical spontaneous motor patterns are constant in form, and therefore, easily recognisable whenever they occur. Such spontaneous movements are present continuously from the 8th post-menstrual week [5] until about the end of the first half year of life [6]. They are patterned and highly coordinated right from the beginning [7]. A case in point are the so-called general movements (GMs). GMs are gross movements involving the whole body in a variable sequence, intensity, force and speed and their onset and offset is smooth [8]. Because of their complexity, frequent occurrence and long duration they are ideally suited for quality assessment. It has been demonstrated repeatedly that the quality of GMs changes if the developing nervous system is impaired (for a review see Ref. [9]).

In particular, fidgety movements (FMs), the type of GMs characteristic at 3 to 5 months, have proved to be highly prognostic for later neurological deficits [10–13]. Fidgety movements (FMs) are circular movements of small amplitude, moderate speed and variable acceleration of neck, trunk and limbs in all directions. They may occur together with other gross movements such as kicking, wiggling-oscillating, swiping arm movements, movements towards the midline and antigravity movements [10,14]. Because of their high validity, FMs and their generation and modulation are of great importance for our understanding of the young nervous system. A previous study showed that visual, acoustic and social stimulation hardly influenced FMs [15]. Our aim now was to stimulate the proprioceptive system by weighting the limbs and to study the effect of weighting on FMs.

We addressed the following questions:

- Does load perturbation on all limbs influence the quality and temporal organisation of FMs?
- Does one-sided weighting influence FMs and if so, is it related to increasing weight?
- Do FMs change under two artificial conditions, i.e. weighting, and no visual feedback of the weighted arm?

2. Subjects and methods

2.1. Subjects

In September 1998, a longitudinal study on normal development was launched at the Department of Physiology, Graz University, Austria. The children were born at the Department of Obstetrics and Gynaecology of the Graz University Hospital. The
selection criteria for enrolment were birth at term, an appropriate birth weight, no pre-
or perinatal complications and a 1 and 5 min Apgar score of at least 9 and 10, respectively. All families belonged to the middle or upper social class, and lived in or close to Graz. Between November 1998 and January 1999, 33 infants (16 girls and 17 boys), whose families had given their informed consent to participate in the study according to the standards of the local research committee, were 12 weeks old. All but two of these infants were found to be neurologically normal [16,17] and had normal FMAs at their 3-month examination [10]. Extensive crying led to the exclusion of another two infants. Finally, 29 infants (13 girls and 16 boys) took part in the various trials with different sensory stimulation during spontaneous movements. The results of the visual, acoustic and social stimulation study have already been reported [15].

Despite the fact that all infants were born around term (38 to 42 weeks postmenstrual age, PMA), their age was corrected for their PMA at birth. Thus, the median age at the time of observation of the FMAs was 11 weeks post term age (PTA) (IQR: 10–12 weeks, range 9–14 weeks).

2.2. Video recording and analysis of fidgety movements

All infants were recorded during active wakefulness while lying supine in a cot in the observation room. A single chip camera was installed high above the cot to avoid attracting the infant’s attention and to provide an optimal (mid-sagittal) view of the infant. The infant was observed continuously on a monitor outside the recording room by one of the examiners, and the infant’s mother. The infants wore a small nappy and a short sleeved bodysuit and they had been fed for the last time about an hour before the observation session [18]. The infants were first recorded without any external stimulation for approximately 2 min. This provided us with a baseline for the temporal organisation and the quality of the FMAs. After the baseline recording, we studied the effect of visual and acoustic stimulation [15] followed by various specific conditions of weighting. The interval between the various experimental trials was 30 s, but had to be adjusted for some infants according to their behavioural state. All the recordings were analysed off-line by both authors separately. Our interscorer agreement was 98%.

As previously reported by Dibiasi and Einspieler [15], the temporal organisation of FMAs was scored as follows:

Continual FMAs (score: ++): FMAs occur frequently but are interspersed with short pauses. As FMAs are by definition GMs, the movements involve the whole body, particularly the neck, trunk, shoulders, wrists, hips and ankles. Depending on the actual body posture, in particular the position of the head, FMAs may be expressed differently in the different body parts.

Intermittent FMAs (Score: +): although FMAs occur regularly in all body parts, the temporal organisation differs from FMAs ++. In fact, the pauses between FMAs are prolonged, giving the impression that FMAs are present for only half the observation time.
Sporadic FMs (Score: +/−): sporadic FMs are similar to FMs + but interspersed with even longer pauses. Thus, FMs may still be observed in all body parts but intermittently and localised.

In all three examples of the different temporal organisations of FMs, gross movements may occur together with FMs in the following ways: FMs may be superimposed on gross movements or gross movements may occur during the pauses between FMs, or both.

Absent FMs (Score: −): no FMs are observed, although some gross movements may occur.

