Development of Sucking Patterns in Preterm Infants

Saakje P. da Costa

Aan alle kinderen die aan het onderzoek hebben meegewerkt en hun ouders

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Contents

1 General introduction

Healthy, fullterm infants are able to suck and swallow from birth. This enables them to take in all the nourishment they need from suckling at the breast or from feeding from a bottle. Oral feeding in infants needs to be efficient in order to preserve energy for growth. In addition, it should be safe so as to avoid aspiration, and it should not jeopardise respiratory status. This is only possible if sucking, swallowing, and respiration are properly coordinated. Coordination means that the infant can suck efficiently and can swallow rapidly as the boluses are formed in the mouth in order to minimise the duration of airflow interruption. Oral feeding skills are defined as the infant's ability to organise and coordinate oral-motor functions efficiently so that it consumes enough calories for growth [1].

There are several circumstances that may compromise the normal development of coordinated sucking and swallowing. Congenital or acquired damage of the central nervous system may lead to feeding problems in the neonatal period such as slow or weak sucking. This could be the first indication that the infant has neurological problems [2]. Dysphagia is common in infants suffering from cerebral palsy or other neurological developmental disorders. Several clinical conditions and side-effects of treatments may threaten the integrity of the central nervous system in foetuses and preterm infants [3]. Preterm infants are at high risk for problems in achieving oral feeding skills and frequently have feeding problems during their first year of life [4;5]. It is unclear whether these problems are also related to the neurological problems these infants often exhibit when they are older. Preterm birth entails an increased risk for abnormal neurological development. Preterms that require artificial respiration have more difficulty stabilising their physiological parameters, as a result of which non-nutritive sucking degrades [6], it takes longer before they are ready to start feeding orally, before they are no longer dependant on tube-feeding, and before they are able to process oral feeding entirely [7-12]. Particularly for preterms suffering from bronchopulmonary dysplasia (BPD), successful feeding can be hampered, on the one hand, by decreased oxygen saturation during feeding, deglutition apnoea [13], and a higher respiratory rate (which is worse for preterms with BPD as the condition worsens) [10]. On the other hand, it may be hampered by the higher risk of neurological damage that leads to impaired sucking. The developmental course of sucking may be a predictor for neurological outcome later. Studies of children between eight and eighteen months point towards such a relationship [14;15].

Annually, in the Netherlands, on average 15,000 infants are born preterm, i.e. prior to the 37th week of gestation (8.1 % of the total number of births). Of these preterms 0.3 % are born after ≤ 25 weeks' gestation, 0.7 % after 26.0 to 31.6 weeks' gestation and 4.7 % after 32.0 to 36.6 weeks' gestation [16]. They often depend of tube-feeding for a varying lengths of time depending on their gestational ages and birth weights. Many preterms can suck and swallow from approximately 34 weeks' PMA. Subsequently, it often takes another few weeks before the infant can coordinate sucking and swallowing with respiration and before it can handle all its nourishment orally. For some preterms it takes longer, or sometimes much longer, before they can cope with oral feeding. Gestational age and birth weight play a role in successful oral feeding, as do conditions like BPD and necrotising enterocolitis (NEC). To date, however, we do not yet fully understand which infants are most at risk for learning problems with feeding.

The reasons for carefully studying the preconditions for sucking and how an infant sucks, are to determine the infant's readiness to feed orally and to detect the nature of its feeding problems. In addition, an abnormal sucking pattern may be an indication that the infant's neurological development is not progressing normally. We used the Early Feeding Skills Assessment [1] to determine whether an infant was ready to feed orally. This observational scale is used to monitor the infant before, during and after each feeding. In general, to assess the way infants suck, a distinction is made between clinical feeding assessment and swallowing assessment [17]. Seven other diagnostic tools have been described in the literature: four are designed for breastfeeding only, two for bottle-feeding only, and one is applicable to both feeding situations [18]. The reliability and user-friendliness of these tools are fair to poor.

To date, we lack a user-friendly, reliable, and non-invasive tool that can be used for both breastfeeding and bottle-feeding and that objectively measures the coordination between sucking, swallowing and breathing, and sucking and swallowing movements. On the one hand, such a diagnostic tool would be useful to determine what kinds of interventions are required to facilitate sucking and swallowing. On the other hand, it would be useful if it could make some predictions regarding the future development of the infant. In addition, infants could be followed-up in order to determine if, and to what extent, sucking behaviour has predictive value for the infant's outcome at a later age. It appears that healthy, fullterm infants develop efficient sucking and swallowing, and patterns of respiration during the first month of life [19]. Aspects of sucking and the development of sucking that have been studied in preterms include the maturation of nutritive and non-nutritive sucking [19], the relation between non-nutritive and nutritive sucking [20], the maturation of respiration [21], the maturation of the swallowing process [22-24], and the coordination of sucking, swallowing, and respiration [25-27]. More specifically, sucking pressure, sucking bursts [16;25;27], intraburst development [19], and volume per suck have been studied. Nevertheless, although several studies were performed on the development of sucking behaviour, most studies were based on one or two recordings or cover a short period of time.

What is lacking is knowledge about how sucking develops longitudinally during the entire neonatal period, to what extent it is a matter of maturation, what the normal developmental course is, and what can be considered abnormal. In addition, it is important to determine which groups of preterms are at greater risk of developing abnormal sucking and to identify the risk factors. More insight in and knowledge of the developmental course of sucking possibly creates more opportunities to intervene, besides determining whether the infant is ready to start feeding orally, or whether the amount and frequency of feeds can be extended. This would apply to SGA preterms, preterms with BPD, and extremely preterm infants.

Aims of the study

Various questions arose with regards to sucking, swallowing and respiration in preterm infants. Within the perspective of the literature we reviewed, our aim was to determine the longitudinal development of sucking patterns in fullterm and preterm infants from birth until the age of ten weeks post-term. Our finding are presented in this thesis.
The study groups were:

- Healthy, fullterm infants
- Preterm, appropriate-for-gestational age (AGA) infants
- Preterm, small-for-gestational age (SGA) infants (birth weight < P10)
- Preterm infants with bronchopulmonary dysplasia (BPD)

The specific questions we addressed were:

1. What methods are available to diagnose sucking and swallowing problems, and which of these were most suitable?
2. What is the developmental course of sucking patterns in healthy, fullterm infants from birth until ten weeks' post-term?
3. What is the developmental course of the development of sucking patterns in preterm infants from the time oral feeding commenced until ten weeks' post-term?
4. Are there differences in the developmental courses of sucking patterns between AGA preterms, SGA preterms, and preterms with BPD?
5. Which factors influences the development of sucking patterns?

To answer these questions, we started an extensive, longitudinally research project in 2003 on the development of sucking patterns in fullterm and preterm infants with a view to plotting the spontaneous course of oral feeding in different groups of preterm infants from the time oral feeding commenced until ten weeks' post-term. We reviewed the literature to find adequate diagnostic tools and investigated these longitudinally in several fullterm and preterm groups of infants at variable risk, until they had reached the age of ten weeks post-term. Knowledge on the typical development of sucking patterns in these groups might lead to a better understanding of problems with sucking, swallowing, and respiration, and might also lead to appropriate interventions.

Chapter Outlines

In Chapter 2 we review recent insights into the development of sucking and swallowing in infants and we examine the factors that play a role in acquiring this skill. In addition, we present a search of the literature for diagnostic tools that focus on the readiness for oral feeding.

In Chapter 3 we consider the Neonatal Oral-Motor Assessment Scale (NOMAS) including the test-retest agreement and its inter-rater reliability. In Chapter 4 we describe the sucking patterns in healthy, fullterm infants from birth until ten weeks' post-term.

In Chapter 5 we deal with the maturation of sucking in small-for-gestational age (SGA) preterm infants in comparison with adequate-for-gestational age (AGA) preterm infants. We also investigated which factors influenced the maturation of sucking patterns.

In Chapter 6 we describe the maturation of sucking patterns in preterm infants with bronchopulmonary dysplasia (BPD) in comparison with age preterm infants without BPD matched for gestational age. In this chapter we also investigated whether clinical factors influenced the maturation of sucking patterns.

In Chapter 7 we place the investigations in a general perspectives and we give directions for future studies.

Chapter 8 provides a summary of the thesis in English.

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2 Sucking and swallowing in infants and diagnostic tools

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Abstract

Preterm infants often have difficulties learning how to suckle from the breast or how to drink from a bottle. As yet it is unclear whether this is part of their prematurity or whether it is caused by neurological problems. Is it possible to decide on the basis of how an infant learns to suckle or drink whether it needs help and if so, what kind of help? In addition, can any predictions be made regarding the relationship between these difficulties and later neurodevelopmental outcome?

We searched the literature for recent insights into the development of sucking and the factors that play a role in acquiring this skill. Our aim was to find a diagnostic tool that focuses on the readiness for feeding or that provides guidelines for interventions. At the same time we searched for studies on the relationship between early sucking behaviour and developmental outcome.

It appeared that there is a great need for a reliable, user-friendly and non-invasive diagnostic tool to study sucking in preterm and fullterm infants.

Introduction

Oral feeding in infants should be efficient in order to preserve energy for growing. Moreover, it should be safe so as to avoid aspiration, and it should not jeopardise respiratory status. This can only be achieved provided sucking, swallowing and breathing are properly coordinated. This means the infant can suck efficiently and that it can swallow rapidly as the boluses are formed, thus minimising the duration of airflow interruption. Put differently, an infant's oral feeding skills are reflected by its skill to organise and coordinate oral-motor functions efficiently so that it takes in enough calories to grow [1].

There are several circumstances that could compromise normal coordination of sucking and swallowing. Congenital or acquired damage to the central nervous system during the neonatal period may lead to feeding difficulties, such as slow or weak sucking. It could be the first indication that the infant has neurological problems [2]. Dysphagia is common in infants suffering from cerebral palsy or other developmental deficits.

Preterm infants frequently have feeding problems during their first year of life. It is unclear whether these problems are related to the neurological problems these infants often exhibit later on [3]. Preterms in need of artificial respiration have more difficulty stabilising their physiological parameters. It is unclear whether their sucking and swallowing problems stem from their reaction to the tubes, from their breathing difficulties or from a combination of both.

There is an urgent need for a user-friendly, reliable and non-invasive tool that objectively measures sucking and swallowing movements and the coordination between sucking, swallowing and breathing. On the one hand, such a tool would be useful to determine what kinds of interventions are required to facilitate sucking and swallowing. On the other hand, some predictions could be made regarding the further development of the infant. In addition, infants could be followed-up in order to determine if and to what extent sucking behaviour has predictive value for the infant's outcome at a later age.

The aim of this review is threefold. Our first aim is to find out what is known about the normal developmental course of sucking and swallowing during early age. Our second aim is to evaluate a number of currently available diagnostic methods that measure the coordination of sucking and swallowing with breathing. Finally, our aim is to establish the prognostic value of an abnormal developmental course of sucking, swallowing and breathing for the infant's later neurodevelopmental outcome.

To achieve these aims we searched the literature on Medline and CINAHL using Silver Platter and WinSPIRS. The restrictions we used were AGE (All Infants). TG: Human, PT Journal-Article, publication date: 1995-2006. This search strategy consisted of all combinations of 1) Sucking Ability [Mesh] OR Sucking Behaviour [Mesh] AND 2) Deglutition [Mesh] AND Respiration [Mesh]. Fifty-two articles were found in this way. On the basis of the titles and abstracts we selected twenty-five articles for further reading. The main selection criterion was the patient group. We excluded articles on infants with cleft palate, Pierre Robin Sequence and cerebral palsy. We included articles on preterm and fullterm infants without congenital anomalies. We selected a further twenty-five articles by reviewing the references of all the articles identified.

Sucking and swallowing, and the brain structures involved

The sucking pattern of fullterm infants is composed of the rhythmic alternation of suction and expression. Two forms of sucking are distinguished: nutritive sucking (NS) and non-nutritive sucking (NNS). NS is an infant's primary means of receiving nutrition while NNS can have a calming effect on the infant. Moreover, NNS is regarded as an initial method for exploring the environment. The rate of NNS is approximately twice as fast as that of NS 4-6. Both NNS and NS provide insight into an infant's oral-motor skills. In NS however, the ability to integrate breathing with sucking and swallowing is a prerequisite for coordinated feeding.

During NS, fluid moves primarily due to change in pressure. With the oral cavity sealed, as the jaw and tongue drop down, the cavity is enlarged. This enlargement creates negative intra-oral pressure, suction, which draws fluid into the mouth and propels the expressed fluid backwards toward the pharynx for the swallow. Jaw and tongue movements are also involved in the propulsion of fluid. As the tongue compresses the nipple, sufficient positive pressure, compression, is created by the jaw and the front part of the tongue pressing the nipple against the hard palate to draw the fluid from the nipple. The tongue plays a key role in all aspects of sucking by helping to seal the oral cavity. It does so anterior, in conjunction with the lower lip, and posterior, by sealing against the soft palate during swallowing. In addition, the tongue stabilises the lower jaw and transports the bolus to the pharynx. The jaw provides a stable base for movements of the tongue, lips and cheeks.

The next phase is pharyngeal. Swallowing is elicited involuntary by afferent feedback from the oral cavity and has a duration of approximately 530 ms. It depends on a critical volume of fluid, gathered in the valleculae. In order to initiate and modify the swallow the pharynx and larynx are richly supplied with chemoreceptors, slow-adapting stretch and pressure receptors and temperature receptors.

Effective sucking requires coordination of both the swallowing and breathing processes in which many brain structures are involved, including cranial nerves, brain stem areas, and cortical areas. The rhythmic processes involved in NS are under maturing bulbar control, especially in the regions of the nuclei ambiguus, solitarius and hypoglossus in the lower medulla. Efferent and afferent cranial nerves (N V, VII, IX, X, and XII) are involved in deglutition (which includes mastication, respiration and swallowing). These movements are considered to be under the control of central pattern generators and are controlled by sensory feedback and supra-bulbar parts of the brain. The central pattern generator for sucking seems to consist of two distinct parts: a) in the brain stem (in the nucleus tractus solitarius and the dorsal medullar reticular formation) for motor control, and b) parts of the surrounding reticular formation for sensory control.

During pharyngeal swallowing respiration is inhibited centrally 7. The three parts of the cerebral cortex that are involved in chewing and swallowing are the primary motor cortex, the premotor cortex anterior to it and the anterior insula 8. These areas process incoming and outgoing signals to and from the swallowing centre in the brain stem. This is the case for both the reflexive and voluntary stages of swallowing.

The development of sucking and swallowing from foetal age to term age

At approximately 26 days' foetal age the developmental trajectories of the respiratory and swallowing systems diverge and start to develop independently. Swallowing in foetuses has been described as early as 12 to 14 weeks' gestational age. A sucking response can be provoked at 13 weeks' postconceptional age by touching the lips 9. Real sucking, defined by a posterior-anterior movement of the tongue, in which the posterior movement is dominant, begins at 18 to 24 weeks' postconceptional age 10. Between 26 and 29 weeks' gestational age, there is probably no significant further maturation of sucking (4;11).

By week 34, most healthy foetuses can suck and swallow well enough to sustain nutritional needs via the oral route if born at this early age. Sucking movements increase in frequency during the final weeks of foetal life. This is accompanied by an increase in amniotic fluid swallowed by a foetus during pregnancy from initially 2 to 7 ml a day to 450 ml a day. This is approximately half of the total volume of amniotic fluid at term 8;12;13.

The development of sucking and swallowing from birth at term up to the first months of life

The normal maturation of sucking and swallowing during the first months of life after fullterm birth can be summarised by increased sucking and swallowing rates, longer sucking bursts and larger volumes per suck 4;14-17. The skill of safe and efficient oral feeding is based on oral-motor competence, neurobehavioral organisation and gastro-intestinal maturity 18. It is important that behavioural states are well controlled, that the airway is patent and that overall cardiorespiratory activity is stable 18. Internal factors that influence the normal development of sucking and swallowing patterns are the infant's state of health, his oral feeding experience, the ability to regulate oxygen, development of alertness and sucking strength and the organisation of the sucking pattern. External factors are size and speed of milk flow, the impact of nasogastric tubes in place during feeding and the type of feeding support provided by the caregiver 1.

Normal infants are able to adapt to varying environments. They are able to distinguish differences in fluctuations of milk flow, nipple hole, taste and temperature, and they can adapt their sucking behaviour to these variations [14].

Rhythmicity

The underlying rhythms of sucking and swallowing follow quantifiable, predictable maturational patterns that correlate with postmenstrual age (PMA). From this point of view it is likely that these behavioural patterns are congenital rather than acquired [19]. However, the rhythmicity of the suck-swallow-breath relationship depends also on non-maturational factors, such as satiety, behavioural state and milk flow. Milk flow depends on the hole size of the nipple (bottle feeding), the milk ejection reflex (in breastfeeding), but it also depends on the infant. Within certain ranges the infant can autoregulate milk flow by changing the suction pressure and frequency [14;20].

Rhythmic stability can be expressed in a measure used by Gewolb et al. [21;22]: the Coefficient of Variation (COV). The COV is the standard deviation of the intervals between two processes (such as swallow-swallow, suck-suck, suck-swallow divided by the mean interval between these processes. It is independent of the number of sucking movements per swallow. A low COV indicates that the rhythm is normal. The higher the COV the more variable the rhythm. The rhythmic stability of sucking and swallowing changes during the first month of life, both individually and interactively. The biorhythms of sucking and swallowing follow a predictable maturational pattern (stabilisation of sucking rhythmicity, more sucking movements and swallows in bursts and quicker and longer sucking bursts). This stabilisation correlates more with postmenstrual age than with postnatal age [21]. The studies by Gewolb et al. [21] show that rhythm is an integrated part of maturation. Quereshi et al. [17] expand on this theme by explaining that the changes observed at one month of age may be an adaptation of the drinking pattern to include volition, with longer sequences and a larger number of sucking movements. It would seem, therefore, that these rhythms follow a reasonably predictable maturational pattern and that disturbance of this maturation could be an important diagnostic clue.

Interaction with breathing

Feeding activity appears to override normal ventilatory chemoreceptor control mechanisms [19] and the act of swallowing has a significant impact on breathing during feeding. As infants commonly swallow as often as 60 times a minute, and there is an airway closure averaging 530 ms associated with swallows, this means that during the initial period of continuous sucking the airway closure lasts up to 30 seconds a minute [23]. This makes it important for respiration to be exquisitely coordinated with swallowing.

During breast-feeding swallowing is segregated from breathing. Sucking and breathing patterns create 'windows of opportunity' for swallows and the central nervous system may look for opportunities within ongoing sucking and breathing patterns in which to fit swallows, allowing an infant to continue feeding without interruption [22]. In fullterm infants the coordination between breathing and swallowing develops and matures during the first month of life [17].

In general, swallowing rhythm is maintained at the expense of functional and rhythmic respiration, even in fullterm infants [24]. Deviations from these patterns can be predictive for feeding, respiratory and neurodevelopment disorders [24]. Various studies demonstrated that sucking and swallowing influences the normal pattern of breathing: it decreased inspiratory time, decreased respiratory frequency, decreased minute ventilation and decreased tidal volume [24;25]. This is important in pathological circumstances when breathing is compromised.

Studies of the coordination between sucking, swallowing and breathing show the following possibilities: a swallow could be preceded by inspiration, expiration or apnoea and could be followed by inspiration, expiration or apnoea, yielding nine possible relationships [20]. Sixty per cent of fullterm neonates have an I (inspiration)- S (swallow)- E (expiration) or an E (expiration)- S (swallow)-I (inspiration) relationship. Swallows followed by expiration would be safer because any milk remaining in the pharynx would be cleared before the next inspiration. Besides, it is most efficient to swallow after inspiration because then pharyngeal pressure is at its highest [16]. The optimal pattern in nutritive feeding thus seems to be I-S-E.

Whether breast-fed or bottle-fed with expressed breast milk, infants show a significantly higher breathing rate than when receiving other liquids. Coordination between swallowing and breathing could improve with breast milk [26].

Special considerations on the development of sucking and swallowing in preterm infants

When describing the normal development of the preterm infant one is in fact describing an abnormal situation: a preterm infant develops in an extra-uterine environment while intra-uterine development would be normal. This complicates the matter of distinguishing between normal and abnormal development of sucking and swallowing. Which aspects of the development of sucking and swallowing in the preterm infant are deviant and what is part of normal maturation? With this in mind we would like to make the following comments.

The moment an infant gains sufficient control over its physiological parameters determines the time it is ready to successfully process oral feeding. From the literature it would appear that it is taken for granted that on reaching term age the infant has developed a sucking pattern (or that the infant is able to coordinate sucking, swallowing and breathing) that is comparable to that of a fullterm infant. If the infant is unable to do this, its development is considered to be deviant or premature 6. Gewolb et al. 17 indicated that the number of sucking movements in preterm infants increases from 55 per minute at 32 weeks' PMA to 65 per minute at 40 weeks. This is comparable to the level reached by fullterm infants at one month of age. On the one hand, this implies that during the first days after birth the sucking rate does not follow the maturation curve. On the other hand, age expressed in terms of PMA correlates better with the development of sucking and swallowing than chronological age, which presumes that oral feeding is a congenital behavioural pattern rather than acquired behaviour 27.

Lau and Kusnierczyk 4 divided the normal maturational process into five primary stages based on the presence or absence of suction and rhythmicity for the two components of sucking: suction and expression / compression Table 1. Lau and Kusnierczyk used this scale to indicate the relation between the development of sucking and the preterm infant's oral feeding skill. The scale can be applied to both NS and NNS.

Table 1 The five primary stages of non-nutritive sucking (NNS) and nutritive sucking (NS).

Stage 1a	The sucking pattern consists primarily of arrhythmic expression without suction.
Stage 1b	Sucking with attempts to generate suction and expression.
Stage 2a	Although suction may be still absent, the expression component becomes rhythmic.
Stage 2b	The alternation of suction / expression begins to appear. Rhythmicity not yet established.
Stage 3a	Sucking still consists of rhythmic expression without suction.
Stage 3b	The appearance of more rhythmic alternation of suction / expression with longer sucking bursts and stronger suction amplitude.
Stage 4	Only rhythmic alternation of suction and expression is observed.
Stage 5	Greater suction amplitude and longer duration of sucking bursts than seen in Stage 4

Adapted in 2005 by Rogers and Arvedson from Lau et al., 2000 (18, 28).

Non-nutritive sucking (NNS)

In the past, several studies on NNS were performed in preterm infants because this behavioural pattern is more readily observed in preterm infants than is NS. Usually NNS is at the same stage of development as NS or one level ahead 4;28. The stage of NNS is an indication of the infant's oral-motor skills. If an infant shows stage 5 NNS and its NS skill is Stage 2, then the coordination of swallowing or breathing is ineffective. Oral feeding performance improves as the infant's sucking skills mature 4;9. A significant correlation was found between the level of maturation of an infant's sucking skill and gestational age and the infant's skill to ingest oral food.

Several studies have shown the advantages of NNS. These include a quicker change from tube feeding to oral feeding, better saturation during NS when the infant received NNS prior to NS. NNS at the empty breast promotes infant state control, weight gain, breast-feeding skill and milk production in the mother 4;29;30.

Rhythmicity

In preterm infants of 26 to 33 weeks' gestational age at birth, Gewolb 21 found that the basic rhythmic nature of swallowing stabilises before suck rhythmicity does. A stable swallow rhythm already exists at the age of 32 weeks' PMA and does not change from 32 weeks' PMA through to term age. Concerning sucking rhythm, stability is established later.

Mizono and Ueda 16 found significantly increased sucking efficiency, (sucking pressure and frequency) between 34 and 36 weeks' gestational age. They found a 30 seconds continuous phase (during the continuous phase the sucking pattern is stable and is only influenced by oral reflex activity) and an intermittent phase (the sucking pattern changes and becomes less stable as a result of fatigue, gastro-intestinal and respiratory influences) during sucking. Although only bottle-fed infants were observed in most studies, it is supposed that the basic rhythmic pattern is similar in breast-feeding, even though breast-feeding often involves more sucking movements.

Interaction with breathing

The coordination of breathing and swallowing undergoes significant developmental maturation from 34 weeks to 42 weeks' PMA. Generally speaking, minute ventilation increases during sucking and swallowing with increasing PMA 17. This might influence sucking and swallowing patterns in infants whose minute ventilation is at risk under normal circumstances, e.g. in infants suffering from bronchopulmonary dysplasia (BPD). Gewolb 21;31 described the development of sucking and swallowing in preterm infants suffering from severe BPD. Up to 35 weeks' PMA sucking and swallowing develops as in healthy preterm infants. Subsequently, difficulties in coordinating breathing and sucking arise to an increasing extent, but the rate of swallowing, length of the swallowing sequence and the swallow-swallow interval are not influenced by BPD. The main problem arises in the coordination between breathing and sucking and swallowing. Because of the BPD, swallowing is relatively long to meet the infant's ventilatory demands, whereas sucking patterns are not adapted to this situation. If the infant continues to suck, desaturation occurs due to the necessity to swallow, with insufficient time to breathe, leading to deglutition apnoea. Only after a number of weeks after term age does coordination recover and does the infant develop a normal sucking pattern once again. This may possibly be caused by discongruent maturation of the breathing and swallowing centres in the brainstem. The coordination of swallow-respiration and suck-swallow rhythms may be predictive for feeding, respiratory and neurodevelopmental abnormalities 19. Infants with BPD, however, do not follow predicted maturational patterns of sucking–swallowing rhythmic integration. A follow-up study of Gewolb 32 suggests that ventilatory needs may modulate sucking rhythm and organisation. Hanlon et al. 33 investigated the maturation of deglutition apnoea times in fullterm and preterm infants (28 to 37 weeks' gestational age). They found that deglutition apnoea times decrease as infants mature, as does the number and length of episodes of multiple-swallow deglutition apnoea. The maturation appears to be related to postmenstrual age rather than feeding experience (chronological age).

Reliance on preterm infant behavioural cues for impaired oxygenation during bottle-feeding will be insufficient for the detection of oxygen desaturation during oral feeding. Attention to changes in breathing sounds and to the pattern of sucking are potentially important intervention strategies to prevent the decline of oxygenation during feeding. Sucking pauses may be a moment when preterm infants aim to regulate their breathing pattern and thereby increase oxygenation 34. It remains unclear whether this pattern changes on reaching term age. In preterm infants the predominant breathing patterns are E-S-I and E-S-S with 'apnoeic swallows' or 'apnoeic-related' swallows accounting for approximately 30 per cent of all swallows in infants ≤35 weeks' PMA and approximately 15 per cent in preterm infants of 35 to 40 weeks' PMA. This is quite different from the situation in fullterm infants, where the predominant pattern is I-S-E and where 'apnoeic(-related)' swallows are rare.

