Spontaneous behaviour in pre-term infants : a study from 32 to 36 weeks of postmenstrual age

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SPONTANEOUS BEHAVIOUR IN PRE-TERM INFANTS:
a study from 32 to 36 weeks of postmenstrual age

to Rinske and Joris

SPONTANEOUS BEHAVIOUR IN PRE-TERM INFANTS:

a study from 32 to 36 weeks of
postmenstrual age

PROEFSCHRIFT

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CONTENTS

Chapter 1	: Introduction and review of the literature	7
Chapter 2	: Infants and methods	17
Chapter 3	: Quantitative aspects of pre-term motor behaviour: a longitudinal study of 15 'low-risk' pre-term infants	23
Chapter 4	: Posture of low-risk pre-term infants: a study from 32-36 weeks of postmenstrual age	41
Chapter 5	: Head position in low-risk premature infants: the impact of nursing routines	55
Chapter 6	: The influence of head position and head position-change on body posture in pre-term infants (asymmetric tonic neck reflex = ATNR)	65
Chapter 7	: Posture during head turnings in pre-term infants: a longitudinal study of 15 low-risk infants of 32-36 weeks of postmenstrual age	75
Chapter 8	: General discussion	87
Chapter 9	: Clinical implications and suggestions for further research	95
Chapter 10	: Summary	96
	: Résumé	99
	: Sumario	101
	: Samenvatting	103
References		105
Appendix I	: Clinical characteristics of the infants studied and maternal data	115
Appendix II	: Computer programs	121
Dankwoord		123
Curriculum vitae		128

Chapter 1.

INTRODUCTION

Aim of the study

The object of the present longitudinal study is to describe the spontaneous behaviour of low-risk pre-term infants of 32-36 weeks of postmenstrual age (postmenstrual age: equals the time past after the first day of the last menstrual period and the moment of observation; pre-term: born before the postmenstrual age of 37 completed weeks; low-risk: not requiring intensive care). Why is it necessary to describe spontaneous behaviour in low-risk pre-term infants during this postmenstrual period?

The existing examination schemes used to evaluate the neurological condition of premature infants, require manipulation. However, manipulation of a pre-term infant is limited, since handling in general is minimized, and because it is very difficult to manipulate under intensive care treatment.

The study of spontaneous behaviour including its motor repertoire in well defined surroundings, is the most direct and global way to assess the nervous system in animals as well as in humans. A neurological assessment in all age groups should start with an observation of spontaneous behaviour followed by a more structured observation of a series of age specific movements and should finally include a series of stimulus-response tests. Although this idea is more and more accepted in paediatric- and adult neurology, the observation of spontaneous behaviour in perinatal neurology is even more relevant since the number of stimulus response tests that can be applied is very limited. The knowledge of the spontaneous behaviour in perinatal life is scarce and up to the present there is a bias towards the periods in which the baby moves actively or is involved in feeding behaviour. There is only limited information on spontaneous behaviour over a longer time-period including all observable events. Therefore a neurological examination should not be limited only to stimulus response examinations, but should be extended to the observation of behaviour with a minimum of interactions.

Moreover, most of the assessment schemes, developed to determine neurological maturation and/or condition, appear to be partly based on data obtained from sick babies and they do not reveal normal spontaneous behaviour.

The population of today's neonatal care units changed when compared with that of several decades ago because of a decrease in perinatal mortality due to a better obstetrical, neonatal and nursing care. The knowledge of spontaneous behaviour of this 'new' population has until now been rather limited, and it is an essential reference (=normal behaviour) for the description of the spontaneous behaviour of sick pre-term infants.

Review of the literature

Most of the studies published compared neurological scores obtained from pre-term infants, who had reached 40 weeks of postmenstrual age, with that of full-term newborns (Beckwith et al, 1977; Bench and Parker, 1971; Dubowitz and Dubowitz, 1981; Ferrari et al, 1983; Finnstrom 1971; Forslund and Bjerre, 1983; Gesell and Amatruda, 1945; Howard et al, 1976; Kopp and Parmelee, 1979; Kopp et al, 1975; Kurtzburg et al, 1979; Paludetto et al, 1982; Saint-Anne-Dargassies, 1977). Recent reports compared the behaviour of pre-term infants with the behaviour of fetuses at the same postmenstrual age (Nijhuis et al, 1982; Saint-Anne-Dargassies, 1979; Visser et al, 1982).

Other investigators compared foetal behaviour in obstetrically complicated and uncomplicated pregnancies, stimulated by the clinician's need to assess neurological condition of the compromised fetus (Natale et al, 1983; Nijhuis, 1984; Van Geijn et al, 1986; Visser et al, 1986).

Studies comparing the behaviour of pre-term infants, who had reached 40 weeks of postmenstrual age, with that of full-term newborns:

In 1945 Gesell and Amatruda compared what they called "the Mature Foetal Infant (= a full-term neonate who has not experienced recent birth) with the Full-Term Neonate (= a mature foetal infant without experience in extra-uterine living)". Both were the same age, reckoning from conception, but they differed in their life histories. Although both groups showed similarities (body temperature, heart rate, blood pressure, sleep and wakefulness, orientation to sound stimuli, basic patterns of behaviour), Gesell and Amatruda (1945) explained the observed differences in breathing, sucking, visual and attentional behaviour between the two groups by the trauma of birth (Full-Term Neonate) and by habituation (Mature Foetal Infant).

Even now, a comparison between the two groups is still made and may be of interest to those concerned with the influence of environmental factors upon maturation.

Paludetti et al (1982) observed that pre-term infants reaching term without any serious disorder do neurologically on the whole as well as full-term infants. However, a difference was noted in the ability to bring hand to mouth, getting used to visual stimuli and orientation to a voice and face. Ferrari et al (1983) observed that the pre-term infants were inferior in orientation, motor performance, regulation of state and autonomic regulation. Palmer et al (1982) and Dubowitz and Dubowitz (1981) observed differences in posture between the two groups. Palmer et al (1982), in accordance with Dubowitz and Dubowitz (1981), observed that pre-term infants reaching 40 weeks of postmenstrual age showed less flexion in their posture compared with the newborn full-term infants. Furthermore, Palmer et al (1982) observed that pre-term infants, who had reached 40 weeks of postmenstrual age, had a better visual and auditory

orientation and a better alertness compared with the full-term infants. Howard et al (1976) performed a neurological examination standardized for full-term infants on 97 full-term newborn infants and 97 pre-term infants at their expected date of birth (=40 weeks of postmenstrual age). The pre-term infants had weaker responses than full-term infants in head extension when seated, arm and leg traction, leg recoil, sucking and the Moro reflex despite their having a higher level of activity state throughout the examination.

In summary: the literature suggests that differences between pre-term infants who had reached 40 weeks of postmenstrual age and term infants in respect to physical and behavioural aspects might be due to a difference in environmental experience.

Studies describing foetal behaviour:

Studying foetal behaviour as an expression of central nervous system activity might partly inform us about the neurological condition of the foetus.

In the past, it was not possible to study the motor activities of a foetus in utero. Early observations of spontaneous foetal behaviour were incidental and unsystematical (Bautzmann 1956, Preyer 1885, Szendi 1940). An aborted foetus at a postmenstrual age of 4 months showed twitching movements of the extremities (Preyer 1885); roentgenograms with small doses of radiopaque substance injected into the amniotic cavity showed changes in foetal position (Szendi 1940); Bautzmann (1956) differentiated between active embryokinesis (=active movement of the developing product of conception in the embryonic sac) and passive embryokinesis (=passive movement of the amniotic sac contents, i.e. the conceptus, by muscles of the embryonic sac). The first systematically planned studies of human foetuses in vitro were carried out by Minkowski (1921). They were based upon the observation that foetuses removed by surgery in an intact gestational sac ("en pratiquant, en cas d'indications médicales diverses: tuberculose avancée, maladies de coeur, néphrite, épilepsie, etc.", Minkowski 1921) or obtained after spontaneous abortion at a postmenstrual age of 2-3 months often continued to show some movements. A wealth of different movements were recorded. After he had studied foetal movements he started to study foetal reflexes. The purpose of these studies was to determine at what time neural centres became functional during foetal development. Hooker (1952) succeeded in identifying the onset of various reflex movements during foetal development. The first reflexes elicitable in a foetus were found to occur at a postmenstrual age of seven and a half weeks: stroking of the facial skin elicited contralateral flexion of head and trunk.

In contrast to these unique but artificial observations, intra-uterine foetal behaviour can now be studied in vivo, with the help of real-time ultrasound scanning (Prechtel, 1985). Reinold (1971 a,b) made a first attempt at describing

and classifying the different types of foetal movement using ultrasound in early pregnancies.

From a practical point of view, the obstetrician can now be presented with a wide array of foetal biophysical (=physical condition) parameters (foetal breathing movements, gross body movements, total foetal activity, 'foetal tone', foetal heart rate patterns, qualitative amniotic fluid) which can be accurately monitored (Birnholtz et al, 1978; Manning et al, 1986; Roberts et al, 1980; Valentin and Marsal, 1986; Visser, 1984). Other clinical implications of the new information about foetal motor behaviour obtained with real-time ultrasound scanning are:

- diagnosis of neurological disorders in utero;
- new guidelines for understanding the nature of motor disorders in childhood.

Thanks to ultrasound techniques it is now possible to compare the foetus with the pre-term infant with respect to development at the same postmenstrual age (Prechtl, 1985; Saint-Anne-Dargassies, 1979). Nijhuis et al (1982) demonstrated that behavioural states are present during the foetal period and that the time course of the development of these states in utero is similar to that observed by Prechtl et al (1979) in pre-term infants. Visser et al (1982) compared episodic heart-rate patterns in the foetus and the newborn and observed that low heart-rate variation episodes might reflect quiet sleep in the human foetus. De Vries et al (1982) showed that 16 distinct movement patterns, closely resembling those observed in pre-term and full-term newborns, could be distinguished in utero. Also, spontaneous foetal behaviour was studied related to maternal factors such as carbohydrate intake, diabetes, anti-epileptic medication and smoking (Natale et al, 1983; Nijhuis, 1984; Van Geijn et al, 1986; Visser et al, 1986).

In summary: the literature suggests that with ultrasound methods foetal biophysical parameters can reliably be studied. These variables probably reflecting foetal physical condition might be related to maternal factors.

The influence of environmental factors upon maturation:

In 1955, Saint-Anne-Dargassies analysed a group of 100 prematures of known postmenstrual age and concluded that neurological maturation followed a constant time scale which was unaffected either by the time of birth, postnatal age or variations in body weight. Robinson (1966) studied a number of reflexes in infants born between 25 and 42 weeks of postmenstrual age and observed that the postmenstrual age after which these reflexes were detectable was the same whether the baby had been maturing inside or outside the uterus. These clinical results have been compared with the electroencephalographic and anatomical stages of development of the brain (Amiel-Tison, 1968). Saint-Anne-Dargassies (1979) compared knowledge of the infant living in the incubator with knowledge of the foetus observed in utero.

She concluded, confirming her earlier statement, that concerning posture, motility and reactivity, development in the normal infant depends essentially upon foetal age, and not upon environment.

Early observations of spontaneous foetal behaviour (Minkowski 1921) were carried out in a non-physiological foetal environment (foetuses removed by surgery or obtained after spontaneous abortion). The importance of environment for foetal behaviour was demonstrated by Barcroft (1967). He observed that as long as conditions corresponded as closely as possible to the physiological foetal environment (intact umbilical cord - intact gestational sac) foetuses were found to make spontaneous movements which followed a certain rhythmical pattern, even without external stimulation at different intervals and in different sequences. After cutting of the cord, the spontaneous movements soon ceased, while the reflex movements, e.g. those elicited by tactile stimuli, persisted. Liggins (1972) described the intra-uterine environment of the foetus as highly constant. The intra-uterine noise level lies around 50-80 dB., light intensity is low, temperature shows only minor variations, tactile stimuli, if any, are mitigated by the amniotic fluid.

Despite all attempts made to simulate intra-uterine conditions (e.g. temperature and humidity) there are important differences between the intra and extra-uterine environment.

- The foetal body floats in the amniotic fluid. Its specific weight estimated from the ratio foetal body weight to foetal volume is only slightly above that of the amniotic fluid. Consequently, only little effort is needed for the foetus to move on account of buoyancy.

- Before birth, in our society the human being spends most of his time in a vertical position; an infant's life, however, is largely a horizontal one.

Furthermore, comparing the behaviour of foetuses with that of infants of the same postmenstrual age, we must realize that the data of the two groups are obtained with different techniques.

There is no consensus about the role of the environment on developmental processes. Saint-Anne-Dargassies (1977) suggests that neurological development is mainly dependent on the maturation of the nervous system. Others attach more importance to the environment (Dubowitz and Dubowitz, 1981; Parmelee, 1975): feeding, nursing position, physical contact and stimulation are some of the environmental factors that might affect development. According to Touwen (1980) "the differences observed should be categorized as an increased variability of performance within the accepted (full-term) normal range". Post-mortem examination of the brain showed that anatomic processes such as the sequence of neuronal migration or of myelination is not changed by delivery. Quantitative analysis of the cell number in human forebrains showed that two phases can be distinguished as a function of age: a neuronal proliferation phase and a glial multiplication phase.

The progress of myelination in the human nervous system begins in the second trimester of pregnancy and continues into adult life (Sarnat, 1984; Volpe, 1987). Human behaviour, which has its beginning very early in prenatal life, has been correlated with the development of the nervous system (= anatomic processes, Humphrey, 1978). In summary: although it is assumed that in full-term and pre-term infants the central nervous system matures at the same rate regardless of the postmenstrual age at which the foetus was born, some aspects of neurological behaviour in full-term infants compared with pre-term infants who had reached 40 weeks of postmenstrual age were observed to be different. It must be realized, however, that different behaviour does not necessarily reflect different (advanced/delayed) maturity of the nervous system but might reflect a difference in experience to different stimuli in different environmental conditions.

Assessment of pre-term infants:

Several authors studied pre-term infants (Dreyfus-Brisac et al, 1968; Dreyfus-Brisac, 1970; Dubowitz and Dubowitz, 1977; Gesell and Amatruda, 1945; Parmelee, 1975; Prechtl et al, 1979; Saint-Anne-Dargassies, 1955). The methods of collecting data, the analysis used and the infants studied were, however, rather different. Direct observation (Gesell and Amatruda, 1945), polygraphic recordings (Dreyfus-Brisac et al, 1968; Dreyfus-Brisac, 1970), direct observation combined with polygraphic recordings (Prechtl et al, 1979) were used to study the development of neural function. For some of these studies, the primary objective was the assessment of neurological maturity. Many authors (Amiel-Tison, 1968; Ballard et al, 1979; Beintema, 1968; Brazelton, 1973; Dubowitz et al, 1970; Dubowitz and Dubowitz, 1977; Farr, 1968; Finnstrom, 1971; Koenigsberger, 1966; Robinson, 1966; Saint-Anne-Dargassies, 1954; see for a review Casaer and Akiyama, 1970) have described schemes for the neurological assessment of the maturity of newborns. Neurological evaluation of the maturity of newborn infants was mainly based on the work of Gesell and Amatruda (1945) and the experience of Thomas (Thomas and Saint-Anne-Dargassies, 1952). In the first 125 pages of the "Etudes Neurologiques", Thomas described his experiences in examination and observation of term and pre-term infants of the foregoing twenty years. He tested and observed the reactions to stimuli. Saint-Anne-Dargassies, a student of Thomas, first systematized the neurological examination of the premature infant (Saint-Anne-Dargassies, 1966) by proposing a series of descriptive qualitative steps. Assessment of neurological maturation using schemes based on the original work of Gesell and Amatruda (1945) and Thomas and Saint-Anne-Dargassies (1952) was performed by testing muscle tone, reflexes and responses to stimuli.

Such assessment apart from being used to show neurological maturity (=postmenstrual age) can also be used:

- to serve as the initial examination in the continuing evaluation of the infant;
- to diagnose a fixed deficit or syndrome;
- to develop a differential diagnosis;
- to predict neurological outcome (Brown et al, 1974).

For most of the items studied, the infants had to be manipulated: i.e. appreciation of muscle tone was a fundamental feature in this examination (resting posture, passive tone and active tone). However, in this way mainly the reactions to stimulation were investigated and scored. With these schemes, we are only partly informed about spontaneous behaviour. Furthermore, according to several authors (Ballard et al, 1979; Parkin et al, 1976), the majority of these neurological items do not correlate as highly with postmenstrual age as do the external characteristics used (skin, lanugo, plantar crease, breast, ear, genitals). The neurological items were more frequently affected by intercurrent diseases than the physical criteria.

In general, assessment of a pre-term infant is often limited due to minimal handling of the infants. Pre-term infants may deteriorate with excessive handling and even routine nursing care procedures can be associated with both transient disturbances of oxygenation and abrupt changes in blood pressure (Greenough et al, 1988).

