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Skin-to-Skin Contact and Suckling in Early Postpartum: Effects on Temperature, Breastfeeding and Mother-Infant Interaction

A Study in St. Petersburg, Russia

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*In memory of my father
and
to my family*

Thus conscience does make cowards of us all ...
William Shakespeare

Abstract

The overall aim of this thesis was to explore the role of closeness versus separation on infant and maternal temperature adaptation, breastfeeding outcome and mother-infant interaction. In addition, we aimed to study a potential influence of swaddling on all outcomes measured.

Material and design. A randomized factorial design and a longitudinal approach were used. One hundred and seventy six (176) mother-infant pairs from Maternity Home 13 in St. Petersburg were randomized into four groups. Group I infants were placed skin-to-skin with their mothers after birth, and had rooming-in two hours later. Group II infants were dressed and placed in their mothers' arms after birth, and had rooming-in two hours later. Group III infants were kept in the nursery both after birth and during the rest of maternity stay. Group IV infants were kept in the nursery after birth, but roomed-in with their mothers two hours later. Equal numbers of infants were either swaddled or dressed in baby clothes.

Methods included assessment of infant axillar, thigh, back and foot temperature and maternal axillar and breast temperature, at 15-minute intervals from 30 to 120 minutes after birth. A diary was filled in daily by mothers with their estimation of feeling "low/blue" (Visual Analogue Scale), perception of physiological breast engorgement, and number of breastfeeds. In addition, on day 4 time of breastfeeds, milk amount ingested and extra food given to the infants were registered. Recovery of the neonatal weight loss was calculated. The duration of "nearly exclusive" breastfeeding was noted. At the age of one year infants were video-filmed with their mothers and interaction scored according to the Parent-Child Early Relational Assessment (PCERA) method.

Results. *Maternal axillar and breast temperature* exhibited a small but significant rise after delivery in all groups. In contrast, the variation in maternal breast temperature increased by close contact and suckling. *Infant skin temperature*, except for foot temperature in the Nursery group, rose in all groups and was the highest in infants with skin-to-skin contact. The rise of foot temperature was most pronounced in the Skin-to-skin group, and it remained high during the maternity stay. Furthermore, in unseparated mother-infant dyads maternal axillar temperature was positively related to the infant foot temperature at 120 minutes postpartum. Infant foot temperature rose about 2 units per unit of change in the maternal axillar temperature.

Breastfeeding. Infants who stayed in the nursery and had standardized breastfeeding frequency (7 times per 24 hours) ingested less breast-milk, suckled for a shorter time and received more supplements day 4, than rooming-in infants. Supplementation was one of the main factors reducing milk production/ingestion. Swaddling did not affect these breastfeeding parameters. In contrast, swaddled infants separated in the nursery, who were in addition supplemented by formula, had significantly less weight gain. Milk production/ingestion on day 4 postpartum in primiparas was positively correlated with early suckling, with the level of perception of breast engorgement and with the suckling frequency of the previous day. It was negatively correlated with high levels of feeling "low/blue." Milk production/ingestion in multiparas was related to early suckling and rooming-in. The duration of "nearly exclusive" breastfeeding was related to amount of breast-milk produced/ingested on day 4 after birth.

Maternal-infant interaction. Skin-to-skin contact between the mother and infant during the first two hours after birth significantly influenced the level of *maternal* sensitivity, *infant* ability to regulate behavior (self-regulation), and mutuality and reciprocity in the *dyad* when the infant was one year old. In the absence of skin-to-skin contact, early suckling induced these effects. Swaddling of the infant decreased the *mother's* ability for positive affective involvement in the infant and also mutuality and reciprocity in the *dyad*. These results were revealed using the PCERA.

Conclusions. The data suggest that regulation of skin temperature and of milk production seems to be mediated by different and independent physiological mechanisms. In addition, the data show that early skin-to-skin contact influences the development of maternal-infant interaction recorded at the age of one year, suggesting the existence of an early "sensitive period."