Diagnostic methods to investigate an abnormal developmental course of the coordination of sucking, swallowing and breathing

The reasons to carefully study both the preconditions for sucking and how an infant sucks are to determine if an infant is ready to feed orally and to detect the nature of feeding problems. In addition, an abnormal sucking pattern may be an indication of the neurological development of the infant is not progressing normally.

We performed a literature search for both types of assessments and distinguished between the following elements:

1. the reliability of the study
2. the reliability and validity of the tool
3. whether the tool be used for preterm infants?
4. whether the tool is designed for breast-feeding, bottle-feeding or for both?
5. for which age is it suited?
6. how invasive is it / hands off or hands on?
7. what does it measure?
8. is the tool designed for nutritive or non-nutritive sucking or for both?
9. how much does the tool cost and what costs are involved in its use?

Determining whether an infant is ready to feed orally

Certain physiological parameters, behavioural aspects, NNS and the infant's behavioural state are important indicators, apart from the infant's oral-motor functioning, to determine whether a preterm infant is ready to feed orally 1;34.

The vision on readiness is strongly determined by the fast-increasing options of medical treatment of preterm infants in the NICU. Basing ourselves primarily on the date of publication of the articles from our literature search, we selected six approaches that all stem from nursing practice. On the basis of the set-up of the study, whether or not it is standardised and the description of the items to be observed, we selected two methods Table 2.

McGain 29 described the use of NNS to promote awake behaviour for feeding, the use of behavioural assessment to identify readiness for feeding and systematic observation of and response to infant behavioural cues to regulate frequency, length and volume of oral feeding. She used individualised semi-demand feeding. This means that every three hours the infant is offered NNS for five to ten minutes, followed by an assessment of the infant's behavioural state. If asleep, the infant is permitted to sleep for another half an hour and then again offered NNS. If awake and restless the infant is offered nipple feeding, if the infant is still sleeping the feeding is given by gavage 1.

Thoyre et al. 1 developed the Early Feeding Skills Assessment (EFS). This tool is a 36–item observational scale divided in three sections: Early Feeding Readiness, Oral Feeding Skill and Oral Feeding Recovery. In addition, the EFS must be re-administered at each feeding to determine whether the infant is able to feed orally, how it reacts to the feeding and how it recovers from the effort. The physiological parameters are monitored during feeding.

In the case of Early Feeding Readiness the infant has to demonstrate 'behavioural organization and energy for the work of feeding by attaining and maintaining an awake state, a flexed body posture with sufficient muscle tone, and interest in sucking' (1, p. 10). Gestational age is less important. For

Table 2 Standardised diagnostic tools for assessing an infant's readiness for oral feeding

Assessment	Description	Reliability of the study	Reliability and validity of the tool	Age suitability
1. An Evidence-Based Guideline for introducing Oral sucking to promote Feeding to Healthy Preterm Infants, McCain, 2003 (29)	The method combines the use of non-nutritive sucking to promote waking behaviour for feeding, the use of behavioural assessment to identify readiness for feeding and systematic observation of and response to infant behavioural cues to regulate frequency, length and volume of oral feedings	A semidemand method based on a randomised experimental study of 41 healthy preterm infants (32 to 34 weeks PMA). Making the transition from gavage to oral feeding five days (p <.001) faster compared to a control group (n=41)	Different elements of this approach are based on evidence found in references	Preterm infants
2. Early Feeding Skills Assessment for Preterm Infants (EFS), Thoyre, Shaker and Pridham, 2005 (1)	A checklist for assessing infant readiness for and tolerance of feeding and for profiling the infant's developmental stage regarding specific feeding skills	The authors based all the items of the tool on 69 references. No information is provided about the results of the EFS, about the study group, control group, etc	The authors state that 'content validity has been established with expert neonatal nurses' and 'intra- and inter-rater reliability have been found to be stable and acceptable', but no data are provided to support this statement	Preterm infants

Breast- or bottle-feeding	NS or NNS	What is measured?	Degree of invasiveness	Equipment, costs, training
Both	Both	State, behavioural organisation, suck-swallow-breathe pattern and cardiorespiratory control	Non- invasive	The method requires a trained nurse and time investment; no capital outlay required
Both	Both	EFS is a 36-item observational measure, used to assess four domains: to remain engaged in feeding; to organise oral-motor functioning; to coordinate swallowing and breathing and to retain physiological stablility	Non-invasive	Does not require any apparatus. Requires a two-day workshop to train nursing staff in using the tool

Table 3 **Standardised diagnostic tools for assessing NS or oral feeding**

Assessment	Description	Reliability of the study	Reliability and validity of the tool	Age suitability
1. Systematic Assessment of the Infant at the Breast (SAIB), Association of Women's Health, Obstetric and Neonatal Nursing, 1990 (35)	Observations related to alignment, areolar grasp, areolar compression and audible swallow	As yet we have received no detailed information	As yet we have received no detailed information	Preterm infant
2. The Neonatal Oral-Motor Assessment Scale (NOMAS), Palmer, Crawley and Blanco, 1993 (6)	Checklist of 28 items in categories of normal, disorganised and dysfunctional tongue and jaw movements	Thirty six infants, term and preterm. No control group. Twenty references were used. For more than half of the items there is no acknowledgement of the source. The method was not subjected to any test of validity	In a previous version interrater agreement was determined on the basis of percentage agreement. After revision, the final scale was not tested for reliability	From birth up to 8 weeks' corrected age. Suitable for both groups, according to the authors. In the manual hardly any distinction is made regarding the assessment of preterms
3. LATCH: a breast-feeding charting system and documentation tool. Jensen et al. 1994 (36)	A systematic method for gathering information about individual breast-feeding sessions	Riodan et al., 2001 (52) measured the validity of 133 dyads and the relationship between the LATCH scores and duration of breast-feeding		No distinction is made in terms of gestational age when using this tool
4. Preterm Infant Breast-feeding Behaviour Scale (PIBBS), Nyqvist et al., 1996 (37)	Diary kept by mother: rooting, amount of breast in mouth, latching, sucking, sucking bursts, swallowing, state, letdown and time	Study of 35 infants: 12 fullterms (control group) and 23 preterms. Thirty eight references. The source of all nine elements is acknowledged. The tool is subjected to tests of both reliability and discriminative validity	Interrater agreement of the PIBBS was tested on the basis of eight infants and adjusted accordingly. Subsequently, the interrater agreement of the tool was tested twice and adjusted	Suitable for both groups.

Breast- or bottle-feeding	NS or NNS	What is measured?	Degree of invasiveness	Equipment, costs, training
Breast	NS	Eighteen aspects are observed, seven of which refer to sucking/ swallowing movements	Not	Training of nurse and mother
Both	Both	Coordination between sucking, swallowing and breathing. Jaw and tongue movements are divided into three categories for jaw movements and three categories for tongue movements	Hands off, bedside observation	Video camera. A 3-day certification course
Breast-feeding	NS	The tool assigns a numeral score to five key elements two of which refer to sucking and swallowing	Mainly hands off, except for cervical auscultation	Training in scoring and cervical auscultation
Breast-feeding	NS	Nine aspects are measured and sub-divided into 22 sub-items. Nine of these refer to sucking	Hands off, direct observation	No apparatus. Training required

Assessment	Description	Reliability of the study	Reliability and validity of the tool	Age suitability
5. Breast-feeding Evaluation and Education Tool. Tobin, 1996 (38)	A take-home sheet gives parents ample criteria for determining how well breast-feeding is progressing	No data are available for assessing this tool. The set-up of the tool is based on six references four of which have not been published. Not subjected to any test of validity	No information is provided regarding reliability and validity	Suitable for fullterm infants
6. Analysis of feeding behaviour with direct linear transformation, Mizuno et al., 2005 (41)	By placing markers on the lateral angle of the eye, tip of the jaw and throat during sucking while the face of the infant is recorded in profile, the jaw and throat movements are calculated using the direct linear transformation (DLT) procedure	Ten 'normal' infants (control group) and two infants with neurological disorders were studied. Eleven references were used. Not subjected to any substantial test of validity	According to their previously published data on infants with severe neurological disorders, who were unable to generate intra-oral negative pressure, the authors observed a significant relationship between throat movement and suction pressure	Not indicated
7. Ultrasound observation of lingual movement patterns, Miller and Kang, 2006 (40)	Examination of the lingual-hyoid mechanics with a non-invasive ultrasound imaging technique of lingual movement	N=1 as a pilot study to find out whether ultrasound can be used to determine abnormal lingual movements. Thirty two references were used. Not subjected to any test of validity	The authors underscore the importance of lingual motor activity as a driver of sucking mechanics. In addition, they describe the differences in lingual movements between NS and NNS	Fullterm and preterm

Breast- or bottle-feeding	NS or NNS	What is measured?	Degree of invasiveness	Equipment, costs, training
Breast-feeding	NS	Eight aspects are observed, four of which refer to sucking movements. A description of the test has not been published	Hands off, direct observation	Applying the tool is typified as being ‘simple’ and ‘inexpensive’
Bottle-feeding	NS and NNS	Suction and expression pressure and the movements of jaw and throat are measured to detect abnormal movements, for instance in infants with neurological disorders	Hands off, direct observation	Digital videocamera. Training in placing the linear markers and in interpreting the analysis
Bottle-feeding	NS and NNS	It is used to discern aspects of oral feeding candidacy, which is the evaluation of intra-oral lingual movements during sucking	Hands on, yet non-invasive, according to the authors	B-mode ultrasound imaging system. Training in using ultrasound and in interpreting the images

Oral Feeding Skill, the coordination of sucking, swallowing and breathing, and the sucking and swallowing movements are observed. During five minutes following feeding, the caregiver observes the behavioural and physiological recovery from feeding to determine Oral Feeding Recovery. This information is of great importance when deciding whether or not to feed the infant orally the next time it needs to be fed.

Methods to detecting feeding problems in young infants

In order to detect feeding problems a diagnostic tool is needed to assess the oral-motor patterns underlying poor feeding.

In general, one can distinguish between clinical feeding assessment and swallowing assessment 7. Whether NNS or NS and swallowing are observed as standard procedure depends on the infant's age and on the clinical situation.

No standardised method is available to assess NNS. A common approach to assess NNS is to place one's little finger into the infant's mouth halfway the tongue. The rate of NNS should be approximately two sucks per second. If the infant shows good NNS this does not automatically mean that it is ready for oral feeding. During NNS only sucking and breathing are coordinated, and not sucking, swallowing and breathing as in NS 9.

Standardised assessments are available to assess NS or oral feeding. A literature search using the nine search elements mentioned earlier resulted in our finding seven assessment tools Table 3. Four of these were suited exclusively for breast-feeding, two for bottle-feeding and only one for both breast-feeding and bottle-feeding. The assessments designed exclusively for breast-feeding also include maternal elements such as the mother's feeding position, nipple pain, and the mother's health. The part aimed at the oral motor patterns is limited: two out of five items in the case of LATCH 35;36, nine of the twenty-two sub items in the Preterm Infant Breast-feeding Behavior Scale (PIBBS)37, four out of eight items in the Breast-Feeding Evaluation for term infants 38. The PIBBS was the only tool subjected to tests of validity and reliability.

The non-invasive assessment tools for bottle-feeding only focus on the intra-oral movements of the infant. Both assessments are still in an experimental stage (N=1 and N=12). Nevertheless, they seem to offer many possibilities for the future 39-41.

Because the only assessment tool used for breast-feeding and bottle-feeding is the non-invasive Neonatal Oral-Motor Assessment Scale (NOMAS) 6 we describe it here in more detail. The tool contains checklists for feeding behaviour and provides an analysis of, and diagnoses, sucking patterns by assessing the oral-motor components of the tongue and jaw during neonatal sucking. In addition, it identifies the type of sucking pattern the infant uses. Two abnormal patterns are defined: a disorganised sucking pattern and a dysfunctional sucking pattern. A disorganised sucking pattern refers to a lack of rhythm in the total sucking activity. This means that the infant is unable to coordinate sucking and swallowing with breathing. When an infant's sucking pattern is disorganised, it is unable to feed well and may exhibit laboured breathing with colour changes and/or spells of apnoea and bradycardia. A dysfunctional sucking pattern is characterised by abnormality in orofacial tone. In case of orofacial hypertonia, a restriction in the range of motion at the tempomandibular joint may result, in turn resulting in minimal jaw excursions and/or tongue retraction. In case of orofacial hypotonia, one may note a flaccid tongue and/or excessively wide excursions of the jaw when sucking. Infants with dysfunctional sucking patterns are likely to benefit from therapeutic intervention providing compensatory strategies during oral feeding.

Palmer published data concerning the reliability of the NOMAS in 1993. In recent years, a number of articles by Palmer [6;42-45] and by others [39;46] have been published in which the NOMAS was employed as a diagnostic tool. The NOMAS seems particularly useful for studying fullterm infants with sucking problems, but less so when it comes to sucking patterns in preterm infants [44].

The prognostic value of an abnormal developmental course of sucking, swallowing and breathing for later neurodevelopmental and feeding outcome

It is known that early feeding problems may be the first symptom of disability. Infants with severe neurodevelopmental problems in later life did not generate sucking pressure or coordinate suction and expression during their neonatal period. Several studies found that both feeding problems and nutritional problems are most common in children with severe disability (2;47). Gisel and Patrick [48] suggest that early quantitative assessment of feeding efficiency should be made to identify infants who cannot be nourished adequately without ancillary feeding. The identification of risk factors associated with malnutrition is important for its early detection and treatment and for the prevention of later behavioural, health and growth consequences. However, only few studies have prospectively identified risk factors in cohorts of fullterm and preterm infants. Moreover, there are hardly any publications on the relationship between the development of sucking and later neurodevelopmental outcome even though there are several authors who suspect that the relationship does exist.

Since the rhythmic processes involved in feeding are under bulbar control, quantitative analyses of rhythms and patterns of feeding times can be meaningful. This is the case especially after the 35th week PMA, not only as an indication of feeding problems but also as predictors of subsequent long-term neurological problems [25].

The eating and drinking patterns of 34 former preterms (with an average gestational age of 34 weeks) and 21 healthy infants born at term were studied from six to twelve months [47]. At the age of six months 12 former preterms were more likely to vomit and were slightly more inclined to cough when fed viscous food. At the age of 12 months the same 12 children had more problems with small chunks in their food and they coughed much more often when eating chewable food. Only six of these children and their parents enjoyed the meal.

Palmer [42] followed 18 children whom she had assessed with the NOMAS shortly after birth. She saw the children again between the ages of 24 to 36 months. For these assessments she used the Bayley Scales of Infant Development and the Vineland Social Maturity Scale. All seven children who had a dysfunctional sucking pattern in infancy showed developmental delay. The two children who had a normal sucking pattern in infancy developed normally. Of the nine children who had shown a disorganised sucking pattern in infancy four had developed abnormally at the age of 24 months. However, the numbers in this study are limited and no specific details are provided about the extent of the developmental delay. Besides, the NOMAS is not a reliable tool as the intra-rater agreement with respect to the diagnosis is 'moderate' to 'substantial' (Cohen's κ between 0.40 and 0.65) [49].

Mizuno and Ueda [46] studied the relationship between the feeding behaviour (measured in terms of expression and suction) of 65 neonates (mean gestational age 37.8 weeks, SD 0.5) and neurological development (measured with the Bayley Scales of Infant Development II) at 18 months of age. They found an association, namely the weaker suction and expression were, the lower the score on the Bayley Scales of Infant Development II.

Pridham et al. [50] explored the level and variation in feeding skill performance in 45 preterm infants at 1, 4, 8 and 12 months' post-term age using the Child Feeding Skills Checklist. They found that feeding skill performance varied widely among infants at all four assessments. A minority of infants had a delay and lack of opportunity to engage skills like eating new food, drinking from a cup, and self-feeding skills at the age of 8 and 12 months.

Medoff-Cooper et al. [51] did a study in 19 very low birth weight infants to identify early predictors of developmental outcome. They found that the mean pressure generated by each suck and the length of sucking bursts correlated positively with the Psychomotor Scale of the BSID at the age of 6 months.

In summary we can state that over the years a relationship between sucking patterns and later outcome has been suggested by several authors, but exact data do not exist. There is an urgent need for prospective studies on feeding behaviour and later neurodevelopmental and motor outcome. To begin with, a reliable and non-invasive research tool to assess sucking and its development is required to achieve this aim.

Conclusion

Many studies on sucking and the development of sucking in preterm infants and infants born at term have been published over the past seven years. A number of these publications assume that there is a relationship between the way an infant sucks and his later neurodevelopmental and feeding outcome. In these studies various aspects of learning how to suckle from the breast or how to drink from a bottle are mentioned and investigated. Internal and external factors are distinguished. Internal factors are stable physiological parameters, rooting, suction pressure and suction frequency, movements of jaw and tongue, the rhythmicity of the suck-swallow-breathe relationship, length of sucking bursts and alertness. External factors are milk flow, nipple size, nasogastric tube in situ and the role of the caregiver. Several research tools have been developed to assess sucking behaviour. In these studies only a few aspects of the development of sucking are measured or investigated; often they cannot be used for both breast-feeding and bottle-feeding; are more or less invasive and require expensive or complicated measuring equipment. Most studies were done with a small experimental group and often without a control group. Only a few tools were tested for validity (specificity and sensitivity). Therefore, the need remains for a user-friendly, reliable and non-invasive tool to measure objectively all the aspects mentioned above and one that is applicable to both breast-feeding and bottle-feeding. With such a tool in hand we would be able to determine which interventions to use to enhance sucking and swallowing in newborns. It is tempting to speculate that such a tool could also predict later development or neurodevelopmental sequelae or later feeding problems. In that case, it would enable us to decide which interventions to use to enhance sucking and swallowing in infants, and hopefully improve their outcomes.

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3 The reliability of the Neonatal Oral-Motor Assessment Scale

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Abstract

Objectives Sucking problems in preterm infants can be specified by means of visual observation. The Neonatal Oral-Motor Assessment Scale (NOMAS) is the visual observation method most commonly used to assess the non-nutritive sucking (NNS) and nutritive sucking (NS) skills of infants up to approximately eight weeks post term. During the first two minutes of a regular feeding the infant's sucking skill is assessed, either immediately or on video. Although NOMAS has been used since 1993, little is known about the method's reliability. The aim of our study was to determine the intra-rater agreement and inter-rater reliability of NOMAS.

Methods The 75 infants included in this study were born at 26 to 36 weeks' postmenstrual age (PMA). Four observers participated in the study. They were trained and certified to administer NOMAS in the Netherlands by M.M. Palmer between 2000 and 2002.

Results We found the intra-rater agreement of NOMAS to be 'fair' to 'almost perfect' (Cohen's Kappa (κ) between 0.33 and 0.94), while the inter-rater agreement with respect to the diagnosis was 'moderate' to 'substantial' (Cohen's κ, between 0.40 and 0.65). As a diagnostic tool, however, the current version of NOMAS cannot be used for both fullterm and preterm infants. For a measuring instrument such as NOMAS one should aim at reliability coefficients for inter-rater and test re-test agreement of at least 0.8. A Cohen's κ of 0.6 or less we find unacceptable. Nonetheless, by observing sucking and swallowing according to a protocol much useful information can be gathered about the development of an infant's sucking skills. For instance, whether the infant is able to co-ordinate sucking and swallowing, whether the infant can maintain sucking, swallowing and breathing during the

continuous phase and whether the infant is able to suck rhythmically with equally long bursts. In addition, NOMAS offers useful aids for intervention.

Conclusions NOMAS should be re-adjusted in order to improve inter-rater agreement and at the same time current insights into the development of sucking and swallowing should be incorporated in the method.

Introduction

Feeding problems occur frequently in preterm infants during their first year of life 1, particularly in infants of gestational age (GA) of 32 wks or less 2 - 4. However, the exact prevalence of feeding problems in preterm infants is unknown. In the case of preterm infants feeding difficulties usually have a medical cause (gastrointestinal, neurological or pulmonary) due to immaturity and diseases of one or more organ systems and often painful, but medically necessary interventions in the infant's face, mouth and throat region related to these problems. Infants born prior to 34 weeks' gestational age suffer more gastrointestinal and oral sensory problems, such as abnormal oral reflex activity 1, 3, 4.

Most feeding difficulties in preterm infants are caused by immature or inadequate coordination of the sucking, swallowing and breathing sequence. In cases of impaired coordination, liquid may be aspirated into the trachea and so into the lungs. Aspiration may occur with no observable signs. In some cases infants may choke, be short of breath or disorders of the respiratory tract, a decrease in oxygen saturation, apnoea and bradycardia may occur 5. In case of low birthweight in addition to prematurity these problems are often more serious and longer lasting, particularly in the case of gastrointestinal disorders and if medical interventions like artificial ventilation had been necessary 3, 4. Difficulties during feeding may also lead to insufficient intake. Insufficient intake, especially in the case of a newborn that is ill, may lead to tension on the part of the caregiver. And tense interactions between the infant and his environment could be a breeding ground for behavioural and parent-related feeding problems in the long run. For these reasons it is important to intervene as quickly as possible and to find out whether feeding problems persist over time, or recover.

Sucking and swallowing movements of newborns can be assessed in different ways. In the case of direct assessment, sucking and swallowing can be described by means of various measures such as measuring saturation, heart rate, pharyngeal pressure, breathing pattern and the duration of inhaling and exhaling 2, 6- 9. On the basis of these assessments conclusions may be drawn regarding the coordination of breathing and swallowing, sucking pressure, efficiency, frequency and duration, and the respiratory

Table 1 Assessments of Infant Oral-Sensorimotor Function for Feeding

Assessment	Description
1. Neonatal Oral-Motor Assessment Scale (NOMAS), Palmer, Crawley and Blanco, 1993 (10)	Checklists of behaviours in categories of normal, disorganised and dysfunctional tongue and jaw movements. From birth up to 8 weeks' corrected age.
2. Systematic Assessment of the Infant at the Breast (SAIB), Shrago and Bocar, 1990 (11)	Observations related to alignment, areolar grasp, areolar compression and audible swallow.
3. Preterm Infant Breast-feeding Behaviour Scale (PIBBS), Nyqvist et al., 1996 (12)	Diary kept by mother: rooting, amount of breast in mouth, latching, sucking, sucking bursts, swallowing state, letdown and time.
4. Breast-feeding Evaluation for term infants, Tobin, 1996 (13)	Purpose: to identify when a mother would benefit from lactation support. List of expectations for feedings. Fullterm infants in the neonatal intensive care unit.
5. Bottle-feeding Flow Sheet, Vandenberg, 1990 (14)	Observations of state, respiratory rate, heart rate, nipple, form of nutrition, position, coordination, support quantity and duration changes over time.
6. Infant Feeding Evaluation, Swigert, 1998 (15)	Non-standardised evaluation: means of documenting a variety of observations, including infants' responses to attempted interventions. Devised for birth to four months, components for preterm or ill infants not specified.
7. Semi-demand Feeding Method for Healthy Preterm Infants, McCain, 2003 (16)	The method combines the use of non-nutritive sucking to promote waking behaviour for feeding, use of behavioural assessment to identify readiness for feeding, and systematic observation of and response to infant behavioural cues to regulate frequency, length, and volume of oral feedings.
8. Early Feeding Skills Assessment for preterm infants (EFS), Thoyre, Shaker and Pridham, 2005 (17)	A checklist for assessing infant readiness for and tolerance of feeding and for profiling the infant's developmental stage regarding specific feeding skills.
9. Analysis of feeding behaviour with direct linear transformation, Mizuno et al., 2005 (18)	By placing markers on the lateral angle of the eye, tip of the jaw and throat during sucking while the face of the infant is recorded in profile, the jaw and throat movements are calculated using the direct linear transformation (DLT) procedure.

Adapted from Rogers and Arvedson, 2005 5(10) phase in which swallowing occurs. A drawback of these invasive measuring techniques is the impact they have on the ill newborn, like tubes down the infant's throat to measure pressure, and the complex measuring and analysing instruments necessary to generate the data.

Problems with sucking and swallowing can also be specified by means of indirect observation. We can distinguish between clinical feeding assessment and swallowing assessment 9. The standardised assessment methods available to assess nutritive sucking (NS) or oral feeding skills are presented in Table 1 11- 19. Most of these methods can be used either for observing bottle-fed infants 14 or for breast-feeding 11-13, 15-17. Five methods, including the Neonatal Oral-Motor Assessment Scale (NOMAS) and the Analysis of Feeding Behaviour with Direct Linear Transformation (DLT) can be used for observing both breast-feeding and bottle-feeding (11, 16- 19) infants. The fact that the markers on the infant's face have to be placed very carefully and the fact that a DLT procedure is used, is probably the main reason why the latter method is still little used.

The NOMAS 11, 20, a visual observation method, is a much used, non-invasive instrument to assess the NS and NNS skills of infants up to the age of about eight weeks post term Table 2. NOMAS allows infant sucking to be divided into three categories on the basis of the 28 items on the scale.

- A normal sucking pattern is displayed by infants who can coordinate sucking, swallowing and breathing properly during both NNS and NS.
- A disorganised sucking pattern can be observed in infants who are unable to coordinate sucking, swallowing and breathing. This pattern is displayed by newborns who suffer from breathing problems, infants with a heart condition or infants with gastrointestinal problems. Before reaching term, preterm infants usually display an immature sucking patterns that matches their age. If this sucking pattern is seen after term it is considered abnormal. Therefore, the infant's age is an important element to take into account before diagnosing a sucking pattern as disorganised.
- A dysfunctional sucking pattern is displayed by infants whose motor reactions and jaw and tongue movements are abnormal and therefore inadequate, as is the case in infants with neurological (or anatomical) disorders.

The infant's sucking skill is assessed during NNS and during the first two minutes of a regular feeding, either immediately or recorded on video for assessment later on.