Although early observations are of great importance for understanding some aspects of an infant's reactivity, as far as spontaneous neurological behaviour of pre-term infants is concerned, our knowledge is still very limited. Prechtl et al (1979) studied postures, motility and respiration of low-risk pre-term infants. He stated that the observed variables were rather independent from each other before 36 weeks of postmenstrual age. Therefore, the concept of behavioural states, used in young infants to describe spontaneous behaviour (= nervous function), cannot be applied before 36 weeks of postmenstrual age.

Another major problem is that with regard to follow-up studies of pre-term infants, information about the neonatal neurological condition of these premature infants is limited. If information about the neonatal neurological condition was given, mostly the neurological examination scheme of the full-term newborn by Prechtl (1977) was used. In general, this means that the neurological condition of the pre-term infant who had reached more than 36 weeks of postmenstrual age and not earlier was described.

Furthermore, one cannot deny, that the pre-term infants of today are in many aspects different from the infants studied several decades ago. Obstetrical care has changed; perinatal assessment and care have been changed and intensified; the extra-uterine environment differs in many aspects (Prechtl and Nolte, 1984). Although neonatal survival and outcome are related to birth weight and/or postmenstrual age, a decrease in neonatal mortality has been observed in all birthweight categories during the last decades (Comney and Fitzhardinge, 1979; Hack et al, 1979; Kitchen et al, 1982; Ross et al,

1986; Hadders-Algra, 1987 and Verloove-Vanhorick and Verwey, 1987). The mortality of infants weighing less than 1500 grams decreased to 30% in 1980 (Stewart et al 1981). However, no evidence was found that the falling mortality rate had been achieved at the expense of an increasing proportion of children who were handicapped. (Stewart et al, 1981). Dijkhoorn (1986) studied the influence of postmenstrual age, growth retardation and asphyxia at birth on neurological outcome. At all ages, the poorest outcome was found in growth-retarded fetuses born pre-termly, which is in accordance with earlier findings (Comney and Fitzhardinge, 1979).

Recently, Cioni et al (1986) reported some preliminary results of a study on spontaneous general movements in normal pre-term infants. Their cross-sectional data showed a wide interindividual variability, and no developmental trend with regard to postmenstrual age was noted. They stated (referring to Cioni, 1985) that similar results were obtained for the majority of motor patterns evaluated, such as stretching, startles and isolated limb movements. They concluded that at least during the period after 32 weeks of postmenstrual age, the pre-term's motor repertoire did not change significantly up to the moment of discharge from hospital.

In summary: as far as spontaneous neurological behaviour of low-risk pre-term infants is concerned, our knowledge of today's situation is very limited.

This Study:

The present longitudinal study is essentially concerned with a careful description of spontaneous behaviour of the low-risk pre-term infant. It was decided to study these infants from 32 weeks to 36 weeks of postmenstrual age for the following reasons:

- neurological data of this kind are still quite scarce;
- infants with a postmenstrual age of less than 32 weeks are generally in need of intensive care and therefore observation of spontaneous behaviour is more difficult due to intensive medical and nursing care;
- infants of 32 weeks are in a more stable condition than infants of less than 32 weeks of postmenstrual age;
- low-risk infants of 36 weeks of postmenstrual age are mostly in such a condition that they are discharged home;
- from 32 weeks of postmenstrual age onwards we assumed that conditions such as respiratory distress syndrome, metabolic disorders, infectious diseases, intracranial haemorrhage and/or leukomalacia (subcortical or periventricular) and congenital anomalies might influence spontaneous behaviour (generally, low-risk pre-term infants don't require intensive care).

Septicaemia can alter the state of consciousness (Fenichel, 1985). According to Gartner et al (1970) and Ritter et al (1982) premature babies with bilirubin encephalopathy often appear to be asymptomatic.

This could be due to a different distribution of bilirubin deposition in premature infants (Ritter et al, 1982) compared with full-term infants, but it could also be explained by our lack of adequately sensitive skills and tools for evaluating the neurological status of these babies (Sarnat, 1984). Dubowitz et al (1981) correlated the presence or absence of several clinical signs (popliteal angle, tone and motility, visual orientation and eye movements) with the presence or absence of haemorrhages as diagnosed by ultrasonography. Furthermore, follow-up studies suggested that the outcome of infants with haemorrhages of a certain degree, especially those infants who developed marked ventricular dilatation and periventricular leukomalacia were at risk of developmental delay or motor handicap (McMenamin et al, 1984; Palmer et al, 1983; Papile et al, 1983; Stewart et al, 1983; De Vries et al, 1985, 1987).

According to De Vries (1987) extensive cystic leukomalacia is the most important predictor for the development of cerebral palsy later in infancy. That congenital anomalies such as spina bifida, arthrogryposis multiplex congenita, congenital muscular dystrophy might influence spontaneous behaviour is self-evident.

The low-risk pre-term infants were studied to determine:

- the quantity of motor activity (see chapter 3);
- preference posture at rest (see chapter 4);
- head position preference (see chapter 5);
- body posture related to head position (see chapter 6);
- preference posture during a well defined activity (see chapter 7).

The object of this longitudinal study is to describe some aspects of spontaneous behaviour of pre-term infants of 32-36 weeks of postmenstrual age and to answer the following questions:

- Is the incidence of some movement patterns related to postmenstrual age?
- Have pre-term infants a preference posture at rest?
- If such a preference posture exists, does it change with age?
- Is there a spontaneous head position preference?
- Is there an influence of head position and head position change on body posture?
- If so, does this pattern change with postmenstrual age?
- Is there a preference posture during activity?
- If such a preference posture exists, does it depend on the "state" of the infant, the initial side the head was turned to and does it change with postmenstrual age?
- Are the data obtained "useful" as a "reference" for studying sick pre-term infants of comparable age?

Chapter 2

Infants and methods:

Data of the infants observed and included in this study, and the maternal data are shown in Appendix I. The infants included were selected by one of the neonatologists (see below for selection criteria). The parents were told that their baby was a low-risk pre-term infant and permission was asked to observe. The parents were told that data of spontaneous motor behaviour of low-risk pre-term infants were scarce and might be important in order to help pre-term infants at risk; that we would only observe and not manipulate their baby, and that they would receive a copy of a video recording as an expression of thanks. After the parents' permission had been obtained the infant was included in the study.

Pilot study

At the beginning of this study spontaneous motor behaviour of the pre-term infant was observed real-time and every important item was noted on a precoded sheet. According to the method described by Prechtl et al (1979) a picture of the posture of the infant was made every minute when the infant did not move. In this way the spontaneous behaviour of three low-risk pre-term infants at 32, 34 and 36 weeks of postmenstrual age was observed. The postmenstrual age was determined by the first day of the last menstrual period, or in case this date was unknown, estimated from the biparietal diameter of the foetal head measured by ultrasound. All three pre-term infants were judged to be low-risk infants. The observation always started after a manipulation by the nurse which included a feeding and lasted for three hours. The various items (variables) of spontaneous motor behaviour, such as general movements, isolated arm and leg movements, startles, twitches, stretches, mouth movements, yawns, smiles, fussing and frowning were noted on precoded sheets in the order of occurrence. Besides the visual analysis a polygraph was used to register heart and respiration rates, eye movements and movements of one extremity. Furthermore, with an event recorder some arbitrarily chosen items (general movements, eyes open/eyes closed, mouthing and stretches) were scored. In order to facilitate a supine position, the infants were put between rolled-up nappies.

However, this method of observation had several disadvantages:

- the infant was not observed in a 'normal' clinical situation due to polygraphic registration and the nappies used;
- during the annotation of items no good observation was possible;

- the precise timing, the duration and the coincidence of items were difficult to notice and score;
- information got lost due to fatigue of the observer during the three-hour observation session;
- re-analysis of the scored items was possible with this method, but not of the spontaneous behaviour itself;
- always one observer and one person to manage the polygraph were needed.

This study

Therefore, it was decided to make video recordings of the infant's spontaneous motor behaviour and to audio-tape the spoken comments of the observer with respect to the items of spontaneous motor behaviour to be studied. Only electrodes that are "routinely" applied in a neonatal-care unit were used (registration of heart and respiration rates). In this way the infants were allowed to move "freely" in their incubator. An observation like this, closely resembles the situation in which the infants in a neonatal-care unit are taken care of. The data obtained can be used in every neonatal-care unit without special equipment (such as a polygraph).

Furthermore, it was decided to observe the infants weekly, because if we wanted to show a developmental trend, it was better to have five instead of three observation points.

To begin with 29 infants were selected (by the neonatologist) for this study. All pre-term infants were judged to be low-risk pre-term infants (not requiring intensive care).

Fourteen infants were excluded from the final analysis:

- because the three infants used in our pilot study were not weekly observed;
- one infant developed a periventricular haemorrhage grade II (Papile et al, 1978);
- two infants were treated for a sepsis during the observation period;
- one infant developed a delayed prolonged icterus neonatorum;
- five infants were transferred to the referring hospital before 36 weeks of postmenstrual age;
- one infant was not available for follow-up;
- one infant showed a monoparesis at two years of age.

Observation session:

The infants were studied in the University Hospital Gasthuisberg of Leuven, Belgium (n=10), and the University Hospital of Maastricht, the Netherlands (n=5). Data of the infants observed and included in this study are shown in table I.

Table 1

Medical characteristics of the pre-term infants

N infants	:	15	
postmenstrual age (wks)	:	30.1±1.3	(mean±sd)
birthweight (g)	:	1427.3±268.5	(mean±sd)
length (cm)	:	40.1±2.2	(mean±sd)
head circumference (cm)	:	28±2.2	(mean±sd)
sex (m:f)	:	(9:6)	
1-min. Apgar score	:	6.8±1.4	(mean±sd)
5-min. Apgar score	:	8.6±1.2	(mean±sd)
Bayley			
-MDI 7 months	n=14'	93.4±11.2	(mean±sd)
-PDI 7 months	n=14'	91.6±16.8	(mean±sd)
-MDI 18 months	n=10	93.9±12.4	(mean±sd)
-PDI 18 months	n=10	99.9±12.5	(mean±sd)

'1 infant: Stanford Binet test: normal at the age of
2 years

Figure 1 is a schematic presentation of a set-up to make the observations and shows the various steps used in this study.

Fig. 1

A total of 75 three-hour observation sessions have been included in this study.

The infants were observed in their incubator in the neonatal care department. They were studied in a supine position. Although we are aware of the fact that a certain postural position affects the outcome for all infant research investigations (Brackbill et al, 1973; Casaer, 1979), the supine position was chosen because thereby a higher rate of spontaneous motor activity was expected.

The equipment for monitoring respiration and heart rates was placed on the left side of the incubator. The video camera was placed in such a way that its position did not interfere with nursing routine. During the observation sessions the illumination and nursing practice were constant, and adapted to the individual need of the infants studied. The observation sessions always took place after a nursing control and most sessions started at eight o'clock in the evening. The infants were video-taped with one camera, placed at the foot of the incubator. The observer was able to observe the infant from all sides. Because some observation items, such as frowning, and fussing, could be missed due to invisibility on video, the spoken comments of the observer were audio-taped.

Playback:

After the observation session, the observer scored the various variables by carefully studying the video recordings, also using the audio-taped comments. The computer programs used to store and analyse the observation data were run on an Apple IIe and were mainly written in Applesoft-Basic (see appendix II).

Figure 2 is an example of a profile of spontaneous motor behaviour actogram of a pre-term born infant of 32 weeks of postmenstrual age, during a three-hour observation session.

Statistical analysis

The data were analysed by an analysis of variance (ANOVA); by calculating linear, exponential, logarithmic and quadratic regressions; by calculating median + range and mean and standard deviations; by the Wilcoxon signed rank test; the U-test; the T-test; the chi-square test; and the Spearman Rank Correlation Coefficient test.

Figure 2

Actogram of 3 hours observation of a pre-term infant at 32 weeks of postmenstrual age

Chapter 3

Quantitative aspects of pre-term motor behaviour:
a longitudinal study of 15 low-risk pre-term infants.

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(Submitted)

Introduction

Recently, systematic studies on human foetal motility were published describing both quantitative and qualitative aspects. With the use of real-time ultrasound incidence and developmental course of foetal body movements were investigated and were related:

- to human foetal heart rate (Timor-Tritch et al, 1978; Dawes et al, 1981, 1982; Visser, 1984)
- to a certain age and time of the day (Roberts et al, 1980; Visser, 1984; de Vries, 1987)
- to acoustic stimuli (Schmidt et al, 1985)
- to maternal smoking (Nijhuis 1984)
- to maternal hyperglycaemia (Natale et al, 1983; Visser et al, 1986)

Quantitative aspects of motor behaviour in low-risk pre-term infants were studied by Prechtl et al (1979). Six pre-term infants in the so-called midstage period of infancy (Gesell and Amatruda, 1945) were studied. This group of low-risk pre-term infants was compared with a group of high-risk and sick pre-term infants with regard to some of the quantitative aspects of motor behaviour (Prechtl and Nolte, 1984). Except for the incidence of cloni, no clear difference in quantitative output of motor patterns between the low-risk and high-risk or sick pre-term infants could be observed, which is a remarkable observation. It must be realized that Prechtl et al (1979) studied only 6 low-risk preterm infants; that a possible influence of nursing care is not taken into account, and that the results partly differ with earlier observations. For example with respect to body posture: Prechtl et al (1979) found no preference in posture, while others (Amiel-Tison, 1968; Dubowitz et al, 1970) reported a preference posture related to postmenstrual age.

The present study is a longitudinal investigation of the spontaneous motor behaviour of a highly selected group of low-risk pre-term infants of 32-36 weeks of postmenstrual age.

The object of this longitudinal study was:

1. the determination of some specific movement patterns in pre-term infants of 32-36 weeks of postmenstrual age;
2. to investigate whether the incidence of specific movement patterns showed a developmental trend;
3. to determine whether the obtained data are "useful" as a "reference" for study of sick pre-term infants of comparable postmenstrual age.

Infants and Methods

After informed consent had been obtained from the parents, 15 low-risk pre-term infants were weekly studied from 32 weeks of postmenstrual age onwards. The first day of the last menstrual period and/or the biparietal diameter of the foetal head, measured with ultrasound, were used to determine the postmenstrual age. All infants were selected by a neonatologist and were judged to be low-risk at birth and during the observation period. The pre-term infants were observed in supine position and recorded on videotapes. The movements noted by the observer were also recorded with an audiotape recorder.

The observer neither influenced the infant's head position nor interfered with the nursing activities. Because of the combined video and audio recordings the risk for missing data due to video or audio malfunctions were minimal. Furthermore, this method allowed a good control of the alertness of the observer and could be used in the study of some small movements which might otherwise have been missed due to inadequate visualisation. During play-back of the three-hour recordings the movements studied were put into an Apple IIe computer for which a special event-detecting program had been developed. For each different movement (item) studied, incidence and duration in seconds (total time, minimal and maximal duration) could be determined.

The following items were observed:

- a. general movements: unco-ordinated, slow movements of arms, legs and trunk, often including the head;
- b. isolated arm or leg movements: rapid or slow movements, involving flexion, extension, rotation or abduction and adduction of arm or leg, without movements of any other part of the body;
- c. startles: brief generalized contraction of all muscles;
- d. twitches: isolated, rapid movement of arm or leg, or isolated head movement;
- e. stretches: co-ordinated movement patterns consisting of retroflexion of the head, flexion of the arms or exorotation at the shoulder: the legs may or may not be extended;
- f. mouth movements: rhythmical mouthing or opening of the mouth;
- g. yawns, smiles, fussing and frowning;
- h. periods without general or isolated movements.

Startles, stretches, twitches, smiles and yawns are represented by the number of times (frequency) they occurred (median + range). The duration of general movements, isolated movements, mouthing, fussing, frowning and periods without body movements are expressed in minutes or seconds per three-hour observation session (median + range). Furthermore we calculated the number and duration of manipulations (total time) at various postmenstrual ages.

Statistical methods:

The items studied were analysed by calculating median and range, performing linear regression analysis, exponential regression analysis, one way analysis of variance (ANOVA: Systat 312864.5670), and the Wilcoxon signed rank test.

Results

During the three-hour observation session the infants were regularly manipulated by the nurses. The number of manipulations is recorded as it might influence their behaviour.

The total number of manipulations of the 15 infants diminished with increasing postmenstrual age (see figure 1, solid line; linear regression $\rho=0.94$, exponential regression $\rho=0.97$). This decline was more or less observed in seven of the 15 infants, whereas the other eight infants showed an irregular pattern.

In contrast, the duration of the total manipulation time of the 15 infants increased with postmenstrual age (fig. 1, dashed line; linear regression $\rho=0.97$, exponential regression $\rho=0.99$).

However, considering individual data it can be seen that only one child showed a monotonous increase of the total manipulation time. All others showed a very irregular pattern.

manipulation related to postmenstrual age (n=15) fig.1

Figure 1: shows the total number of manipulations (curve A) and the total duration of the manipulation time (curve B) related to postmenstrual age (n=15).