Key-words: breastfeeding outcome, early suckling, maternal temperature, mother-child interaction, newborn infant temperature, sensitive period, separation, skin-to-skin contact, swaddling.

PUBLICATIONS

This thesis is based on the following articles, which will be referred to by their Roman numerals:

- I. Bystrova K, Matthiesen A-S, Widström A-M, Ransjö-Arvidson A-B, Vorontsov I and Uvnäs-Moberg K.
Maternal axillar and breast temperature after giving birth: effects of labor ward practices and relation to infant temperature.
Birth 2007;34(4):291–300.
- II. Bystrova K, Widström A-M, Matthiesen A-S, Ransjö-Arvidson A-B, Welles-Nyström B, Wassberg C, Vorontsov I and Uvnäs-Moberg K.
Skin-to-skin contact may reduce negative consequences of “the stress of being born”: a study on temperature in newborn infants, subjected to different ward routines in St. Petersburg.
Acta Paediatrica 2003;92:320-326.
- III. Bystrova K, Matthiesen A-S, Widström A-M, Ransjö-Arvidson A-B, Welles-Nyström B, Vorontsov I and Uvnäs-Moberg K.
The effect of Russian Maternity Home routines on breastfeeding and neonatal weight loss with special reference to swaddling.
Early Human Development 2007;83:29-39.
- IV. Bystrova K, Widström A-M, Matthiesen A-S, Ransjö-Arvidson A-B, Welles-Nyström B, Vorontsov I and Uvnäs-Moberg K.
Early lactation performance in primiparous and multiparous women in relation to different Maternity Home practices. A randomised trial in St.Petersburg.
International Breastfeeding Journal 2007, 2:9. Article URL - <http://www.internationalbreastfeedingjournal.com/content/2/1/9>
- V. Bystrova K, Ivanova V, Edhborg M, Lundh W, Matthiesen A-S, Ransjö-Arvidson A-B, Welles-Nyström B, Vorontsov I, Mukhamedrakhimov R, Uvnäs-Moberg K and Widström A-M.
Effect of closeness *versus* separation after birth and influence of swaddling on mother-infant interaction one year later: a study in St. Petersburg.
Submitted.

LIST OF ABBREVIATIONS AND DEFINITIONS

ACTH	Adrenocorticotrophic hormone
BAT	Brown Adipose Tissue
BFHI	Baby-Friendly Hospital Initiative
CCK	Cholecystokinin
CGRP	Calcitonin-Gen Related Peptide
CNS	Central nervous system
CRF	Corticotrophin-Releasing Factor
GI hormones	Gastrointestinal hormones
HPA-axis	Hypothalamic-Pituitary-Adrenal axis
KC	Kangaroo Care
NTS	Nucleus Tractus Solitarius
PCERA	Parent-Child Early Relational Assessment
PVN	Paraventricular Nucleus
SON	Supraoptic Nucleus
VIP	Vasoactive Intestinal Polypeptide
WHO	World Health Organization

“Early suckling” – suckling within the first two hours postpartum.

“Milk production” was equalled to the amount of breast-milk ingested by infant as calculated as the difference in weight before and after breast-feeding.

“Nearly exclusive” breastfeeding – breastfeeding including *irregular* supplementation of juices or solids in a daily volume of 30 ml or less or formula in a daily volume of 100 ml or less (Vorontsov et al, 1998).

“Long-term” separation after birth in the present study is defined as separation of the infant from his/her mother during the first two hours after birth and subsequent care in the nursery.

“Short-term” separation after birth in the present study is defined as separation of the infant from his/her mother during the first two hours after birth.

Content

ABSTRACT

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1 BACKGROUND AND INTRODUCTION

1.1 Consensus conference in St. Petersburg

In the beginning of the 1990's St. Petersburg was included in the WHO Healthy Cities Project. At that time a group of experts from Sweden were invited to examine the care practices in the maternity homes of the city in order to consider what the reasons were for the lowered rate of breastfeeding, high level of infant morbidity and mortality and increased incidence of infant abandonment.