Many authors 2, 7, 8, 11, 21 indicate that fullterm infants have a continuous sucking phase during the first two to three minutes. In this phase the oral reflex activity is present most strongly and the sucking

Table 2 Neonatal Oral-Motor Assessment Scale (NOMAS) original 1993 revision

Jaw

Normal	Disorganization	Dysfunction

• consistent degree of jaw depression
• rhythmical excursions
• spontaneous jaw excursions occur upon tactile presentations of the nipple up to 30 minutes prior to feed
• jaw movement occurs at the rate of approximately one per second (1/2 the rate of NNS)
• sufficient closure on the nipple during the expression phase to express fluid from the nipple
	• inconsistent degree of jaw depression
	• arrhythmical jaw movements
	• difficulty initiating movements *
	  ◦ inability to latch on
	  ◦ small, tremor-like start-up movements noted
	  ◦ does not respond to initial cue of nipple until jiggled
	• persistence of immature suck pattern beyond appropriate age
	• under 40 weeks PC
		• excessively wide excursions that interrupt the intra-oral seal on the nipple
		• minimal excursions; clenching
		• asymmetry; lateral jaw deviation
		• absence of movement (% of time) **
		• lack of rate change between NNS and NS (NNS = 2/sec; NS = 1/sec

Tongue

Normal	Disorganization	Dysfunction

• cupped tongue configuration (tongue groove) maintained during sucking
• extension-elevation-retraction movements occur in anterior-posterior direction
• rhythmical movements
• movements occur at the rate of one per second
• liquid is sucked efficiently into the oro-pharynx for swallow
	• excessive protrusion beyond labial border during extension phase of sucking without interruption sucking rhythm
	• arrhythmical movements
	• unable to sustain suckle pattern for two minutes due to *
	  ◦ habituation
	  ◦ poor respiration
	  ◦ fatigue
	• incoördination of suck/swallow and respiration which results in nasal flaring, head turning, extraneous movements •
		• flaccid; flattened with absent tongue groove
		• retracted; humped and pulled back into oro-pharynx
		• asymmetry; lateral tongue deviation
		• excessive protrusion beyond labial border before/after nipple insertion with out/down movement ••
		• absence of movement (%of time) **

* Two items are subdivided into three subitems each

** Item transferred from category 'disorganized' to 'dysfunctional'

• Redefined item

•• One item is added to the category 'dysfunction' bursts are most stable (the sucking-swallowing-breathing rhythm). After two minutes, due to gastrointestinal influences - the stomach filling up so the infant feels less hungry and a reduction of the oral reflex activity - the continuous sucking phase is replaced by the intermittent phase. This phase is characterised by bursts of sucking and a few swallows followed by a three to five seconds pause. Therefore, sucking becomes less stable and more difficult to assess. In the case of preterm infants (approximately until fullterm age), the continuous phase only lasts about 30 seconds, influenced bij neurologic function and cardiorespiratory control 2.

During observation by using NOMAS the researcher does not touch the infant nor is the infant attached to any measuring apparatus. If the infant is too sleepy or does not want to drink for another reason (such as stomach cramps or distractions in its surroundings), the attempt is postponed to a next feeding time. The number of sucking movements during one sucking burst is counted and the duration of the pauses between bouts of sucking are noted. Jaw and tongue movements, like the degree and rhythm of jaw lowering and tongue cupping, are analysed on the basis of 28 items and entered on the NOMAS form Table 2. Even though NOMAS may be used during breast-feeding as well as bottle-feeding, it may be more difficult to administer during breast-feeding because of the flow: infants adjust their way of swallowing to the flow of their mother's milk 11, 20. This results in jaw movements of varying speed and magnitude. As a consequence, our clinical observation was that the infants' jaw movements could erroneously be scored as disorganised.

Method

In 2004 we started a study on the development of swallowing in preterm infants. Seventy-five infants were included in the study: 15 were at risk for bronchopulmonary dysplasia, 17 were extremely low birthweight preterms and 20 were healthy preterms. The control group comprised 23 healthy fullterm infants. The preterm infants were born at 26 - 36 week GA. We excluded infants from the study who suffered severe multiple congenital disorders, severe predispositional cerebral disorders and periventricular echo densities with cysts. In addition, infants of drug addicted mothers were also excluded. We examined each infant 10 to 12 times: once a week between the ages of 34 and 40 weeks PMA and once a fortnight between 40 and 50 weeks PMA. The reliability study was part of the first phase of a research project on the development of sucking patterns in preterm infants and its relationship with neurodevelopmental outcome at two and five years of age.

Four NOMAS observers participated in our study. They had been trained and certified by M.M. Palmer in the Netherlands between 2000 (observers A and B) and 2002 (observers C and D). In order to qualify for a certificate the

Table 2a Neonatal Oral-Motor Assessment Scale (NOMAS) original 1990 version Copyright © 1990 Marjorie Meyer Palmer

Jaw

Normal	Disorganization	Dysfunction

• consistent degree of jaw depression
• rhythmical excursions
• spontaneous jaw excursions occur upon tactile presentations of the nipple up to 30 minutes prior to feed
• jaw movement occurs at the rate of approximately one per second (1/2 the rate of NNS)
• sufficient closure on the nipple during the expression phase to express fluid from the nipple
	• inconsistent degree of jaw depression
	• arrhythmical jaw movements
	• difficulty initiating movements
	• persistence of immature suck pattern beyond appropriate age
	  • under 40 weeks PC
	  • lack of rate change between NNS and NS (NNS = 2/sec; NS = 1/sec)
		• excessively wide excursions that interrupt the intra-oral seal on the nipple
		• minimal excursions; clenching
		• asymmetry; lateral jaw deviation
		• absence of movement (% of time)

Tongue

Normal	Disorganization	Dysfunction
• cupped tongue configuration (tongue groove) maintained during sucking • extension-elevation-retraction movements occur in anterior-posterior direction • rhythmical movements • movements occur at the rate of one per second • liquid is sucked efficiently into the oropharynx for swallow	• excessive protrusion beyond labial border during extension phase of sucking without interruption sucking rhythm • arrhythmical movements • unable to sustain suckle pattern for two minutes • incoördination of suck/swallow and respiration which results in choking, sputtering, gagging	• flaccid; flattened with absent tongue groove • retracted; humped and pulled back into oropharynx • asymmetry; lateral tongue deviation • absence of movement (% of time)

assessor is required to correctly assess all three the diagnoses on five NOMAS video recordings (i.e. a 100 % correct classification into the categories normal, disorganised or dysfunctional) and to obtain 80% agreement on all 28 items per recording 22. Due to practical reasons (illness or pressure of work) the four observers were unable to all perform the same number of assessments. Although A observed 54 recordings and B 126, they observed 50 of the same recordings together. Observer C observed 71 recordings and D 42, and they observed 20 recordings together. The four observers together assessed a total of 293 recordings.

Following Palmer's method, a video recording was made of the infants at different ages during the first two minutes of NS. We stored the recordings on a digital videodisc and two NOMAS assessors assessed each recording. Subsequently, we determined the intra-rater agreement and inter-observer reliability. In contrast to Palmer, we determined the reliability of the diagnoses and not that of the items. On average, the four assessors assessed 70 recordings twice with an interval of three months between assessments. The data of the first assessment were not available to them on the occasion of the second assessment.

Statistical analysis

Assessor agreement is defined by Palmer as 'sameness of classification' 23. According to Popping, Cohen's Kappa (κ), that is 'the proportion of agreement after chance agreement is removed from consideration' 24, is the best measure to determine agreement between assessors in case of the a posteriori method of coding nominal data. As shown in Table 3 a reliability coefficient of 0.60 is considered the minimum for acceptable assessor agreement, while $\kappa = 0.80$ or higher is considered 'almost perfect' or 'satisfactory' (24, 25, 26). While no absolute definitions are possible, the following guidelines should help: Cohen's κ is determined between two observers and between two viewings of the same recording by each assessor.

Results

For test re-test agreement Table 4 there was a considerable difference between assessor A with the highest score ($\kappa = 0.948$) and D with the lowest score ($\kappa = 0.331$). Thus intra-rater agreement ranged from 'fair' tot 'almost perfect'. With an average reliability coefficients of 0.67 the intra-rater agreement of assessors B and C was 'substantial'.

Table 3 **Interpretation of Cohen's Kappa (K) values between 0 and 1 (Landis & Koch, 1977)**

Value of K	Strength of agreement
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost perfect

Table 4 **A comparison of the intra-rater agreement between recordings of preterm and fullterm infants (number of observations).**

Assessors	Total		Preterm infants		Fullterm infants	
	Kappa	Number of observations	Kappa	Number of observations	Kappa	Number of observations
A	0.948	54	1.00	31	0.841	23
B	0.694	126	0.685	77	0.718	49
C	0.659	71	0.752	37	0.630	34
D	0.331	42	na	13	0.410	29

Table 5 **A comparison of the inter-rater agreement between recordings of preterm and fullterm infants (number of observations).**

Assessors	Total		Preterm infants		Fullterm infants	
	Kappa	Number of observations	Kappa	Number of observations	Kappa	Number of observations
A vs. B	0.406	50	0.484	26	0.385	24
C vs. D	0.652	20	0.714	16	na	4

na = not available

We were curious to know whether there was a difference in reliability between the assessments of recordings of preterm infants as compared to those of fullterm infants. The reason being that it is perhaps easier to assess a mature sucking pattern than it is to assess an immature sucking pattern (see Table 4). Although the number of the observations was incomplete, making it impossible to do a comparison based on figures, we found no indication that there was a difference between the intra-rater agreement of the preterm infants and that of the fullterm infants. In the case of inter-rater agreement Table 5, assessors C and D had assessed less than half of the recordings together due to the practical reasons mentioned above. Our results in Table 4 show that assessors A and B agreed with each other less often than did C and D. The interpretation of the reliability coefficients ranged from 'moderate' to 'substantial'.

Discussion

We found the intra-rater agreement of NOMAS with respect to the diagnosis to be 'fair' to 'almost perfect' Table 4 while the inter-rater agreement with respect to the diagnosis was 'moderate' to 'substantial' Table 5. The reason for the 'moderate' inter-rater agreement possibly lay in the lack of agreement in scoring the separate items and/or in the interpretation of some items belonging to the diagnosis 'disorganization'. It is remarkable that the items that score lowest in Palmer's study are the same items that caused confusion and disagreement in our study. What struck us was that one assessor would attach a different diagnosis to the same score than would the other assessor. In particular, this was the case for the items 'inconsistent jaw degree' and 'arrhythmic jaw/tongue movements'.

Inconsistent jaw degree

The degree of jaw opening that occurs during the suction component can be noted to vary each time, causing jaw excursions to be of unequal size' (Palmer, 1993 b, p. 74).

During different courses Palmer issued different statements on this point. During the course she offered in the Netherlands in May 2006, she stated that the diagnosis 'disorganization' might not be given in the presence of this item alone (pers. comm.).

Arrhythmic jaw movements

During a 2-minute timed segment of sucking, the jaw movements that occur are jerky, inconsistent, irregular, and do not flow in a co-ordinated way. Sucking bursts are of unequal length, and the number of sucks per burst continues to vary throughout the duration of sucking. There may also be intra-burst variability as the sucking- swallowing-breathing ratio changes' (Palmer, 1993 b, p. 74).

In case of a segment of sucking counting less than ten sucking-swallowing-breathing movements it is classified as 'arrhythmic jaw movement' also if it occurs towards the end of the 2-minute observation segment. In the meantime it has become clear, however, that in the case of preterm infants it is not realistic to take a 2-minute observation segment as point of departure before they have reached term age because a continuous phase in these infants only lasts 30 seconds. Some assessors diagnose such situations as normal since the overall impression of sucking is normal.

One of our concerns about using NOMAS as a diagnostic tool is that since NOMAS was developed in 1993 many studies have been published that describe the nutritive and non-nutritive aspects of sucking. We compared Palmer's findings as set out in NOMAS with recent studies on sucking and the development of sucking, swallowing and sucking patterns. Four questions arose regarding several aspects of NOMAS.

1. Palmer indicates that NOMAS ought to be administered during at least two minutes [10]. More recently she suggested that NOMAS be administered during at most two minutes because the continuous phase of sucking lasts two minutes [23]. Mizuno et al. found a continuous phase of 30 seconds in preterm infants [2]. Does this imply that for the assessment of sucking pattern in preterm infants NOMAS should only be administered during 30 seconds?

2. Palmer mentions '10-30 suck/swallows per burst' as being part of a mature sucking pattern (Palmer, 1993a, p. 28). She states that:

- 'The inter-burst variation should be stable'.
- 'Ten or more sucks per burst means a mature sucking pattern, less than ten sucks per burst is abnormal and is not part of a mature sucking pattern'.

Palmer does not mention a development in the number of sucking movements per sequence nor does she specify whether there is a quantitative difference between the number of movements an infant shows in its sucking pattern. Recently, Qureshi et al. spoke of an average of ten sucking movements per sequence at term and of 20 sucking movements per sequence at one month post term [7]. It seems advisable to consider the results of the study by Qureshi et al. when using NOMAS.

3. Palmer only speaks of a 1:1:1 rhythm when considering bottle-feeding and indicates a non-rhythmic intra-burst as abnormal and one that should be scored as disorganised. In breast feeding rhythm depends on the flow and a non-rhythmic intra-burst (e.g. suck-swallow-breath suck-suck-swallow-breath) is not abnormal and should not be diagnosed as 'disorganization' [11, 20].

Qureshi et al. concluded that during the first month of life infants develop from a 1:1:1 suck-swallow-breath rhythm to a 2:1:1 or 3:1:1 rhythm, thus displaying their increased skill to collect a larger amount of food in the valleculae that is swallowed at once 7.

Palmer does not mention the infant's ability to collect food from a number of sucking movements as part of the maturation process. It signifies the first step towards developing a new way of feeding. We advise to note the number of sucking movements per burst when using NOMAS 11, 20. And, in accordance with Qureshi, we advise to not regard a rhythm different from 1:1:1 as abnormal.

4. In her publications Palmer points out that NOMAS informs us about the jaw and tongue movements during sucking, about the coordination of sucking-swallowing-breathing and about the difference between nutritive and non-nutritive sucking. She also suggests noting the bolus volume the infant ingests during the two minutes of NOMAS administration 23. According to Qureshi, during the first month of life, the amount of cm3 per swallow doubles and the number of swallowing movements increases to 46-50 a minute 7. We recommend counting the number of swallowing movements per minute as a measure of swallowing efficiency.

Palmer states that NOMAS has predictive value 22. She bases this statement on the finding that nine infants out of 34 who had a dysfunctional sucking pattern in infancy had developed abnormally when they were re-examined at two years of age. The follow-up study included only 18 of the original 34 children and the result does not specify the degree of abnormal functioning at the age of two. In our opinion to say that NOMAS has predictive value on the basis of this evidence, is insufficient. Nevertheless, it appears that practitioners set great store by the value the diagnosis 'dysfunction' may have regarding expectations of neurodevelopmental outcome at a later age.

NOMAS is used mainly for fullterm infants with sucking and swallowing difficulties. Even though it has been in use since 1993, little is known about the instrument's intra-rater and intra-rater agreement. Palmer 11 studied inter-rater agreement of each NOMAS item in 35 infants aged 35 to 49 weeks and weighing more than 1900 gram at the time of assessment (23 to 42 weeks' gestational age). Palmer did not study the reliability of the method with regards to the diagnosis as was our aim. The inter-rater agreement of all 26 items, i.e. 13 items dealing with the functioning of the tongue and 13 items dealing with the functioning of the jaw, is expressed in percentage agreement and ranges between 63% and 100%. The score on 17 of the 26 items is 80% or higher. Subsequently, Palmer revised NOMAS. She added one items category 'dysfunction', she subdivided two items into three sub items each, she transferred one item from category 'disorganized' to ‘dysfunctional’ and she redefined one item. (Table 2 and 2 a). The reliability of the revised version was not investigated. The large range in agreement between the assessors made it impossible to say anything about the reliability of the classifications by the instrument as a whole. Moreover, Palmer’s study did not take into account agreement based on chance as determined by, for instance, Cohen’s κ .

In conclusion, the following issues need to be addressed:
NOMAS requires adjustment as far as the instructions about the interpretation of the items is concerned. At present the interpretation and/or classification of the items (especially with regard to the diagnosis ‘disorganization’) is not consistent. In addition, a clear distinction should be made between the interpretation in the case of bottle-feeding and breast-feeding.

As far as the diagnosis ‘disorganization’ is concerned the emphasis should lie on the fact that breathing is not coordinated with sucking and swallowing. Taking into account the extent to which sucking behaviour is diagnosed as disorganised seems meaningful when assessing preterms. In so doing it is possible during follow-up to better assess the development of sucking behaviour and the necessity of intervention.

The length of the time segment to be measured, either preterm or postterm, should be determined on the basis of Mizuno’s recent data on the continuous phase prior to term age [2].

According to Qureshi, NOMAS should be extended with the fact that at term an infant should be able to do ten sucking-swallowing-breathing movements per burst and at four weeks of age this should have increased to approximately twenty [7]. If an infant is unable to do this, this fact should be incorporated in the diagnosis. The number of swallowing movements per minute should count as a measure for increased efficiency of sucking and swallowing.

Moreover, Qureshi recommends that the diagnosis ‘disorganization’ should not be based on intra-burst arrhythmicity. In the case of this diagnosis care should be taken with inter-burst arrhythmicity [7]. Until such adjustments come into effect, NOMAS can be used for detailed observation of an infant’s sucking pattern for purposes of intervention but not for diagnoses because especially in the case of preterm infants, the differentiation into three diagnoses is not sufficiently reliable if the assessment is performed by different observers. We recommend testing the intra-observer reliability of NOMAS observers. In addition, we advise against involving more than one assessor in the longitudinal follow-up of one and the same infant.
In case NOMAS is used as a means to measure neurodevelopmental outcome for research purposes, we recommend:

- that each measurement be assessed by two reliable assessors, and
- to reach a consensus in case of absence of agreement.

Because the intra-rater agreement is not sufficient for everyone, the individual observer should be tested regularly and receive extra training if need be. We expect the inter-rater agreement to improve when the intra-rater agreement increases, and when the instrument is adjusted. Our point of departure is that the intra-rater agreement- and inter-rater agreement of measures such as NOMAS should have a Cohen's κ of at least 0.8. As far as we are concerned a Cohen's κ of 0.6 or lower is unacceptable.

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4 Sucking patterns in fullterm infants from birth to ten weeks of age

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Abstract

Objective Coordinating sucking, swallowing and breathing to achieve effective sucking is a complex process and even though sucking is essential for nutrition, little is known about sucking patterns after birth. Our objective was to study sucking patterns in healthy fullterm infants and to describe the age-specific variations.

Method We studied the sucking patterns of 30 healthy, fullterm infants longitudinally from two or three days after birth to 10 weeks of age. During this time we recorded five to seven feeding episodes that we assessed off-line with the Neonatal Oral-Motor Assessment Scale (NOMAS).

Results We found a normal sucking pattern on the second or third day after birth in 27 out of 30 infants. During the following weeks we found abnormal sucking patterns in 23 out of 171 feeding episodes (14 %) and normal patterns in 148 episodes (86%). Altogether, between 38 and 50 weeks' postmenstrual age (ten weeks after birth), 10 infants displayed a deviating, arrhythmical sucking pattern. Dysfunctional sucking patterns and problems of coordinating sucking, swallowing and breathing did not occur. Birthweight, gestational age, type of labour and gender did not influence sucking patterns. Arrhythmical sucking was seen more often in bottle-fed infants.

Conclusion Our study demonstrated that practically all healthy fullterm infants started off with a normal sucking pattern soon after birth. One third of the infants displayed one or more deviating episodes up to the age of ten weeks. Apart from bottle-feeding, no other factors were found that influenced sucking patterns.

Introduction

The ability to suckle at the breast or suck from a bottle is of vital importance to newborns. Sucking and swallowing in combination with a sound gastrointestinal system enables infants to take in food and grow. Coordinating sucking, swallowing and breathing requires complex neural mechanisms. Feeding difficulties during the neonatal period could be the first indication that an infant has neurological problems.

Healthy fullterm infants that are developing normally during the neonatal period can also be expected to have normal, mature sucking patterns from birth onward. A normal sucking pattern is defined as a continuous burst pattern of more than ten sucks per burst with only brief pauses in between the bursts, and with swallows and respirations occurring during the sucking bursts in a sequential pattern 1-4. The normal developmental course of sucking and swallowing during the first months of life after fullterm birth is characterised by increased rates of sucking and swallowing, longer bursts of sucking and larger volumes per suck (5). An assessment tool to analyse sucking patterns in both breast-feeding and bottle-feeding is the non-invasive Neonatal Oral-Motor Assessment Scale (NOMAS) 6. The tool contains checklists for feeding behaviour and provides an analysis of, and diagnoses, sucking patterns by assessing the oral-motor components of the tongue and jaw during neonatal sucking. The tool is suitable for infants up to the age of 10 weeks post term. As yet, sucking patterns have not been assessed longitudinally, using the NOMAS, in term born infants during the first ten weeks after birth. Therefore the aim of the longitudinal study presented here was to describe the sucking patterns and its variations in healthy, fullterm infants during the first months after birth. A related question was whether we could identify factors that might influence normal sucking in a normal infant population.

Methods

Thirty healthy, fullterm infants (18 boys and 12 girls) were selected through midwifery practices and maternity courses, and notices in the media. The criteria for inclusion were a gestational age ranging from 37 to 42 weeks and no complications during neonatal development. Low birth weights were allowed. Infants that had been exposed to drugs and alcohol during gestation, infants with congenital defects or infants that had been seriously ill during their first ten weeks after birth were not included in our study. Twenty-four infants were born vaginally (including one vacuum extraction) and six were delivered by caesarean section. Twenty-eight infants were appropriate for gestational age and had birth weights of more than 2500 grams. Two infants born at 37+4 weeks were small for gestational age (< P10). All the infants had an Apgar score of ≥8 at 5 minutes. Seventeen infants (51%) were breast-fed from birth up to ten weeks of age, while nine (27%) were bottle-fed. The mothers of four infants (13%) switched from breast-feeding to bottle-feeding after two to eight weeks. The study commenced after permission was granted by the medical and ethical review committee of the University Hospital of Groningen, the Netherlands, and informed parental consent had been obtained.

From two or three days after birth to the age of 10 weeks we video recorded the first ten minutes of a feeding episode with the infant in the quiet alert state 7. The second recording was made a week later and subsequently every two weeks until the infants were ten weeks old. All recordings were performed during daytime, mostly at early afternoon. The infant was videoed in profile so that its jaws, the base of the mouth, lips and cheeks were clearly visible. This camera viewpoint is essential for the successful assessment of the infant's feeding behaviour and a prerequisite of the assessment tool. At the time of the recording the infants were all healthy and were fed by either one of the parents. The following details were noted for each feeding episode: breast-feeding or bottle-feeding, the type of milk (i.e. breast milk, or a choice of five formulae without thickening agents), any changes in behavioural state during feeding, and signs of choking, breathlessness, discolouring or stress.

From the ten-minute recording we selected the first two-minute episode of feeding in order to assess the infant's sucking pattern with the NOMAS. The NOMAS suited our research purposes because it is a non-invasive, observational method that takes a number of aspects of sucking and swallowing into account, and it can be used for both breast-feeding and bottle-feeding (6;8). The NOMAS consists of twenty-eight items; fourteen of which relate to movements of the jaws and fourteen to movements of the tongue Table 2. Jaw movements and some tongue movements are scored as observed from the video recordings, and the other tongue movements are scored indirectly from the movements of lips, cheeks and the base of the mouth, as described in the NOMAS manual. The NOMAS distinguishes three sucking patterns: a normal (or mature), a disorganised and a dysfunctional sucking pattern. A normal sucking pattern is characterised as a continuous burst pattern of 10 to 30 sucks per burst with only brief pauses between bursts. Suck, swallow and respiration occur during the sucking bursts in a 1:1:1 sequential pattern. This normal nutritive suck occurs at approximately one half the rate of the non-nutritive suck, that is, one per second (9). An infant that shows a sucking pattern that deviates from this norm is assessed as 'abnormal' and is subsequently classified as disorganised or dysfunctional Table 2. A disorganised sucking pattern refers to a lack of rhythm in the total sucking activity. This means that the infant is unable to coordinate

Table 2 **Neonatal Oral-Motor Assessment Scale (NOMAS (6) 1993 revision** Copyright © 1990/1993 Marjorie Meyer Palmer

Jaw

Normal	Disorganization	Dysfunction

• consistent degree of jaw depression
• rhythmical excursions
• spontaneous jaw excursions occur upon tactile presentations of the nipple up to 30 minutes prior to feed
• jaw movement occurs at the rate of approximately one per second (1/2 the rate of NNS)
• sufficient closure on the nipple during the expression phase to express fluid from the nipple
	• inconsistent degree of jaw depression
	• arrhythmical jaw movements
	• difficulty initiating movements inability to latch on:
	  • small, tremor-like start-up movements noted
	  • does not respond to initial cue of nipple until jiggled
	• persistence of immature suck pattern beyond appropriate age
		• excessively wide excursions that interrupt the intra-oral seal on the nipple
		• minimal excursions; clenching
		• asymmetry; lateral jaw deviation
		• absence of movement (% of time)
		• lack of rate change between NNS and NS (NNS = 2/sec; NS = 1/sec)

Tongue

Normal	Disorganization	Dysfunction

• upped tongue configuration (tongue groove) maintained during sucking
• extension-elevation-retraction movements occur in anterior-posterior direction
• rhythmical movements
• movements occur at the rate of one per second
• liquid is sucked efficiently into the oro-pharynx for swallow
	• excessive protrusion beyond labial border during extension phase of sucking without interruption sucking rhythm
	• arrhythmical movements
	• unable to sustain suckle pattern for two minutes due to:
	  • habituation,
	  • poor respiration,
	  • fatigue
	• uncoordinated sucking/ swallowing and respiration which results in nasal flaring, head turning, extraneous movements
		• flaccid; flattened with absent tongue groove
		• retracted; humped and pulled back into oro-pharynx
		• asymmetry; lateral tongue deviation
		• excessive protrusion beyond labial border before/after nipple insertion with out and down movement
		• absence of movement (% of time)

sucking and swallowing with breathing. A dysfunctional sucking pattern is characterised by abnormal jaw and tongue movements which results in interruption of the feeding process 6.

Previously, we had found that the intra-rater agreement of the NOMAS was 'fair' to 'almost perfect' (with values for Cohen's κ between 0.33 and 0.94), whereas the inter-rater agreement with respect to the diagnosis was 'moderate' to 'substantial' (Cohen's κ between 0.40 and 0.65)(10). For the purpose of the present study eleven Dutch speech and language pathologists, who were certified NOMAS assessors, carried out the assessments. Each recording was assessed by two assessors independently of one another. If they were unable to reach consensus about a particular episode in a recording, it was discussed with all the assessors. Eventually consensus was reached in all cases.

Altogether we analysed 171 episodes in 30 infants, corresponding with a median of 6 episodes (range 4-8) per infant. The results of the repeated assessments of each infant (either normal, disorganised or dysfunctional) were graphically displayed on the time-axis, thus depicting the individual, longitudinal course of normal and abnormal sucking patterns. We checked whether deviating episodes were related to patient characteristics. Finally, we planned to determine whether feeding had been effective, i.e. an intake of at least 10 ml, during the first two minutes of the recording. If possible, we weighed the infants after 2 minutes of breast-feeding, or, in case of bottle-feeding, we measured the residual.