During the three-hour observation session the infants did not move at all for some time (see figure 2, median and range). At each age more or less the same time was spent without movement (i.e. 46-48%). The large ranges indicate the wide interindividual variance of mobility (ANOVA: $F=0.876$; $p=0.484$; $df=14$).

Minutes without body movements

median + range per 3-hour observation session (n=15) fig.2

Figure 2: shows the median and range of the minutes without body movements per three-hours observation session related to postmenstrual age (n=15).

Figure 3 shows how long the infants showed generalized body movements during the three-hour observation session (median and range). With increasing age more time was spent on gross body movements. Both linear and exponential regression analyses of the median show a high correlation coefficient with postmenstrual age (0.95 and 0.98 respectively). The large ranges, however, indicate the wide interindividual variance: the individual data show no consistent temporal trend (correlation coefficient $\rho < 0.41$) (ANOVA: $F=0.661$; $p=0.621$; $df=14$).

Figure 3: shows the median and range of the minutes with general body movements per three-hour observation session related to postmenstrual age (n=15).

How much time the infants spent on isolated body movements is shown in figure 4 (median and range). With increasing age, the time spent on small body movements decreased. Both linear and exponential regression analyses of the median show a high correlation coefficient (0.94 and 0.95 respectively).

The large ranges, however, indicate again the wide interindividual variance: the individual data show no consistent temporal trend (correlation coefficients $\rho < 0.52$) (ANOVA: $F=0.988$; $p=0.442$; $df=14$).

Minutes with isolated limb movements

median + range per 3-hour observation session (n=15) fig.4

Figure 4: shows the median and range of the minutes with isolated body movements per three-hour observation session related to postmenstrual age (n=15).

With increasing age, the number of startles during the three-hour observation session decreased (figure 5). Both linear and exponential regression analyses showed a high correlation coefficient (both 0.99). The large ranges, however, indicate the wide interindividual variance: the individual data showed no consistent temporal trend (correlation coefficients $\rho < 0.46$) (ANOVA: $F=0.670$; $p=0.616$; $df=14$).

Figure 5: shows the median and range of the number of startles per three-hour observation session related to postmenstrual age (n=15)

Figure 6 shows how many twitches the infants made during the three-hour observation session (median and range). With increasing age the number of twitches decreased. Both linear and exponential regression analyses showed high correlation coefficients (both 0.99). Seven of the 15 infants showed such a monotonous decrease of the number of twitches with a high correlation coefficient of the linear and exponential analyses. Though the number of twitches decreased not monotonously in the other infants, a high correlation coefficient was found in all infants ($r=0.85-0.93$) (ANOVA: $F=4.156$; $p=0.005$; $df=14$).

Figure 6: shows the median and range of the number of twitches per three-hour observation session related to postmenstrual age (n=15).

With increasing age, the time spent with frowning decreased (see figure 7, median + range). Both linear and exponential regression analyses showed a high correlation coefficient (both 0.98). Though only three of the 15 infants showed a monotonous decrease of the time spent with frowning, a relatively high correlation coefficient per infant was found ($r=0.82-99$) (ANOVA: $F=9.196$; $p=0.001$; $df=14$).

Figure 7: shows the median and range of the seconds with frowning per three-hour observation session related to postmenstrual age (n=15).

Figure 8 and 9 show the time spent fussing and mouthing as a function of postmenstrual age.

Figure 8: shows the median and range of the seconds with fussing per three-hour observation session related to postmenstrual age (n=15).

Figure 9: shows the median and range of the seconds with mouthing per three-hour observation session related to postmenstrual age (n=15).

Figure 10, 11 and 12 show the number of smiles, stretches and yawns made during the observation sessions (median + range).

Figure 10: shows the median and range of the number of smiles per three-hour observation session related to postmenstrual age (n=15).

Figure 11: shows the median and range of the number of stretches per three-hour observation session related to postmenstrual age (n=15).

Figure 12: shows the median and range of the number of yawns per three-hour observation session related to postmenstrual age (n=15).

No clear relation with postmenstrual age was found (the coefficients of linear and exponential regression analyses were between 0.01 and 0.59) (ANOVA: $F=0.218-1.840$; $p=0.133-0.927$; $df=14$). The individual data showed no consistent developmental trends either. We tested the items non-parametrically (Wilcoxon signed rank test) comparing the data obtained in weeks 32 and 36. For the items startles, twitches, frowning and yawns a significant decrease was observed ($p < 0.05$). All other items showed no significant changes with postmenstrual ages ($p > 0.05$).

Discussion

The purpose of our study was to describe some aspects of spontaneous motor behaviour of 15 pre-term infants of 32-36 weeks of postmenstrual age and to look for possible specific (temporal) patterns. Prechtl et al (1979) suggested that observation with video recording of sufficient duration would bring more insight into the quantitative aspects of motor behaviour in pre-term infants. This study fulfils this methodological criterion.

With increasing age the duration of the total manipulation time of the group increased, though the total number of manipulations decreased (see figure 1). This is due to an increasing duration of the separate manipulations; thus the interaction time per manipulation between nurse and infant increased with increasing age or with prolonged care (i.e. in postnatal age).

There appeared to be no clear statistical correlation (individual and median values) between spontaneous motor behaviour and postmenstrual age between 32 and 36 weeks of postmenstrual age with respect to:

- the time spent without making any movements, fussing and mouthing and the number of smiles, stretches and yawns (fig. 2, 8-12).

Developmental trends with increasing age were observed in the following items studied:

- an increase of the -median- time spent on general body movements (fig. 3)
- a decrease of the -median- number of startles, twitches and the -median- time spent on isolated body movements and frowning (fig. 4, 5-7).

However, with respect to the -individual- data, this developmental trend (analysed by using linear and exponential regression analyses) was only found for the items twitches and frowning. These findings were supported by the one-way analysis of variance which showed a significant temporal trend for the items frowning and twitches. This development trend with regard to twitches might indicate that these "isolated" movements are inhibited by (sub)cortical structures.

In general the absence of a clear correlation as reflected by a low ($\rho < 0.90$) correlation coefficient, might be explained by:

- a real absence of correlation
- too small a correlation to be (significantly) shown by the number of observations (infants) studied.

A developmental trend was found in some items for the median values, but was lacking in the -individual- data (general and isolated body movements, startles). A possible explanation might be that the correlation is too poor in one individual to be distinguished but shows up in the summed-up data.

Wide inter-individual variability

Similar to the spontaneous behaviour in the human fetuses (Roberts et al, 1980; Nijhuis, 1984; de Vries et al, 1985), a wide inter-individual variability was shown in our study of spontaneous behaviour in pre-term infants, despite the many aspects in which the objects studied differed. Our quantitative results of motor behaviour are difficult to interpret in relation to the results of intra-uterine studies because of:

- the relevant differences between the intra and the extra-uterine environment
- the different ages (de Vries et al, 1982, 1985) of the fetuses
- the differences in items studied (Nijhuis et al, 1982).

To our knowledge only one longitudinal quantitative study of motor behaviour in low-risk pre-term infants has been performed (Prechtl et al, 1979: six infants longitudinally studied from 32-36 weeks of postmenstrual age). Although their study differs with respect to the precise method of observation and analysis, a wide inter-individual variability was also noted. This wide variability makes it rather ambiguous to speculate on normality based upon a single observation of spontaneous motor behaviour of an infant. The problems introduced by quantifying motor behaviour in order to obtain a diagnostic tool has been pointed out by Prechtl et al in studies on human preterm behaviour (Prechtl et al, 1984) and human foetal behaviour (Prechtl, 1985):

- different criteria for selection of subjects
- different criteria for classification of movements
- no differentiation between distinct movement types
- large inter-individual differences.

Hopkins and Prechtl (1984) introduced a qualitative analysis of movements by form and quality and by consequence and orientation. Their results showed that before 6-9 weeks of postnatal age most of the infants were not strikingly different from the newborns in their movement quality. Furthermore, the observed changes after nine weeks showed an inter-individual variability of 3-6 weeks. Whether this approach is useful in studying qualitative aspects of motor

behaviour in pre-term infants has yet to be investigated but it seems questionable. Not only because it seems clinically impracticable to make a sufficiently long video recording of every pre-term infant, but moreover, the interval between the observation sessions is limited due to the duration of hospitalization of the low-risk pre-term infants.

In summary, we were not able to discover a clear individual developmental trend, although a certain trend of the median in the incidence and duration of some of the items studied could be observed. On the contrary, the main characteristic of our observation appears to be the large inter- and intra-individual variability. The latter might depict a normal neurological development and suggest that a daily relatively short observation might be of more use.

Chapter 4

Posture of low-risk pre-term infants:
a study from 32 to 36 weeks of postmenstrual age

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(Dev Med Child Neurol : in press)

Introduction

Passive tone, examined by resting posture, angle of flexion, resistance to extension and passive recoil, is used in the neurological assessment of a neonate (Amiel-Tison, 1968, 1986). Saint-Anne-Dargassies (1955) described a gradual acquisition of flexor tone in a caudocephalic direction in pre-term infants from 28-37 weeks of postmenstrual age, resulting in a preference posture related to postmenstrual age. This preference posture is used in various schemes as an indicator of maturation (postmenstrual age) (Amiel-Tison, 1968; Ballard et al, 1979; Dubowitz et al, 1970; Dubowitz and Dubowitz, 1977, 1981). Prechtl et al (1979) could not replicate the patterns of preference posture in pre-term infants originally described by Saint-Anne-Dargassies (1955).

The object of this longitudinal study of spontaneous behaviour is to answer the following questions:

- have pre-term infants a preference posture?
- if such preference does exist, does it change with age?

Infants and methods

Fifteen low-risk pre-term infants were weekly observed and registered on video in their incubator for a three-hour period between 32 and 36 weeks of postmenstrual age. Posture was always assessed at the beginning of each minute and a sketch of the assumed posture was made. If the infant was moving around, no posture was registered (assessment technique identical with that described by Prechtl et al, 1979). The infants were observed in their incubator in a supine horizontal position without any restriction of their movements. The observation session always took place immediately after a nursing control and did not interfere with nursing routine. Nursing routine incorporates the instruction that the newborns are placed alternately with the head to the right and left. During the observation sessions the illumination and nursing practice were constant, related to the individual need of the infants studied. The first day of the last menstrual period and/or the biparietal diameter of the foetal head measured with ultrasound were used to determine the postmenstrual age. All prematures were judged to be low-risk. Neonatal and neurological assessments were judged

to be normal at the start and at the end of the observation period and before discharge. Neurological examination consisted of: inspection at rest (spontaneous motor behaviour); response to arousing stimuli; examination of the head and cranial nerves; examination of resistance to movement and some reflexes were elicited.

Both preference posture (the most frequently observed posture during an observation session) and the longest uninterrupted posture noted during an observation period, were determined. Postures were classified and subsequently analysed in various ways. The shoulder and the hip were classified according to the degree of ad- or abduction resulting in 7 classes:

-neutral (along the body)

-adduction

-abduction: 0 < abduction < 90 degrees

: abduction = 90 degrees

: 90 < abduction < 180 degrees

: abduction = 180 degrees

: abduction > 180 degrees.

The classification of the elbow and the knee was based upon four grades of flexion and extension and upon the exo- or endorotation of shoulder and hip. This resulted in 7 classes:

- fully extended (= 180 degrees)

- partly extended (> 90, < 180 degrees) + endorotated

- partly extended + exorotated

- partly flexed (≥ 60, ≤ 90 degrees) + endorotated

- partly flexed + exorotated

- fully flexed (< 60 degrees) + endorotated

- fully flexed + exorotated.

The classification of the posture of the limb therefore resulted in $7 \times 7 = 49$ classes of which some postures were not observed and are probably anatomically impossible.

With respect to the abduction of the hip exceeding 90 degrees, the real movement includes an abduction, flexion and or rotation. However, seen in a two dimensional plane (figure 1) we designated the above mentioned classification for simplicity.

Posture was analysed:

- concerning the complete observed posture (analysis 1)

- without concerning endo- and exorotation (analysis 2)

- without concerning endo-/exorotation and ab-/adduction (analysis 3)

- without concerning endo-/exorotation and flexion and extension (analysis 4).

Furthermore each limb was analysed separately:

- without concerning endo-/exorotation and flexion and extension (analysis 5)

- without concerning endo-/exorotation and ab-/adduction (analysis 6).

Statistical analysis of the data was performed using χ^2 tests, the Spearman Rank Correlation Coefficient test and

analysis of variance (Croxtan, 1953) as indicated in the results.

Results

A. General (analyses 1-4):

Only part of the observation events could be classified with respect to posture due to movements of the infant or handling by the nurse (32 wks: 60%; 33 wks: 59%; 34 wks: 60%; 35 wks: 61%; 36 wks: 61%).

In the longitudinally observed group of 15 low-risk pre-term infants the head was manipulated 215 times. A significant dominance concerning the initially imposed head position towards the right (67% versus 33%) was observed. Analysis of posture according to the very detailed classification (analysis 1) showed that the infants assumed a great number of different postures.

weeks	range	median
32	11-49	33
33	11-51	29
34	19-46	32
35	18-47	28
36	10-40	27

No clearly dominant pattern of posture was observed. In the analyses 2-4 the number of classes was reduced in order to find a possible dominant pattern of postures which might be masked by the too detailed classification used in analysis 1.

In 30-39 per cent of the observation sessions concerning the total body posture, preference posture and longest uninterrupted posture were different (analyses 1-4). It seems there is a rather small correlation between the two postures. If there should exist a dominant posture preference this posture would most likely be adopted for the longest period, i.e. the preference posture would be equal to the longest uninterrupted posture.

The preference posture and the longest uninterrupted posture at each postmenstrual age, invariable of the analysis performed, showed no dominant pattern (analyses 1-4: see infants and methods).

Furthermore no specific developmental trend was noted with increasing postmenstrual age (fig. 1).

Neither the number of different postures nor the number of times that the preference posture was observed, nor the duration of the longest uninterrupted posture showed a correlation with postmenstrual age (analyses 1-4, Spearman Rank Correlation Coefficient $p > 0.01$).

Fig.1 Preference posture as a function of postmenstrual age

B 1. Analysis of shoulder and hip per limb according to the degree of adduction and abduction (analysis 5)

The degree of adduction and abduction per limb of neither arms nor legs was related to postmenstrual age (Spearman Rank Correlation Coefficient varying from 0.006-0.16 N.S. (fig. 2a-d)).

We found no correlation of the degree of adduction and abduction of both arms with the degree of abduction and adduction of both legs (Spearman Rank Correlation Coefficient 0.1-0.7 N.S.).

FIG. 2A

Classification of right shoulder
degree of ad / and abduction

FIG. 2B

Classification of left shoulder degree of ad / and abduction

FIG. 2C

Classification of right hip degree of ad / and abduction

FIG. 2D

Classification of left hip
degree of ad / and abduction

B 2. Analysis of elbow and knee per limb according to the degree of flexion and extension (analysis 6)

The degree of flexion and extension per limb of neither arms nor legs was related to postmenstrual age (Spearman Rank Correlation Coefficient ranging from 0.006-0.15 N.S. (fig. 3a-d)).

Furthermore, we found no correlation of the degree of flexion and extension of both arms with the degree of flexion and extension of both legs (Spearman Rank Correlation Coefficient ranging from 0.2-0.7 N.S.).

FIG. 3A

Classification of right elbow degree of extension and flexion

FIG. 3B

Classification of left elbow degree of extension and flexion

FIG. 3C

Classification of right knee degree of extension and flexion

FIG. 3D

Classification of left knee degree of extension and flexion

Discussion

Preference posture and longest uninterrupted posture

Regardless of the way of analysing the data (analyses 1 to 4) no correlation between the preference posture or longest uninterrupted posture and postmenstrual age was found. A problem in interpreting the data was how to define preference of posture. Our observations show that irrespective of the type of analysis no really dominant preference posture was found: there was of course, almost always one posture that was adopted most frequently, but we often observed a great number of other postures which occurred almost equally frequently. These other (somewhat less) frequently adopted postures did not show a correlation with postmenstrual age either. Our results of preference posture are in accordance with those of Prechtl et al (1979), but disagree with those described by Saint-Anne-Dargassies (1955), Amiel-Tison (1968), Dubowitz et al (1970) and Dubowitz and Dubowitz (1977, 1981). This discrepancy might be attributed to methodological aspects or to differences in selection criteria of the populations studied (e.g. sick versus low-risk infants).

Methodological differences

We used the same observation and analyses methods as Prechtl et al (1979). The assessment techniques used by other authors (Amiel-Tison, 1968; Dubowitz et al, 1970; Dubowitz and Dubowitz, 1977, 1981; Saint-Anne-Dargassies, 1955) were not described in detail (especially not the length of the observation) and therefore no comparison can be made.