The quality of FMs was assessed according to Prechtl’s method of qualitative assessment of GMs which is based on visual Gestalt perception (for a recent review see Ref. [9]). In addition, any gross movements concurrent with FMs were noted.

2.3. First experiment: all limbs weighted

Eight randomly chosen infants (five girls, three boys) participated in this experiment. For weights, we used small lead pearls (used for weighting a fishing line) that were sewn onto an elastic cotton bracelet with a Velcro fastener. A bracelet with one lead pearl weighed 14 g. One of the experimenters (either J.D. or C.E.) fastened a bracelet around the infant’s ankles and around his/her wrists. While fastening and removing the bracelets, the experimenter was careful to engage the infant as little as possible. The median duration of stimulation was 65 s (IQR: 61.5–68; range: 38–90). The quality and temporal organisation of FMs were assessed 10 s before, during and after stimulation.

2.4. Second experiment: one-sided weighting

Twenty-three infants (9 girls, 14 boys) took part in this experiment. We used the same material as in the first experiment, but we increased the weight by sewing up to four lead pearls onto one bracelet and using up to three different bracelets. The maximum weight was obtained by using three bracelets with four pearls each. Thus we could use weights of 14, 22, 32, 40, 54, 63, 72, 80, 94, 100, 110 and 120 g. The experimenter fastened the bracelet(s) around one of the infant’s ankles and wrists on either the right or on the left side of his/her body. Due to the infants’ behavioural states, each experimental trial turned out to have a different number of subjects (the least was two infants, the maximum was 21). The interval between the different trials was 30 s. The side of the body, sequence and load were randomly chosen. The median duration for each load varied between 31 and 86 s. FMs were assessed as described above.

2.5. Third experiment: no visual feedback of the weighted arm

Six randomly chosen infants (two girls, four boys) participated in this experiment. We fastened the bracelet around the infant’s right or left wrist. To prevent visual feedback of the weighted arm, we placed a cardboard screen covered with pink terry cloth over the infant’s arm. The screen did not restrict the infant’s movements. We studied the effect of 40, 72 and 100 g in various infants, either on the left or on the right side of the body with a
median duration between 66 and 100 s. The quality and temporal organisation of FMs were assessed as described.

3. Results

During the 2-min baseline recording, continual FMs were observed in the majority of infants (n = 17; 59%). Twelve infants (41%) had intermittent FMs. For 22 infants, the temporal organisation of FMs in the baseline recording and in the sequence before the different experiments was the same. For the remaining seven infants, the temporal organisation of FMs varied between the baseline recording and the sequences before the different experiments. The quality of FMs did not change during any of the experiments.

Besides FMs, the other movement patterns we observed were: kicking [19], swipes [14], wiggling-oscillating [14], saccadic arm movements [14], hand–hand contact, hand–mouth contact, hand–hand–mouth contact, manipulation of clothes, trunk rotation, hand–knee contact and foot–foot contact. Spontaneous asymmetric tonic neck response was also noted but was easily overcome by flexion of the “jaw-arm” by all infants.

Strikingly, gross movements remained symmetrical during all the experiments, including one-sided weighting.

3.1. First experiment: all limbs weighted

During the entire stimulation sequence and immediately afterwards, the temporal organisation of FMs did not change in seven (87.5%) out of eight infants. After removing the loads, the temporal organisation did not change either. In one infant, the temporal organisation increased during weighting. After the load had been removed in this infant, the FMs also reappeared with the same temporal organisation as before stimulation (Fig. 1).

Fig. 1. First experiment. The temporal organisation of fidgety movements during weighting of all limbs with 14 g each. The behavioural course is given for each infant (n = 8) before, during and after weighting.
Table 1
The influence of one-sided weighting on FMs in a varying number of infants for various trials from 14 to 120 g

<table>
<thead>
<tr>
<th>Weight in grams</th>
<th>14</th>
<th>22</th>
<th>32</th>
<th>40</th>
<th>54</th>
<th>63</th>
<th>72</th>
<th>80</th>
<th>94</th>
<th>100</th>
<th>110</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>11</td>
<td>12</td>
<td>21</td>
<td>14</td>
<td>13</td>
<td>14</td>
<td>12</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Weighted on the left or right side</td>
<td>6 L/5 R</td>
<td>7 L/5 R</td>
<td>10 L/11 R</td>
<td>7 L/7 R</td>
<td>5 L/8 R</td>
<td>6 L/8 R</td>
<td>5 L/7 R</td>
<td>2 L/3 R</td>
<td>1 L/1 R</td>
<td>3 L/3 R</td>
<td>1 L/1 R</td>
<td>1 L/1 R</td>
</tr>
<tr>
<td>The t.o. of FMs did not change</td>
<td>8 (73%)</td>
<td>10 (84%)</td>
<td>18 (86%)</td>
<td>11 (79%)</td>
<td>11 (84%)</td>
<td>12 (86%)</td>
<td>12 (100%)</td>
<td>4 (80%)</td>
<td>1 (50%)</td>
<td>5 (83%)</td>
<td>2 (100%)</td>
<td>1 (50%)</td>
</tr>
<tr>
<td>The t. o. of FMs decreased</td>
<td>1 (9%)</td>
<td>1 (8%)</td>
<td>2 (9%)</td>
<td>1 (7%)</td>
<td>1 (8%)</td>
<td>–</td>
<td>–</td>
<td>1 (20%)</td>
<td>1 (50%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>The t.o. of FMs increased</td>
<td>2 (18%)</td>
<td>1 (8%)</td>
<td>1 (5%)</td>
<td>2 (14%)</td>
<td>1 (8%)</td>
<td>2 (14%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1 (17%)</td>
<td>–</td>
<td>1 (50%)</td>
</tr>
</tbody>
</table>