Statistical analysis

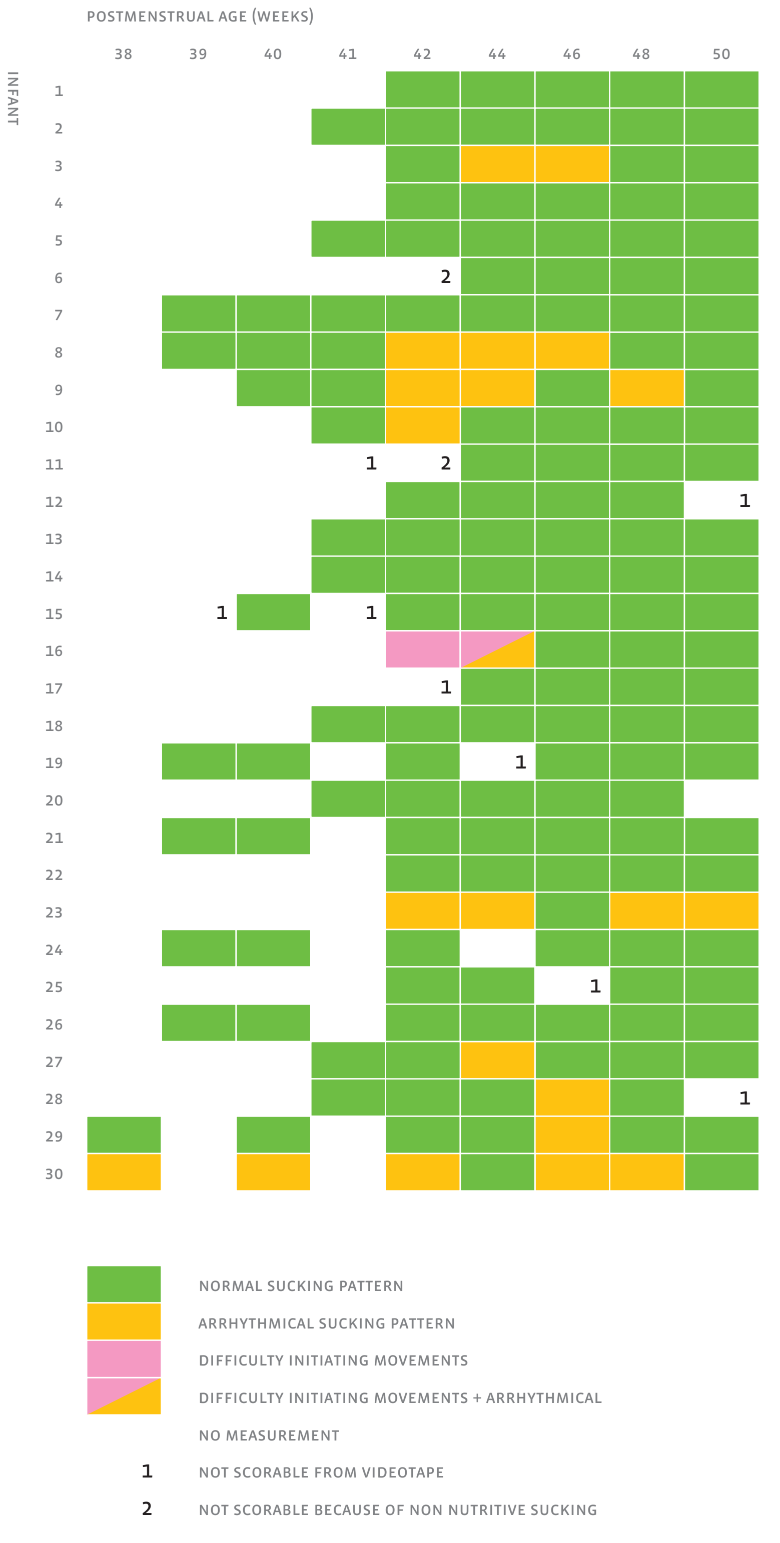
For the statistical analysis of our data we used version 15.0 of the statistical software package SPSS for Windows. In order to determine whether type of feeding, gestational age, birth weight, gender and type of delivery influenced the sucking pattern, we used the Mann Whitney U and Chi^2- tests. Probability values of < 0.05 were taken to be significant.

Results

We found a normal sucking pattern in 27 out of the 30 infants during their first feeding episodes. Out of the 171 episodes we assessed between 38 and 50 weeks' postmenstrual age, 148 (87%) were normal and 23 (13%) deviated from the normal sucking pattern Figure 1.

In two thirds of the study group, (20 infants, 67%), we found a normal sucking pattern from the first to the last recorded episode at 10 weeks after birth (Figure 1). The 23 abnormal episodes occurred on one or more occasions

Figure 1 **Sucking patterns in term infants** The results of the repeated assessments of each infant, according to the sucking patterns, were graphically displayed on the time-axis, thus depicting individual trajectories.



in a third of the study group, (10 infants, 4 boys and 6 girls). Seven of these 10 infants (70%) showed normal sucking during their first episode at two or three days after birth. Four out of the 10 infants showed abnormal sucking patterns during three or more episodes, two were abnormal during two episodes, and four were only once scored as abnormal. At ten weeks of age all but one of the infants showed a normal sucking pattern.

In accordance with the NOMAS all abnormal episodes were classified as 'disorganised'. Of the possible items in the 'disorganised' category, only two were observed: arrhythmical in 22 episodes (96%) and difficulty initiating movements in one episode (4%). In one instance we found a two-fold deviation in the sucking pattern: both difficulty initiating movements and arrhythmical. A dysfunctional sucking pattern was not found in any of the children during any of the episodes recorded. Details on the results of individual infants are provided in Table 3.

In order to identify factors that might influence normal sucking, we determined whether deviating sucking patterns bore any relation to gestational age, birthweight, gender, type of labour and breast-feeding or bottle-feeding. As far as the type of feeding was concerned we found more arrhythmical episodes in bottle-fed infants than in breast-fed infants. In total, 113 episodes were assessed while on breast-feeding, and 58 while on bottle-feeding. Nineteen abnormal episodes were seen in the case of bottle-feeding in 7 infants and four in the case of breast-feeding in 3 infants. This was significant on an infant level, (Chi^2- test-for trend = 5.853, p=.016), on measurement level this was highly significant (Chi^2- test = 28.1, p<.001). No other factors were found that influenced the sucking patterns.

We are not able to report reliably on the effectiveness of feeding. In only approximately half of the measurements, it was possible to measure the amount of oral intake during the first two minutes of feeding. This was due to the inability of the caretakers to interrupt feeding after 2 minutes.

Discussion

Our study showed that sucking is satisfactory for practically all the infants from as early as two to three days after fullterm birth. At ten weeks of age all but one of the infants showed a normal sucking pattern. In two thirds of the infants we found that sucking was completely normal without any abnormality. However, in a third of the infants we found one or more deviating episodes. In these instances disorganization was based mostly on arrhythmical episodes, meaning that one or more bursts of sucking counted less than ten sucking movements. The NOMAS proved to be a sensitive tool to assess deviations in the coordination of sucking, swallowing and breathing. Since sucking, swallowing and breathing at this age are an expression of

Table 3 **Details on deviant episodes**

Infant	Episode in weeks PMA	State	Bursts of sucking	Bottle/Breast
003	44	3	31-12-7-6-3-5-18-15-10-6.	Bottle
003	46	3	13-4-6-26-3-17-3-5:	Bottle
006	43	3	>10 – 18, >20-4-4-3-2-3	Breast
008	42	3	>12-20-11-12-4-4-17.	Bottle
008	44	3	12-20-11-12-4-4-17.	Bottle
008	46	3	46-9-32	Bottle
009	44	3	25-12-4-9-9-15	Bottle
009	46	3	23-14-9-7-4-15-15.	Bottle
009	48	3	>60-5-18-15-7.	Bottle
010	42 (2nd episode recorded)	3 > 2	17-6-3-2-3-3-3-4-3.	Breast
017	42	3	Unable to score	Finger-feeding
017	44	3	Unable to score	Finger-feeding
024	42 (1st episode recorded)	3	1-1-2-1-2-2-2-1-2-9- 1-2-2-2-2-3-6-2-4-4-4-2	Bottle
024	48	3	3-8-16-5-7-6-11-6-18	Bottle
027	44 (3rd episode)	3	43-10-25-11-7-5-5-4-5-11	Breast
029	43 (3rd episode)	2	40-30-15-5-5-14-5	Bottle
029	46	3	29-14-14-8-6-17	Bottle
030	46	3	67-6-5-15-18-4-7	Bottle
031	5	3	54-8-15	Bottle
	7	3	59-10-6-12-20-10	Bottle
	8	3	>40-9-5-6	Bottle
	10	3	53-3-4-4-13-6-15	Bottle
	11	3	77-9-16-9-6-27-2	Bottle

Amount cc/2 min	Particulars in anamnesis	Particulars concerning episode	Diagnose
30 cc			Arrhythmical
15 cc			Arrhythmical
unknown			Arrhythmical
unknown		Chokes, leaks milk. Hospital nipple.	Arrhythmical
unknown		Chokes, leaks much milk. 'Avent' nipple	Arrhythmical
unknown		Chokes, leaks much milk. 'Avent' nipple	Arrhythmical
20 cc			Arrhythmical
10 cc			Arrhythmical
unknown			Arrhythmical
unknown	Caesarean		Arrhythmical
unknown			Difficulty initiating movements
unknown			Difficulty initiating movements
unknown	Caesarean		Arrhythmical
unknown			Arrhythmical
10 cc	Caesarean		Arrhythmical
10 cc			Arrhythmical
10 cc			Arrhythmical
25 cc	Gemelli, 2155 (<P10), Apgar 9/10. After choking incident on 2e day oxygen was administered briefly		Arrhythmical
24 cc 10 cc 20 cc 23 cc 25 cc	Gemelli, 2320 gram (<P10), Apgar 8/10 intra-uterine growth retardation. Drip-fed for a few days.	Scores deviant on 5 episodes	Arrhythmical

Table 1 **Subject Characteristics**

Total	30
Boys / Girls	18 / 12
Gestational age	40 + 1 (37+4 – 42 + 2)
Caesarean section	6
Type of feeding	Breast: 17 infants (57%)
	Bottle: 9 infants (30%)
	Both: 4 infants (13%)
Birthweight	3592 (2110 – 4590 gram)
Singleton / Multiple birth	26 / 2

a complex and coordinated function of the central nervous system, we suggested that the NOMAS might also prove to be a sensitive tool to evaluate the neurological condition of infants during this age range.

Our study was unique for its longitudinal design. To our knowledge no other studies have followed sucking patterns during the entire neonatal period up to 10 weeks post term. Most studies of sucking behaviour and sucking patterns in healthy full term infants are based on one or two recordings only 8;11-15. In our study we recorded and examined full term infants from two or three days after birth until they were ten weeks old. Depending on the gestational age this meant that our description of the sucking patterns was based on six or seven feeding episodes. Some aspects that required our special attention were the characteristics of the infants that had one or more deviating episodes, and some differences between breast-feeding and bottle-feeding.

We noticed that in particular bottle-fed infants had an arrhythmical sucking pattern. During breast-feeding there is a naturally occurring surge in milk flow triggered by the milk injection reflex in the lactating mother and under influence of the sucking pressure of the infant . When the infant stops sucking, the flow decreases. During bottle-feeding the flow of milk depends especially on the nipple hole, the thickness of the formula and the internal pressure of the bottle. When the infant stops sucking, the flow remains continuous. Not all infants are capable of adapting their sucking skills to this constant flow 12;16-18. Research has shown, for instance, that infants on bottle-feeding with a commonly used nipple showed greater instability in coordinating sucking, swallowing and breathing and had more perturbation of breathing than breast-fed infants 19.

A limitation of the present study was that both breast-feeding and bottle-feeding was used not equally distributed Table 1 because it proved difficult to include infants whose parents opted for bottle-feeding from birth. Another shortcoming was the impossibility to get exact information about the oral intake in about 50% of the measurements. Although our study group was small, our findings were nevertheless interesting in that they provided new information about sucking patterns during the first 10 weeks after fullterm birth. Our study illustrated that if infants had a normal pattern of sucking from two or three days after birth, they stood a good chance that the further sucking ability would also be uncomplicated, although an incidental deviating episode with arrhythmical sucking was not uncommon.

Conclusion

Out of 30 healthy, fullterm infants 27 displayed a normal sucking pattern at two or three days after birth, i.e. 90%. Up to ten weeks after birth, ten infants sometimes deviated from the normal sucking pattern during a single episode. Almost all displayed the slightest deviation, i.e. an arrhythmical sucking pattern. Six out of these ten infants (20% of the entire group) had more than one deviating episode. Apart from bottle-feeding, no other factors were found that influenced sucking. At the age of ten weeks all infants but one (96%) showed normal sucking patterns.

The coordination of sucking, swallowing and breathing requires complex neural mechanisms. It is reassuring to know that dysfunctional sucking patterns and problems coordinating sucking, swallowing and breathing do not occur in healthy fullterm infants.

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5 The maturation of sucking patterns in preterm, small-for-gestational age infants

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Abstract

Objective To determine whether the development of sucking patterns in small-for-gestational age (SGA) preterm infants is different from appropriate-for-gestational age (AGA) preterm infants.

Study Design We studied sucking patterns of 15 SGA and 34 AGA preterms (gestational age ≤36 weeks) longitudinally from 34 to 50 weeks postmenstrual age (PMA) with the Neonatal Oral-Motor Assessment Scale (NOMAS). We diagnosed them as normal, dysfunctional, or disorganised. We examined the course of sucking patterns in relation to clinical characteristics.

Results SGA preterms developed a normal sucking pattern later than AGA preterms (median 48 versus 42 weeks PMA, p=.002). At term equivalent age, none of the SGA and 38% of the AGA preterms showed normal sucking (p<.05); this was 54% and 81% at 48-50 weeks PMA (p=.064). Abnormal clusters including 'incoordination' and dysfunctional sucking were more prevalent in SGA preterms than in AGA preterms (median 11% of measurements per child, versus 0%, p<.05). A higher gestational age and standard deviation score for birth weight were predictive of normal sucking at 50 weeks PMA.

Conclusions SGA preterms developed a normal sucking pattern later than AGA preterms. AGA preterms also needed time till after they had reached term age to develop a normal sucking pattern.

Introduction

For nourishment newborn infants rely heavily on their ability to suck and swallow liquids effectively. Characteristic of the development of sucking and swallowing in healthy, fullterm infants is an increase in the rate of sucking and swallowing, longer sucking bursts, and larger volumes per suck with increasing post-menstrual age (PMA) 1-4.

Preterm infants, and small-for-gestational age (SGA) preterm infants in particular, are at increased risk for impaired sucking and swallowing. They have two disadvantages: prematurity and increased nutritional needs for catch-up growth. Both factors may affect the development of their sucking patterns. During the neonatal period, the neurobehavioral organization of SGA preterm infants is poorer compared to that of their appropriate-for-gestational age matched peers. This is expressed in instable state organization, poor motor maturity, and lower orientation to social and non-social stimuli 5. During follow-up, former SGA preterm children are at increased risk for subtle motor, cognitive, and behavioural developmental deficits later on 6. Feeding disorders are also more prevalent in these children 7. In a study on a cohort of 465 children under the age of ten years, that had been referred to a multidisciplinary eating disorder clinic in Belgium, they found that children with feeding disorders had significantly lower birth weights for gestational age 7. Especially feeding disorders caused by gastrointestinal or neurological pathology were related to lower birth weights for gestational age. Therefore, deviant development of sucking and swallowing might be the basis of persistent feeding problems in former SGA preterm children 7.

It is unknown, however, whether the development of sucking and swallowing is impaired in SGA preterm infants. The Neonatal Oral-Motor Assessment Scale (NOMAS) 8 is a method that could help to investigate sucking patterns in young infants up to the age of several months post-term. It is a standardised, non-invasive tool that can be used to assess both breastfeeding and bottle-feeding. Inter-rater and intra-rater reliabilities are fair 9. Of all the available non-invasive tools, it emerged as the best tool for assessing sucking patterns in young infants 10. It sets standards for normal and abnormal (disorganised and dysfunctional) sucking patterns. Recently, the typical development of sucking patterns from birth to 10 weeks post-term was investigated in healthy fullterm infants using this assessment method 11. To date, the NOMAS has not been used longitudinally in a study of SGA preterm infants. The aim of our study was, therefore, to investigate the development of sucking patterns from birth to 10 weeks post-term in SGA preterm infants and to compare this with a group of appropriate-for-gestational age (AGA) preterm infants. We hypothesised that SGA preterm infants would develop a normal sucking pattern later, would need to rely on tube-feeding longer, and would be hindered by a dysfunctional sucking pattern more often than AGA preterm infants. In particular, we expected that this group of infants would have more difficulty initiating sucking movements and that sucking and swallowing would be arrhythmical as a result of their poor state organization. Moreover, abnormal jaw and tongue movements, as a component of the poor motor maturity of these infants, would probably interrupt effective sucking movements.

Methods

Subjects

This was a prospective, longitudinal study. We enrolled 15 SGA preterm infants (birth weight below the tenth percentile) and 34 appropriate-for-gestational age preterm infants. The infants had been admitted to the Neonatal Intensive Care Unit of the University Medical Center of Groningen Hospital and the neonatal ward of the Martini Hospital, also in Groningen, the Netherlands. The criterion for inclusion was a gestational age below 36 weeks PMA. Infants with major congenital defects and syndromes (such as e.g. esophageal atresia and Down's syndrome), and infants that had been exposed to substance or alcohol abuse while in utero, were excluded. During the study we excluded infants who developed necrotising enterocolitis.
We collected several demographic perinatal and neonatal clinical data such as birth type (whether vaginal birth or caesarean section), gender, birth weight characteristics, including the standard deviation (SD) score of birth weight in relation to gestational age, the Apgar scores at 1 and 5 minutes, need for ventilatory support, presence of bronchopulmonary dysplasia (BPD, defined as oxygen dependency at 36 weeks post menstrual age), presence of brain lesions on ultrasound scans, and the Nursery Neurobiologic Risk Score 12 (Table 1, online). This test was administered at discharge around term equivalent age. Brain lesions were determined from serial, weekly ultrasound scans and scored in both groups. Germinal matrix haemorrhages (GMH) were classified according to Volpe 13 and periventricular leukomalacia was classified according to De Vries et al 14.

The study commenced after permission was granted by the medical and ethical review committee of the University Hospital of Groningen, and after written informed parental consent had been obtained.

Recording of sucking patterns

The NOMAS was assessed from video-taped recordings. The infants were recorded as soon as possible, following parental consent after they had started feeding orally, i.e. from 34 weeks PMA, at the earliest. The decision to start oral feeding was made by the attending neonatologist around 33 to 34 weeks PMA. We recorded the first ten minutes of breastfeeding or bottle-feeding while the infant was in a quiet, alert state [15]. The infants were recorded in profile. At the time of the recording they did not suffer any intercurrent illness. The infants were fed either by one of the parents or, in some cases, by a nurse. The following details were registered for each recording: breastfeeding or bottle-feeding, whether the teat a regular one or a SpecialNeeds Feeder. This was included in the analyses. We also noted the type of nourishment: (mother's milk or a choice of 12 formulae (or a combination of two formulae). All these kinds of nourishments were allowed but we did not include them in the analyses. If possible, we noted the amount of cm3 the infants had consumed in two and thirty minutes, any change in their behavioural states during feeding, and whether there had been any choking, breathlessness, discolouring, or stress.

From 34 to 40 weeks PMA, we recorded the infants at weekly intervals and every 2 weeks from 40 to 50 weeks PMA (10 weeks post-term). At most we made twelve recordings per infant. Altogether we assessed 465 usable recordings of 49 infants (120 recordings in the SGA group and 345 recordings in the AGA group). Before term equivalent age there were 44 recordings in the SGA group and 168 in the AGA group. After term age there were 76 recordings in the SGA group and 177 in the AGA Group.

Analysis of sucking patterns

From the ten-minute recordings we selected the first two-minute episodes of feeding to assess the infant's sucking pattern with the NOMAS. The NOMAS is an often used, non-invasive observation instrument consisting of 28 items: 14 for assessing jaw movements and 14 for assessing tongue movements [8,9]. The instrument distinguishes during the first two-minute episodes of feeding three sucking patterns: a normal (mature) sucking pattern, a disorganised sucking pattern, and a dysfunctional sucking pattern. In case of a disorganised sucking pattern the coordination between sucking, swallowing and breathing is disrupted while the tongue and jaw movements are normal. In case of a dysfunctional sucking pattern abnormal jaw and tongue movements cause sucking to be impossible or inefficient [8]. A dysfunctional sucking pattern is considered to be more abnormal than a disorganised sucking pattern.

In order to gain insight into the way preterm infants developed a normal sucking pattern, we also assessed the separate items during each two-minute episode. In addition, we distinguished between a slightly abnormal sucking pattern (only the item arrhythmical was scored) and a definitely abnormal sucking pattern (arrhythmical combined with other abnormal items, or a dysfunctional pattern).

Inter-rater and intra-observer reliability

Previously, we had found that the intra-rater agreement of the NOMAS was 'fair' to 'almost perfect', whereas the interrater agreement with respect to the diagnosis (normal, disorganised, dysfunctional) was 'moderate' to 'substantial' [9]. For the purpose of this study two NOMAS assessors judged each recording independently from each other. These assessors were among twenty Dutch speech therapists who were certified NOMAS assessors. If two assessors were unable to reach consensus about a particular item during an episode, it was discussed with all the assessors. Finally, consensus was reached in all cases.

Longitudinal trajectories

The results of the repeated assessments of each infant (normal, disorganised, or dysfunctional) were graphically displayed on the time-axis, thus depicting individual developmental trajectories. In case of abnormal assessments, we also depicted details of the abnormalities found.

From the longitudinal trajectories we tried to determine when the sucking patterns had normalised. Since we were not aware of any study that had used the NOMAS in a longitudinal design, no benchmark existed to determine at what point in time an infant can be considered to have acquired a normal sucking pattern. Therefore, based on our findings in term infants [11] we decided that an infant had acquired a normal sucking pattern, if at least two out of three consecutive episodes were diagnosed as 'normal'. The infant is said to have acquired a normal sucking pattern on the first of these three episodes.

Effectiveness of oral feeding

For each episode we determined whether feeding had been effective. The amount of intake was measured in case of bottle-feeding, and by weighing the infant before and after nursing in case of breast-feeding after two and thirty minutes. We noted whether the infants choked or whether they showed any signs of stress while feeding (colour change, nasal flaring, head turning, and extraneous movements). Finally, we noted whether the infant required additional tube feeding.

Relation between sucking patterns and clinical characteristics

We examined the developmental course of sucking patterns, age at normalisation of the sucking pattern, and specific abnormal patterns in relation to several relevant clinical characteristics. Regarding the infant's age when the sucking pattern normalised, we chose deliberately to investigate both at term equivalent age and at 10 weeks post-term age, which was the end of period under study. The clinical characteristics we examined included the variables mentioned in Table 1: gestational age, birth weight, the SD score for birth weight, gender, birth type, the Apgar scores at 1 and 5 minutes,

Table 1 The clinical characteristics of the study group. Data are given as median (range) or numbers (%) unless specified otherwise

	SGA preterms	AGA preterms
N	15	34
Male/female	12/3*	17/17
Gestational age, wk	31.4 (26.9 - 35.7)	31.9 (25.1 - 34.6)
Birth weight, g	995 (710-1813)*	1537 (569-2700)
SDS of birth weight (Z score)	-1.79 (-2.79 - -1.30)*	0.12 (-1.26 – 2.98)
Birth type		
Vaginal	2*	24
Caesarean Section	13*	10
Apgar 1 min.	7 (3 - 10)	7 (1 - 10)
Apgar 5 min.	9 (6 - 10)	8 (2 - 10)
The way of feeding		
Full breast feeding	N=1 (7%)	N=8 (24 %)
Both breast and bottle, >50% breast	N=2 (13%)	N=2 (6%)
Both breast and bottle, >50% bottle	N=3 (20%)	N=10 (29%)
Full bottle feeding	N=9 (60%)	N=14 (41%)
Respiratory data		
Number of infants on positive airway pressure	N=5 (33%)	N= 16 (47%)
Positive pressure ventilation > 28 days	N=1 (7%)	N=3 (8%)
Bronchopulmonary dysplasia (O_2 dependency beyond 36 weeks PMA)	N=2 (14%)	N=1 (3%)
Ultrasound findings:		
Normal	N=6 (40%)	N=21 (62%)
GMH grade 1	N=1 (7%)	N=1 (3%)
GMH grade 2 - 4	none	none
PVL grade 1	N=4 (27%)	N= 12 (35%)
PVL grade 2 - 3	none	none
No ultrasound performed:	none	N=1 (3%)
NBRS	2 (0-9)	1 (0-9)

* Significant, p < .05

NBRS: Nursery Neurobiologic Risk Score 11

AGA: appropriate-for-gestational age

SDS: standard deviation score

SGA: small-for-gestational age

GMH : germinal matrix haemorrhage

PMA: postmenstrual age

PVL: perventricular leukomalicia

necessity and duration of positive airway pressure, the presence of BPD, the presence and degree of periventricular leukomalacia13 and germinal matrix haemorrhages (GMH)14, and the Nursery Neurobiologic Risk Score (NBRS) at discharge 12 (Table 1, online).

Finally, we examined the relationship between the developmental course and the normalisation of sucking patterns and the necessity and duration of tube feeding.

Statistical analyses

The data were analysed with the statistical software package SPSS for Windows, version 16.0. The Chi^2 test, and where appropriate the Fisher's exact test were used to compare both groups for frequencies of normal and abnormal sucking patterns, both on the level of measurements and on the level of infants. We also calculated per child the percentage of specific categories relative to all measurements for that particular child. The Mann-Whitney U Test was used to evaluate whether these percentages differed between groups. The Mann-Whitney U Test was also used to evaluate whether the age at which the infant had developed a normal sucking pattern differed between groups. To test whether clinical variables influenced the rate of occurrence of normal and abnormal sucking patterns per infant, and the postmenstrual age at which the sucking pattern normalised, we used the Spearman's rank correlation test in case of ordinal or continuous clinical variables (gestational age, NBRS, SD score for birth weight, Apgar scores) and the Mann-Whitney U test in case of 2 nominal variables (birth type, need for ventilatory support, BPD, IVH and PVL status, gender, breast or bottle-feeding) in univariate analyses. Because perinatal and neonatal characteristics are likely to be interdependent, we performed a multivariate logistic regression analysis to investigate which factors contributed independently to developing a normal sucking pattern at term equivalent age and at 10 weeks post-term. Only factors identified by the univariate analysis (with $p<.10$) were included in the multivariate model. Throughout the analyses $p<.05$ was considered to be statistically significant.

Results

Analysis of the sucking patterns

The results of all the individual assessments of all the infants, grouped according to their gestational age, are shown in Figure 1a for SGA infants and in Figure 1b for AGA infants.