Differences in statistical analyses

We observed a great variety of postures, without finding a clearly dominant preference posture. This does not exclude the possibility of a significant preference posture, but it shows that the number of infants studied does not allow us to demonstrate a possibly very small preference. Therefore the discrepancy between our results and those of Prechtl et al (1979) versus those of Saint-Anne-Dargassies (1955), Amiel-Tison (1968, 1986), Dubowitz et al (1970) and Dubowitz and Dubowitz (1977, 1981) could be attributed to too few infants in our study (15 pre-term infants of 32 weeks of postmenstrual age) and that of Prechtl et al (1979) (6 pre-term infants of 32 weeks of postmenstrual age), whereas Dubowitz and Dubowitz (1977, 1981) observed a group of about 80 infants which, however, consisted of a rather nonhomogeneous population.

Differences in infants studied

Like Prechtl et al (1979) we only studied low-risk pre-term infants. Part of the population studied by other authors (Saint-Anne-Dargassies, 1955; Amiel-Tison, 1968; Dubowitz et al 1970; Dubowitz and Dubowitz, 1977, 1981) included neurologically abnormal infants.

From the original data of Dubowitz and Dubowitz (1977, 1981), also used by Palmer et al (1982) it is clear that almost all infants born before 32 weeks of postmenstrual age had severe to moderate complications of prematurity.

Final comments

From our results we conclude with regard to postures

- 1) that pre-term infants show no clearly dominant preference posture; and that there was
- 2) no correlation between posture and postmenstrual age.

Therefore, the main clinical conclusion of our study is that if an obligatory posture is observed, abnormality should be suspected.

Chapter 5

Head position in low-risk premature infants: impact of nursing routines

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(Biol Neonate : in press)

Introduction

Previous studies showed that term and pre-term infants turn their heads more to the right (Turkewitz and Creighton, 1974; Gardner et al, 1977; Casaer, 1979; Prechtl et al 1979). However, the reason for this preference and its clinical relevance are not known (Casaer, 1979). Some authors assume that head position in full-term infants might be determined by interactive behaviour with the care-giver (Alegria and Noirot, 1978; Noirot and Alegria, 1983). Gardner et al (1977) suggest that laterality in neonatal head position might contribute to hemispheric differentiation. Prechtl et al (1979) suggest that a spontaneous turning of the head to the right is a sign of normality in pre-term neonates.

Gardner et al (1977) noticed a developmental trend in the preferred head position in pre-term infants. At 35 weeks of postmenstrual age and increasingly thereafter, more time was spent with the head to the right than to the left. In contrast, Prechtl et al (1979) could not find any relationship between preferred head position and postmenstrual age.

The object of this study is to answer the following questions:

- is the head of the pre-term infant turned more to the right than to the left?
- If such a preference should exist, does it change with age?
- Is there a correlation between routine nursing procedures and head position in pre-term infants?

Infants and methods

Fifteen low-risk pre-term infants, between 32 and 36 weeks of postmenstrual age, were observed in their incubators for a 3-hour long period. The weekly observation sessions always started immediately after a nursing control. To determine the postmenstrual age, the first day of the last menstrual period and/or the biparietal diameter of the fetal head measured with ultrasound were used. During the observation period all prematures were judged to be low-risk. The observer neither influenced the infant's head position nor interfered with the handling by the nurses. Routine nursing incorporates the instruction that the newborns are placed alternately with the head to the right and the left. During

the observation sessions the illumination remained constant. Head positions to the left or right were noted in seconds during the whole observation session of three hours, except when the infants were manipulated.

The following variables are used in the data analysis:

- manipulation period, the period during which the nurse handled the infant
- imposed head position, the position in which the head was placed (to the right or the left) by the care-giver at the end of a manipulation period
- sustained imposed head position, the period in which the head position remained in the imposed position
- spontaneous head position, the head position in which the head remained after a head turning, not resulting from a manipulation
- observation period, the time span in minutes between two manipulations.

The above-mentioned variables were analysed in relation to the side of the manipulation and the number of spontaneous head turnings.

We performed U test, t test, x² test and ANOVA (analysis of variance) and we calculated median and range and mean and standard deviation (SD) for statistical analyses (Croxtan, 1953; Siegel, 1956).

Results

General

During the total observation time between the 32 and 36 weeks of postmenstrual age the 15 pre-term infants were manipulated 282 times. The analysis was limited to those 215 manipulations in which the head was turned.

Imposed head position

Table 1 shows the distribution of the imposed head positions related to the side of nursing.

Table I. Imposed head position related to the side of manipulation

	Manipulation from the right side (N=184)	Manipulation from the left side (N=31)
Imposed head position to the right	138	6
Imposed head position to the left	46	25

Although the routine nursing incorporates the instruction that the newborn's head ought to be placed alternately to the right and the left, a significant dominance concerning the imposed head position towards the right (67 versus 33%) and towards the nursing care (76%(138 + 25) versus 24%(6 +46)) was observed (χ^2 test, $p < 0.05$).

In 33 of the 71 (47%) and in 59 of the 144 (41%) observation sessions with an imposed head position to the left and to the right, no spontaneous head turnings were observed. The duration (mean + SD) of the sustained imposed head position lasted 58 ± 60 min ($n=59$) and 40 ± 60 min ($n=33$) for the right and left respectively, which is not significantly different (t test, $p > 0.05$).

The sustained imposed head position per group was not related to postmenstrual age (ANOVA, $p > 0.05$; table II).

Table II. Sustained imposed head position (in minutes) related to postmenstrual age

	Head position to the right tot.time/med + range	Head position to the left tot.time/med + range
week 32	1101 (71%)/14: 0-180	425 (29%)/ 3: 0-180
week 33	1475 (89%)/15: 0-180	181 (11%)/ 0: 0-103
week 34	870 (57%)/14: 0-138	646 (43%)/35: 0-180
week 35	836 (82%)/16: 0-108	184 (18%)/ 7: 0-80
week 36	1258 (69%)/15: 0-143	568 (31%)/17: 0-162
t o t a l observa- tion time in min.	5540	2004

During 73% of this observation time the sustained imposed head position was directed to the right, and during 27% to the left, but showed no developmental trend (ANOVA, $p > 0.05$).

Spontaneous head position

Table III shows the number of manipulations, the number of observation sessions, the total number of head turnings, the number of head turnings per 3-hour video recording, the number of observation sessions with spontaneous head turnings, the number of head turnings per observation session and the time between two spontaneous head turnings related to postmenstrual age.

Table III. General data obtained at weekly intervals

	32	33	34	35	36wks
-total number of manipulation sessions (median + range)	74 4 (1-15)	59 4 (0-6)	52 4 (2-7)	50 3 (0-9)	47 3 (1-8)
-number of observation sessions	39	45	38	46	47
-number of observation sessions with spontaneous head turnings	27	27	15	31	23
-total number of spontaneous head turnings	157	165	208	258	123
-number of spontaneous head turnings per 3 hours videorecording (median + range)	8 (0-37)	7 (0-42)	4 (0-103)	12 (0-70)	4 (0-39)
-number of spontaneous head turnings per observation session (median + range)	3 (1-35)	4 (1-24)	6 (2-67)	4 (1-64)	3 (1-34)
-mean time between two spontaneous head turnings (mean + SD)	7.07±14.08	5.55±10.45	5.20±13.30	5.19±25.25	5.26±14.3

911 spontaneous head turnings were observed. Table IV shows the spontaneous head position in minutes at various postmenstrual ages.

Table IV. Spontaneous head position (in minutes) related to postmenstrual age

	Head position to the right	Head position to the left
week 32	629 (57%)	473 (43%)
week 33	519 (59%)	357 (41%)
week 34	854 (77%)	250 (23%)
week 35	604 (44%)	768 (56%)
week 36	300 (45%)	372 (55%)
total observation time in min.	2906	2220

The total time with spontaneous head positions lasted 5126 minutes. The time spent with a 'spontaneous head position' was not related to postmenstrual age (ANOVA, $p > 0.05$). Analysing the summed-up data we found that in 57% the head was turned to the right and in 43% the head was turned to the left. The analysis of the data obtained at the various postmenstrual ages showed a significant 'spontaneous head position' preference of which the direction however varied with postmenstrual age (first 3 weeks to the right, last 2 weeks to the left, table IV).

The duration of the 'sustained imposed head position' for all the observation sessions with spontaneous head turnings was for the right imposed head position 24 ± 30 min ($n=86$) and 18 ± 22 min ($n=37$) for the left which is not significantly different (t test, $p > 0.05$).

The number of spontaneous head turnings varied widely per observation session (table III). The lower the frequency of the spontaneous head turnings the more sleep and inactivity may determine spontaneous head positions.

Therefore we analysed the spontaneous head positions separately in four groups depending on the number of spontaneous head turnings per observation session (table V).

Table V. Spontaneous head position related to the imposed head position divided to the number of spontaneous head turnings per observation session

number of head turnings		1		2		3		>4	
imposed head position	N	right 21	left 6	right 14	left 6	right 9	left 3	right 41	left 23
spontaneous head position to the right		----	100%	98%	7%	11%	83%	62%	40%
left		100%	----	2%	93%	89%	17%	38%	60%

Observation sessions with only one spontaneous head turning

In 21 of the 144 (14%) and in 6 of the 71 (9%) observation sessions with an 'imposed head position' to the right and to the left respectively, only one spontaneous head turning was observed. The total duration of the 'spontaneous head position' lasted 29 minutes (median 2, range 0-25) to the right and 172 minutes to the left (median 2, range 0-65).

Observation sessions with two spontaneous head turnings

In 14 of the 144 observation sessions with an 'imposed head position' to the right, 2 spontaneous head turnings were observed. The total duration of the 'spontaneous head positions' was 563 minutes (median 30, range 1-126) to the right and 14 minutes (median 0, range 0-5) to the left, which is 98% and 2% respectively.

In 6 of the 71 observation sessions with an 'imposed head position' to the left, 2 spontaneous head turnings were observed. The total duration of the 'spontaneous head positions' was 64 minutes (median 8, range 1-27) to the left and 5 minutes (median 0, range 0-2) to the right, which is 93% and 7% respectively.

Observation sessions with three spontaneous head turnings

In 9 of the 144 observation sessions with an 'imposed head position' to the right, 3 spontaneous head turnings were observed. The total duration of the 'spontaneous head position' was 19 minutes (median 1, range 0-9) to the right and 154 minutes (median 17, range 0-50) to the left, which is 11% and 89% respectively.

In 3 of the 71 observation sessions with an 'imposed head position' to the left, 3 spontaneous head turnings were observed. The total duration of the 'spontaneous head position' was 2 minutes (median 0, range 0-2) to the left and 10 minutes (median 2, range 0-8) to the right, which is 17% and 83% respectively.

Observation sessions with more than three spontaneous head turnings

In 41 of the 144 observation sessions with an 'imposed head position' to the right, 4 or more spontaneous head turnings were observed. The total duration of the 'spontaneous head position' was 1594 minutes (40+37) to the right and 975 minutes (23+32) to the left, which is 62% and 38% respectively.

In 23 of the 71 observation sessions with an 'imposed head position' to the left, 4 or more spontaneous head turnings were observed. The total duration of the 'spontaneous head position' was 860 minutes (40+40) to the left and 569 minutes (27 +29) to the right, which is 60% and 40% respectively.

By using t test we investigated whether there are correlations between the following parameters:

- the duration of the period with 'spontaneous head position'
- the frequency of the head turnings
- the 'spontaneous head position' preference
- the direction and duration of the 'sustained imposed head position'.

Because the relative 'spontaneous head position preference' is defined as:

$$\left(\frac{\text{duration of spontaneous position to the right (left)}}{\text{duration of total spontaneous positions}} \right) \times 100\%$$

the preference might be mainly determined by one relative long-lasting, 'spontaneous head position'. For that reason we also calculated the preference, if the longest period had not occurred at all.

This correction did not affect the outcome of this correlation analysis. No correlations (t test, $p > 0.05$) were found except for the number of spontaneous head turnings with the duration of the 'spontaneous head position' (t test, $p < 0.05$).

By using ANOVA we found no clear correlation with postmenstrual age and no developmental trend with respect to the same parameters mentioned above ($p>0.05$).

Discussion

Influence of nursing care

From the present results (table I) we may conclude that the 'imposed head position' is more frequently directed towards the nursing side: i.e. mainly to the right side. This observation did not change with postmenstrual age. Apparently, regardless of the instructions given, the nurse prefers to manipulate in such a way that she can see the infant's face.

In addition, we observed no clear difference in the duration that the imposed position was sustained to the left and to the right. The differentiation between 'sustained imposed' and 'spontaneous head position' might be artificial, because a 'sustained imposed head position' may reflect some kind of spontaneous behaviour. However, in the observation sessions with and without spontaneous head turnings, the duration of the 'sustained imposed head position' for right and left was not significantly different. Thus, the duration of a 'sustained imposed head position' seems not to reflect a preference position of the head.

Spontaneous head position

The frequency of spontaneous head turnings is not clearly different after an 'imposed head position' to the left or to the right. Furthermore, the influence of the 'imposed head position' on 'spontaneous head position' diminished by the number of spontaneous head turnings and by increasing observation time (table V). Apparently, after several spontaneous head turnings the normal infants show no preference any more.

Duration of spontaneous head position

In weeks 32, 33 and especially in week 34, a 'spontaneous head position' to the right was longer adopted than to the left, whereas in weeks 35 and 36 the position to the left was adopted longer than to the right (table IV). A suggested preference of the summed-up data is wholly determined by the finding in week 34; this phenomenon requires further study. Regarding the discrepancies between the different studies (Gardner et al, 1977; Precht et al, 1979; Michel and Goodwin, 1979) and our own results, one might wonder whether there is a real 'spontaneous head position' preference or 'spontaneous head orientation' preference at all.

Final Comments

From our results we may conclude that the seemingly 'spontaneous head position' preference might be ascribed to the influence of the foregoing 'imposed head position' and that a head position preference to the right is evident with respect to the head position 'imposed' by the nurse.

Chapter 6

Influence of head position and head position change on body posture in pre-term infants

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(Neuropediatrics: 1988; 19:96-100)

Introduction

Posture is an active process, regulated by a large variety of sensory and central inputs, which tends to prevent any not-desired change of position. It is the result of the cooperation of a great number of reflexes, many of which have a tonic character (Magnus, 1926). Primitive reflexes influence body posture in pre-term infants (Allen and Capute, 1986) and full-term infants (Capute et al, 1984) and contribute to the development of infant posture in the first year of life (Capute et al, 1982). The primitive reflexes studied by many authors (Pacella and Barrera, 1940; Pollack, 1960; Willemse, 1961) are brain-stem mediated responses of which the tonic neck reflex, originally described by Magnus and de Kleyn (1912) is one of them. Magnus and de Kleyn (1912) demonstrated that in decerebrated animals turning the head to one side resulted in extension of the fore and the hind limb towards which the jaw is rotated and a relaxation of the limbs towards which the vertex is rotated. The posture was tonically maintained (Gesell, 1938). This reflex was called the Asymmetric Tonic Neck Reflex (ATNR). According to Gesell (1938) the Tonic Neck Reflex is a dominating characteristic of normal infancy and is clearly present in the spontaneous waking postures of the normal infant. In contrast, Magnus and de Kleyn (1912) and Magnus (1924), who examined 26 healthy neonates and infants, did not observe a clear dominance of the ATNR. Other authors reported that these 'primitive' reflexes are very inconstant in infancy (Vasella and Karlsson, 1962).

In conclusion

There is no consensus about the influence of head position (changes) upon body posture.

The object of this longitudinal study is to answer the following questions:

- is there an influence of head position and head position change on body posture?
- If there is any influence, does it show a specific pattern?
- If so, does this pattern change with postmenstrual age?
- Does a spontaneous head turning elicit an asymmetric tonic neck reflex as described by Magnus (1926).

Infants and methods

Fifteen low-risk pre-term infants were weekly observed in their incubators for a three-hour period between 32 and 36 weeks of postmenstrual age. The first day of the last menstrual period and/or the biparietal diameter of the foetal head measured with ultrasound were used to determine the postmenstrual age. All prematures were judged to be low-risk. The infants were video-taped under standardized conditions. During these observation sessions possible influences of the spontaneously assumed head position and head rotation on the position of the extremities were studied. Body posture was noted just before an initial head turning and immediately after the head turning. Only those head turnings were analysed when rotation of the head was noted without dorsiflexion, ventroflexion or deviation of the head. Furthermore, the head turnings appearing during a Moro reflex or a stretch were disregarded. Thirty head turnings were classified by two observers (JSH V and R v O) in order to test the reliability of the classifications. In 28 of 30 head turnings there was full agreement about the classification. Postures were classified according to the method described by Prechtl et al (1979) and the degree and pattern of flexion and extension of elbow and knee were analysed. The ultimate limb position was compared with the initial limb position with regard to the degree of flexion and extension of the limbs on the face side compared with the degree of flexion and extension of the limbs on the occiput side.