A typical Russian maternity care practice at that time was to keep the babies swaddled soon after birth and separated from their mothers even at the delivery ward. The swaddled babies were kept in the nursery, and swaddling was continued during the rest of the almost weeklong maternity stay. Seven times per 24 hours the infants were transported from the nursery on small gurneys to the mothers' rooms at the maternity ward for breastfeeds.

At that time in Sweden it was a maternity practice to put the baby skin-to-skin with the mother at the delivery ward and later, at the maternity ward, dress the baby in ordinary baby clothes. Swedish infant care included the practice of rooming-in and breastfeeding on demand, as well as a free access of fathers and other family members to the new mother and newborn infant.

The tradition of swaddling and separation still persisting in Russia offered the ideal natural research situation to compare the effects of Swedish care routines with the traditional Russian infant care practices. Thus, Russian and Swedish researchers were inspired to begin a joint project to study the influence of mother-infant closeness versus separation at all levels of post-birth care, including a potential influence of tight swaddling. Consequently, the natural basic needs for infant's survival – temperature adaptation after birth, establishment of adequate breastfeeding and optimal interaction with the mother, were the selected targets of interest of the study. Basic regulatory mechanisms and the concise summary of previous findings relevant to the above chosen variables will be reviewed below.

1.2 Factors influencing temperature

1.2.1 Basic physiology of temperature regulation

In the mother

Not much is known about the development of axillar and breast skin temperature after delivery in human mothers. However, it has been shown that during labor there is a decrease in maternal axillar, vaginal, rectal and between-breasts temperatures in non-medicated women, with a consequent rise in temperatures during the following postpartal hour (Goodlin and Chapin, 1982; Harper et al, 1991). This drop in temperatures was explained as being due to heat loss caused by perspiration and hyperventilation in response to pain and to the increased physical activity of labor. However, this drop in temperature was not observed in women with epidural analgesia (Goodlin and Chapin,

1982), which has been suggested to be a consequence of an impairment of central thermoregulatory control (Mercier and Benhamou, 1997).

Studies on maternal breast skin temperature have primarily been conducted in conjunction with breastfeeding. Some case reports suggest that during breastfeeding heat dissemination from the mother's chest is increased as demonstrated by a heat-sensitive camera (Vuorenkoski et al, 1969). Breast skin temperature rose in relation to suckling, and remained high during the whole period of suckling and up to 5 minutes after. Interestingly, temperatures rose simultaneously in both the suckled and the non-suckled breasts and skin breast temperatures were significantly higher than core breast temperatures, measured by a special temperature-compensated probe, enabling temperature measurement 9 to 11 mm below the skin surface (Kimura and Matsuoka, 2007).

A case report of two mothers, studied during skin-to-skin contact without suckling, showed that the mother's breast temperature appeared to adapt to the thermal needs of premature infants. Differential patterns of thermal response were noted in the separate breasts as a reaction to the different skin temperatures of the premature twins placed simultaneously skin-to-skin with their mother (Ludington-Hoe et al, 2006). It was also reported that in full-term infants in skin-to-skin contact with their mother, infant's skin temperature could be lowered if infants were too warm (Chiu et al, 2005).

Further, it is known that each suckling episode is associated with a rise in blood flow to the mammary gland in general (Janbu et al, 1985), and also with an increase of blood flow to the skin overlying the mammary gland (Eriksson et al, 1996,b). A release of oxytocin from the posterior pituitary, as well as of vasoactive intestine polypeptide (VIP) and calcitonin gene-related peptide (CGRP) from neurons in the mammary gland, may mediate these effects since the latter were found to be present in neurons around the vessels in the mammary gland, and to be able to induce a similar increase in blood flow (Eriksson et al, 1996,a). Oxytocin may increase blood flow indirectly as it is known that neurogenic VIP can be released by oxytocin (Stock and Uvnäs-Moberg, 1985). In addition, VIP and CGRP may be released via activation of reflexes at different levels (axon, spinal, brain-stem) in connection with skin-to-skin contact and/or suckling to cause vasodilation (Dhondt et al, 1977).