We found that 15 out of all 120 recordings (13%) for the SGA preterm and 133 out of 345 (38%) for the AGA preterm group were diagnosed 'normal' (Chi^2 = 27.8, $p<.001$). For the SGA group, 5 out of 120 recordings (4%) were diagnosed 'dysfunctional', and 100 (83%) were diagnosed 'disorganised'. For the AGA group, 2 out of 345 recordings (0.6%) were diagnosed 'dysfunctional' and 210 out of 345 (61%) were diagnosed 'disorganised'. The frequencies of both dysfunctional and disorganised patterns were also significantly different between the AGA and SGA group: $Chi^2 = 9.9$, $p<.01$ for dysfunctional patterns, and $Chi^2 = 20.2$, $p<.001$ for disorganised patterns. Of the episodes that were diagnosed as 'disorganised' 187 were 'arrhythmical only', 58 (48%) in the SGA group, and 129 (37%) in the AGA group ($Chi^2 = 4.44$, $p<.05$). Definitely abnormal sucking patterns (all abnormal patterns except 'arrhythmical only') were more prevalent in the SGA group - 47 recordings (44%) in 14 infants - than in the AGA group - 83 recordings (24%) in 30 infants. ($Chi^2 = 10.1$, $p<.01$). Even though, given the fact that there are 28 items, one could possibly find many combinations of items in the diagnosis 'disorganised', it appeared that only a limited cluster of items were found. Apart from the item 'only arrhythmical ', we scored only three other clusters, i.e. arrhythmical + unable to sustain, arrhythmical + incoordination, and arrhythmical + unable to sustain + incoordination. If the infant did not start sucking this was due to 'difficulty initiating movements'. If the infant did eventually start sucking during that same episode, it was possible that the infant would have an arrhythmic sucking pattern afterwards or a combination with one of the clusters. In that case, we scored the pattern that the infant showed while sucking.

The prevalence as percentage of the total measurements per child for each of these clusters, separately for the AGA and the SGA preterms, is shown in figure 2. The numbers of infants showing the normal and abnormal patterns are presented as well. Additionally, SGA preterms were hindered more by not being able to suck in a coordinated way (assessed as 'incoordination' in the NOMAS), than AGA preterms. This was expressed by stress signals, such as colour change, nasal flaring, head turning, extraneous (inappropriate) movements of the extremities (in 14, 12%, of the recordings in SGA preterms versus 14, 4%, of the recordings in AGA preterms, $Chi^2 = 9.1$, $p<.05$). On an infant level, 8 of 15 (53%) of SGA preterms showed 'incoordination' versus 10 of 34 (29%) AGA preterms (Fisher's exact, 2-sided, $p=0.124$). In case of the SGA preterms, 1 of the 15 infants (7%) had a dysfunctional sucking pattern. It was diagnosed five times. In the case of the AGA preterm infants, this was the case in 2 out of 34 infants (6%). In both infants it was seen only once. Altogether, there were seven episodes (2%) where minimal jaw excursions and a retracted tongue were seen repeatedly. The percentage per child of clusters including 'incoordination' and dysfunctional sucking were significantly higher in SGA preterms than in AGA preterms (median 11% [0-63] versus 0% [0-40], Mann Whitney U test, $p<.05$). Regarding the way of feeding, many infants received breastfeeding as well as bottle-feeding (Table 1). Due to logistic reasons, the mother was not

Figure 1a **The maturation of sucking patterns in SGA preterm infants** The results of the repeated assessments of each infant were horizontally displayed on the time axis, depicting individual developmental trajectories. The children were vertically displayed according to increasing gestational age. The results of the individual measurements are shown in each box as normal, dysfunctional, and disorganized (arrhythmical + unable to sustain + incoordination sucking pattern, arrhythmical + incoordination sucking pattern, and difficulty initiating movements).

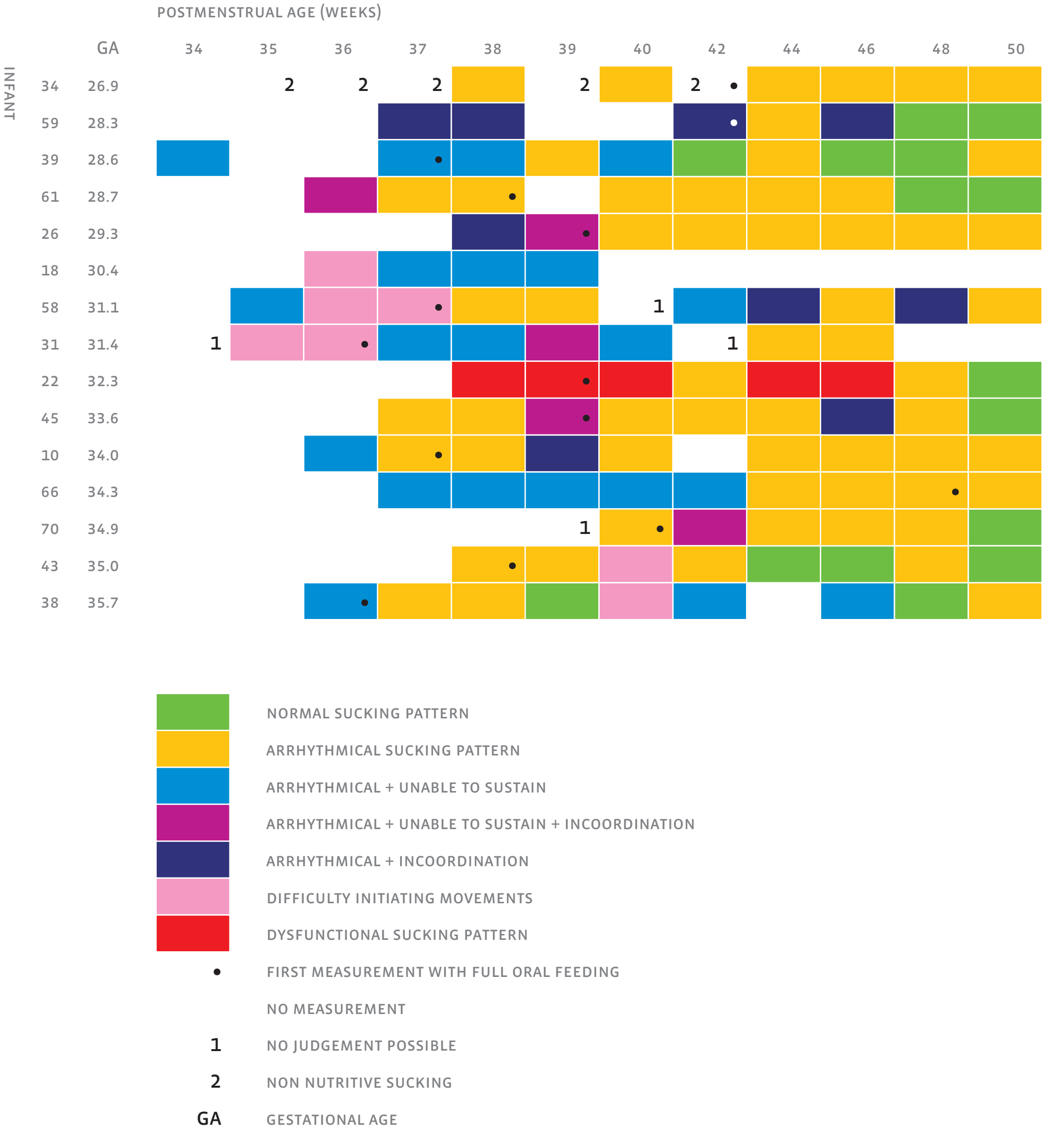


Figure 1b **The maturation of sucking patterns in AGA preterm infants** The results of the repeated assessments of each infant were horizontally displayed on the time axis, depicting individual developmental trajectories. The children were vertically displayed according to increasing gestational age. The results of the individual measurements are shown in each box as normal, dysfunctional, and disorganized arrhythmical + unable to sustain + incoordination sucking pattern, arrhythmical + incoordination sucking pattern, and difficulty initiating movements).

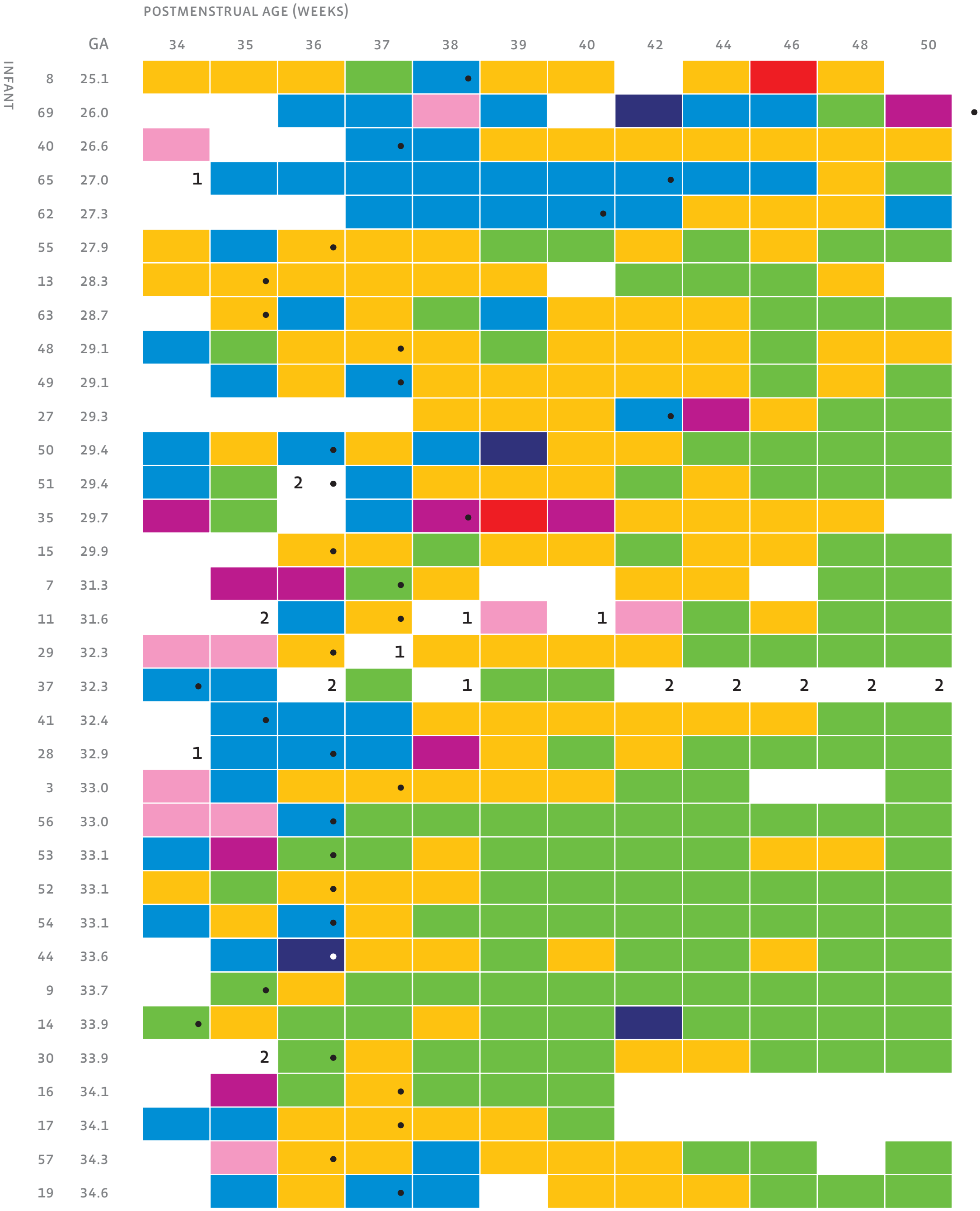


Table 2 Postmenstrual age (PMA) at which SGA and AGA preterm infants had a normal sucking pattern for the first time.

	Before term age (≤ 40 weeks' PMA)	Between 40 and 50 weeks' PMA	At 48-50 weeks' PMA the infant did not suck normally	Not measured at 48-50 weeks' PMA	Total
AGA Preterms	13	15	6	3*	34
SGA Preterms		7	6	2	15
Total	13	22	12	5*	49

* Included were 3 AGA children who all had normal sucking patterns before term

PMA: post-menstrual age

Chi² for trend, $p < 0.05$

Table 3 Effectiveness of feeding of SGA and AGA preterms. Data are given as median (range).

	SGA preterms	AGA preterms
N	14[a]	34
Week of normal sucking pattern	50 (42 - >50)*	44 (34 - >50)
Week of independency of tube feeding	38.5 (36 - 48)*	36 (34 - >50)

* Mann-Whitney U test, $p < .05$

a Data lacking of one infant

AGA: appropriate-for-gestational age

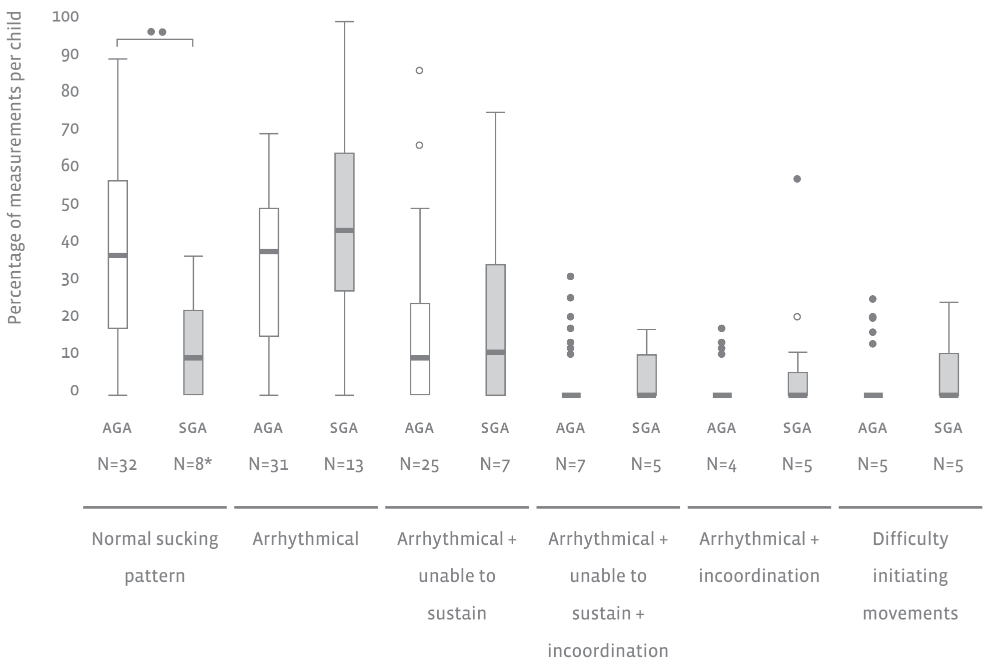
SGA: small-for-gestational age

always available to breastfed the baby. A vast majority of infants received most of their feeding by bottle, 12 of 15 infants in the SGA group (80%), and 24 of 34 infants in the AGA group (71%). The distribution of breast and bottle feeding was not different between groups (Table 1). Only one AGA preterm infant (infant nr 62) was fed during 5 measurements with a SpecialNeed feeder. The way of feeding, whether by bottle or by breast did not influence the occurrence of normal, disorganized, and dysfunctional sucking patterns (Figure 3a and 3b).

Longitudinal trajectories

Individual developmental trajectories of sucking patterns can be derived from Figure 1a and 1b. These findings are summarised in Table 2. The SGA preterm children needed more time to acquire a normal sucking pattern than

Figure 2 Median percentages of rate of occurence of normal and abnormal measurements per child, in each group. The abnormal measurements were grouped according to the separate disorganized categories. The numbers of infants who had this particular pattern on one or more occasions in each group is provided at the bottom of the figure. Significant differences between the percentages and number of children were marked • *p*<.01 and •• *p*<.001.



the AGA preterms (median 48 weeks versus 42 weeks, Mann-Whitney U test *p*=.002). At term equivalent age, none of the 15 SGA preterms and 13 out of the 34 AGA preterms (38%) showed a normal sucking pattern ($Chi^2 = 5.5$, $p<.05$). At 48 to 50 weeks PMA (8 to 10 weeks post-term), 7 out of 13 SGA preterms (54%) and 25 out of 31 AGA preterms (81%) had acquired a normal sucking pattern (Table 2, $Chi^2 = 3.3$, $p=.064$). At that age, data on 5 infants are lacking.
From birth up to 50 weeks PMA the sucking patterns of the SGA preterms developed from definitely to slightly abnormal. At 8 to 10 weeks post-term the 6 infants that still had not acquired a normal sucking pattern all had the slightest abnormal form of a disorganised sucking pattern, i.e. ‘arrhythmical only’.

In the case of the AGA preterms, 13 out of 34 infants (38%) had acquired a normal sucking pattern prior to term age. Three of them were not

Figure 3a The use of bottle feeding (marked B) and formula feeding (marked F) for each measurement in SGA preterm infants, in relation to normal, disorganized or dysfunctional sucking patterns.

POSTMENSTRUAL AGE (WEEKS)

INFANT	GA	34	35	36	37	38	39	40	42	44	46	48	50
34	26.9		2	2	2	B	2	B	• 2	B	F	F	F
59	28.3				F	F			• F	F	F	F	F
39	28.6	F			• F	F	F	F	F	F	F	F	F
61	28.7			F	F	• F		F	F	F	F	F	F
26	29.3						• B	F	F	F	F	F	F
18	30.4			B	B	B	B						
58	31.1		B	F	• B	F	F	1 B	F	F	F	F	F
31	31.4	1 B	B	• F	F	F	F	F	F	F	F		
22	32.3					F	• F	F	F	F	F	F	F
45	33.6				F	F	• F	F	F	F	F	F	F
10	34.0			F	• F	F	F	F	F	F	F	F	F
66	34.3				F	F	F	F	F	F	F	• F	F
70	34.9						1	• F	F	F	F	F	F
43	35.0					• F	F	F	F	F	F	F	F
38	35.7			• F	F	B	B	B	B		B	B	B

(green)	NORMAL SUCKING PATTERN
(red)	DYSFUNCTIONAL SUCKING PATTERN
•	FIRST MEASUREMENT WITH FULL ORAL FEEDING
	NO MEASUREMENT
1	NO JUDGEMENT POSSIBLE
2	NON NUTRITIVE SUCKING
B	BREAST FEEDING
F	BOTTLE FEEDING

Figure 3b The use of bottle feeding (marked B) and formula feeding (marked F) for each measurement in AGA preterm infants, in relation to normal, disorganized or dysfunctional sucking patterns.

POSTMENSTRUAL AGE (WEEKS)

INFANT	GA	34	35	36	37	38	39	40	42	44	46	48	50
8	25.1	F	F	F	F	• F	F	F		F	F	F	
69	26.0			B	B	B	B		F	F	F	F	F •
40	26.6	B			• B	B	B	B	B	B	B	B	B
65	27.0	1	F	B	B	B	B	B	• F	F	F	F	F
62	27.3				F	F	F	• F	F	F	F	F	F
55	27.9	B	B	• F	F	F	F	F	F	F	F	F	F
13	28.3	B	• B		B	B	B		B	B	B	B	
63	28.7		• F	F	F	F	F	F	F	F	F	F	F
48	29.1	B	B	F	• F	F	F	F	F	F	F	F	F
49	29.1		B	F	• F	F	F	F	F	F	F	F	F
27	29.3					F	F	F	• F	F	F	F	F
50	29.4	B	F	• B	B	B	B	B	B	B	B	B	B
51	29.4	B	F	• 2	B	B	B	B	B	B	B	B	B
35	29.7	F	F		F	• F	F	F	F	F	F	F	
15	29.9			• B	B	B	B	B	B	B	B	B	B
7	31.3		F	F	• F	F			F	F		F	F
11	31.6		2	B	• B	1	B	1	F	F	F	F	F
29	32.3	B	B	• B	1	F	F	F	F	F	F	F	F
37	32.3	• B	B	2	B	1	B	B	2	2	2	2	2
41	32.4		• F	F	F	F	F	F	F	F	F	F	F
28	32.9	1	B	• B	B	F	F	F	F	F	F	F	F
3	33.0	B	B	B	• B	B	B	B	B	B			B
56	33.0	B	B	• B	B	B	B	B	B	B	B	B	B
53	33.1	F	F	• F	F	F	F	F	F	F	F	F	F
52	33.1	F	F	• F	F	F	F	F	F	F	F	F	F
54	33.1	F	F	• F	F	F	F	F	F	F	F	F	F
44	33.6		F	• F	F	F	F	F	F	F	F	F	F
9	33.7		B	B	B	B	B	B	B	B	B	B	B
14	33.9	• B	B	B	B	F	F	F	F	F	F	F	F
30	33.9		2	• F	F	F	F	F	F	F	F	F	F
16	34.1		F	F	• F	F	F	F					
17	34.1	F	F	F	• F	F	F	F					
57	34.3		B	• F	F	F	F	F	F	F	F		F
19	34.6		B	B	• B	B		B	B	B	B	B	B

measured after term age. Out of these 13 infants there were 9 (26%) infants that initially had a definitely abnormal sucking pattern for one to six weeks. One half of these infants acquired a normal sucking pattern following a slightly disorganised sucking pattern. Of the 15 AGA preterms (44%) that only developed a normal sucking pattern between 40 and 50 weeks PMA, we noticed that 12 still made short sucking bursts up to the age of 44 to 46 weeks PMA. This fits in with the slightest abnormal form of sucking, i.e. an 'arrhythmical only' sucking pattern. Three out of these 15 infants showed a more abnormal sucking pattern during this period; apart from the fact that the bursts of sucking were too short, they were also unable to sustain it. Six AGA preterms (18%) had not acquired a normal sucking pattern at 8 to 10 weeks post term. This was expressed differently in the 6 infants: 2 remained definitely abnormal, the other 4 showed a slightly abnormal sucking pattern on most of the episodes from term age.

Effectiveness of oral feeding

All fifteen SGA preterm infants and 33 out of the 34 (97%) AGA preterms were feeding orally completely at 10 weeks post-term (Table 3).

A total of six infants (13%, one unknown), divided over three out of 14 SGA preterms (21%) and three out of 34 AGA preterms (9%) still received supplemental tube feeding beyond 40 weeks post term age, and one AGA preterm infant was still partially tube-fed at 10 weeks post-term. SGA preterms depended on supplemental tube feeding longer than AGA preterms (Mann Whitney U-test, p= .002) (Table 3). AGA preterm infants that had acquired a normal sucking pattern before the age of 10 weeks post-term, required tube feeding less long (Mann Whitney U-test, $p < .0001$). In the AGA group, the age at which tube feeding was no longer required correlated with the age at which the infant acquired a normal sucking pattern (Spearman's rho = 0.714, $p < .0001$). This was not the case for the SGA group.

The relation between the sucking patterns and the clinical characteristics

Clinical characteristics of both groups differed regarding the distribution of both sexes, with the SGA group having relatively more males (Fisher's exact, p=0.064). There were 3 infants with mild BPD. Two of them were SGA, and needed supplemental oxygen until 37 and 38 weeks PMA; one infant was AGA, and needed supplemental oxygen until just beyond 36 weeks PMA.

The age at which AGA preterm infants acquired normal sucking not only correlated strongly with gestational age (Spearman's rho = -0.691, $p<.01$), but also with birth weight (Spearman's rho = -0.764, $p<.01$) and with the NBRS (Spearman's rho = 0.611, $p<.01$). We did not find such correlations for the SGA preterm infants.

Clinical characteristics are likely to be interdependent. Therefore, we performed first a univariate logistic regression to determine which factors were associated with a normal sucking pattern at term equivalent age as well as at 10 weeks post-term. At term equivalent age, the factors BPD, IVH and PVL status, breast- or bottle-feeding, Apgar score at 5 minutes, need for ventilatory support, and gender were not significant (p>0.10), whereas gestational age, SD score for birth weight, birth type and NBRS were with p < 0.10. Next we performed a multivariate logistic regression analysis for the total group to determine which factors contributed independently to whether the infant reached a normal sucking pattern. For abnormal sucking at term age we entered gestational age, SD score for birth weight, birth type, and NBRS in the model. Only NBRS (OR: 0.24 [95% confidence interval (CI): 0.09-0.70]; p=.009) and SD score for birth weight (OR: 2.2 [95% CI: 0.98-5.1]; p=.056) remained in the model, which explained 51.2% of the variance of normal and abnormal sucking patterns at term. The same procedure was followed for the associations found at 8 to 10 weeks post-term. Now the factors BPD, IVH and PVL status, breast- or bottle-feeding, Apgar score at 5 minutes, need for ventilatory support, and gender were not significant (p>0.10). The following variables were entered as predictors: gestational age, SD score for birth weight, birth type, and NBRS. Only gestational age (OR: 1.5 [95% CI: 1.1–2.0]; p=.013) and SD score for birth weight (OR: 2.8 [95% CI: 1.3– 6.4]; p=.012) remained in the model. It now explained 35.0% of the variance of normal and abnormal sucking patterns at 8 to 10 weeks post term.

Discussion

This study demonstrates that the development of sucking patterns in SGA preterm infants was slower than in AGA preterms from when they started feeding orally during the first 10 weeks post-term. It also took a different developmental course. In the SGA group we diagnosed a dysfunctional and disorganized, uncoordinated, sucking pattern more often. Particularly prior to term age, the SGA infants were hindered by a lack of coordination between sucking, breathing and swallowing. A substantial part of the AGA preterms, however, also only acquired normal sucking after having reached term age. We stress that an abnormal sucking pattern did not necessarily mean that the infant was unable to suck effectively. Almost all preterm infants were fed orally completely even though they still had abnormal sucking patterns. This improved towards the end of the period under study. At the age of 10 weeks post-term, one infant was still supplementary tube-fed. This infant had an abnormal sucking pattern: it was unable to sustain sucking and had difficulty coordinating breathing with sucking and swallowing. Therefore, he needed some extra intake by tube.

Our study, which spanned the first 10 weeks post-term, cannot confirm the assumption that SGA preterm infants mature more rapidly [17].

After they had reached term age, we indeed found that sucking patterns normalised, but a substantial number of SGA preterms were hindered longer by abnormal sucking patterns. SGA preterm infants are at risk for an impaired postnatal neurological condition and an impaired neurodevelopmental outcome [6, 17-19]. It is conceivable that the abnormalities we found in the development of their sucking patterns could be related to their abnormal neurological condition. Another possibility is that their developmental course was delayed rather than abnormal and that eventually the majority of SGA preterms would start sucking normally, but only after they had reached the age of 10 weeks post-term, i.e. outside the scope of our study. The development of normal and abnormal general movements (GMs) too, is slower in some SGA preterm infants than is the case for AGA preterm infants [20].