Preference posture (the most frequently observed posture) noted during an observation period, was determined (assessment technique identical with that described by Prechtl et al, 1979).

The duration of the newly assumed body posture after a head turning, and the relation of a head position to the observed preference posture with regard to the degree of flexion and extension were studied.

The state of the child was classified as:

- state A: eyes closes, eye movements, irregular respiration
- state B: eyes open, gross body movements.

Statistical analysis of the data was performed using the U test, Wilcoxon matched-paired signed-rank test and chi-square test as indicated in the results. A possible pattern was regarded as significant if it differed significantly ($p < 0.05$) from a pattern in which flexion and extension were similar:

$$U = \frac{N1-N2-1}{\sqrt{N1-N2}}$$

(N1 and N2 are the observed occurrences of the incidences of flexion and extension respectively.)

Results

Seven hundred and two head turnings without flexion, extension or lateral deviation of the head were included in the final analysis. 539 (80%) of these 702 head turnings were accompanied by a positional change of at least one of the extremities with the following distribution:

- right arm 36%
- left arm 33%
- right leg 47%
- left leg 48%.

Table I shows the median number of head turnings (with range) at the ages under investigation (32-36 weeks of postmenstrual age).

Table I. The median number of head turnings (with range) at the ages under investigation.

Weeks	Median	Range
32	8	0-33
33	6	0-31
34	5	0-52
35	6	0-39
36	2	0-35

Figure 1a and 1b show the relationship between the head turnings and the different positional changes of the extremities per postmenstrual age.

Fig. 1 a.

Limb position change as a function of postmenstrual age (starting position: head to the right).

The total number of analysed head-turnings to the left mounted 69, 73, 79, 83, 60 at respect. 32, 33, 34, 35, 36 weeks postmenstrual age.

Fig. 1 b.

Limb position change as a function of postmenstrual age (starting position: head to the left).

The total number of analysed head-turnings to the right mounted 80, 56, 70, 73, 59 at respect. 32, 33, 34, 35, 36 weeks postmenstrual age.

Of these 702 head turnings, 297 head turnings were noted during state A, 375 during state B, while 30 were noted during a state which could not be classified. 458 position changes of extremities occurred during state A and 691 during state B.

Table II shows the flexion and extension patterns of all four extremities in relation with the direction of the head turning (the data from Fig. 1a and 1b are summed-up for all ages).

Table II. Relation between head turning and flexion/extension pattern of the extremities

	Head to the right		Head to the left	
	Extension	Flexion	Extension	Flexion
Right arm	65	41	80	67
Left arm	26	63	94	49
Right leg	139	34	35	120
Left leg	25	160	125	26

Turning of the head to the left (Table II) was more often accompanied with extension than flexion of the left arm and the left leg (U test: $p < 0.05$). The right leg was significantly more often flexed than extended (U test: $p < 0.05$), but flexion and extension of the right arm occurred almost equally often (U test: $p > 0.05$).

Turning of the head to the right was accompanied more often with extension than flexion of the right arm and leg (U test: $p < 0.05$). The left arm and leg were significantly more often flexed than extended (U test: $p < 0.05$).

With respect to the legs, this flexion and extension pattern was present at every postmenstrual age. The pattern only became significant for the left arm (chi square, $p < 0.05$) from the 34th week (Fig 1a and 1b). A pattern of flexion and extension for the right arm was seen only at 36 weeks of postmenstrual age.

The extension/flexion pattern of the leg was found significant in both state A and state B (U test: $p < 0.05$). But, the extension/flexion pattern of the arm was no longer significant if we consider the data of the two states separately.

Table III. Frequency of the various position changes after a head turning as a function of postmenstrual age*

Posture	Head turnings				
	N=149	N=129	N=149	N=156	N=119
- No change	26%	20%	8%	11%	11%
- Extension chin extremities + flexion occip. extremities (ATNR)	1%	-	1%	2%	3%
- Extension chin extremities + flexion occiput arm	3%	2%	3%	6%	3%
- Extension chin extremities + flexion occiput leg	1%	2%	8%	8%	8%
- Extension chin arm and leg	7%	9%	16%	19%	15%
- Flexion occiput arm and leg	5%	7%	9%	10%	9%
- Extension chin leg + flexion occiput leg	10%	11%	10%	14%	6%
- All other patterns (not specified)	47%	49%	45%	30%	45%
Weeks postmenstrual age	32	33	34	35	36

*For further explanation: see text

Table III shows some of the noted simultaneous limb posture changes.

The number of head turnings is not related to postmenstrual age. The frequency of appearance of the specified patterns with extension of the chin-side extremities with or without flexion of the occiput leg significantly increased with postmenstrual age (U test: $p < 0.05$). With increasing age the number of position changes increased (U test: $p < 0.05$). Extension of both chin-side extremities combined with flexion of both occiput extremities (ATNR) as described by Magnus and de Kleyn (1924) in relation to head turnings was observed varying from 0-3%, without regard to the time the assumed position was maintained. On basis of the preference of the extension and flexion pattern, one should expect a preference of the ATNR by coincidence of about 12%. Furthermore the ATNR position was assumed for less than 4 seconds.

Extension of the chin-side leg combined with flexion of the occiput leg was observed varying from 6-14%.

Figure 2 shows the time in seconds during which the assumed position of the extremities after the head turning was maintained.

Table IV shows the relative degree of extension of the limbs in the observed preference posture at various ages.

Table IV. Relative degree of extension of the limbs in the observed preference posture (total group) in relation to postmenstrual age

Age (wks)	Extension CA > OA	Extension CA < OA	Extension CA = OA	Extension CL > OL	Extension CL < OL	Extension CL = OL	A.T.N.R
32	4	6	5	4	1	10	2
33	5	3	7	7	1	7	1
34	6	3	6	2	0	13	0
35	5	1	9	6	3	6	2
36	1	1	13	6	0	9	1
Total	21 (28%)	14 (19%)	40 (53%)	25 (33%)	5 (7%)	45 (60%)	6 (8%)

CA = chin arm, CL = chin leg, OA = occiput arm, OL = occiput leg.

With increasing age a more symmetrical pattern of the arms was observed (CA=OA). A statistically significant difference was proven between 32 and 36 weeks (Wilcoxon matched-paired signed-rank test, $p < 0.01$). No clear relationship between the pattern of the legs and postmenstrual age was observed. At each age the chin-side leg was equally or less extended than the occiput leg (50-87%) which is not expected if a clearly dominating ATNR is present. In only 8% of the observed preference postures, the influence of head position was in accordance with a pattern known as the ATNR.

Discussion

If all observed 'spontaneous' head turnings are considered, no typical pattern of limb position was noted. If only those head turnings are analysed which were associated with a positional change of one of the four extremities related to a head turning, only a significant flexion/extension pattern of the leg was observed:

- during the whole period under investigation
- at every postmenstrual age
- in various states.

An extension pattern of the chin-side leg (with head turning) was also reported by Pacella and Barrera (1940) in pre-term infants and by Pollack (1960) and Vasella and Karlsson (1962) in healthy newborns.

With respect to the arm, apparently the patterns in several cases significantly differ from a 50-50 (extension/flexion) distribution but to such a small extent that with a subdivision of the data a possible pattern was no longer significant. This is in contrast to Gesell (1938) who noted an extension pattern of the chin arm with head turnings.

In our study the observed limb position after a head turning was maintained for only a few seconds. We could not confirm the finding of others (Allen and Capute, 1986; Gesell, 1938; Pollack, 1960) that head position influences body posture as long as the head is turned to one side (fig. 2).

In our study, at least within the first twenty seconds after a head turning, the initial posture change had already disappeared. The observed interside difference of the upper occiput extremity related to a head turning (table II) may show some kind of neurological dysfunction or physiological laterality. However, no 'other' signs of laterality, except for a head position preference to the right, was noted. Whether there is a correlation between the observed interside difference and head position preference is not known.

The discrepancies observed with respect to the incidence and dominance of the ATNR (Byers, 1938; Pacella and Barrera, 1940; Pollack, 1960; Vasella and Karlsson, 1962; Willemse, 1961) might be due to:

- a) a non-uniform description of the reflex.

For example Amiel-Tison (1986): 'the fencing position is exhibited in the extension of the arm on the side

toward which the face is turned; the occipital arm remains flexed. The position is reversed in the lower extremities (i.e., occipital leg extended, opposite leg flexed)'.

- b) Different criteria for judging the ATNR positive. For example:
 - Pacella and Barrera (1940): 'relative extension of one or both limbs on the chin side of the body and corresponding flexion of one or both limbs on the opposite side'.
 - Vasella and Karlsson (1962): 'the response was considered to be an ATNR when one or both chin extremities were extended, compared with the corresponding occiput extremities, but only if this absolute or relative extension lasted at least five seconds'.
- c) Different ways to study the ATNR:
For example: spontaneous tonic neck reflex patterns were studied by Schoo (1933), Vasella and Karlsson (1962), Willemse (1961), while passively elicited tonic neck reflex patterns were studied by Allen and Capute (1986), Schaltenbrand (1925).
- d) Differences in children studied.
Allen and Capute (1986) stated that beyond 33 weeks of postmenstrual age all infants had an ATNR. Part of the population studied by these authors included neurologically abnormal infants. In our longitudinal study only low-risk pre-term infants were included and an ATNR was observed varying from 0-3%.
Therefore, in agreement with Capute et al (1982), an unusual 'strong' or 'persistent' ATNR can probably be classified as a marker of neurological dysfunction.

Conclusion

In our longitudinal study of low-risk pre-term infants we only found after a head turning an extension/flexion pattern for the legs. This pattern may support the physiological principle that the neurological development occurs in a caudal-cephalic direction if we define the ATNR as a primitive reflex.

Chapter 7

Posture during head turning in pre-term infants:
a longitudinal study of 15 low-risk infants of
32-36 weeks of postmenstrual age

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Introduction

In our previous study (Vles et al, 1988) on resting posture we observed that the infants of 32-36 weeks of postmenstrual age assumed a great number of different postures. No really dominant preference posture correlating with postmenstrual age was found. No consensus exists whether there is a typical posture related to postmenstrual age (Amiel-Tison and Grenier, 1986; Prechtl et al, 1979; Saint-Anne-Dargassies, 1955; Vles et al, 1988). Our results of preference postures are in accordance with those of Prechtl et al (1979), but disagree with those described by Amiel-Tison and Grenier (1986), Dubowitz and Dubowitz (1981) and Saint-Anne-Dargassies (1955).

This discrepancy might be attributed to methodological differences. In the same way as Prechtl et al (1979) we studied body posture of low-risk pre-term infants in repose (= resting posture), reflecting passive tone (Vles et al, 1988). The assessment technique used by others (Amiel-Tison and Grenier, 1986; Dubowitz and Dubowitz, 1970, 1981; Saint-Anne-Dargassies, 1955) was not described in detail. They studied posture as part of the neurological examination of the infant. It is not clear whether they studied posture at the beginning, during or at the end of a movement. In other words, the degree of activity is not known.

Therefore, we studied posture during a well-defined activity. The object of this longitudinal study is to answer the following questions:

- a) have low-risk pre-term infants a preference posture during activity?
- b) if such preference exists,
 - does it depend on the 'state' of the infant?
 - does it depend on the initial side the head was turned to?
 - does it change with postmenstrual age?

Infants and Methods

Infants

Fifteen low-risk pre-term infants of 32 weeks of postmenstrual age, were weekly observed and registered on video recording during a three-hour period, until the age of 36 weeks of postmenstrual age. The infants were observed in

their incubators in a supine position without any restriction of their movements. The observation sessions took always place immediately after the nursing control and did not interfere with nursing routines. The first day of the last menstrual period and/or the biparietal diameter of the foetal head measured with ultrasound were used to determine the postmenstrual age. All prematures were judged to be low-risk.

Description of postures

Body posture was noted during a head turning at the moment the head crossed the midline on a frozen video frame. Only those positions were analysed with the head in the midline, without dorsiflexion, ventroflexion or deviation of the head, and the midpositions during a MORO reflex or a stretch or when the infant cried were disregarded. Postures were classified and subsequently analysed in various ways.

-The shoulder and hip were classified according to the degree of ab- and adduction resulting in seven classes. The classification of the elbow and the knee was based upon four grades of flexion and extension and upon the exo- or endorotation of shoulder and hip. This also resulted in seven classes. The classification of the position of a limb therefore resulted in $7 \times 7 = 49$ classes of which some postures were not observed and are probably anatomically impossible. With respect to the abduction of the hip exceeding 90 degrees, the real movement includes an abduction, flexion and or rotation. However, seen in a two dimensional plane we designated this classification for simplicity.

Posture was analysed:

- with regard to the complete observed posture (I)
- without regard to endo- or exorotation (II)
- without regard to endo- or exorotation and ad- and abduction (III)
- without regard to endo- or exorotation and flexion and extension (IV).

Furthermore, each limb was analysed separately:

- with regard to the initially observed position (V)
- without regard to endo- or exorotation and ad- and abduction (VI)
- without regard to endo- or exorotation and flexion and extension (VII).

We also compared the position of both upper limbs with the position of both lower limbs. Furthermore, the right limbs (arm and leg) were compared with the left limbs.

Interobserver reliability

Fifty midpositions were classified by two observers separately to test the reliability of the classification. In 48 of 50 midpositions there was full agreement about the classification, therefore all classifications were used for analysis.

Initial head position and 'state'

The classified postures were related to the initial head position before the head turning resulted in an opposite head position. The mostly observed position per limb and the mostly observed combined position of both arms and both legs were related to the 'state' of the infant.

State

Since the concept and definition of 'state' are still debatable between 32 and 36 weeks of postmenstrual age we used a purely descriptive categorization:

- 'state A': eyes closed; eye movements; irregular respiration
- 'state B': eyes open; body movements.

Statistical analysis

The data were analysed by an analysis of variance (ANOVA) and by calculating linear, exponential, logarithmic and quadratic regressions (using an IBM compatible P.C. statistical program Systat: version 3.0, copyright 1985, Systat Inc., 2902 Central Street, Evanston, Ill 602001, U.S.A.) of several parameters as a function of postmenstrual age, expressed by the correlation coefficient.

Results:

Table 1 shows the distribution of the head turnings per child per age.

Table I: Distribution of the head turnings per child per postmenstrual age.

	postmenstrual age (weeks)				
	32	33	34	35	36
Infant					
1	14	1	5	1	16
2	7	0	6	6	1
3	10	13	22	6	11
4	6	7	0	6	0
5	9	6	0	0	0
6	8	3	0	0	0
7	33	31	22	32	33
8	6	5	6	12	8
9	6	5	0	0	0
10	7	0	52	6	6
11	8	7	17	39	2
12	16	20	19	22	35
13	15	3	0	15	1
14	4	9	0	4	6
15	0	19	0	7	0
total	149	129	149	156	119

Seven hundred and two postures with the head in the midline were included in the final analysis, divided over the five postmenstrual ages studied. The variety of postures, i.e. the number of different postures observed each week, showed no clear correlation with postmenstrual age (table II: ANOVA: $p > 0.05$; correlation coefficient < 0.61).

Table II.

	postmenstrual age (weeks)				
	32	33	34	35	36
number of observations	149	129	149	156	119
different postures:					
absolute number	96	78	110	102	77
relative number	65%	60%	74%	65%	65%

Of these 702 head turnings, 297 head turnings were noted during state A, 375 head turnings occurred during state B, while 30 were noted during a state which could not be classified.

The most frequently observed posture at every age in state A as in state B was a symmetrical one in which the arms were fully flexed and the legs were partly extended. However, we observed other postures which were adopted with an almost equal or somewhat lower frequency, which are shown in figure 1.

Figure 1

5 most frequently observed postures
per postmenstrual age in 15 infants

The second mostly observed posture was, except for in the 32nd and 34th weeks of postmenstrual age, also a symmetrical posture. The arms were again more flexed than the legs, although this difference was less pronounced, regardless of the 'state', and the initial head position.

Analysing the arms and the legs separately, regardless of the 'state' or the initial head position, we observed that for both the arms and the legs the most frequently observed position was a symmetrical one. The incidence varied from 25-36% for the arms and 33-58% for the legs between 32 and 36 weeks of postmenstrual age (figure 2).

Figure 2

most frequently observed combined position of
both arms and both legs

The most frequently adopted position of this symmetrical position:

- was for both arms a fully flexed position. The incidence did not change with postmenstrual age (correlation coefficient: <0.7), if the number of symmetrical positions were related to the total of observed positions at every postmenstrual age.
- was for both legs a partly extended position. The incidence did not change with postmenstrual age (correlation

coefficient: <0.7), if the number of symmetrical positions were related to the total of observed positions at every postmenstrual age. If the limbs were analysed separately, regardless of the 'state' or the initial head position, the most frequently observed position for the right and the left arm was a fully flexed position, which preference did not change with postmenstrual age (correlation coefficient <0.7). For the right and the left leg the preference position was a partly extended one the preference of which did not change with postmenstrual age (correlation coefficient <0.7 , figure 3).