In the infant

Being born, a human neonate meets the challenge of adapting to the environmental temperature, which in average is approximately 15° C lower than that to which he or she was used to before birth. In order to be able to adjust his or her thermal needs to the cooler postpartum environment the neonate is equipped by a specialized organ for heat production, brown adipose tissue (BAT). Newborn infants can not improve heat production in response to cold stress with an increase in physical activity, but it is possible for the baby to raise it by non-shivering thermogenesis, resulting from the metabolic activity of BAT. In full-term infants BAT accounts for 4 per cent of total adipose mass (Hull and Smales, 1978) and is found superficially (especially between the scapulae) and deep within the body (especially along the aorta). Circulating

catecholamines, released during and immediately after birth (“the stress of being born” [Lagercrantz and Slotkin, 1984]; Vogl et al, 2006), or later, in response to cold, act directly on BAT, uncoupling oxidative phosphorylation and releasing energy as heat (Rutter, 2005). Accordingly, after elective cesarean section, which is not accompanied by a surge of catecholamines (Irested et al, 1982; Vogl et al, 2006), skin and body temperatures of infants placed in a cot were found to be significantly lower during a 90 minutes observation period after birth than in vaginally delivered infants cared for in a similar way (Christensson et al, 1993).

Peripheral vasoconstriction is a heat saving mechanism which functions in response to cold by diverting blood from the infant’s surface to the core. Still the neonate is vulnerable and may not achieve thermal equilibrium because of a high surface-to-weight ratio, predisposing him or her to experience rapid heat loss.

There are four known ways of heat loss: heat is lost during direct contact of exposed skin surface with cooler objects (*conduction*); with cooler air (*convection*); and by radiating from the exposed infants’ surface to the directly surrounding surfaces (*radiation*). Finally, there is *evaporative* heat loss, which is the primary cause of heat loss immediately after birth when neonatal skin is wet from amniotic fluid (Hammarlund et al, 1979). Preterm infants have poorer thermoregulation than neonates born at term, because they have an even larger surface-to-weight ratio, smaller storage of BAT, lack of insulation due to thinner skin and sub-skin fat layer and higher evaporation due to a more frequent breathing rate and trans-epidermal water loss (Rutter, 2005).

When the infant’s temperature is stable and is within the normal range (36.5-37.5° C), and the metabolic rate (oxygen consumption) is at the lowest level sufficient to preserve heat, then the environment temperature is defined as “the thermoneutral zone”. If heat loss exceeds heat production, body temperature falls, which can lead to hypothermia, which in turn increases the risk for morbidity and mortality (Sterky et al, 1985). According to WHO (1993), the range of body temperature in newborns is defined as normal when it is 37.5-36.5° C; as an expression of cold stress when it is 36.5-36.0° C; as moderate hypothermia when it is 35.9-32.0° C, and as severe hypothermia when it is below 32° C.

1.2.2 Influence of post-birth practices on temperature

Early skin-to-skin contact

It has been shown that infants allowed skin-to-skin contact with the mother after birth demonstrated higher axillar, interscapular and thigh temperatures than infants who were wrapped and placed in a cot near the mother’s bed (Christensson et al, 1992) or who were also wrapped, but held in the mother’s arms (Carfoot et al, 2005). This thermal response can be altered by administration of analgesia during labor (Ransjö-Arvidson et al, 2001). Additionally, low-risk hypothermic neonates allowed skin-to-skin contact have been shown to reach normal temperature range more quickly than did the hypothermic infants placed in incubators (Christensson et al, 1998).