In this study we found several differences in the development of sucking between SGA preterms and AGA preterms. Firstly, we found a dysfunctional sucking pattern in SGA preterms more often. This sucking pattern refers to the interruption of the feeding process by abnormal movements of the tongue and jaw, and according to Palmer [8], it is caused by abnormal oral facial structures, or it can be due to abnormal oral muscle tone [21]. Because oral facial anomalies were excluded, we presumed that abnormal oral muscle tone might have caused a dysfunctional sucking pattern. The tone of the facial and intra-oral muscles are dependent on the function of the cranial nerves, therefore, a dysfunctional sucking pattern could point towards neurological dysfunction [2].

A second finding was that SGA preterms, especially prior to term age, were often hindered by a definitely abnormal, disorganised sucking pattern, that is expressed in uncoordinated sucking, swallowing and breathing. The infant was unable to sustain a sucking pattern for two minutes due to its inability to coordinate breathing with sucking and swallowing, which was interrupted because of respiratory incompetence. This may result in oxygen desaturation, and stress signals such as nasal flaring, and head bobbing [21, 22]. Often the infant was fatigued because of energy depletion. Respiratory difficulties and disorganization of the central nervous system play a key role in exacerbating these problems [22]. It is, therefore, most likely that abnormal sucking patterns indicate neurological abnormalities in the SGA preterms. A physiologically intact and functioning central nervous system may be one of the crucial elements for an infant to successfully latch on and start feeding [23]. Our study indicated that SGA preterms have more difficulty organising their neurobehavioral functioning than do AGA preterms.

We identified several perinatal factors that were predictive of achieving a normal sucking pattern at term equivalent age and at 10 weeks post-term in both groups. Independent predictors were SD score for birth weight and gestational age. This means that SGA preterms and extreme preterm infants are at risk for achieving a normal sucking pattern at a later age and for developing an abnormal sucking pattern. In the case of these infants we recommend checking the necessary preconditions to start oral feeding carefully and to allow an infant to learn to drink only while its physiological parameters and neurobehavioral functioning are carefully monitored.

This study is strong for two reasons. Firstly, due to its longitudinal design. We have followed the development of sucking and sucking patterns during the entire neonatal period. Most studies of sucking behaviour and sucking patterns in preterm infants are based on one or two recordings, or during a short period of time. In our study we recorded and examined preterm infants from two to seven days after they started feeding orally until they reached 50 weeks PMA. Secondly, our study focussed on the sucking development of the preterm SGA infant. To the best of our knowledge, no other studies to date have described the development of sucking and sucking patterns of SGA preterm infants. In addition, our study included both breastfeeding and bottle-feeding infants and during recording there were no interventions with regards to feeding.

There were some limitations to this study. We described the development of sucking up to the age of 10 weeks post-term only. Approximately 13% of the total group still received supplemental tube feeding at more than 40 weeks post term age. This seems a rather high percentage, and is counter to experience in that virtually all preterm infants, whether SGA or AGA, are discharged home on full oral feeds a few weeks before term. Prolonged additional tube-feeding may partially be explained by the clinical characteristics of our group, such as e.g. BPD. It may also reflect local feeding policy, stressing the prerequisite for sufficient oral intake, if deemed necessary by additional tube feeding. Being merely a twin-centre study, caution should be taken when generalising our results to other centres. Although it was rather a heterogeneous group in which only a few infants were artificially ventilated, we did nonetheless find a number of essential differences in the development of sucking between SGA and AGA preterm infants. The disproportionate number of males in the SGA group could have biased the results, since males often attain feeding milestones a little later than females. However, logistic regression analysis did not reveal male gender as an additional risk factor for abnormal sucking patterns, whereas the degree of growth restriction did. Further research will have to reveal whether our findings can be generalised to all SGA preterms.

Our study may have implications for the daily feeding practice of preterms, particularly SGA preterm infants. Sucking problems in SGA preterms may recover as a result of normal development. Sometimes, however, these problems may persist for a longer period of time which then interferes with the need for catch–up growth to overcome the growth retardation in these infants.[7] Our finding that only half of the SGA preterms had acquired a normal sucking pattern at 8 to 10 weeks post-term, indicated that when taking care that SGA preterms grow sufficiently, learning to drink should be carefully guided. In the case of this group of infants, the point is not that the infant should be able to feed orally as quickly as possible. On the one hand, policy should be aimed at ensuring that the infant's intake by means of tube feeding is sufficient to guarantee growth while, on the other hand, by allowing the infant to practise oral feeding, it is given both the time and opportunity to develop a normal sucking pattern. Insight into the development of sucking and swallowing may contribute to decisions concerning when to start oral feeding in relation to the development of sucking in this group of infants. If, as far as starting and scheduling oral feeding is concerned, the individual infant and the development of its sucking behaviour are monitored carefully, it will quickly become clear whether it has a dysfunctional sucking pattern. This is important, because a dysfunctional sucking pattern is characterized by abnormal tongue and jaw movements, which requires assessment by a speech therapist. Together with the paediatric nurse, they can draw up a plan of intervention.

Conclusion

SGA preterms developed a normal sucking pattern later than AGA preterms. They had a dysfunctional and disorganized, uncoordinated sucking pattern more often and, prior to term age, they had more difficulty coordinating breathing with sucking and swallowing. But AGA preterms too needed time after having reached term age to develop a normal sucking pattern. A longer gestational age and higher SD score for birth weight were associated with acquiring a normal sucking pattern at 8 to 10 weeks post-term.

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6 The development of sucking patterns in preterm infants with bronchopulmonary dysplasia

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Abstract

Background Preterms with bronchopulmonary dysplasia (BPD) are at risk of acquiring brain abnormalities. In combination with ongoing breathing difficulties this may influence the development of the sucking patterns of these infants.

Objective To investigate the longitudinal development of sucking patterns from birth until the age of ten weeks post-term in preterm infants with and without BPD.

Methods A longitudinal, comparative study of the sucking patterns of 16 preterm infants with BPD and 15 preterms without BPD from the start of oral feeding at around 34 weeks' postmenstrual age (PMA) until 50 weeks' PMA. The infants were matched for gestational age (less than 30 weeks). We recorded approximately twelve feeding episodes per infant and assessed these with the Neonatal Oral-Motor Assessment Scale (NOMAS). We diagnosed the infants' sucking patterns as normal, dysfunctional, or disorganised. We examined the development of the sucking patterns in relation to relevant clinical characteristics.

Results Thirty (21%) out of 142 feeding episodes of the preterms with BPD and 36 (23%) out of 156 feeding episodes of the preterms without BPD were diagnosed as normal (not significant). Of the infants with abnormal patterns only three were diagnosed as dysfunctional and 229 as disorganised. Especially before term-equivalent age, definitely abnormal sucking patterns, i.e. all the abnormal patterns except 'arrhythmical only', were more prevalent in the preterms with BPD than in the preterms without BPD: 69 (49%) and

47 (30%) episodes, respectively (chi-squared = 10.7, $p<.01$). In particular, the abnormal patterns including the item 'incoordination' were more prevalent in the preterms with BPD: 25 (36%) out of 69 definitely abnormal patterns were found in this group and 7 (15%) out of the 47 episodes in the preterms without BPD (chi-squared = 6.37, $p<.05$). There was no difference between the two groups regarding the age at which they acquired normal sucking patterns, and relevant clinical characteristics did not influence the development of the sucking patterns.

Conclusions Characteristic of the development of sucking patterns in infants with BPD was that these infants were unable to coordinate swallowing with breathing. This was the case especially prior to term-equivalent age; after term-equivalent age the development of sucking closely resembled that of preterms without BPD.

Introduction

Preterms with bronchopulmonary dysplasia (BPD) have less favourable neurodevelopmental [1-3] outcomes than preterms without BPD [4;5]. They are more at risk of acquiring brain abnormalities [6-8]. In addition, they have continuous respiratory problems. Both these aspects influence the development of sucking. From the onset of oral feeding until they reach term-equivalent age, it is more difficult for preterms with BPD to learn to suck in a coordinated fashion than it is for preterms without BPD [9;10]. Moreover, their feeding endurance and feeding performance is poor [10]. In the first place, successful feeding for these infants is hindered by decreases in oxygen saturation during feeding, so-called deglutition apnoea [9;11] and their higher respiratory effort with increasing BPD [10]. In the second place, successful feeding is hindered by their abnormal neurological development. We know that in preterm infants with BPD, maturational patterns of individual rhythms of sucking, swallowing, and respiration are disrupted [9;11]. Preterm infants with BPD do not follow the predicted maturational patterns of suck-swallow rhythmic integration until 40 weeks' PMA [9]. To date, the developmental course of the sucking patterns of preterms with BPD after they have reached term-equivalent age, is unknown.

A useful method to investigate sucking patterns in young infants up to the age of several months post-term is the Neonatal Oral-Motor Assessment Scale (NOMAS) [12]. It is a standardized, non-invasive tool for both breastfeeding and bottle-feeding situations. Inter-rater and intra-rater reliabilities are fair [13]. Of all available non-invasive tools, it turned out to be the most suitable method for assessing sucking patterns in young infants [14]. The NOMAS has not been used previously in a longitudinal study of preterm infants with BPD.

Our aim was to investigate the longitudinal development of sucking patterns from birth until ten weeks' post-term in preterm infants with and without BPD. We hypothesised that preterm infants with BPD acquire a normal sucking pattern later, experience feeding difficulties due to an abnormal sucking pattern longer, and as a consequence, depend on tube-feeding longer than do preterm infants without BPD.

Methods

Subjects

We enrolled 16 preterms with BPD, who had been admitted to the Neonatal Intensive Care Unit of the University Medical Center in Groningen, in a prospective, longitudinal study. The inclusion criteria were a gestational age of less than 30 weeks and oxygen dependency at 36 weeks' postmenstrual age (PMA). The control group comprised 15 preterm infants without BPD, who were matched for gestational age. For one preterm infant with BPD, we were unable to find an appropriate matched control. Infants with major congenital defects were excluded from both groups.

The BPD group comprised preterm infants who either received supplemental oxygen or assisted ventilation or both, at a postmenstrual age of 36 weeks 15. The severity of the BPD was determined by the duration of the supplemental oxygen.

We collected perinatal and neonatal clinical data including gender, birth weight, Apgar scores at 1 and 5 minutes, need for ventilatory support, the presence of brain lesions and the Nursery Neurobiologic Risk Score at discharge at around term-equivalent age 16. Possible brain lesions for both groups were determined from serial, weekly ultrasound scans. Germinal matrix haemorrhages (GMH) were classified according to Volpe 17 and periventricular leukomalacia classified according to De Vries et al. 18. Table 1 provides the infants' demographics and clinical characteristics.
The study commenced after permission was granted by the medical and ethical review committee of the University Medical Center Groningen, the Netherlands and after obtaining informed parental consent

Recording of sucking patterns

The NOMAS was assessed from video-taped recordings. The infants were recorded immediately after oral feeding started, i.e. from 34 weeks' PMA, at the earliest. We recorded the first ten minutes of breastfeeding or bottle-feeding while the infant was in a quiet, alert state 19. The infants were recorded in profile. At the time of the recording they did not have any concurrent illness. The infants were either fed by one of the parents or, in some cases, by a nurse. We registered the following details for each recording: breastfeeding or bottle-feeding, whether a regular teat was used or a Special Needs Feeder. Mother's milk or a choice of 12 formulae (or a combination of two formulae), were allowed. If possible, we noted the amount the infants had consumed, any change in their behavioural states during feeding, and whether there had been any choking, breathlessness, discolouring, or stress.

From 34 to 40 weeks' PMA, we recorded the infants at weekly intervals and every two weeks from 40 to 50 weeks' PMA (ten weeks' post-term). At most, we obtained twelve recordings per infant. Altogether we analysed 298 usable feeding episodes in 31 infants: 142 in the preterms with BPD and 156 in the preterms without BPD. Before term-equivalent age we recorded 56 episodes in the preterms with BPD and 72 episodes in the preterms without BPD. After term-equivalent age we recorded 86 measurements in the preterms with BPD and 84 episodes in the preterms without BPD.

Analysis of the sucking patterns

From the ten-minute recordings we selected the first two-minute episode of feeding to assess the infant's sucking pattern with the NOMAS 12. The NOMAS is an often used, non-invasive observation instrument consisting of 28 items: 14 for assessing jaw movements and 14 for assessing tongue movements. The instrument distinguishes three sucking patterns: a normal (mature) sucking pattern, a disorganised sucking pattern, and a dysfunctional sucking pattern 12.

In case of a disorganised sucking pattern, the coordination between sucking, swallowing and breathing is disrupted while the tongue and jaw movements are normal. In case of a dysfunctional sucking pattern, abnormal jaw and tongue movements cause sucking to be impossible or inefficient. A dysfunctional sucking pattern is considered to be more abnormal than a disorganised sucking pattern.

We also assessed the separate items of the NOMAS during each two-minute episode. In addition, we distinguished between a slightly abnormal sucking pattern (only the item 'arrhythmical' was scored) and a definitely abnormal sucking pattern ('arrhythmical' combined with other abnormal items, or a dysfunctional pattern).

Interobserver and intra-observer reliability

Previously, we found that the intra-observer agreement of the NOMAS was 'fair' to 'almost perfect' whereas the interobserver agreement with respect to the diagnosis was 'moderate' to 'substantial' 13. For the purpose of this study two NOMAS assessors judged each episode independently of each other. The assessors were 20 Dutch speech therapists, who were certified NOMAS examiners. If two assessors were unable to reach consensus about a particular episode in a recording, it was discussed with all the assessors. Consensus was reached in all cases.

Longitudinal trajectories

The results of the repeated assessments of each infant's sucking pattern (diagnosed as normal, disorganised or dysfunctional) were displayed graphically on the time-axis, thus depicting individual developmental trajectories. In case of abnormal assessments, we depicted the details of the abnormalities found.

From the longitudinal trajectories we attempted to determine at what age the sucking patterns had normalised. Since we were not aware of any study that had used the NOMAS in a longitudinal design, no benchmark existed to determine at what point in time an infant could be considered to have acquired a normal sucking pattern. Therefore, based on our findings in term infants [20] we decided that an infant had acquired a normal sucking pattern if at least two out of three consecutive episodes were diagnosed as normal. The infant is said to have acquired a normal sucking pattern on the first normal pattern of these three episodes.

Effectiveness of oral feeding

For each episode we determined whether feeding had been effective. In case of bottle-feeding intake was measured from the bottle in cm3. In case of breastfeeding we weighed the infant two minutes before nursing and again thirty minutes after nursing. We noted whether the infants choked or whether they showed any signs of stress while feeding (colour change, nasal flaring, head turning, and extraneous movements). Finally, we noted whether the infant needed additional tube feeding.

Relation between sucking patterns and clinical characteristics

We examined the course of sucking patterns, the infant's age at the time sucking normalised, and specific abnormal patterns in relation to several relevant clinical characteristics. Table 1 shows the infants' clinical characteristics. With regard to the age at which the sucking patterns normalised, we deliberately chose to determine whether the sucking pattern had normalized at term-equivalent age, and again at the age of ten weeks post-term, the end of the period under study. The clinical characteristics we investigated included gestational age, birth weight, gender, Apgar scores at 1 and 5 minutes, the necessity and duration of continuous positive airway pressure (CPAP) and nasal low flow, the presence and degree of periventricular leukomalacia [18] and the presence and degree of germinal matrix haemorrhages [17]. At discharge from the hospital we determined the Nursery Neurobiologic Risk Score (NBRS) [16]. In the preterms with BPD, the severity of BPD, determined on the basis of the duration of supplementary oxygen during the postmenstrual weeks, was also investigated in relation to the normalisation of sucking patterns. Finally, we examined the relationship between the course and normalisation of sucking patterns and the necessity of additional tube- feeding.

Statistical Analysis

Data were analysed using the statistical software package SPSS for Windows, version 16.0. The chi-squared test was used to compare the two groups for frequencies of normal and abnormal sucking patterns. Where appropriate we used the Fisher's Exact test. The Kruskal-Wallis test and the Mann-Whitney U test were used to evaluate the associations between clinical data and the age at which the infant had developed a normal sucking pattern. Because perinatal and neonatal characteristics are likely to be interdependent, we performed a multivariate logistic regression analysis to investigate which factors contributed independently to developing a normal sucking pattern at term-equivalent age and at ten weeks' post-term age. Only factors detected by the univariate analysis (with $p < .10$) were included in the multivariate model. Throughout the analysis we considered $p < .05$ to be statistically significant.

Results

Analysis of sucking patterns

Figure 1a shows the results of the individual assessments, grouped according to postmenstrual age for preterms with BPD. Figure 1b shows the results for the preterms without BPD. We found that 30 (21%) out of all 142 episodes in the preterms with BPD were diagnosed as normal. In the preterms without BPD this was 36 (23%) out of 156 episodes. The prevalence of normal episodes was not different between groups (Chi^2 = ns). In the preterms with BPD, one (0.7%) of the 142 episodes was diagnosed as dysfunctional and 111 (78%) out of 142 were diagnosed as disorganized. In the preterms without BPD, two (1.3%) out of the 156 episodes were diagnosed as dysfunctional and 118 (76%) out of the 156 assessments were diagnosed as disorganised. We found no differences between the frequencies of the dysfunctional and disorganised patterns between the group of preterms with BPD and the group of preterms without BPD. Of the episodes that were diagnosed as disorganised, 116 were 'arrhythmical only': 43 (30%) in the preterms with BPD, and 73 (47%) in the preterms without BPD (chi-squared = 31.0, $p<.001$). Definitely abnormal sucking patterns (all abnormal patterns except 'arrhythmical only') occurred in 116 episodes. They were more prevalent in the preterms with BPD than in the preterms without BPD: 69 (49%) and 47 (30%) episodes, respectively (chi-squared = 10.7, $p<.01$). In particular, the abnormal pattern including the item 'incoordination' was more prevalent in the preterms with BPD: 25 episodes (36%) out of the 69 definitely abnormal patterns in this group and 7 (15%) out of 47 episodes in the preterms without BPD (chi-squared = 6.37, $p<.05$).

Given the fact that there were eight items, one could possibly find many combinations of items in the diagnosis 'disorganised'. It appeared, however, that only a limited cluster of items were found (Figure 1). Apart from the item 'only arrhythmical', there were three other clusters, i.e. 'arrhythmical + unable to sustain', 'arrhythmical + uncoordinated', and 'arrhythmical + unable to sustain + uncoordinated'. If the infant did not start sucking this was due to 'difficulty initiating movements'. If the infant did eventually start sucking during that same episode, it was possible that the infant would have an arrhythmic sucking pattern afterwards or a combination of one of the clusters.

Figures 1a and 1b might create the impression that the prevalence of normal, slightly abnormal ('arrhythmical only') and definitely abnormal patterns differed between the groups for the postmenstrual ages before and after term-equivalent age. The prevalence of normal and abnormal patterns separately for the postmenstrual ages up to 40 weeks, and for postmenstrual ages between 40 and 50 weeks, is shown in Tables 2a and 2b. Indeed, analysis showed that the differences between the groups were confined to the period before term-equivalent age: the group of infants with BPD had less 'arrhythmical only' sucking patterns (chi-squared = 10.1, $p<.01$) and more 'arrhythmical' + 'incoordination' (chi-squared = 7.3, $p<.01$).

The longitudinal course of sucking patterns

As is depicted in Figures 1a and 1b, the longitudinal course of the development of sucking patterns varied considerably in both groups.
We found no differences between the two groups as far as the age at which they acquired normal sucking was concerned. Eleven (64%) preterms with BPD and eight (53%) preterms without BPD acquired a normal sucking pattern before the age of ten weeks post-term (not significant). It was striking that one preterm infant with BPD had normalised his sucking pattern before reaching term-equivalent age, but he became consistently abnormal again afterwards (infant 24). In the group of infants without BPD, again only one infant had normalised his sucking pattern before term-equivalent age, but in this case it remained consistently normal (infant 55).

Of the ten preterms with BPD who had not yet acquired a normal sucking pattern at term-equivalent age, but who had acquired it by ten weeks' post-term, we noted that up to the age of six weeks' post-term corrected age, five infants still found it difficult to coordinate breathing with sucking and swallowing, they were unable to sustain sucking, and they still had short bursts of sucking.

The sucking patterns of all but one of the preterms with BPD (15 out of 16) were repeatedly diagnosed as definitely abnormal until term-equivalent age. For the group of preterms without BPD this was the case for 12 of the 15 infants. Only in the case of six infants, however, it involved more than two

Figure 1a **The development of sucking patterns in preterm infants with BPD** The results of the repeated assessments of each infant according to the gestational age, were graphically displayed on the time-axis, thus depicting individual developmental trajectories.

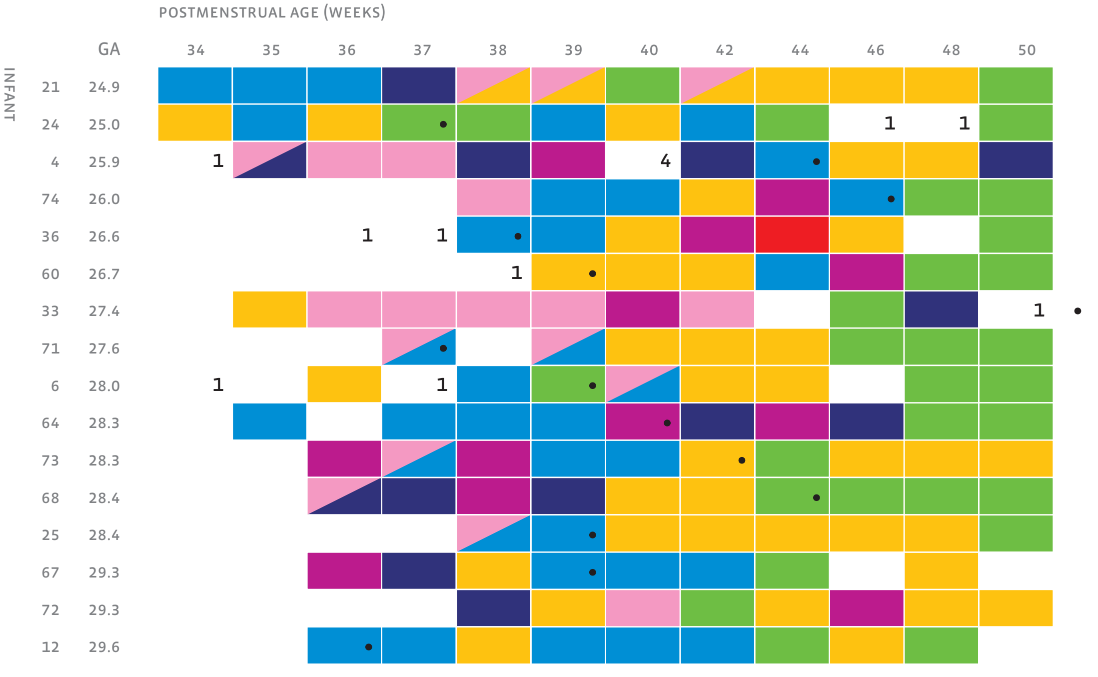

Figure 1b **The development of sucking patterns in preterm infants without BPD** The results of the repeated assessments of each infant according to the gestational age were graphically displayed on the time-axis, thus depicting individual developmental trajectories.

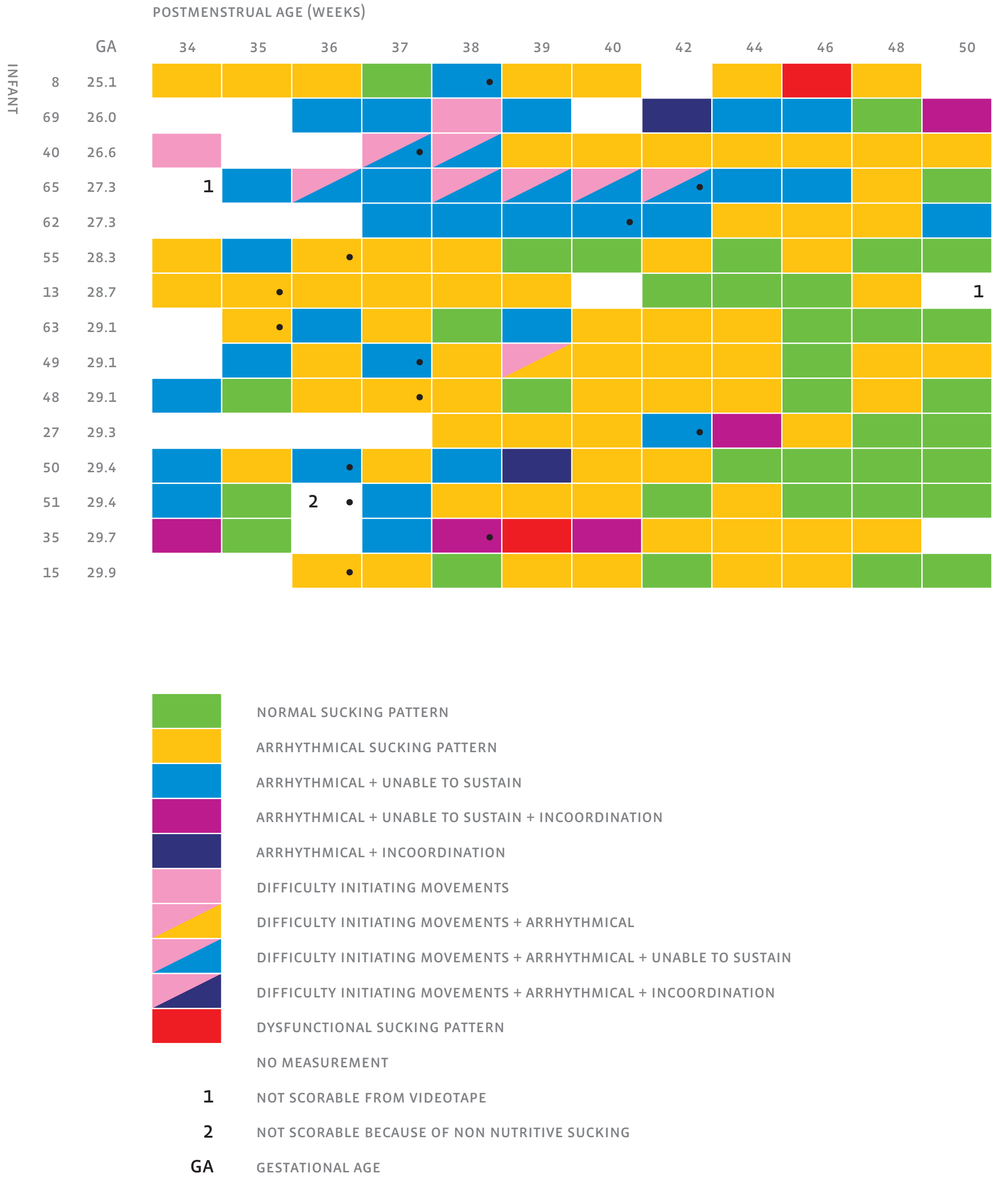

Table 1 The clinical characteristics of the study group. The data are presented as median (range) or numbers (%) unless specified otherwise

	Preterm with BPD	Preterm withoutBPD	*p* value
Male/female	7/9	5/10	ns
Gestational age, weeks	27.8	28.7	ns
	(24.9- 29.6)	(25.1-29.9)	
Birth weight, grams	925	1200	ns
	(560-1340)	(560-1575)	
Apgar 1 min	6 (1-8)	7 (1-9)	ns
Apgar 5 min	8 (3-9)	9 (2-10)	ns
Number of infants on IPPV	15 (94 %)	7 (47%)	.006
Days on IPPV (d)	30 (1-150) (n=16)	13.5 (1- 46) (n=7)	.001
1 - 6 days	2	3	
7 - 13 days	1	1	
14 - 20 days	4	0	
21 - 27 days	1	0	
> 28 days	7	3	
Duration of oxygen dependency			
(PMA, weeks)	40 (36-60)		
Duration CPAP or low flow			
(PMA, weeks)	40(37-60)	33 (30-42)	.001
Ultrasound findings:			
Normal	4	10	.04
GMH grade 1-2	1	none	ns
GMH grade 3-4	1	none	ns
PVL grade 1	10	5	ns
PVL grade 2	none	none	ns
NBRS	6 (3-11)	3 (1-9)	.001

BPD: Bronchopulmonary dysplasia

IPPV: Intermittent positive pressure ventilation

PMA: Postmenstrual age

CPAP: Continuous positive airway pressure

NBRS: Nursery Neurobiologic Risk Score

episodes. This difference was significant (Fisher's exact test p= 0.004). This was not the case after 40 weeks. From the term-equivalent date until ten weeks' PMA, six infants with BPD and seven infants without BPD normalised their sucking pattern (not significant). Five (31%) of the 16 preterm infants with BPD changed abruptly from a definitely abnormal sucking pattern to a normal sucking pattern. This was the case for only one infant in the group of preterms without BPD. In this group 94% first had one or more episodes with an 'arrhythmical only' sucking pattern.