Figure 3

most frequently observed position of the right
and left arm and the right and left leg

However, an increase of the partly flexed position from 13% at 32 weeks to 30% at 33 weeks up to 36 weeks was observed.

If the combination of an arm and a leg were analysed with respect to right and left, regardless of the 'state' or the initial head position, a fully flexed position of the upper extremity combined with a partly extended position of the lower extremity was observed most frequently for both sides at every postmenstrual age. No developmental trend was noted (correlation coefficient <0.7 , figure 4).

Figure 4

most frequently observed combined position of
the right arm and leg and left arm and leg

In this study a great variety of postures was observed partly due to our method of detailed classification; in order not to overlook more rude patterns of posture, we reduced the variety of postures by using less detailed classifications (see infants and methods). The patterns of posture described above were very similar and became even more pronounced due to this 'lower' degree of differentiation (figure 5).

Figure 5

most frequently observed posture per postmenstrual age in 15 infants by using different classifications (see material & methods)

Furthermore, we analysed:

- the most frequently observed limb position related to 'state' A and 'state' B, and related to the initial head position (summed-up data)

- the observed symmetrical combined position for both arms and both legs related to 'state' A and 'state' B and to the initial head position (summed-up data).

The most frequently observed arm position was for the right and the left arm a fully flexed position in both 'states' independent of the initial head position. However, this predominant arm position was more frequently observed in 'state' B compared with 'state' A (see table III).

The most frequently observed leg position was for both legs a partly extended position in both 'states', independent of the initial head position. However, the predominant leg position was more frequently observed in 'state' B compared with 'state' A (see table III).

Table III

	initially imposed head position to the right		initially imposed head position to the left	
	state A	state B	state A	state B
fully flexed				
right arm (n)	42	77	53	100
left arm (n)	62	96	40	88
partly extended				
right leg (n)	81	112	81	124
left leg (n)	89	108	82	113

The initial head position did not influence the observed degree of symmetry of both arms and both legs. The symmetrical arm and leg position was observed more frequently in 'state' B compared with 'state' A when summed-up for all ages (data not shown).

Discussion

From our results we may conclude that regardless of the type of analysis performed a fully flexed position of the upper extremities and a partly extended position of the lower extremities was the most frequently noted position at all ages studied.

With regard to the arm position:

- no clearly developmental trend was observed
- the symmetrically fully flexed position was not related to the initial head position
- the dominant fully flexed posture occurred more frequently when the infants' eyes were open.

With regard to the leg position:

- a predominant partly extended position was mostly observed at all ages
- the partly flexed position occurred less frequently (13%) at 32 weeks compared with the period between 33 and 36 weeks (30%)
- the symmetrically partly extended position and the later occurring partly flexed position was not related to the initial head position
- the dominant partly extended posture occurred more frequently when the infants' eyes were open.

The most intriguing findings were:

- 1) the occurrence of a more flexed position of the upper extremities compared with the lower extremities at all postmenstrual ages, and
- 2) the observed symmetry of both upper and both lower extremities.

The first finding is in contrast with the assumed caudocephalic progression in flexor tone as used as a criterion for maturity (Dubowitz and Dubowitz, 1981).

The present paper describes posture during a movement. Posture analysed in this way may show active tone. To our knowledge only two reports are available in which posture is studied during activity. The observed active posture during feeding in term (Casaer, 1979) and pre-term (Daniels and Casaer, 1985) infants is very similar to the observed active posture in our study and shows a cephalocaudal acquisition of flexor tone. This is a remarkable finding if we realize again that a caudocephalic acquisition of flexor tone is always assumed to be related to maturation (i.e. postmenstrual age: Amiel-Tison and Grenier, 1986; Ballard et al, 1979; Dubowitz and Dubowitz, 1981; Saint-Anne-Dargassies, 1955) and used in various schemes for neurological assessment of the newborn (Amiel-Tison and Grenier, 1986; Ballard et al, 1979; Dubowitz and Dubowitz, 1981).

Development is characterized for several items by a cephalocaudal maturation:

- muscle spindles, joint receptors and skin receptors (Humphrey, 1964)

- spinal cord differentiation (Okado and Kojima, 1984)
- the H-response (Mayer and Mosser, 1973)
- the supra-spinal inputs to the cervical and spinal cord (Okado and Kojima, 1984).

Wyke (1975) stated that cortical systems play a little effective part in the control of movement because of small diameters and the degree of myelination. We must realize, however, that the function of nerve fibres is not exclusively determined by myelin lamellae. The development of the corticospinal tract was examined by Humphrey (1978): "fibres originating from the cerebral cortex descend to the cerebral peduncle and to the caudal level of the pyramidal decussation; after the corticospinal fibres finish decussating, they rapidly descend to the midthoracic spinal cord at 17 weeks of postmenstrual age". All central tract fibres are unmyelinated until the 12th (Okado and Kojima, 1984) or the 16th week of intra-uterine life (Hamilton and Mossman, 1972) while already from seven weeks of postmenstrual age onwards different motor patterns have been observed (de Vries et al, 1982) with ultrasound. Furthermore, ultrasound studies of the foetus in utero showed that already at 22 weeks posture is in flexion (Saint-Anne-Dargassies, 1979). This observation may suggest that the development of flexor muscle activity comes before extensor muscle activity.

Conditions ex utero are, however, different from in utero. Ex utero, flexion of the arm at the elbow has to counteract gravity. Flexion of the leg at the knee not only has to counteract gravity, but also has to overcome the resistance of a hard surface on which the infant rests in a supine position and has to be associated with flexion and/or rotation at the hip. So the relative absence of flexion of the leg may not reflect a good development of extensor activity but might reflect that flexor muscle activity is not yet able to overcome the above-mentioned forces. In physiological studies it has been shown that the corticospinal fibres in general have a facilitatory action on motor neurons which supply flexor muscles. Schulte (1974) found that tonic myotatic responses in flexor muscles are stronger than those in extensor muscles between the 34th and the 40th week of postmenstrual age.

The observed cephalocaudal acquisition of flexor tone during activity very well suits the law of cephalocaudal development and might reflect corticospinal influence.

Final comments

We submit for consideration that the observed posture with a more flexed position of the upper extremities compared with the lower extremities, reflects a temporal difference of development in a cephalocaudal direction of antigravity muscle activity.

Furthermore, a symmetrical posture during a spontaneous head turning, with the head in the midline, may be a sign of normality in the pre-term infant.

GENERAL DISCUSSION

The object of this longitudinal study was to investigate spontaneous behaviour of low-risk pre-term infants of 32-36 weeks of postmenstrual age. Motor behaviour, posture, head position preference and the influence of a head position and a head position change on limb position was studied. A study of spontaneous motor behaviour introduces a major initial problem: what is meant by spontaneous? In the introduction we indicated that motor behaviour has been studied predominantly after some kind of stimulus and therefore had to be considered as responsive motor behaviour. However, even in our study of motor behaviour, some perhaps -not observed- stimuli might have been present. In general, we seriously tried to prevent any evident stimulus-response situation and observed the infant's motor behaviour while minimizing any interaction, apart from the 'natural' need for care.

In general, a wide inter-individual and intra-individual variability with respect to the different variables of spontaneous motor behaviour (chapter 3) and posture (chapter 4) were observed.

The time spent without making any movements, or with fussing or mouthing or the number of smiles, stretches or yawns showed no clear correlation with postmenstrual age neither for the individual data nor for the group averages. The number of twitches and the time spent with frowning, however, decreased with increasing age, though not monotonously in all infants. With increasing age the "median" time spent with general body movements increased and the "median" time spent with isolated body movements decreased, the individual data however showed no trend related to postmenstrual age.

With increasing age, the "median" number of startles decreased; but again the individual data showed no developmental trend. The observation that some items show a developmental trend with regard to the group averages and not with regard to the individual data reflect that the observed trends were smaller than the intrinsic intra-individual variations and will have a poor clinical relevance.

Analysis of posture showed that the infants assumed a great number of different postures. The number of different postures, the number of times the "preference" posture was observed and the duration of the longest uninterrupted posture showed no correlation with postmenstrual age. Regardless of the numerous ways of analysing the data no really dominant preference posture was found.

Summing-up all data we found a head position preference to the right (averaged over the total group). The imposed head position was more frequently directed towards the side from where nursing took place. The observed spontaneous head position preference diminished with increasing observation time and can be ascribed to the influence of the foregoing imposed head position.

If the head was spontaneously turned to one side, only an extension pattern of the chin-side leg and a flexion pattern of the occiput leg was observed at all postmenstrual ages. No consequent significant pattern was observed with respect to the other limbs. An asymmetrical tonic neck reflex was seen after only 3 per cent of the head position changes.

If posture was studied during spontaneous activity at the moment the head position was in the midline, the observed posture was mostly a symmetrical one, in which the arms were fully flexed and the legs partly extended. The observed posture during activity in our study showed a cephalocaudal acquisition of flexor tone.

Part of the observed variability could possibly be caused by different obstetrical characteristics, which were not taken into account: the population of mothers could be rather nonhomogeneous. However, the intraindividual variability appeared to be of the same magnitude as the interindividual variability (see below).

Wide inter-individual variability:

The wide inter-individual variability observed in our study of spontaneous motor behaviour and posture might be a consequence of normal biological variability. Extensive growth data also show considerable variations in an otherwise homogeneous population of children at any age (Eveleth and Tanner, 1976; Tanner, 1970). Furthermore, the observed variability might be explained by the presence of the well-known biological variability observed during brain maturation and development.

One would expect that (normal) variations of brain maturation would influence the course of (normal) behavioural development. Measuring the Brainstem Auditory Evoked Potentials (BAEP) is one of the methods of determining (subcortical auditory brainstem) maturation. In a longitudinal study of BAEP of pre-term infants, we observed that the absolute latency of all BAEP peaks and the interval latency I to V varied widely between these infants (Vles et al, 1987). Because of the large inter-individual variability in BAEP latencies, we calculated the decay of the peak I to V interval latency by exponential regression analysis. Inaccurate determination of postmenstrual age (time shift), because of the mathematical properties of exponential regression analysis, does not affect the time

constant of the individual fits. The time constant (time course) of the I to V interval latency most likely correlates to some extent with maturation of the central subcortical auditory function. The time-constant shows a similar wide variation compared with the absolute latencies. Most likely, as with the absolute BAEP latencies, BAEP age dependency (i.e. maturation) varies greatly from one individual to another (Vles et al, 1987). Although, we carefully selected infants (low-risk, postmenstrual age), a wide (intrinsic) variability was observed, possibly due to intrinsic factors and individual differences with respect to environmental processes (Touwen, 1980; Waddington, 1975; Weis, 1939).

This supports our hypothesis that the observed inter-individual variability of motor behaviour and posture might also be due to intrinsic factors.

Wide intra-individual variability:

Regardless of the numerous ways of analysing the data, the pre-term born infants show no clearly dominant posture in repose and no correlation between posture and postmenstrual age was found. Our data of spontaneous motor behaviour also show a wide intra-individual variability.

Earlier studies of pre-term infants (Prechtl et al, 1979) and human fetuses (Nijhuis, 1984; De Vries, 1987) also showed a wide intra-individual variability in the incidence of most movement patterns in the individuals studied.

The significance of this variability has often been described as a property of normal development (Touwen, 1978, 1980).

Behaviour does not appear to be a simple reflex relationship between input and output. Both biological (genetic) and experiential (environmental) factors are important and modify the whole nervous system (memory, feedback) and thus behaviour.

The observation that the intra- and intervariability are of about the same magnitude supports the hypothesis that variability within these infants and between these 'normal' infants reflects normal development.

Some remarks with respect to body posture:

The time-linked sequence of maturation changes of the various motor pathways (myelination) has been used to explain posture changes with postmenstrual age, noted by Amiel-Tison (1968, 1986), Saint-Anne-Dargassies (1955, 1979) and Dubowitz and Dubowitz (1981). Lawrence and Kuypers (1968, I, II) concluded that all descending motor tracts could be physiologically grouped into three pathways according to their effects on selective motor-neuron activity. Progressive myelination is seen first in tracts composing the medial and then the lateral subcorticospinal pathways. The corticospinal tract myelinates latest of all (Rorke and Riggs, 1969). However, some considerations have to be made when such a correlation is suggested:

Firstly, Lawrence and Kuypers (1969, I,II) studied the effects of peracute lesions of the descending pathways which are different from a normal, disturbed or delayed maturation.

Secondly, they concluded that the noted effects were correlated with the artificial lesions made. One could, however, also conclude that the effects are due to an altered function of the remaining intact pathways.

Thirdly, the dependence of brain function on myelinogenesis alone remains a debated point (McKhann et al, 1973). Some behaviour (visual versus auditory orienting behaviour) in the young infant does not develop in the sequence expected from myelination patterns alone.

At last we must realize that they studied monkeys and not pre-term infants. Extrapolation from animal studies may be of help, but only if full account is taken of species differences (Touwen, 1980).

Although these observations might offer insight into postures of infants with brain damage, a strong not antagonized or not balanced influence of a certain tract by (an)other tract(s) due to function impairment is not the same as a particular step in normal development. For example spasticity is not simply the result of release from corticospinal tract inhibition alone (Lance, 1981).

Regardless of the way we analysed our data, no dominant preference posture in repose was observed. Our findings are in accordance with those of Prechtl et al (1979). In our opinion the studies (Amiel-Tison, 1968; Dubowitz and Dubowitz, 1981; Saint-Anne-Dargassies, 1955) in which a developmental trend of body posture was observed, recovery from illness or reaction to a manipulation before the observation, may have influenced the obtained data.

Head position:

In the nursery most if not all of the equipment used is constructed for right-handed people. As a result of this asymmetrical nursing procedure stimulation will also be asymmetrical. Supine head position orientation preference has been correlated with hand preference and adult handedness in humans (Michel, 1981; Konishi et al, 1986). Right-handedness may be genetic in origin (Annett, 1972) or may be influenced by environmental circumstances (Collins, 1975). Noirot and Alegria (1983) stated that development of spacial skill in neonates was linked to interaction with the mother. Head turning toward human voices differed with the type of feeding in term babies: breast-fed infants generally mouthed in the same direction as the voice, while bottle-fed infants usually mouthed towards the left, wherever the voice came from (Alegria and Noirot, 1978; Noirot and Alegria, 1983).

Annett (1972) assumed that external factors, such as early handling (=nursing care) of the infant could not account for the infant's head preference and adult handedness in humans. An infant's rightward head preference may be part of the

underlying rightward asymmetry which leads to the development of right-handedness. Newborns tend to reach more frequently for an object with the right hand (Coryell and Michel, 1978), begin the stepping reflex with the right foot (Melekian, 1981; Peters and Petrie, 1979) and respond more frequently to auditory, visual and tactile stimuli presented from the right (Turkewitz, 1977). Several of the rightward tendencies have been shown to depend on parental handedness. Neonates with right-handed parents initiate stepping (Kamptner et al, 1983) and placing (Cioni and Pellegrinetti, 1982) more frequently with the right than the left leg and respond to visual, tactile and gustatory stimuli with a rightward head turn (Liederman and Kinsbourne, 1980). However, no data are available which show a genetic factor with neonates with left-handed parents. Michel and Goodwin (1979) and Gardner et al (1977) studied supine head orientation preference in term infants by placing the infant's head in the midline and observing the initial direction of head turning. Conflicting results were obtained. The observed head orientation preference to the right by Michel and Goodwin (1979) was not found by Gardner et al (1977).

We observed a clear head position preference, which was directly caused by nursing care (imposed head position). The subsequently adopted spontaneous head position preference also showed a preference, which can be ascribed to the influence of the foregoing imposed head position. A head position preference was also found by Prechtl et al (1979). However, Prechtl et al (1979) did not discriminate between spontaneous and imposed head positions and neither implied the influence in routine handling of the infants, nor included the infant's head position before the observation started. Therefore, a precise interpretation of their observed preference is not possible. Despite these considerations, they suggested that spontaneous turning of the head to the right, could be interpreted as an expression of a normal pre-term nervous system. In a study of head position preference in sick pre-term infants (unpublished results, Vles), we also found a head position preference, which is similar to the one observed in our low-risk pre-term infants.

Together with our observation that the head position preference is predominantly determined by the nursing care, we conclude that a spontaneous head position preference in pre-term infants cannot be used as a criterion for normality.

Body posture related to spontaneous head turning:

When the head is in the midline, the observed posture during a well-defined activity is mostly a symmetrical one, showing a cephalocaudal acquisition of flexor tone. If all observed spontaneous head-turnings are considered at the moment the head is turned to a side, no typical pattern of limb position is noted. If only the head turnings are analysed which were associated with a positional change of

one of the four extremities related to a head turning, only a significant flexion/extension pattern of the leg was observed.

The cephalocaudal acquisition of flexor tone during a spontaneous headturning with the head in the midline is a different situation compared with the postural changes after a passive head turning and cannot easily be interpreted and understood.