Nursery care/short-term separation

Separation of newborn infants from their mothers is a normal hospital routine in many countries, where babies are placed immediately in a nursery for the entire hospital stay. Research conducted on infants placed in the nursery has shown that there is a decrease in axillary temperature one hour after birth (Jansson et al, 1995).

1.3 Factors influencing early breastfeeding outcome

1.3.1 Basic physiology of breastfeeding regulation

Currently it is a well-known fact that milk production in humans is governed by two hormones, prolactin and oxytocin (Riordan, 1993). Prolactin is produced by neurons located in the anterior pituitary and is released into the circulation 10 minutes after the start of suckling, and reaches the highest level at approximately 20 minutes later, thus promoting future milk production (Uvnäs-Moberg et al, 1990). Oxytocin is synthesized in the supraoptic (SON) and paraventricular (PVN) nuclei of hypothalamus. Magnocellular neurons producing oxytocin send projections to the posterior pituitary, from which the peptide is released into circulation. The release of oxytocin is known to occur immediately in relation to suckling, but can with time become easily conditioned to begin prior to sucking, as when a mother views her child or thinks about him or her. In the mammary gland oxytocin causes milk ejection by inducing a contractile effect on smooth muscles in the myoepithelial cells surrounding the alveoli and in the small milk ducts (Lincoln and Paisley, 1982). In addition oxytocin opens up the sphincters at the end of the milk ducts.

The success of breastfeeding development is usually evaluated in several ways. Breastfeeding success can be measured by the amount of milk ingested by a baby per 24 hours; by infant weight gain; by the duration of exclusive breastfeeding; and sometimes by other methods (e.g., success of the first breastfeed, nipple pain and so forth).

1.3.2 Influences of post-birth practices on breastfeeding

Practices in labor and maternity wards have been shown to influence the outcome of breastfeeding. Skin-to-skin contact between mother and baby after birth in combination with early and/or frequent suckling has been shown to be conducive to breast-feeding, i.e., promoting milk production and prolonging duration of exclusive breastfeeding (de Chateau and Wiberg, 1977; Salariya et al, 1978; Anderson et al, 2004; Mizuno et al, 2004; Moore et al, 2007). There is as yet no evidence showing that skin-to-skin contact alone is beneficial to breastfeeding outcome (Carfoot et al, 2003; 2005). Still skin-to-skin contact has been shown to stimulate the baby's inborn pre-feeding behavior (Widström et al, 1987; Matthiesen et al, 2001), and to promote the success of the first post-birth breastfeeding (Carfoot et al, 2005). In addition, infants having two-hour skin-to-skin contact with their mothers after birth were found to suckle sooner within this time interval than did control swaddled infants held by their mothers (Moore and Anderson, 2005).

Early suckling in the absence of skin-to-skin contact was shown to prevent early termination of breastfeeding (DiGirolamo et al, 2001) and to increase breastfeeding

duration (Salariya et al, 1978, Nylander et al, 1991). In addition, more frequent feeds during the first days after birth increase milk amount (Houston et al, 1983) as well as duration of breastfeeding (Salariya et al, 1978, Houston et al, 1983, Nylander et al, 1991). In contrast, nursery care and supplementation of infants by formula, glucose solution, or water have been shown to decrease milk amount during the first days after birth (Houston et al, 1983; Nylander et al, 1991; Widström et al, 1990), and also to shorten the duration of breastfeeding (Widström et al, 1990; Blomquist et al, 1994; Ekström et al, 2003a).