Effectiveness of oral feeding

Preterms with BPD started feeding orally entirely later than preterms without BPD, but the difference was small (median 39 versus 37 weeks' PMA, $p<0.05$). Almost all the preterms with BPD, i.e. 15 (94%), and 14 (93%) of the preterms without BPD, fed orally entirely by the age of 10 weeks postterm. Frequently, an infant was already fed orally entirely even though it still had an abnormal sucking pattern for weeks afterwards. Other infants acquired a normal sucking pattern as soon as they no longer needed tube-feeding. For the 11 preterms with BPD and the eight preterms without BPD who had acquired a normal sucking pattern by ten weeks' post-term, we found no relationship between the duration of tube-feeding and the age at which they acquired a normal sucking pattern.

The relation between the sucking patterns and the clinical characteristics

In neither of the two groups did gestational age, birth weight, the NBRS, and the Apgar score at 1 and 5 minutes influence the age at which an infant stated sucking normally. Nor were there any differences between boys and girls in the two groups. In the preterms with BPD the duration of artificial ventilation correlated with the duration of tube-feeding (Spearman's rho = .55, $p < .01$), but not with the age at which normal sucking commenced. Duration of nasal low flow also did not correlate with the age at which sucking patterns normalised, nor did the presence of PVL exert an influence on whether the infant acquired normal sucking or not.

Discussion

This study demonstrated that prior to reaching term-equivalent age, preterm infants with BPD have much difficulty coordinating their breathing with sucking and swallowing. Reckoned from birth they depended on tube-feeding longer, although the difference is limited to two weeks. It was remarkable that after the term-equivalent age had been reached, there were no longer any differences between the preterm infants with BPD in comparison to

Table 2a Prevalence of clusters of NOMAS items before 40 weeks' PMA for preterm infants with and without BPD

		Normal / Slightly abnormal		Definitely abnormal	
N of episodes 34-40 weeks' PMA, and number of infants		Normal sucking pattern	Arrhthmical sucking pattern only	Arrhythmical + unable to sustain	Arrhythmical + unable to sustain + incoordination
Preterms with BPD	62 (6 no judgement possible, 10%) N=16	3 (5%) N=2	10 (16%) N=8	23 (37%) N=11	5 (8%) N=5
Preterms without BPD	74 (2 no judgment possible, 3%) N=15	8 (11%) N=7	32 (43%) N=11	26 (35%) N=12	2 (3%) N=1
p value* (N of episodes)		ns	<.01	ns	ns
p value** (N of infants)		ns	ns	ns	ns

Table 2b Prevalence of clusters of NOMAS items between 42 and 50 weeks' PMA for preterm infants with and without BPD

		Normal / Slightly abnormal		Definitely abnormal	
N of episodes 42-50 weeks' PMA, and number of infants		Normal sucking pattern	Arrhthmical sucking pattern only	Arrhythmical + unable to sustain	Arrhythmical + unable to sustain + incoordination
Preterms with BPD	90 (4 no judgement possible, 4%) N=16	27 (30%) N=15	33 (37%) N=14	11 (12%) N=8	7 (8%) N=6
Preterms without BPD	85 (1 no judgment possible, 1%) N=15	28 (33%) N=11	41 (48%) N=14	10 (12%) N=4	3 (4%) N=3
p value* (N of episodes)		ns	<.01	ns	ns
p value** (N of infants)		ns	ns	ns	ns

Definitely abnormal		
Arrhythmical + incoordination	**Difficulty inititating movements**	**Dysfunctional**
8 (13%) N=5	16 (26%), of which 9 (15%) in combination with another abnormal sucking pattern N=10	none
1 (1%) N=1	9 (12%), of which 7 (9%) in combination with another abnormal sucking pattern N=4	1 (1%) N=1
<.01	ns	ns
ns	ns	ns

Definitely abnormal		
Arrhythmical + incoordination	**Difficulty inititating movements**	**Dysfunctional**
5 (6%) N=3	4 (4%), of which 2 (2%) in combination with another abnormal sucking pattern N=4	1 (1%) N=1
1 (1%) N=1	2 (2%), of which 2 (2%) in c ombination with another abnormal sucking pattern N=1	1 (1%) N=1
ns	ns	ns
ns	ns	ns

During some episodes an infant may have two diagnoses

Incoordination = stress signals as: colour change, nasal flaring, head turning or extraneous movements are visible

N= number of infants concerned

BPD, bronchopulmonary dysplasia

ns = not significant

* chi-squared test
** chi-squared test, Yates correction

the preterm infants matched for gestational age. The difference was found especially in the period prior to term-equivalent age. Preterms without BPD needed just as much time to acquire a normal sucking pattern.

We also found reports in the literature that preterms with BPD have more difficulty learning to coordinate breathing with sucking and swallowing than do preterms without BPD [9-11;21]. From our study it appeared that prior to reaching term-equivalent age, preterms with BPD more often had an abnormal sucking pattern with coordination problems than preterms without BPD. It was not so much that they were unable to sustain sucking, or that they had more difficulties initiating sucking movements than the preterms without BPD. Rather, they had more problems coordinating breathing with sucking and swallowing. Even after reaching the term-equivalent age, some of the infants with BPD still had difficulties coordinating their breathing with sucking and swallowing, but by this time it no longer differed from our findings on the preterms without BPD. Thus it would seem that, especially prior to reaching term-equivalent age, preterms with BPD had more problems with organising neurobehavioral functioning than preterms without BPD.

Our findings are difficult to explain. We found no differences between the relevant clinical variables, such as abnormal neuro-imaging results or duration of nasal low flow or CPAP. Possibly, our study group had a relatively mild BPD as a result of which the differences with the control group, who were matched for gestational age, were limited. As previously described by Gewolb, [11], the development of sucking seems irregular and unpredictable. On the one hand, there were the large differences between the fastest and the slowest infants and, on the other hand, the fact that many infants in the BPD group developed a normal sucking pattern in just four weeks, from 44 to 48 weeks' PMA. This finding could not be explained by taking into account the difference in gestational age. The fact that BPD is a chronic disorder characterised by a clinical picture that can vary from day to day, might also have exerted an influence.

Within ten weeks' post-term, many very preterm infants had normalised their sucking patterns, and nearly all of them no longer depended on tube-feeding. Dysfunctional patterns which, according to the NOMAS, are found in neurologically abnormal children [22] were rare.. The longitudinal design of our study permits us to state that the abnormalities of the sucking patterns, mostly diagnosed as disorganised, were resolved in a considerable proportion of very preterm infants after reaching term-equivalent age.
Our study was unique for its design. To our knowledge no other studies to date on preterm infants with BPD, have followed the development of sucking and sucking patterns during the entire neonatal period and on into early infancy. We recorded and assessed preterm infants from two or three days after starting oral feeding until they reached 50 weeks' PMA. In addition,

we studied both breastfeeding and bottle-feeding infants. During video-recording no interventions with regards to feeding took place.

There were some limitations to our study. Since it was a single-centre study, caution should be taken in generalising our results to the general population. Our study groups were small, and differences might have been concealed by the fact that our infants with BPD generally only had mild symptoms. Nevertheless, prior to term-equivalent age, we did find significant differences in the development of sucking patterns.

Our study may have implications for starting and scheduling oral feeding. The difference in the course of sucking development prior to term-equivalent age means that, especially when starting preterms with BPD on oral feeding and setting up their feeding schedules, account should be taken of the fact that they have more difficulty sustaining their oxygen saturation while drinking due to their lung problems. It is not improbable that decreases in oxygen saturation levels during feeding play an important role in the origin of feeding problems, for which preterms with BPD are at risk 2;3;23;24. In this respect, breathlessness could lead to refusing to swallow and even to refusing teat or nipple. Such a defence is, therefore, also linked to the development of eating problems later on 1;3;10. Particularly in the case of these infants we recommend careful consideration of the necessary preconditions for starting oral feeding. Moreover, we recommend to only start teaching the infant to drink while at the same time carefully monitoring its physiological parameters (oxygen saturation, heart rate, neurobehavioral functioning including muscle tone, and behavioural state), as well as its potential to recover during the first five minutes after feeding (oxygen saturation, heart rate, neurobehavioural functioning) 25.

To conclude, we found that the development of sucking patterns in preterms with and without BPD differed, but only prior to term-equivalent age. Preterms with BPD, in particular, had difficulty coordinating sucking and swallowing. After reaching term-equivalent age their sucking ability normalised and closely resembled that of preterms without BPD. Apparently, BPD after the due date exerted less influence than we are led to expect from the literature 9-11;21;26. After reaching term-equivalent age, gestational age in both groups influenced the developmental course of sucking more than did BPD.

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7 General discussion

Introduction

This thesis addresses the development of sucking patterns in fullterm and preterm infants from birth until the age of ten weeks post-term. We assessed the sucking patterns in fullterm infants and four groups of preterm infants by means of the Neonatal Oral-Motor Assessment Scale (NOMAS) (1). The four groups of preterm infants that participated in our study were appropriate-for-gestational age (AGA) preterms, small-for-gestational age (SGA) preterms, preterms with bronchopulmonary dysplasia (BPD) and an age-matched group of preterms without BPD.
The aims of the study were:

- To determine which diagnostic tool was the best option for assessing sucking and swallowing problems in preterm infants, and to describe some of its psychometric properties;
- To gain insight into the developmental course of the sucking patterns of fullterm and preterm infants and into the factors that could influence the development of sucking. The implications of the results are discussed in this chapter.

Main results

The study provided insight into the reliability of the NOMAS. In addition, it provided the general insight that very preterm infants and SGA preterm infants are at risk for disturbances in the development of sucking patterns. Not all our expectations regarding the development of sucking patterns in preterms came out. Indeed, new questions arose. Some of our findings were at variance with findings reported in the literature or with current practice regarding when to start oral feeding and how to set up oral feeding schedules. This called for a critical look at the everyday procedures that surround starting and scheduling of oral feeding of preterms in the Netherlands. Our study is an initiative to look at the sucking patterns of different groups of preterms from a different perspective. From the literature search it was apparent that no reliable, non-invasive, inexpensive, and user-friendly diagnostic tool was available that could be used in both breastfeeding and bottle-feeding situations. The NOMAS emerged as the best option: it is non-invasive and user-friendly, and it can be used in both situations. Since no sound research data were available regarding the reliability of the NOMAS, we started off by doing a reliability study. From this study it appeared that the intra-rater reliability was sufficient, but not so the inter-rater reliability. Since the NOMAS did satisfy the other requirements of a research instrument we chose to use it for our study purposes. In order to increase the inter-rater reliability each recording was assessed by two certified NOMAS speech therapists. In case they disagreed the recording was reassessed by a consensus group consisting of other certified NOMAS speech therapists.

The NOMAS is an observational method consisting of 28 items: 14 relate to jaw movements and the other 14 to tongue movements. The NOMAS is administered during the first two minutes of a feed. The infant is observed in profile in such a way that its jaws, the base of the mouth, lips and cheeks are clearly visible. The instrument distinguishes three sucking patterns: a normal or mature sucking pattern, a disorganised sucking pattern, and a dysfunctional sucking pattern. In the case of bottle-feeding, Marjorie Palmer, who described the NOMAS in 1993 in a study on 40 fullterm and preterm infants 1, determined that the cut-off point for scoring rhythmical movements in fullterm infants was ten or more jaw movements (as motor expression of sucking-swallowing-breathing movements) in one burst of sucking. Even though Qureshi also mentioned a minimum of ten jaw movements during bottle-feeding at fullterm age that increases to at least twenty jaw movements at four weeks after term 2, we did not find similar results. A third of the healthy, fullterm infants we observed had sucking bursts of less than ten jaw movements during several measurements. In addition, some infants of fullterm age produced much longer bursts while others, at the age of ten weeks, produced burst that were considerably shorter than twenty jaw movements. In our opinion, it says nothing about the infant's sucking skills if the bursts briefly alternate with short pauses. Shorter bursts of sucking alternating with merely short pauses should probably be regarded as normal in contrast to the infant that produces short bursts alternating with long pauses during which the infant tries to recover its breath. This phenomenon could be seen as a problem of coordinating sucking and swallowing.

In practice it is assumed that when preterms reach fullterm age their drinking skill is the same as that of fullterm infants. It appeared from our study, however, that only a quarter of the preterms have a normal sucking pattern at fullterm age and that by the age of ten weeks post-term this had increased to three quarters. Apparently, in current practice there is a tendency to not await the delay in development that evidently accompanies preterm birth, but to more or less push the infant into learning to drink. The paediatric nurse should have insight into the individual infant's sucking skill to decide whether it is ready to start feeding orally and how the feeding schedule should be set up. A conflict of interest is often the case: the infant should be given the opportunity to practise its sucking skills without this causing stress or oxygen saturation drops, or both. We are not aware of research data that show, for instance, that the infant will not learn to drink well if learning to drink is postponed till the due date. Our research showed that almost all preterms needed more time to develop a normal sucking pattern. In accordance with Simpson et al. we state that it is unwise to want to achieve a sucking pattern in preterm infants that is similar to the sucking skill we are used to seeing in fullterm infants(3). If we allow preterm infants time to mature most of them will develop a normal sucking pattern of their own accord. All other things being equal, we emphasise that an abnormal sucking pattern does not mean that the infant cannot suck effectively. Almost all preterm infants are fed orally entirely even though they still show some abnormalities in their sucking patterns. Fifteen infants (22%), divided over the four groups, were still tube-fed at term age. Two infants, one preterm with BPD and one preterm infant without BPD, were still tube-fed at ten weeks' post-term. The sucking patterns of these two infants were abnormal in the sense that they were unable to sustain sucking or they had problems coordinating breathing with sucking and swallowing, or both. Before reaching fullterm age, preterm infants with BPD experienced much difficulty coordinating breathing with sucking and swallowing. Gewolb 4-6 and Mizuno 7 demonstrated also that until they reach fullterm age, preterm infants with BPD experience more difficulties in learning to coordinate breathing with sucking and swallowing than do infants without BPD. We found, however, that after reaching fullterm age, the development of these infants was comparable to that of fullterms without BPD who had comparable gestational ages. An important point in this connection is the fact that the infants in our study had a relatively mild form of BPD. The largest part of the BPD group developed a normal sucking pattern within a period of merely four weeks (from 44 to 48 weeks' PMA).

Nevertheless, the development of sucking and swallowing in BPD infants is experienced differently in the daily practice of the paediatric nurse and speech therapist: when it comes to learning to drink, preterms with BPD require extra attention longer than do other preterms, even after they have reached fullterm age. In the case of preterms with BPD, sucking appeared to develop in fits and starts and rather unpredictably, as described by Gewolb 5;6. Additionally, BPD is a chronic condition with a variable clinical picture.

It should be noted that not only infants with BPD experienced difficulties in coordinating sucking patterns, but also preterm infants without BPD. Like infants with BPD, very preterm infants without BPD are also at risk for impaired lung development. Birth prior to 30 weeks gestation, with early exposure of the immature lung to air flow, higher oxygen tensions and changes in lung perfusion and blood volume, alters pulmonary development and lung function. This may have impact on the development of sucking patterns. It might explain the delay of both groups in their ability to attain and sustain a normal sucking pattern 8;9. Still, the large differences between the fastest and the slowest infants could not be explained on the basis of gestational age.

Another notable finding of our study was that generally speaking the SGA preterm infants performed the worst: not one of the infants in this group had developed a normal sucking pattern by the time it had reached term age. More often they had difficulty coordinating breathing with sucking and swallowing, in some cases combined with a dysfunctional sucking pattern. According to Palmer, dysfunctional sucking points to a neurologic dysfunction in the motor control of sucking and swallowing movements [1;10]. Only half of the SGA preterms had a normal sucking pattern at ten weeks' post-term. This indicated that in SGA preterm care, learning to drink should be carefully supervised. In the case of this group of infants the point is not that they should be fed orally completely and as fast as possible. Precisely by pursuing the policy where by, on the one hand, the infant receives the necessary nourishment by tube-feeding for it to thrive, while on the other hand, it can practise drinking. In this way the infant is afforded time and given the opportunity to develop a normal sucking pattern. By monitoring the development of sucking of these infants carefully it will soon become clear whether it has a dysfunctional sucking pattern that requires intervention.

Recommendations for practice

Primarily, teaching an infant to drink properly is striving for functionality: how can we help the infant to take in sufficient nourishment orally as normally as possible in order for it to grow. The main purpose is not to strive for an entirely normal sucking pattern. It is, rather, a matter of observing closely whether the infant can sustain its sucking, that it does not show any stress signals such as nasal flaring, extraneous movements, and head turning [1;11] that there is no drop in saturation, and that it can coordinate breathing with sucking and swallowing. A slightly abnormal sucking pattern is no reason to stop oral feeding, even though it does indicate that everything is not as it should be regarding the rhythm of sucking and swallowing. A definitely abnormal sucking pattern, however, does require extra attention from the paediatric nurse.

There is an increasing tendency in the USA to use oral stimulation programmes to stimulate the development of sucking [12-14]. Data are emerging, however, that indicate that later eating problems can be traced back to pushing the infant into sucking while it cannot yet handle the coordination between sucking, swallowing and breathing. This leads to serious oxygen saturation drops during drinking and eating problems later on [15;16].

In daily practice it is the paediatric nurse, under supervision of the paediatrician, who teaches the preterm infant to drink. In the Netherlands, if problems are encountered or sucking develops differently than expected, a speech therapist is often involved. Involving a speech therapist differs from hospital to hospital as does the needs assessment [17]. Due to the exploratory nature of this study we can only offer provisional recommendations for the way in which the paediatric nurse, in collaboration with the speech therapist, can teach a preterm infant to drink from a bottle or suckle at the breast to its best ability.

An essential topic of discussion in present policy is when to start an infant on oral feeding and how to set up the oral feeding schedules. Our findings could contribute to this discussion in terms of general tendencies and adjusting the recommendations for daily practice. The question is whether present policy, i.e. the infant's age determines when it is started on oral feeding, is indeed the correct policy. A positive development in this respect is the view of Suzanne Thoyre and her 'Early Feeding Skills Assessment' [18]. She recommends not taking age per se as the indicator when to start feeding an infant orally, but to check each infant individually to determine whether it is ready for oral feeding. Internationally, the Netherlands is in the lead when it comes to teaching preterms to suckle at the breast. The Breastfeeding Protocol of the University Medical Center Groningen (UMCG) [19] allows infants to smell and lick the nipple from a very early age, in fact as part of pouching. When the infant starts rooting the nurse will check to see if it is able to keep the nipple in its mouth. In this way the infant is given the opportunity to suck if it wants to and is capable of doing so, or not, if the conditions are not right. This is an essentially different approach from pushing an ever-dripping bottle into an infant's mouth from a set age, even if the infant is not rooting or not in the right behavioural state. Studies demonstrated that by starting early or by stimulating its mouth an infant can usually feed orally completely one to two weeks earlier [12-14]. This raises two questions. Firstly, would this be an advantage in the Netherlands where, contrary to practice in the USA, discharge from hospital is linked to whether or not the infant is capable of all-oral feeding? Secondly, how does the infant drink? Is it drinking calmly, relaxed, and well-coordinated without dips in oxygen saturation? Such data are not mentioned in the studies. Moreover, no data are available on the influence of this method on the development of eating behavior of these stimulated infants later on.
In our opinion, the aim of setting-up oral feeding schedules should not be to strive for a completely normal sucking pattern, but rather to achieve that the infant can sustain sucking, that it shows no signs of stress, and that it can coordinate breathing with sucking and swallowing. Therefore, a slightly abnormal sucking pattern (yellow in the Figures) is no reason to be extra careful when offering this infant oral nourishment. A definitely abnormal sucking pattern (all other colours in the Figures) does require extra attention from the paediatric nurse. This extra attention could be summarized as

follows: be alert during the entire feeding session and stop oral feeding as soon as the infant shows signs of stress.

Many infants are transferred from the NICU to peripheral hospitals before they are ready to learn to drink. It is necessary, therefore, to develop nationwide guidelines for paediatric nurses so as to streamline when to start oral feeding and how to set-up oral feeding schedules for preterms in the Netherlands, thus preventing it from being handled differently throughout the country.

The tendency indicated by our study, that a SGA preterm needs more time to develop a normal sucking pattern than an AGA preterm does, strengthens the recommendation to allow the SGA preterm more time and opportunity to learn to drink, while tube-feeding guarantees the necessary growth. Moreover, the paediatric nurse should be aware of the fact that a dysfunctional sucking pattern occurred more often in this group, so that a speech therapist could be consulted on time. The speech therapist examines the infant's abnormal sucking, determines the possible causes and draws up an intervention plan together with the paediatric nurse.

In the case of very preterms (GA<30 weeks) and especially of those with BPD, one should take into account the fact that due to their lung problems they have more difficulty keeping up their oxygen saturation while drinking. In this respect, breathlessness could lead to refusing to swallow and even to refusing teat or nipple. Such a defence is, therefore, also linked to the development of eating problems later on 15;16;20;21. In the case of these infants in particular, we recommend looking closely at the necessary preconditions for when to start oral feeding and only to allow the infant to learn to drink while physiological parameters (oxygen saturation, heart rate) and neurobehavioral functioning (muscle tone and behavioral state) are carefully monitored. A most promising way of monitoring the infant while monitoring the equipment at the same time is the Early Feeding Skills Assessment (EFS) tool 18. This method assesses whether the infant is ready for oral feeding (oral feeding readiness), which means the infant shows rooting, it is in an awake state and it is able to hold its body in a flexed position, and shows oral feeding skills (the ability of oral-motor functioning, the ability to coordinate swallowing, and to maintain physiologic stability). In addition, the method checks how rapidly the infant recovers after the first five minutes of feeding (with regards to oxygen saturation, heart rate, state, and muscle tone). On the basis of all these details a decision is made regarding the following feeding time. In case the infant recovers rapidly the paediatric nurse will decide to again observe the infant's next feed with the help of the EFS in order to determine whether the infant is capable of oral feeding. Should the infant not recover from the impact of oral feeding within five minutes, the paediatric nurse will decide to only tube-feed the infant at the following feeding time or times.

One of the responsibilities of the paediatric nurse is to offer the parents support in caring for the preterm infant. The paediatric nurse should teach the parents to observe their infant and to correctly interpret the signs emitted by the infant. At a certain point learning to drink becomes a daily recurring event. Parents often want the infant to drink as many cm3s as possible so that it can go without tube-feeding sooner. The example set by the paediatric nurse, who is not primarily interested in how much the infant has drunk, but rather in the way the infant drank, helps parents to view their infant's drinking behavior in a different light. Much attention, explanation, and empathy is required of the paediatric nurse to teach parents to observe whether the necessary preconditions (rooting and state) are present to start oral feeding and to teach them to continuously watch their infant - and the monitors! - during oral feeding. Being alert and stopping as soon as the infant shows signs of stress is the approach that should be explained to parents and the one they should be taught.

Implications for future research

In this thesis we reported on the need for developing a reliable diagnostic tool to assess sucking patterns in infants. The NOMAS is such a tool. We consider it worth the effort to adjust the NOMAS since it enabled us to assess the entire context of a drinking or suckling infant according to a set protocol and thus we obtained important information. In addition, new techniques offer different, supplementary possibilities. One such development is the use of ultrasound, pioneered by Geddes et al. 22, Miller et al. 23, and Mizuno 24, to aid and improve the assessment of tongue movements, especially in the case of a dysfunctional sucking pattern. Until such time as these techniques become available, we recommend that the individual observer be tested regularly and given extra training if need be, in order to increase the intra-rater agreement of the NOMAS. In addition, we advise against involving more than one assessor in the longitudinal follow-up of the same infant. In case the NOMAS is used as a means to assess neurodevelopmental outcome for research purposes, we recommend that each recording is assessed by two reliable assessors, and that they reach consensus in case of absence of agreement. We expect the inter-rater agreement to improve if the intra-rater agreement increases and after the instrument has been adjusted.

Another important point to be considered concerns the optimal age at which to start oral feeding. It is unknown whether there is a relationship between the point in time oral feeding is started and the way the sucking pattern develops. From a study by Simpson et al. (3) it appeared that under special conditions an early start would lead to a shorter transit time from full tube feeding to all oral feeding in healthy preterm infants. It remains unclear how practising their innate sucking skills benefits the infant. An added danger is that of offering the infant oral feeding at a time when it is not yet able to control its physiological parameters. This has a baneful influence on both the developmental course of sucking and on the later development of eating. We need a fundamentally new approach to determine the starting point of oral feeding. No longer should we take the age in weeks' PMA as the starting point. Currently in the Netherlands this is still approximately 34 weeks. On the contrary, we should consider the individual infant, for instance with the help of EFS, to determine whether it is ready to start feeding orally. Policy with regards to setting up the oral feeding schedule should be adjusted to suit the individual skill of the infant.