First, it has been stated that the intermediate joints may behave as either proximal or distal joints, related to stimulation of the three physiologic motor pathways of Lawrence and Kuypers (1968, I,II) (Sarnat, 1984). The postures of elbow and knee should be of less neurological importance in assessing maturation than those of fingers and toes, limb girdle and spine. Furthermore, it must be noted that the semi-tendinosus and the semi-membranosus muscles are flexors of the knee and also extensors of the pelvis and the trunk. Therefore a problem in the interpretation of our data is whether the observed flexion or extension position of the intermediate joint is a good criterion to judge development (= maturation = postmenstrual age).

Secondly, the observed posture cannot be explained by progressive myelination (medial and lateral subcortical spinal tracts and corticospinal tracts) as is often assumed (Sarnat, 1984). According to this theory, a development of flexor tone in a caudocephalic direction is expected, which is in contrast with our findings.

Wyke (1975) stated that cortical systems play a little effective part in the control of movement because of small diameters and the degree of myelination. We must realize, however, that the function of nerve fibres is not exclusively determined by myelin lamellae. In physiological studies it has been shown that the corticospinal fibres in general have a facilitatory action on motor neurons which supply flexor muscles. All central tract fibres are unmyelinated until the 12th (Okado and Kojima, 1984) or the 16th week of intra-uterine life (Hamilton and Mossman, 1972), while already from seven weeks of postmenstrual age onwards different motor patterns (thus function), endogenously generated (Prechtl and Nolte, 1984) have been observed with ultrasound (De Vries et al, 1982). Furthermore, in the adult nervous system regulation of movement continues to be subserved by small, unmyelinated fibres (Brodal 1981).

The development of the corticospinal tract was examined by Humphrey (1978): fibres originating from the cerebral cortex descend to the cerebral peduncle and to the caudal level of the pyramidal decussation; after the corticospinal fibres finish decussating, they rapidly descend to the midthoracic spinal cord at 17 weeks of postmenstrual age. However, whether these early corticospinal fibres are functional is still uncertain (Okado and Kojima, 1984).

The observed cephalocaudal acquisition of flexor tone during activity very well suits the law of cephalocaudal development and might reflect corticospinal influence. The extension/flexion pattern of the leg with the head turned to

one side may reflect influence of brainstem structures. Brainstem structures influence active muscle tone by the lateral vestibular nucleus via the lateral vestibulospinal tract and by the lateral medullary reticular formation. Neither of these tracts is under direct cortical control (Lance, 1981). The lateral vestibulospinal tract exerts a facilitatory action on extensor motor neurons (alpha and gamma, Brodal, 1981). That in low-risk pre-term infants mainly an extension/flexion pattern is observed in the lower extremities may be:

- partly due to the corticospinal influences upon the flexor muscles as described above, or may be
- explained by the developmental primacy of oro-facial mechano-receptor afferents (see Hooker, 1952). From about 14 weeks of intra-uterine life, almost any mechanical stimulus to the upper part of the body leads to reflex flexion of the neck and arms.

The flexion/extension pattern of the lower limbs and the absence of such pattern of the upper limbs at a younger age might thus be explained by an active suppression of the arms (craniocaudal development) but may however also be due to an occurrence of activity in the legs (caudocranial development). With increasing age, we observe a small but significant flexion/extension pattern of the arms, which supports the hypothesis that there is an increase of activity and not an increase of suppression; a caudal-cranial development.

Chapter 9

Clinical implications and suggestions for further research

Our data suggest that with increasing postmenstrual age, the duration of a manipulation increases. This might for example be due to the type of feeding (tube versus bottle feeding) but might also be a sign of an increase in social interaction.

The observation of a cephalo-caudal acquisition of flexor tone is of main interest. The study of body posture in sick pre-term infants and in pre-term infants of a younger age, will probably clarify why some of the findings are in contrast with those described by Amiel-Tison (1968), Dubowitz et al (1970) and Saint-Anne Dargassies (1955).

With the observed decrease in mortality of infants born before 32 weeks of postmenstrual age we are in need of a description of spontaneous behaviour of those infants of less than 32 weeks of postmenstrual age. In a comparable way, as described in this thesis we have so far observed 7 low-risk pre-term infants aged 30 weeks of postmenstrual age. We will expand this study in the near future.

In retrospect, we may conclude that our data of spontaneous motor behaviour and posture show a wide intra and inter-individual variability. Between 32 and 36 weeks of postmenstrual age, most of the items studied showed no developmental trend. Although we studied the infants weekly for a three-hour period, no quantitative profile of motor behaviour for a certain age between 32 - 36 weeks of postmenstrual age was found.

A daily neonatal neurological assessment (=observation) might probably be the next step.

From our results we expect that the main characteristic of such daily observations in low-risk pre-term infants should be the variability in the items observed. This variability can be scored for the items: spontaneous motor behaviour, posture, head position (posture related to head position) and reaction to manipulation by the nurse (change in behaviour, body posture with the head in the midline). Such a variability score is at present being developed and tested in our neonatal care unit.

If variability should prove to be an indicator for normality, as it is suggested, such variability will probably not be observed in pre-term infants who are at risk. To test this hypothesis, we are now studying spontaneous behaviour and body posture in sick pre-term infants in a comparable way.

Chapter 10

Summary:

The object of this longitudinal study was to investigate spontaneous behaviour of low-risk pre-term infants of 32-36 weeks of postmenstrual age.

We studied spontaneous motor behaviour, body posture in 'repose', head position preference and body posture related to a head position and a head position change.

In chapter 1 the literature on pre-term infant behaviour is reviewed. Most studies compare the pre-term infant with the foetus or with the term infants. Studies about spontaneous motor behaviour of pre-term infants are scanty. Neurological behaviour assessment of the pre-term infants is performed by testing muscle tone, reflexes and responses to stimuli. For most of the items investigated, the infants have to be manipulated. In general, assessment of a pre-term infant is often limited due to the required minimized handling of the infants. Observation of an infant is often the only possible way to judge the pre-term infant.

In chapter 2 the infants and the methods are described. We studied low-risk pre-term infants (see appendix I) because we assumed that conditions such as respiratory distress syndrome, infectious diseases, metabolic disorders and intracranial haemorrhage might influence spontaneous behaviour. The supine position was chosen because a higher rate of spontaneous motor activity was expected. Video recordings of the infant's spontaneous behaviour and tape recordings of the observer's comments were made. Subsequently, the observer scored the various items, which were put into an Apple IIe computer (see appendix II), for which special programs were written.

In chapter 3 quantitative aspects of spontaneous motor behaviour are described. No quantitative 'profile' for motor behaviour between 32 and 36 weeks of postmenstrual age was found. A wide inter- and intraindividual variability was observed. The incidence and duration of some of the items studied showed a certain developmental trend. The results are discussed in terms of clinical relevance.

In chapter 4 preference posture is described. Regardless of the numerous ways of analysing the data no really dominant preference posture was found. The infants assumed a great number of different postures. The number of different postures, the number of times a certain posture was observed and the duration of the longest uninterrupted posture showed no correlation with postmenstrual age.

In chapter 5 head position related to postmenstrual age and to nursing care is described. We observed a clear head position preference, which was directly caused by nursing care. The subsequently adopted spontaneous head position preference also showed a preference, which can be ascribed to the influence of the foregoing imposed head position. Together with our observation that the head position

preference in sick pre-term infants (data not shown) is similar to the one observed in our low-risk pre-term infants we conclude that a head position preference cannot be used as a criterion for normality.

In chapter 6 the influence of head position and head position change on body posture is described. If all observed spontaneous head turnings are considered, no typical pattern of limb position was noted. If only those head turnings are analysed which were associated with a positional change of one of the four extremities, only an extension/flexion pattern of the leg was observed. An asymmetrical tonic neck reflex was seen after only three percent of the spontaneous head position changes.

In chapter 7 posture during a head turning, at the moment of a head position in the midline, is described. The most frequently observed posture was a symmetrical one in which the arms were fully flexed and the legs partly extended. Furthermore, a cephalocaudal acquisition of flexor tone was observed.

In chapter 8 the results are compared with what is known from the literature. The observed developmental trends are discussed with respect to what is known about neurological maturation.

In chapter 9 clinical implications and suggestions for further research are discussed.

In general we may conclude that:

- variability in spontaneous motor behaviour may represent normality;
- if an obligatory posture is observed, abnormality should be suspected;
- nursing care should be implicated in studies about spontaneous behaviour;
- if all observed 'spontaneous' head turnings are considered, no typical pattern of limb position was noted.
- the observed developmental trend of flexor tone is in agreement with the 'law of cephalocaudal development'.
- a symmetrical posture during a spontaneous head turning, with the head in the midline, may be a sign of normality in the pre-term infant.

Résumé

L'objet de la recherche était l'étude du comportement moteur spontané d'un groupe de quinze prématurés ayant un âge de grossesse de 32-36 semaines. Les aspects quantitatifs des différents modèles de mouvement, de la posture du corps au repos et pendant que l'enfant tourne la tête, de la posture de la tête et l'influence de celle-ci sur la posture du corps ont été examinés.

Au chapitre 1 on traite la littérature concernant le comportement moteur spontané du prématuré. Il en ressort que la plupart des études sur le prématuré se concentrent sur la comparaison du dernier, soit avec l'enfant né à terme, soit avec le fœtus. De plus, la connaissance dans le domaine du comportement spontané du prématuré est restreinte. Les chercheurs, en effet, n'ont pas marqué le comportement spontané, mais essentiellement le comportement pendant manipulation, jugeant ainsi la condition de l'enfant. Il est même à déconseiller de manipuler ce groupe d'enfants dans l'intention de marquer le tonus musculaire, les réflexes et la réaction à des stimuli administrés. Il ne reste qu'une méthode: l'observation du comportement moteur spontané.

Au chapitre 2, une description du groupe d'enfants concernés et la méthode de recherche appliquée sont expliquées. Des nouveau-nés ayant un âge de grossesse de 32 semaines on été observés chaque semaine pendant trois heures consécutives, jusqu'à l'âge de 36 semaines. Les données obtenues ont été enregistrées sur bande vidéo et cassette. Partant de l'hypothèse que des affections comme la septicémie, les hémorragies intracrâniées, l'hyperbilirubinémie et des anomalies congénitales peuvent influencer le comportement moteur spontané, uniquement des enfants à bas risques ont été l'objet de l'étude, qui consistait à étudier le comportement moteur spontané du prématuré "normal".

Le chapitre 3 traite des données quantitatives des modèles de mouvement étudiés. Bien qu'on ait constaté, au cours de la période d'observation, pour quelques "items" une certaine tendance, la variabilité intra et interindividuelle constitue le résultat le plus remarquable.

Le chapitre 4 traite de la posture corporelle au repos. On n'a pas constaté de posture préférentielle, quelle que soit la méthode d'analyse appliquée. La posture prise par l'enfant a démontré une variation intra et interindividuelle. Aucune tendance n'a été observée.

Le chapitre 5 décrit la position corporelle principale. Pendant toute la période d'observation, on a constaté une posture corporelle préférentielle. Cependant, il résulte des données obtenues que cette posture a été déterminée par l'infirmière. La posture "spontanée" de la tête a également démontré une position préférentielle, influencée par la position déterminée par l'infirmière.

Le chapitre 6 traite de l'influence de la position de tête et des changements de celle-ci sur la posture corporelle. Si tous les mouvements de tête étaient compris dans l'analyse, on n'a pas constaté de modèle. Cependant, si l'analyse comprenait uniquement ces mouvements de tête, entraînant un changement de position d'une ou plusieurs extrémités, on a constaté un modèle de flexion/extension de la jambe. Seulement les 3% des mouvements de tête observés ont montré un modèle correspondant au réflexe tonique asymétrique du cou.

Le chapitre 7 décrit la posture corporelle avec la tête au milieu. La posture corporelle observée la plus fréquente était une posture symétrique, à savoir les bras en flexion et les jambes en extension. On a constaté une tendance concernant la mesure de flexion des jambes.

Aux chapitres 8 et 9, les données sont comparées avec les données connues dans la littérature et l'éventuelle valeur clinique est indiquée.

Conclusions:

1. La variabilité du comportement moteur spontané peut être signe d'un comportement normal.
2. L'absence de variation de la posture corporelle du prématuré doit être considérée comme anormale.
3. En étudiant le comportement moteur spontané, il faut tenir compte de l'influence de l'infirmière.
4. Le pourcentage de prématurés "normaux" présentant le réflexe tonique asymétrique du cou était minime.
5. La tendance observée au modèle de flexion correspond à la loi de la maturation céphalocaudale.

SUMARIO

El objetivo de este estudio longitudinal es investigar el comportamiento espontaneo de los prematuros de bajo riesgo de 32-36 semanas de edad.

Estudiamos el comportamiento motor espontaneo, la postura corporal en "reposo", la posición preferente de la cabeza y la postura del cuerpo relacionada con la posición de la cabeza y los cambios de posición de la misma.

En el capítulo 1 se revisa la literatura del comportamiento del prematuro. La mayoría de los estudios comparan al prematuro con el feto o con el nacido a término. Existen pocos estudios del comportamiento motor espontaneo de los prematuros. La valoración neurológica de los prematuros estudia el tono muscular, los reflejos y la respuesta a los estímulos. Para la mayoría de los hallazgos investigados, fue necesario la manipulación de los recién nacidos. En general, la valoración de un prematuro a menudo es limitada debido a la mínima manipulación requerida. La observación física es en ocasiones el único camino posible para juzgar al recién nacido prematuro.

En el capítulo 2 se describen los recién nacidos y los métodos. Estudiamos a los recién nacidos prematuros de bajo riesgo (ver apéndice I) ya que asumimos que condiciones tales como sepsis, hiperbilirrubinemia, hemorragia intracraneal, etc, podrían influenciar el comportamiento espontaneo. Se escogió la posición supina ya que con ello se esperaba un mayor porcentaje de actividad motora espontanea. Se realizaron grabaciones en video y en cassette del comportamiento espontaneo del recién nacido y de los comentarios del observador. Posteriormente, el observador puntuó los diversos hallazgos detectados que fueron introducidos en un ordenador tipo Apple IIe (ver apéndice B) para ser analizados.

En el capítulo 3 se describen los aspectos cuantitativos del comportamiento motor espontaneo. No se observó un "perfil" cuantitativo del comportamiento motor del recién nacido de 32 a 36 semanas de edad. Se observó una amplia variabilidad inter e intraindividual. La incidencia y la duración de alguna de las variables estudiadas mostró una cierta tendencia de desarrollo. Los resultados son discutidos en términos de relevancia clínica.

En el capítulo 4 se describe la postura preferente. A pesar de un minucioso análisis de los datos encontrados, no se encontró una postura preferente dominante. Los recién nacidos adoptaban un gran número de posturas diferentes. El número de posturas diferentes, el número de veces que una postura determinada fue observada y la duración de la mayor postura ininterrumpida, no mostraron correlación con la edad concepcional.

En el capítulo 5 se describe la posición de la cabeza relacionada con la edad concepcional. Observamos una clara preferencia de la posición de la cabeza, causa directa del cuidado de la enfermería. Las preferencias espontaneas de las posiciones de la cabeza adoptadas mostraron prioritaria a una, que puede ser atribuida a la influencia de la posición de la cabeza impuesta previamente.

Nuestras observaciones muestran que la posición preferente

de la cabeza en prematuros recién nacidos enfermos (datos no expuestos) es similar a la observada en nuestros prematuros de bajo riesgo, por ello concluimos que la posición preferente de la cabeza no puede ser utilizado como criterio de normalidad.

En el capítulo 6 se describe la influencia de la posición de la cabeza y los cambios de la posición de la cabeza en relación con la postura corporal. Si se consideran todos los movimientos de cabeza espontaneos observados, no se detecta un patrón típico de la posición de las extremidades. Si sólo se analizan los que han presentado movimientos de cabeza, que se asociaron con cambios posicionales de una de las cuatro extremidades, se observa exclusivamente un patrón extensión/flexión de la pierna. En un tres por ciento de los niños con cambios espontaneos de la posición de la cabeza se detecta un reflejo asimétrico del tono del cuello.

En el capítulo 7 se describe la postura corporal durante un movimiento de la cabeza, en el momento en que la cabeza cruza la línea media. La postura simétrica, con brazos totalmente flexionadas y piernas parcialmente extendidas, fue la más frecuentemente observada. Se observó además, una adopción cefalocaudal del tono flexor.

En el capítulo 8 se comparan los resultados observados con los descritos en la literatura. Se discuten las tendencias de desarrollo observadas en relación a los conocimientos de la maduración neurológica.

En el capítulo 9 se discuten las implicaciones clínicas y las sugerencias para una mayor investigación.