More than 20 years ago The Baby-Friendly Hospital Initiative (BFHI), a global program sponsored by the World Health Organization and the United Nations Children's Fund, was started. Its goal was to strengthen lactation promotion and to support and recognize hospitals and birthing centers that offer an optimal level of care for lactation. "Ten steps to successful breastfeeding", a summary of the rationale and scientific evidence, was created in 1996 as a strategy for maternity homes in breastfeeding promotion. In a recent large population-based study in Colorado, USA, (Murray et al, 2007), it was found that breastfeeding duration was significantly improved independent of mother's socioeconomic status when mothers experienced five specific hospital practices, based on the BFHI guidelines: breastfeeding within the first hour, breast milk only, infant rooming-in, no pacifier use, and receipt of a support hot-line telephone number for use after discharge. In addition, mothers who experienced all five supportive hospital practices were significantly less likely to stop breastfeeding due to any of the top reasons given for stopping.

However, milk production and breastfeeding duration are not only regulated by labor- and maternity ward practices. A longer duration of exclusive breastfeeding has been shown to be significantly associated with positive maternal attitude toward breastfeeding, adequate family support, and good mother-infant bonding, appropriate suckling technique, and no nipple problems (Ceriani Cernandas et al, 2003). Clear evidence has been obtained for the effectiveness of additional professional support in prolonging any breastfeeding, and additional lay support in promoting exclusive breastfeeding (Sikorski et al, 2003; Ekström et al, 2003b).

1.3.3 Influence of parity and factors linked to postpartal period (physiological breast engorgement and maternal mood)

Parity

It has been found that parity can affect breastfeeding outcome. For instance, it was shown that multiparas have more milk on days 2 to 4 (Zuppa et al, 1988), on day 5 (Chen et al, 1998) and at 1 week after birth (Ingram et al, 1999), while primiparas have a delayed onset of milk production (Dewey et al, 2003).

Physiological breast engorgement

Breast engorgement in the early postpartal period is a normal phenomenon. Breast engorgement is a marker of the normal progression of lactogenesis and can be defined, as suggested by Shrago (1991), as "hormonally induced lymphatic and vascular congestion and interstitial edema in breast tissue combined with increased volume of milk in alveoli,

lactiferous ducts and lactiferous sinuses, occurring with lactogenesis during the first week postpartum.” Estrogen and progesterone levels are high during pregnancy, but since these hormones are, to a great extent, produced in the placenta, the levels of these hormones fall dramatically after birth. Decreased levels of these steroid hormones have been associated with initiation of milk production (Falconer, 1980; Topper and Freeman, 1980; Neville and Morton, 2001). Thus, physiological breast engorgement is suggested to be related to these hormonal changes and onset of milk production. Possibly the experience of physiological engorgement is related to this phenomenon.

Maternal subjective perception of the onset of lactation (breast symptom changes) has been identified as a valid public health indicator of lactogenesis stage II, i.e., the initiation of copious secretion of breast milk after delivery (Chapman and Perez-Escamilla, 2000). Previous studies have demonstrated that the amount of breast milk increases significantly with the degree of physiological breast engorgement (Newton and Newton, 1951). The pattern and extent of physiological engorgement has been reported to be a possible predictor for a sufficient milk supply (Humenick et al, 1994).

Changes in maternal mood

Changes in mood (“maternity blues”) are well-known phenomena coinciding in time with the initiation of lactation. The exact reason for the “blues” is not yet known. It could be an expression of exhaustion, of steroid sex hormones withdrawal, or of activation of brain structures involved in changes in connection with parenting (Miller and Rukstalis, 1998). It is not known whether milk production could be affected by mother’s mood. Previous studies have shown that in the postpartum period mothers cope better with breastfeeding when they are less anxious (Tarkka et al, 1998), while producing less milk is associated with a higher exhaustion score (Chen et al, 1998) in the postpartal period.

1.3.4 Neonatal weight loss

On the average, breastfed newborns lose 5 to 7 per cent of their birth weight during the first few days of life (Manganaro et al, 2001). The risk of excessive neonatal weight loss (that is when it exceeds 10 per cent of birth weight) has been shown to be 7.1 times greater if the mother had a delayed onset of lactation, and 2.6 times greater if the infant had suboptimal breastfeeding behavior at the day of birth (Dewey et al, 2003).