FMs, fidgety movements; L, left; R, right; t.o., temporal organisation.
3.2. Second experiment: one-sided weighting

Neither the temporal organisation nor the quality of FMs changed during any of the trials (Table 1). This was true with weighting and after the load had been removed.

3.3. Third experiment: no visual feedback of the weighted arm

Irrespective of the load used, the temporal organisation of FMs remained the same before, during and after stimulation.

4. Discussion

This study demonstrated that FMs, an age-specific pattern of the spontaneous movement repertoire in 3-month-old infants, are not influenced by stimulation of the proprioceptive system. None of the weighting conditions, namely weighting all four limbs, weighting one side of the body or weighting one arm while preventing visual feedback, had any effect on the quantity or quality of FMs. Moreover, other gross movements also remained symmetrical.

Previously, several studies investigated the effect of weighting and environmental constraints (such as body position) on spontaneous arm and leg movements (stepping and kicking) in small infants. When Thelen et al. [20] added small weights to both legs of 4-week-old infants, the rate and amplitude of their steps decreased. Submerging the infants’ legs in water, in turn, increased the rate and amplitude of the steps. Weighting caused 6-week-old infants to decrease the rate of kicking in the weighted leg and it led to an increase in the unweighted leg, to maintain their overall baseline (both legs unweighted) kicking frequency [21]. Unilateral weighting of one leg resulted in changes in the kicking behaviour of infants of 6 to 24 weeks old in both frequency and in some kinematic parameters in 6- and 12-week-old infants [22]. By 18 and 26 weeks, such frequency and kinematic effects were no longer present [22]. In two groups of 26-week-old infants with and without periventricular leucomalacia, no differences were found in their adjustment to unilateral weight manipulation with regard to the tightness of interlimb couplings [23].

Infants with and without Down syndrome demonstrated bilateral sensitivity and adaptability by increasing activity levels of the unweighted leg relative to the weighted leg [24]. In addition, it has been reported that posture might affect spontaneous leg movements [25] and that weighting affected the biomechanics of toddlers walking down a slope [26].

However, as we found in the first and second experiments this seems not to be the case for FMs. FMs remained unaffected by environmental constraints such as weight perturbation, at least up to 120 g. It remains an open question why other spontaneous movements also believed to be endogenously generated by CPGs (stepping, kicking) are influenced by weight perturbation, whereas FMs are not.

In our third experiment, in a small sample of infants, we investigated the influence of weighting one arm while preventing visual feedback. Infants did not change the quality or the temporal organisation of their FMs, nor their spontaneous motility when we weighted...
one wrist and prevented visual feedback of the weighted arm. Our results are in line with a study on FMs recorded in darkness indicating that actual visual control of the body is not necessary for normal FMs [27]. It has been stated for newborns [28,29] that sight of the arm is essential for opposing external forces and for infant monkeys to reach accurately [30,31]. In addition, several studies [32,33] showed a clear effect of the environment on spontaneous arm movements and body orientation with respect to gravity on the quantity and quality to reaching in infants. In contrast to these studies, we did not find any effect of environmental constraints on FMs, irrespective of whether the weighted arm could be seen or not. Therefore, FMs are insensitive to the infant’s temporary inability to see his/her arm. Indeed, FMs do not even alter under two artificial conditions: weighting, and no visual feedback of the weighted arm.

At the age of 2 to 3 months, a time of transition in the nervous system [34], the calibration of the proprioceptive system has already taken place. We would like to stress once more that FMs are a stable and predominant part of the motor repertoire at this age. Thus, the assessment of FMs is of great significance for infant neurology. These preliminary results indicated that the neural mechanisms responsible for FMs and other gross movements were not influenced by biomechanical properties such as mass. The underlying mechanism has to be explored further since it is not clear whether it is simply a matter of one-sided proprioceptive compensation.

We conclude that infants at 3 months of age can counteract external forces as far as their FMs are concerned. GMs, FMs in particular, are a stable and predominant movement pattern and since they are endogenously generated they are all but impervious to environmental constraints. However, kinematic analysis is needed to help objectify our results.

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References