En general, las conclusiones muestran que:

- la variabilidad observada en el comportamiento motor espontaneo puede corresponder a normalidad.
- si se observa una postura forzada debe sospecharse anormalidad.
- los cuidados de enfermería deberían considerarse en los estudios sobre el comportamiento espontaneo.
- el tono flexor observado como tendencia de desarrollo, está de acuerdo con la "ley del desarrollo cefalocaudal".

Samenvatting

In deze studie werd, bij een groep van 15 te vroeggeboren kinderen met een zwangerschapsleeftijd van 32-36 weken, het spontaan gedrag bestudeerd. De kwantitatieve aspecten van verschillende bewegingspatronen, lichaamshouding in rust en gedurende een hoofddraaiing, hoofdhouding en de invloed hiervan op de lichaamshouding werden onderzocht.

In hoofdstuk 1 wordt de literatuur besproken betreffende het spontaan gedrag van de te vroeggeborene. Het wordt duidelijk dat in de meeste studies de te vroeggeborene hetzij met het a-term geboren kind, hetzij met de foetus wordt vergeleken. Bovendien blijkt de kennis op 't gebied van spontaan bewegingsgedrag van de te vroeggeborene slechts beperkt. Men scoorde niet het spontane gedrag maar voornamelijk het gedrag tijdens manipulatie, op basis waarvan men dan de conditie van het kind beoordeelde. Het is zelfs af te raden deze groep kinderen te manipuleren met als enig doel het scoren van spiertonus, reflexen en reactie op toegediende stimuli. Observatie van spontaan gedrag is dan de enige methode die overblijft.

In hoofdstuk 2 wordt een beschrijving gegeven van de groep bestudeerde kinderen en de gebruikte onderzoeksmethode. Pasgeborenen met een zwangerschapsleeftijd van 32 weken werden iedere week gedurende 3 achtereenvolgende uren geobserveerd tot de leeftijd van 36 weken. De geobserveerde gegevens werden op video- en audioband vastgelegd. Alleen 'low-risk' kinderen werden opgenomen in de studie uitgaande van de veronderstelling dat aandoeningen zoals sepsis, intracraniele bloedingen, hyperbilirubinemie en congenitale afwijkingen het spontaan gedrag beïnvloeden. Het doel van de studie was immers het spontaan gedrag van het 'normale' te vroeggeboren kind te bestuderen.

In hoofdstuk 3 worden de kwantitatieve gegevens van de bestudeerde bewegingspatronen weergegeven. Hoewel er voor enkele items een tendens in de loop van de observatie periode werd gevonden, is de intra- en interindividuele variabiliteit de meest opvallende bevinding.

In hoofdstuk 4 wordt de lichaamshouding in rust beschreven. Er werd geen voorkeurshouding gevonden, ongeacht de gebruikte analyse methode. De ingenomen houding door het kind toonde een grote intra- en interindividuele variatie en er werd geen tendens geobserveerd.

In hoofdstuk 5 wordt de hoofdpositie beschreven. Er werd voor de totale observatie periode een voorkeurspositie geobserveerd. Uit de verkregen gegevens mag echter worden geconcludeerd dat deze voorkeurspositie werd bepaald door de verzorger. De 'spontane' hoofdhouding vertoonde eveneens een voorkeurspositie die werd beïnvloed door de hieraan voorafgaande hoofdpositie bepaald door de verzorger.

In hoofdstuk 6 wordt de invloed van de hoofdpositie en veranderingen in de hoofdpositie op de lichaamshouding beschreven. Indien alle spontane hoofddraaiingen werden betrokken in de analyse werd er geen patroon herkend. Werden uitsluitend die hoofddraaiingen in de analyse betrokken die

gepaard gingen met een positie verandering van een of meer extremiteiten, dan werd een flexie/extensie patroon voor het been waargenomen. Slechts in 3% van de geobserveerde hoofddraaiingen werd een patroon gezien overeenkomend met de 'asymmetrische tonische nek reflex'.

In hoofdstuk 7 wordt de lichaamshouding beschreven met het hoofd in middenpositie. De meest frequent geobserveerde lichaamshouding was een symmetrische, met de armen in flexie en de benen in extensie. Er werd een trend waargenomen in de mate van flexie van de benen.

In hoofdstuk 8 en 9 worden de verkregen gegevens vergeleken met de gegevens die in de literatuur bekend zijn en wordt de eventueel klinische bruikbaarheid aangegeven.

Conclusies

1. Variabiliteit in spontaan gedrag kan een teken van normaal gedrag zijn.
2. Indien de lichaamshouding van de te vroeggeborene geen variatie vertoont, dient men dit als niet normaal te beschouwen.
3. Bij de bestudering van spontaan gedrag dient men rekening te houden met de invloed van de verzorger.
4. De 'spontane asymmetrische tonische nek reflex' werd bij de 'normale' te vroeggeborene slechts in een zeer gering percentage waargenomen.
5. De trend die werd geobserveerd in het flexie patroon is in overeenstemming met de wet van de cephalocaudale rijping.

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Appendix I:

Clinical characteristics of the infants studied, and maternal data.

<u>Infant</u>	: 1	Bayley Scales of	
postmenstrual age	: 31 wks	Infant Development:	
Apgar-score		MDI 7 months	: 111
1 minute	: 6	PDI 7 months	: 120
5 minutes	: 8	MDI 18 months	: 107
birth weight	: 1670 grs (P50)	PDI 18 months	: 113
length	: 43 cm (P50-P97)		
head circumference	: 30 cm (P50-P97)	<u>Mother</u>	: 1
male/female	: male	age	: 28
twin	: -	G/P	: I/O
ECHO-head	: + (normal)	first day of last	
neonat.-examination	: normal	menstrual period	: 11-09-1984
Prechtl examination		ECHO	: +
(36 wks	: normal	Pre-eclampsia	: +
postmenstrual age)		Caesarean section	: +
<u>Infant</u>	: 2	Bayley Scales of	
postmenstrual age	: 31.3 wks	Infant Development:	
Apgar-score		MDI 7 months	: 91
1 minute	: 9	PDI 7 months	: 106
5 minutes	: 10	MDI 18 months	: 100
birth weight	: 1730 grs (P50-P97)	PDI 18 months	: 90
length	: 44 cm (P50-P97)		
head circumference	: 32 cm (P50-P97)	<u>Mother</u>	: 2
male/female	: male	age	: 22
twin	: -	G/P	: I/O
ECHO-head	: + (normal)	first day of last	
neonat.-examination	: normal	menstrual period	: 02-12-1984
Prechtl examination		ECHO	: -(cyclus
(36 wks	: normal		28ds)
postmenstrual age)		Pre-eclampsia	: -
		Caesarean section	: -
<u>Infant</u>	: 3	Bayley Scales of	
postmenstrual age	: 29 wks	Infant Development:	
Apgar-score		MDI 7 months	: 102
1 minute	: 6	PDI 7 months	: 96
5 minutes	: 9	MDI 18 months	: 70
birth weight	: 1650 grs (P50-P97)	PDI 18 months	: 90
length	: 42.5 cm (P50-P97)		
head circumference	: 29.6 cm (P50-P97)	<u>Mother</u>	: 3
male/female	: female	age	: 28
twin	: -	G/P	: IV/II
ECHO-head	: + (normal)	first day of last	
neonat.-examination	: normal	menstrual period	: 14-07-1985
Prechtl examination		ECHO	: +
(36 wks	: normal	Pre-eclampsia	: -
postmenstrual age)		Caesarean section	: -

Infant : 4
 postmenstrual age : 29 wks
 Apgar-score
 1 minute : 7
 5 minutes : 8
 birth weight : 1090 grs (P10)
 length : 38 cm (P50)
 head circumference : 26 cm (P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 108
 PDI 7 months : 110
 MDI 18 months : 109
 PDI 18 months : 90

Mother : 4
 age : 24
 G/P : I/0
 first day of last
 menstrual period : ?
 ECHO : +
 Pre-eclampsia : +
 Caesarean section : -

Infant : 5
 postmenstrual age : 30 wks
 Apgar-score
 1 minute : 4
 5 minutes : 7
 birth weight : 1550 grs (P50)
 length : 41 cm (P50-P97)
 head circumference : 29.8 cm (P50-P98)
 male/female : female
 twin : +
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 90
 PDI 7 months : 90
 MDI 18 months : -
 PDI 18 months : -

Mother : 5
 age : 32
 G/P : III/I
 first day of last
 menstrual period : 14-07-1985
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 6
 postmenstrual age : 31,5 wks
 Apgar-score
 1 minute : 9
 5 minutes : 10
 birth weight : 1870 grs (P50)
 length : 41.2 cm (P3-P50)
 head circumference : 31.6 cm (P50-P98)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 90
 PDI 7 months : 90
 MDI 18 months : -
 PDI 18 months : -

Mother : 6
 age : 30
 G/P : I/0
 first day of last
 menstrual period : 26-03-1984
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : +

Infant : 7
 postmenstrual age : 29, 5 wks
 Apgar-score
 1 minute : 7
 5 minutes : 8
 birth weight : 1350 grs (P10-P50)
 length : 40 cm (P50-P97)
 head circumference : 26 cm (P2-P50)
 male/female : female
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 74
 PDI 7 months : 86
 MDI 18 months : 86
 PDI 18 months : 107

Mother : 7
 age : ?
 G/P : I/I
 first day of last
 menstrual period : 15-07-1984
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 8
 postmenstrual age : 29.5 wks
 Apgar-score
 1 minute : 6
 5 minutes : 9
 birth weight : 1350 grs (P10-P50)
 length : 40 cm (P50-P97)
 head circumference : 25.7 cm (P2-P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 99
 PDI 7 months : 99
 MDI 18 months : 100
 PDI 18 months : 112

Mother : 8
 age : 31
 G/P : II/I
 first day of last
 menstrual period : ?
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 9
 postmenstrual age : 27 wks
 Apgar-score
 1 minute : 6
 5 minutes : 6
 birth weight : 1000 grs (P50)
 length : 36 cm (P50)
 head circumference : 24.3 cm (P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 82
 PDI 7 months : 97
 MDI 18 months : 89
 PDI 18 months : 107

Mother : 9
 age : 35
 G/P : II/I
 first day of last
 menstrual period : 16-11-1985
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 10
 postmenstrual age : 31 wks
 Apgar-score
 1 minute : 8
 5 minutes : 10
 birth weight : 1770 grs (P50)
 length : 41.5 cm (P50)
 head circumference : 28.2 cm (P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 90
 PDI 7 months : 90
 MDI 18 months : -
 PDI 18 months : -
Mother : 10
 age : 23
 G/P : I/O
 first day of last
 menstrual period : 29-05-1985
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 11
 postmenstrual age : 32 wks
 Apgar-score
 1 minute : 6
 5 minutes : 8
 birth weight : 1450 grs (P10-P50)
 length : 39 cm (P3)
 head circumference : 27.3 cm (P2-P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 89
 PDI 7 months : 67
 MDI 18 months : 100
 PDI 18 months : 116
Mother : 11
 age : 31
 G/P : V/II
 first day of last
 menstrual period : 18-02-1984
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 12
 postmenstrual age : 30 wks
 Apgar-score
 1 minute : 7
 5 minutes : 9
 birth weight : 1230 grs (P2.3-P10)
 length : 38 cm (P3-P50)
 head circumference : 28 cm (P50-P98)
 male/female : female
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl
 examination: : normal
 (36 wks
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 81
 PDI 7 months : 54
 MDI 18 months : >80
 PDI 18 months : >80
Mother : 12
 age : 24
 G/P : II/O
 first day of last
 menstrual period : ?
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 13
 postmenstrual age : 30 wks
 Apgar-score
 1 minute : 6
 5 minutes : 9
 birth weight : 1350 grs (P2.3-P10)
 length : 40 cm (P50)
 head circumference : 25.7 cm (P2-P50)
 male/female : male
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 110
 PDI 7 months : 98
 MDI 18 months : 98
 PDI 18 months : 94

Mother : 13
 age : 28
 G/P : III/I
 first day of last
 menstrual period : ?
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : -

Infant : 14
 postmenstrual age : 30.5 wks
 Apgar-score
 1 minute : 9
 5 minutes : 10
 birth weight : 1170 grs (P2.3)
 length : 41 cm (P50)
 head circumference : 28 cm (P50)
 male/female : female
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Stanford Binet : normal

Mother : 14
 age : 29
 G/P : I/0
 first day of last
 menstrual period : 25-08-1984
 ECHO : +
 Pre-eclampsia : -
 Caesarean section : +

Infant : 15
 postmenstrual age : 31 wks
 Apgar-score
 1 minute : 7
 5 minutes : 8
 birth weight : 1180 grs (P2.3)
 length : 37 cm (P3)
 head circumference : 28.6 cm (P50)
 male/female : female
 twin : -
 ECHO-head : + (normal)
 neonat.-examination : normal
 Prechtl examination
 (36 wks : normal
 postmenstrual age)

Bayley Scales of
 Infant Development:
 MDI 7 months : 91
 PDI 7 months : 80
 MDI 18 months : -
 PDI 18 months : -

Mother : 15
 age : 22
 G/P : I/0
 first day of last
 menstrual period : ?
 ECHO : +
 Pre-eclampsia : +
 Caesarean section : +

Registration program

The computer program used to collect observation data runs on an Apple-IIe and is mainly written in Applesoft-Basic. It is set up to register 32 different observation items, with a time accuracy of one second, during a period of three hours. The 32 items can be toggled by typing one of the keyboard letters A through Z and the figures 1 through 6. Each time the key of a corresponding item is hit, the state of that particular item is changed from ON to OFF or vice versa. At the same time an information byte containing the item number and new state is stored in a reversed memory block of 8192 bytes (codes are 1-32 for state OFF and 129-160 for state ON). A one byte time information from a continuously running clock is stored along with every code information byte, so for each change two bytes are stored.

An extra two byte storage is done each 256 seconds, since the time-information byte can only hold 256 seconds.

The code-information byte is replaced by the six most significant bits of the 14 bits clock, with both bits 7 and 6 'ON' to differentiate from Item-state ON or OFF.

Approximately 4000 item changes can be stored in the reserved memory block which seems to be sufficient for an observation period of three hours. When the observation program is stopped, the complete block of 8192 bytes is stored in a disk file for updating analysing.

Analysing program

The analysing program searches for a specified item entered through the keyboard, by which each item can be set ON, OFF or IRRELEVANT. Subsequently the number of times the specific item occurred is calculated, as well as the duration of the presence of this item. Finally the average duration with standard deviation, the longest and shortest periods are also calculated. Optionally a two-level plot (item present or not present) can be obtained over the length of the observation period, showing the distribution of the item in time.

Posture-registration program

This program is used to feed the data concerning the position of the infant's head, left arm and right arm, left leg and right leg into a disk file. Position codes are fed into the Apple-IIe computer for a maximum observation time of 180 minutes, with a minimum interval of one minute. Codes for arms and legs are from 1-49 (see chapter 4). Codes for the head are 1-5, of which 4 and 5 were ment to indicate manipulation or feeding, during which no spontaneous head position and limb position were scored.

Posture-analysing program

Using the disk-file data from the above described posture registration program this program analyses the observed 'posture' with regard to:

- the total time in minutes during which coding was possible
- the duration of each scored head position in minutes
- the combination of head, arm and leg codes which:
 - * occurred most frequently
 - * was maintained for the longest uninterrupted period
- the number of position changes
 - * for the whole body posture
 - * for the extremities separately
- the occurring postures in descending order of frequency.

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Curriculum vitae

De auteur van dit proefschrift werd op 9 mei 1952 te Venlo geboren. In 1968 behaalde hij het eindexamen IVO B te Borculo. In 1971 werd het eindexamen HBS B behaald aan het tweede Vrijzinnig Christelijk Lyceum te Den Haag. Studie medicijnen volgde hij aan de Gemeentelijke Universiteit van Amsterdam. Het artsexamen werd met goed gevolg afgelegd in 1979.

Van januari 1980 tot januari 1986 werd hij opgeleid tot neuroloog in het toenmalige ziekenhuis St. Annadal te Maastricht onder leiding van Prof. dr. P.J.M. van der Lugt. De opleiding werd met een jaar onderbroken (april '83-april '84) voor een jaar kinderneurologie / kinderneurochirurgie in het ziekenhuis Gasthuisberg te Leuven onder leiding van Prof. dr. P. Casaer, kliniekhoofd Kinderneurologie, en Prof. dr. C. Plets, kliniekhoofd Neurochirurgie. Later was hij nog gedurende langere tijd aldaar als consulent verbonden aan de afdeling kinderneurologie en in deze zelfde periode werkte hij als research fellow op de onderzoekseenheid ontwikkelingsneurologie van de afdeling neonatologie van het kinderziekenhuis Gasthuisberg (Directeur-Diensthofd Prof. dr. E.E. Eggermont).

Sedert 1 januari 1986 is hij als staflid neurologie verbonden aan het Academisch Ziekenhuis van Maastricht alwaar hij naast de algemene neurologie een speciale taak heeft in relatie tot de kinderneurologie/neuroneonatologie.