Breastfed infants have been shown to lose more weight the first two days than supplemented infants but instead to regain weight faster than do supplemented infants (Nylander et al, 1991). Neonatal weight loss, as well as recovery from neonatal weight loss, are not only consequences of the amount of the infant's nutritional intake, but also of the infant’s ability to use calories for anabolic purposes. As an example of this, the non-nutritive sucking has been shown to optimise digestion and metabolism of nutrients through sucking-induced vagal activation, by causing a release of gastrointestinal hormones and of insulin (Widström et al, 1988; Marchini et al, 1987).

1.4 Factors influencing mother-infant behavior

1.4.1 Mother-infant interaction

Meaningful mothering begins even before the baby's birth and continues in some form throughout the life of the mother and child. As it is often said, *once a mother, always a mother*. Nonetheless, mothering responsibilities are greatest during infancy, when human babies are most dependent on being taken care of and their ability to cope with the environment alone is minimal. Universally, mothers are expected to establish with their infants successful routine interactions to guide the infants through all of the important "firsts" of life, constituting an initial and encompassing ecology of infant development. Infants and mothers constantly engage in dyadic interactions – to which both contribute, and through which each alters the other. Thus, the infant, the mother, and the dyad each have its own character. Mother-infant interactions serve for the developing infant, among many, for emotional regulation – by both heightening affect and regulating distress (Bornstein and Tamis-LeMonda, 2004).

Overall, mother-infant interaction serves multiple cognitive and linguistic, social and emotional functions for the developing infant. Infants acquire social understanding and a sense of intersubjectivity through ongoing, mutually reciprocal interactions with their mothers. A related function of sensitive mother-infant interactions is to pave the way to secure attachment relationships, thereby providing a foundation for healthy social and emotional development (Ainsworth, 1973; Bornstein and Tamis-LeMonda, 2004).

Mother-infant interaction has to a major extent been described in psychological terms. The role of more basic physiological mechanisms have rarely been considered.

1.4.2 Child attachment

Attachment conveys the idea that an infant has acquired a special emotional relationship with those who care for him or her, and experiences pleasure or security in their presence, while expressing anxiety and distress when they are gone. Attachments are established through interaction with care-giving adults, and vary in quality depending upon the nature of the interaction. Although the physical presence of the mother is ameliorative, her psychological availability has been considered to be even more so (Sroufe & Waters, 1977).

Based on his clinical experience and observations of the effect of the forced institutionalization of many children caused by the two world wars in Europe, John Bowlby, who was one of the first to describe the child's attachment, became convinced that early family relationships shape personality development (Bowlby, 1951). In his general theory of relationships, integrating ethology and psychoanalytic perspectives into a concept of attachment, Bowlby proposed that the child's insistence on maintenance of proximity to protective figures was attributed to an attachment behavioral system, which regulates primate safety and survival. This system is equal in importance to those systems guiding feeding and reproduction (Bowlby, 1969; 1973; 1980). Attachment theory holds that each child will become attached to a caregiver, but the quality of a caregiver-child transactions will result in different patterns of attachment.

To examine children's different attachment patterns, Ainsworth et al (1978) developed a research method, called The Strange Situation Test. In this test a child is videotaped in a strange environment, s/he is then introduced to a strange person and experiences two subsequent separations with the mother and two reunions with her. Three basic child's attachment patterns were identified. They were secure (Type B), insecure-avoidant (Type A) and insecure-ambivalent (Type C). Later on Main and Solomon (1990) added a fourth category, disorganized-disoriented (Type D). Secure attachment pattern is related to sensitive, empathic parenting, while insecure-avoidant and ambivalent types correspond to insensitive and unresponsive parenting. While children with either type A or type C patterns of an insecure attachment seem to use a rather coherent and organized way to find access to their attachment figures in times of stress, the type D-attachment children lack a coherent strategy. This latter attachment pattern has been found to be characteristic of infants in high-risk samples, such as in cases of child maltreatment or child abuse.