In this study we investigated the development of sucking patterns. It would be interesting to examine the relation between our data on the development of sucking patterns and the motor, cognitive, oral-motor, and articulatory development at the age of two and five years. Possibly the development of sucking patterns of preterm infants has predictive value, as the outcome of a number of studies leads us to suspect 25-27.

In conclusion, the studies reported on in this thesis strengthen our opinion that also as far as the development of sucking patterns is concerned preterm infants differ from fullterms. Preterms should be given time to develop their sucking skills. SGA preterm infants and very preterm infants, especially those with a BPD, require extra attention with regard to when to start oral feeding and how to set up oral feeding schedules. Close collaboration between the paediatric nurse and the speech therapist is of the utmost importance for this group of infants.

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8 Summary

The studies reported on in this thesis addressed the development of sucking patterns in preterm newborns. Preterm infants often have problems learning to suckle at the breast or to drink from a bottle. It is unclear whether this is due to their preterm birth or whether it is the consequence of neurological damage. From the literature, as well as from daily practice, we know that there is much variation in the time and in the way children start sucking normally. Factors such as birth weight and gestational age may indeed be risk factors but they do not explain the differences in development. A small spot-check proved that most hospitals in the Netherlands start infants on oral feeding by 34 weeks' post-menstrual age (PMA). By and large the policy is aimed at getting the infant to rely on oral feeding entirely as soon as possible. The underlying rationale is to reduce the stay in hospital, and the idea that prolonged tube-feeding delays or even hampers the development of sucking.

Recent research found a relationship between frequent and serious reductions in oxygen saturation during feeding and behavioural eating problems at a later age. Likewise, not recovering within five minutes from the impact feeding has on the physiological parameters, bears a relationship to eating problems later on. There is no evidence that postponing oral feeding until the infant is ready for it from a physiological point of view has a negative effect on the development of sucking. It is important, therefore, to check carefully whether a preterm infant is ready to start feeding orally. When oral feeding actually commences, it is important to keep a close watch on whether the infant keeps in control of its physiological parameters and recovers rapidly after a feed. Knowledge about the development of sucking patterns in preterm infants and the ability to recognise the risk factors and indicators of abnormalities in this development will provide paediatricians and nurses insight in how they could best set up oral feeding schedules. We studied the development of sucking patterns in preterm infants from the time the infant stated feeding orally until the age of ten weeks post-term. At weekly, or two-weekly intervals we observed sucking, swallowing and respiration with the aid of the Neonatal Oral-Motor Assessment Scale (NOMAS). The sessions were video-taped for future assessment.

In Chapter 1 we discuss the current knowledge concerning the impact of preterm birth on the development of sucking and swallowing. In addition, we address a number of unresolved issues that gave rise to the following research questions:

1. At what age do preterms infants develop a normal sucking pattern?
2. What is the developmental course of sucking patterns from the time oral feeding commenced to ten weeks' post-term?

3 Are there differences in the developmental courses of the sucking patterns between preterms with normal birth weights (AGA), preterms who have intrauterine growth retardation (SGA), and preterms with bronchopulmonary dysplasia (BPD)?
4 Which factors influence the development of sucking patterns?

The groups we studied consisted of:
1 Healthy, fullterm infants as controls.
2 Preterm infants with intrauterine growth retardation whose birth weights were below the tenth percentile.
3 Preterms with serious respiratory problems, i.e. bronchopulmonary dysplasia.

Chapter 2 consists of three parts. The first part describes a search of the literature for knowledge about the development of sucking and swallowing in preterm infants. Almost all the studies we found described some aspect of sucking and swallowing, like sucking pressure, length of the sucking bouts, or rhythm. Usually the researchers limited themselves to two measurements in time and to either breastfeeding or bottle-feeding. This made it difficult to obtain a complete picture of how infants learn to suckle at the breast or drink from a bottle.

The second part of this chapter describes the diagnostic instruments used in the studies to determine whether an infant is ready for oral feeding and the instruments that study sucking and swallowing itself. As part of the present study we investigated the reliability of these studies, the reliability and validity of the instruments and what exactly the instruments measured. We took into account the cost involved, whether the instruments were used for breastfeeding or for bottle-feeding and whether they were suitable for preterms. Finally, we investgated whether they were suitable for nutritive feeding only or whether they could also be used for non-nutritive feeding, and the instruments' degrees of invasiveness.

This investigation brought to light that no instrument available at the time was at once reliable, non-invasive, user-friendly, suitable for both breastfeeding and bottle-feeding, and for both fullterm and preterm infants. The third part of this chapter focuses on the relationship between an abnormal developmental course of sucking and outcome with regard to neurological functioning on the one hand, and the development of eating on the other hand. A growing number of publications reports on such a relationship, even though the groups studied were small and the children in most of the studies were only followed-up till the age of six, twelve, or eighteen months.

In Chapter 3 we discuss the reliability of the NOMAS. The NOMAS, which uses visual observation for its assessments, was the only instrument we found to be suitable for both breastfeeding and bottle-feeding, and it was the only instrument that could be used both before and after preterm age. The NOMAS is a much-used, non-invasive instrument consisting of 28 items: 14 for the observation of jaw movements and 14 for the observation of tongue movements. It distinguishes three sucking patterns: a normal (mature) sucking pattern, a disorganized, and a dysfunctional sucking pattern. In case of a disorganized sucking pattern the coordination between sucking, swallowing and respiration is disturbed while the tongue and jaw movements are normal. In case of a dysfunctional sucking pattern abnormal jaw and tongue movements make sucking impossible or inefficient. From our reliability study it appeared that the intra-rater reliability varied from 'fair' to 'almost perfect' (Cohen's κ ranged between 0.33 and 0.94). The inter-rater reliability varied from 'moderate' to 'substantial' (Cohen's κ ranged between 0.40 and 0.65). For a measuring instrument such as the NOMAS such levels of reliability were unacceptable. Since much useful information about the development of the infant's sucking ability can be gained from observing sucking and swallowing from a protocol, we recommended to amend the NOMAS in order to improve its reliability; partly also on the basis of new insights into the development of sucking and swallowing. This amendment should result in uniformity regarding the interpretation of differences between breastfeeding and bottle-feeding, the interpretation of the length of the sucking bouts, and of the number of sucking movements per swallow. If, in case of specific questions concerning tongue movements, we could use ultrasound in addition to the NOMAS observations, this instrument would become even more reliable and useful in future.

In Chapter 4 we examined the development of sucking patterns in 30 healthy, fullterm infants during either breastfeeding or bottle-feeding. The first video-recordings were made two or three days after birth. Subsequently, the infants were recorded every two weeks until ten weeks' post-term age. This resulted in 171 recordings; five to seven recordings per infant. The recordings were assessed by certified NOMAS experts. With a view to increasing the reliability of the NOMAS, each recording was assessed by two experts independently. If they could not reach consensus, the recording was assessed by a consensus group.

All the infants had a normal sucking pattern from the beginning. In 14% of the recordings (10 infants), however, we found one or more abnormal measurements during the course of the development of sucking. In these cases we found the slightest abnormality, i.e. arrhythmical sucking, that involved one or more burst of less than ten sucking-swallowing-respiration movements. A dysfunctional sucking pattern did not occur, nor problems of coordination between sucking, swallowing and respiration. Birth weight, gestational age, type of birth or sex had no influence on sucking patterns.

Arrhythmical sucking occurred slightly more often in infants that were bottle-fed.

Chapter 5 deals with the development of sucking of 15 preterm infants with intrauterine growth retardation in comparison with 34 preterm infants that had normal birth weights. The two groups differed significantly as regards birth weight and standard deviation score (SDS) for gestational age. These 15 infants performed worse on all aspects of the development of sucking than the group of preterms with normal birth weights: they developed a normal sucking patterns later and needed to be tube-fed for longer. Gestational age and birth weight bore a significant relationship to the age at which an infant sucks normally. Nevertheless, also the preterms infants with appropriate birth weights showed a different developmental course of sucking than the fullterm infants in the control group: only 38% (13 infants) showed a normal sucking pattern on their due dates. At the age of ten weeks post-term one infant still did not depend on oral feeding entirely and 25 of the 31 AGA preterms (81 %) had aquired a normal sucking pattern. With regards to their sucking patterns it was noticeable that the SGA preterms showed abnormal patterns including 'incoordination' and dysfunctional sucking more often. Prior to term age, they had more difficulty coordinating breathing with sucking and swallowing. Presumably, this was a reflection of their neurological functioning. By means of backward multivariate logistic regression we determined the factors that predicted abnormal development of sucking behaviour. Perinatal and neonatal characteristics that showed an association of $p < .10$ with achieving a normal sucking pattern at term age were entered into the model: gestational age, SDS for birth weight, and the Nursery Neurobiologic Risk Score (NBRS). Only NBRS and SDS for birth weight remained in the model. At the age of ten weeks post-term, gestational age and SDS for birth weight remained in the model.

In Chapter 6 we describe the development of sucking of 16 preterms with BPD in comparison to 15 preterms without BPD, matched for gestational age. Preterms with BPD needed to be tube-fed for longer from birth. It should be noticed, however, that neither group was doing exceptionally well. The developmental course of sucking patterns in the two groups only differed significantly prior to term age; the BPD infants experienced more problems with starting to suck and they had more problems with coordinating respiration with sucking and swallowing due to their lung problems. The differences between the two groups disappeared after term age was reached. Apparently, after the due date, BPD had less influence than we were led to expect from the literature. In both groups the course of the development of sucking was determined more by the shorter gestational age than by BPD.
In the General Discussion we state that the development of sucking patterns

in preterms differs from that of healthy, fullterm infants: three quarters of the preterms developed a normal sucking pattern later than fullterm infants did.. In particular, the developmental course of sucking is different in preterms with intrauterine growth retardation and preterms with a BPD. These two groups, as well as the group of very preterm infants (< 30 weeks' PMA) require extra attention when oral feeding schedules are set up. An infant's postnatal age should not be taken as the standard for starting oral feeding and for setting up oral feeding schedules, rather the individual infant's readiness for oral feeding should be taker into account. Close collaboration with a speech therapist is particularly important in case of a dysfunctional sucking pattern.

9 Samenvatting

Dit proefschrift gaat over de ontwikkeling van zuigpatronen bij premature pasgeborenen. Deze baby's hebben vaak problemen met het leren drinken uit de borst of de fles en het is niet duidelijk of dat onderdeel is van hun prematuriteit of een uiting is van neurologische schade. Zowel uit de literatuur als in de dagelijkse praktijk blijkt dat er grote variatie is tussen de kinderen en dat factoren als geboortegewicht en zwangerschapsduur weliswaar risicofactoren zijn maar niet altijd de verschillen in ontwikkeling verklaren. Uit een kleine steekproef blijkt dat in de meeste ziekenhuizen in Nederland gestart wordt met het aanbieden van orale voeding als de baby 34 weken PMA is en dat het beleid er globaal op gericht is om de baby zo snel als mogelijk is volledig oraal te voeden. Beperking van de opnameduur en de gedachte dat langdurige sondevoeding de zuigontwikkeling vertraagd of zelfs belemmerd is daarbij vaak de onderliggende gedachte. Intussen blijkt uit recente onderzoeken dat frequente en ernstige zuurstofsaturatiedalingen tijdens het drinken en het niet binnen 5 minuten na het beëindigen van een orale voeding herstellen van de impact van het drinken op de fysiologische parameters een relatie heeft met het ontstaan van ' gedragsmatige' eetproblemen op latere leeftijd. Daarnaast is er geen evidentie dat wachten met het aanbieden van orale voeding tot het kind hier qua fysiologie aan toe is, de zuigontwikkeling negatief beïnvloed.

Het is dus belangrijk goed te kijken of een prematuur toe is aan orale voeding en bij de start ervan nauwlettend te kijken of het kind controle houdt over zijn fysiologische parameters en snel herstelt na een voeding. Kennis hebben in de ontwikkeling van zuigpatronen bij prematuren en het onderscheiden van risicofactoren en predictoren maakt het voor de arts en kinderverpleegkundige inzichtelijk op welke manier de start en opbouw van orale voeding zo goed mogelijk gedaan kan worden.

We hebben de ontwikkeling van zuigpatronen bij prematuren onderzocht vanaf het moment dat de baby orale voeding kreeg tot tien weken post term, is (twee)wekelijks het zuigen, slikken en ademen met behulp van de Neonatal Oral-Motor Assessment Scale (NOMAS) geobserveerd en beoordeeld door middel van video-opnames.

In hoofdstuk 1 wordt de huidige kennis met betrekking tot impact van prematuriteit op de ontwikkeling van zuigen en slikken besproken en de vragen die nog niet opgelost zijn. Van hieruit werden vervolgens de vraagstellingen van dit proefschrift geformuleerd. Dat zijn:

1 Op welke leeftijd hebben premature pasgeborenen een normaal zuigpatroon?
2 Hoe is het beloop van die ontwikkeling vanaf het moment waarop gestart wordt met orale voeding en 10 weken post term?

3 Zijn er verschillen tussen de groepen premature pasgeborenen met een normaal gewicht, prematuren met een intrauterine groeivertraging en prematuren met een bronchopulmonale dysplasie (BPD)?
4 Wat zijn de factoren die invloed hebben op de ontwikkeling van hun zuigpatronen?

De onderzochte groepen bestonden uit:
1 gezonde, op tijd geboren kinderen als controlegroep.
2 pre- en dysmature pasgeborenen, met een geboortegewicht onder de 10e percentiel (P10).
3 prematuren met ernstige ademhalingsproblemen (BPD).

Hoofdstuk 2 is opgebouwd uit 3 delen. Het eerste deel beschrijft een literatuuronderzoek naar kennis over de ontwikkeling van zuigen en slikken bij pasgeboren. Bijna al deze studies beschrijven een deelaspect van zuigen en slikken, zoals de zuigdruk, lengtes van zuigreeksen, ritmes van zuigen en slikken. En meestal beperkt men zich tot een of twee meetmomenten en tot of borstvoeding of flesvoeding. Het is daardoor moeilijk een goed beeld van het leren drinken uit borst of fles te krijgen.

Het tweede deel van dit hoofdstuk beschrijft de diagnostische instrumenten die in deze studies gebruikt worden om vast te stellen of een kind toe is aan orale voeding, en de instrumenten die het zuigen en slikken zelf onderzoeken. Er is in het huidige onderzoek gekeken naar de betrouwbaarheid van de studie, de betrouwbaarheid en validiteit van het instrument, de kosten ervan, of het voor borst- of flesvoeding gebruikt kan worden en voor prematuur geboren baby's, wat het instrument precies meet, of het alleen voor voedend of ook voor niet-voedend zuigen gebruikt kan worden en de mate van invasiviteit.

Uit dit onderzoek komt naar voren dat er geen geschikt instrument is dat betrouwbaar, niet-invasief, gebruiksvriendelijk, voor zowel borst- als flesvoeding en voor zowel op tijd -geboren als prematuur geboren baby's gebruikt kan worden.

Het derde deel van het literatuuronderzoek richt zich op de relatie tussen enerzijds een afwijkende zuigontwikkeling en de outcome wat betreft het ontwikkelingsneurologisch functioneren, en anderzijds de eetontwikkeling op latere leeftijd. Een groeiend aantal publicaties maakt melding van een dergelijke relatie, al gaat het om het kleine onderzoeksgroepen en zijn in de meeste studies de kinderen maar tot 6, 12 of 18 maanden gevolgd.

In hoofdstuk 3 wordt het onderzoek naar de betrouwbaarheid van de NOMAS besproken. De NOMAS is het enige instrument dat zowel voor borst- als flesvoeding gebruikt kan worden en zowel vóór als na de à terme leeftijd door middel van visuele observatie. De NOMAS is een veelgebruikt, niet -invasief instrument dat uit 28 items bestaat: 14 om de kaakbewegingen te observeren en 14 voor de tongbewegingen. Er zijn 3 zuigpatronen te onderscheiden: een normaal (matuur) zuigpatroon, een disorganized en een dysfunctional zuigpatroon. Bij een disorganized zuigpatroon is de coördinatie tussen zuigen, slikken en ademen verstoord terwijl de tong- en kaakbewegingen normaal zijn. Bij een dysfunctional zuigpatroon is er sprake van afwijkende kaak- en tongbewegingen die het zuigen onmogelijk of inefficiënt maken. Uit het betrouwbaarheidsonderzoek blijkt dat de intrabeoordelaarsbetrouwbaarheid varieerde van ' fair' tot ' almost perfect' (Cohen's κ tussen 0.33 en 0.94). De interbeoordelaarsbetrouwbaarheid varieerde van moderate to substantial (Cohen's κ tussen 0.40 en 0.65). Voor een meetinstrument als de NOMAS is deze mate van betrouwbaarheid niet acceptabel. Omdat het protocollair observeren van zuigen en slikken veel bruikbare informatie geeft over de zuigontwikkeling van het kind, wordt de aanbeveling gedaan om de NOMAS bij te stellen, mede op basis van nieuwe inzichten met betrekking tot (de ontwikkeling van) zuigen en slikken, om zo de betrouwbaarheid ervan te verbeteren. Er moet bij deze bijstelling eenduidigheid komen met betrekking tot de interpretatie van verschillen tussen borst- en flesvoeding, de interpretatie van de lengte van zuigreeksen en het aantal zuigbewegingen per slik. Als er, bij specifieke vragen over de tongmotoriek tevens gebruik gemaakt kan worden in de toekomst van ultrasound als toevoeging aan de NOMAS-observatie zou het instrument betrouwbaarder en bruikbaarder kunnen worden.

Hoofdstuk 4 gaat over de ontwikkeling van zuigpatronen bij 30 gezonde, op tijd geboren baby's tijdens het drinken uit de borst of de fles. De eerste video-opnames zijn twee tot drie dagen na de geboorte gemaakt en de kinderen zijn tweewekelijks gefilmd tot tien weken postterm. Dat leverde in totaal 171 opnames op, wat het resultaat was van vijf tot zeven opnames per kind, die door gecertificeerde NOMASdeskundigen zijn beoordeeld. Om de betrouwbaarheid van de NOMAS te verhogen werd elke opname door twee deskundigen onafhankelijk van elkaar beoordeeld. Als er geen consensus was, werd de opname door een consensusgroep beoordeeld. Alle kinderen hadden direct een normaal zuigpatroon, maar in 14% van de opnames (bij 10 kinderen) vonden we in de loop van de zuigontwikkeling een of meerdere afwijkende meetmomenten. Er was dan sprake van de lichtste afwijking: aritmisch (arrhythmical) zuigen. Daarbij is er sprake van een of meerdere reeksen van minder dan tien zuig-slik-adembewegingen. Een dysfunctional zuigpatroon kwam niet voor, evenmin als coördinatieproblemen tussen zuigen, slikken en ademen. Geboortegewicht, zwangerschapsduur, type bevalling of geslacht had geen invloed op de ontwikkeling van het zuigen. Aritmisch zuigen kwam iets vaker voor bij kinderen die uit de fles dronken.

Hoofdstuk 5 gaat over de zuigontwikkeling van 15 prematuren met een intrauterine groeivertraging   in vergelijking met 34 prematuren met een normaal geboortegewicht. De groepen verschilden significant qua geboortegewicht en SDS voor zwangerschapsduur. Deze 15 kinderen doen het in alle opzichten van hun zuigontwikkeling slechter dan de groep prematuren met een normaal geboortegewicht: ze komen later tot een normaal zuigpatroon en hebben langer sondevoeding nodig. Beide uitkomsten zijn significant. Zwangerschapsduur en geboortegewicht hebben een significante relatie met het moment waarop een kind normaal zuigt. Toch hebben ook de prematuren met een passend geboortegewicht een andere zuigontwikkeling dan op tijd geboren kinderen uit de controlegroep: slechts 38% (13 kinderen) heeft op de uitgerekende datum een normaal zuigpatroon en tien weken post term heeft één kind nog geen volledige orale voeding en hebben 25 van de 31 AGA prematuren (81%) een normaal zuigpatroon.

Wat betreft de ontwikkeling van hun zuigpatroon valt op dat deze kinderen vaker een afwijkend zuigpatroon lieten zien zoals incoordination of suck/swallow and respiration en een dysfunctional sucking pattern) hebben. Te veronderstellen valt dat dit iets zegt over hun neurologisch functioneren. Door middel van multivariate logistische regressie is backward gekeken welke factoren een afwijkende zuigontwikkeling voorspellen. Perinatale en neonatale karakteristieken die een associatie lieten zien van $p < .10$ met het bereiken van een normaal zuigpatroon op de à terme leeftijd zijn als voorspellers in het model ingevoerd: zwangerschapsduur, SDS voor geboortegewicht en de Nursery Neurobiologic Risk Score (NBRS). Alleen de NBRS en de bleven in het model. Op de leeftijd van tien weken postterm bleven geboortegewicht en SDS voor geboortegewicht in het model.
De zuigontwikkeling van 16 prematuren met een BPD, beschreven in hoofdstuk 6, is vergeleken met die van 15 prematuren zonder BPD, gematched voor de zwangerschapsduur. Prematuren met een BPD hebben langer sondevoeding nodig, zowel gerekend vanaf de geboorte als vanaf het moment dat zij orale voeding krijgen. Het beloop van de zuigontwikkeling verschilt bij beide groepen alleen significant vóór de a terme leeftijd; de BPD kinderen hebben dan meer moeite om het zuigen te starten, hebben meer moeite met het coördineren van hun ademhaling met zuigen en slikken als gevolg van hun longproblemen. Na de a terme leeftijd verdwijnen de verschillen tussen beide groepen. Blijkbaar is de BPD na de uitgerekende datum van minder grote invloed dan we verwachtten vanuit de literatuur. De korte zwangerschapsduur in beide groepen bepaalt na de a terme datum meer het beloop van de zuigontwikkeling dan de BPD.

Concluderend kan worden gesteld - hoofdstuk 7- dat de ontwikkeling van zuigpatronen bij prematuren anders verloopt dan bij gezonde, op tijd geboren baby's: driekwart van de prematuren ontwikkelt later dan a terme kinderen een normaal zuigpatroon en met name bij de pre- en dysmature baby's en de pasgeborenen met BPD verloopt de zuigontwikkeling ook anders. Deze 2 groepen hebben extra aandacht nodig bij de start en bouw van orale voeding evenals de groep zeer te vroeg geboren baby's (< 30 weken PMA). Voor de prematuren met een BPD geldt die extra aandacht vooral vóór de a terme datum.

Voor de start en opbouw van orale voeding moet niet de leeftijd van het kind genomen worden. Er moet nauwkeurig bij elk kind individueel, gekeken worden of de voorwaarden om te kunnen drinken aanwezig zijn. Nauwe samenwerking met de logopedist is met name belangrijk als er sprake is van een dysfunctional zuigpatroon.

Abbreviations

AGA	Appropriate for Gestational Age
BPD	Bronchopulmonary Dysplasia
GMH	Germinal Matrix Haemorrhage
IPPV	Intermittent Positive Pressure Ventilation
IRDS	Idiopatic Respiratory Distress Syndrome
NBRS	Nursery Neurobiologic Risk Score
NNS	Non-Nutritive Sucking
NS	Nutritive Sucking
NOMAS	Neonatal Oral-Motor Assessment Scale
PC	Postconceptual
PMA	Post Menstrual Age
PVE	Periventricular echo densities
PVL	Periventricular Leukomalacia
SD	Standard Deviation
SDS	Standard Deviation Score
SGA	Small for Gestational Age

Dankwoord

Veel mensen, groot en klein, hebben een bepalende rol gespeeld in dit promotieonderzoek. Ik wil hen hier bedanken.

In de eerste plaats de 94 kinderen (en hun ouders) die we bijna vier maanden mochten komen filmen. Bijna alle ouders blijven meedoen met het vervolgonderzoek (als de kinderen twee en vijf jaar zijn) dat promovenda Mechteld Stigter vanuit het Lectoraat Transparante Zorgverlening HG doet.

Mijn begeleiders Arie Bos (promotor) en Cees van der Schans (copromotor), die mij altijd serieus hebben genomen en me voortdurend het vertrouwen hebben gegeven dat het mij zou lukken het promotietraject goed af te leggen.

De 23 studenten die tijdens hun opleiding Logopedie aan het onderzoek hebben meegewerkt door de kinderen te filmen en ondersteunende werkzaamheden te verrichten.

De drie collega's/onderzoeksassistenten die de studenten hebben ondersteund en data hebben verzameld.

De 22 Nomas-gecertificeerde logopedisten die alle video-opnames hebben beoordeeld.

En uiteraard mijn medeauteurs bij een of meer artikelen Mar Wiersma-Zweens, Sarai Boelema, Eva van der Meij, Lenie van den Engel-Hoek en Mieke Boerman.

Tot slot: zonder het convenant van de HG en de RUG, dat mij in staat stelde gebruik te maken van de regeling Subsidie promotietrajecten HG–medewerkers, zou het mij niet gelukt zijn mijn onderzoek in een acceptabele tijd af te ronden.

Curriculum vitae

Saakje P. da Costa (1952, Amsterdam) obtained a secondary school certificate (hbs-b) in 1969 at Streeklyceum Buitenveldert, Amsterdam and went to Groningen to study Logopaedics. After completing her studies in 1973, she worked as a speech therapist at Kinderrevalidatiecentrum Lyndensteyn in Beetsterzwaag until 1980. During that time she followed a course on Neuro-Developmental Treatment (NDT) for children. In 1978, she went to Zürich with a colleague and obtained a teaching qualification in Neuro-Developmental Treatment (NDT) from Helen Müller, the Swiss NDT speech therapist. Together with her colleague Clairette van der Weerd, she set up a NDT (pre)logopaedics course at Kinderrevalidatiecentrum Lyndensteyn. They were the first speech therapists outside Switzerland to do so. Saakje was Senior NDT Speech Instructor on the NDT children's course in Groningen until 2007. From 1980 to the present she has been working as a speech therapist at Kinderpraktijk Groningen, treating young children with swallowing and feeding problems, who often have prematurity in their anamnesis. From 1986 she has been teaching Logopaedics at Hanze University, School of Health, Groningen. In 1987, she obtained a qualification from Rijksuniversiteit Limburg, Maastricht to teach students. In 2005, she started her doctoral research on the development of sucking patterns in preterm infants at the Research and Innovation Group in Health Care and Nursing, Hanze University, Applied Sciences, Groningen.

Saakje da Costa has two daughters, Sarai (Boelema), who assisted with the research for this doctoral thesis, and Rivka.