1.4.3 Parent bonding

The concept of bonding originates from the research in the 1970s of two American pediatricians, Klaus and Kennell. They proposed a theory, which rests on the premise that a mother's bond to her child is a biologically determined process, which unfolds spontaneously in an undisturbed natural environment.

The term *bonding* refers to the emotional ties from parent to child and can be defined as a unique relationship between two people that is specific and endures through time (Kennell and Klaus, 1998). Bonding is characterized by various kinds of behaviors, e.g., in the case of mother-infant bonding, behaviors such as kissing, cuddling and prolonged gazing, showing the mother's affection toward her child.

Central to the theory is the postulate of an early sensitive period ("maternal sensitive period"), occurring shortly after birth, the "period during which the parent's bond to their infant blossom" (Kennell et al, 1975; Klaus and Kennell, 1976). The exact limits of the early sensitive period in human mothers are not clearly defined, and some researches have suggested that it lasts less than 12 hours after birth (Hales et al, 1977), but the others have proposed that it lasts several postpartal days (Klaus and Kennell, 1982).

1.4.4 Basic regulatory mechanisms underlying mother-infant interaction

The mechanisms underlying mother-young interactions have been disclosed using animal models. Initially the role of separation was studied. Later on in the experiments conducted by Hofer and his colleagues (1994) it was shown that there are special "hidden regulators" within the mother-infant interaction, which control infant physiology and behavior. According to Hofer, these regulators comprise three general categories: thermal-metabolic, nutritional-interoceptive and sensorimotor. The vast amount of behavioral and physiological consequences of the infant to separation was then possible to view as a reflection of one single common mechanism, that is the release from regulation, caused by the natural closeness to the mother.

Furthermore, there is a growing body of evidence that social behavior and bonding in animals are influenced by neuroendocrine factors. Thus, oxytocin has been shown to promote maternal behavior and to induce parental bonding to the young in several species, such as rats, sheep, goats, cows and monkeys (Uvnäs-Moberg K, 1996; Keverne & Kendrick, 1994; Pedersen, 2004; Winberg, 2005). Conversely, the role of oxytocin is supported by experimental data showing that administration of an oxytocin antagonist in the postpartal period or by an epidural analgesia during labor, inhibits the expression of maternal behavior and bonding (Levy et al, 1992).

Sensory stimulations are of importance for adaptation of the young after birth. If newborn rats are subjected to extra sensory stimulation by intense maternal licking or by extra brushing, the animals will become less anxious, more social and less easily stressed as adults when compared to animals that have not received such extra sensory stimulation (Liu et al, 1997). Also, blood pressure is lower in these animals (Holst et al, 2002). The extra sensory stimulation given to the pups during the first week has also been shown to induce neurobiological consequences such as an increased amount of oxytocin receptors in the amygdala. This in turn is accompanied by decreased levels of anxiety and increased social behavior, as well as by a reduced activity in the hypothalamic-pituitary-adrenal (HPA) axis and consequently to a reduced release of cortisol in response to stress (Francis et al, 2002).

1.4.5 Influences of post-birth practices on mother-infant behavior

Effects of skin-to-skin contact in the infant

Research starting during the 1980s showed that a baby left skin-to-skin with the mother after birth soon started to search for the mother's breast. In fact, the whole behavioral sequence involving crawling movements, hand-to-mouth activity, hand-massage of the mother's breast was exhibited by newborn infants. Infants were even observed to locate the breast and start to suckle without help from either mother or care staff (Widström et al, 1987; Matthiesen et al, 2001; Ransjö-Arvidson et al, 2001). Although fragments of this behavior can be observed even in separated babies, the complex behavioral sequence seems to be facilitated by the skin-to-skin contact. The infants also prefer to suckle a breast with its natural odor, but not a washed one (Varendi et al, 1994; Varendi and Porter, 2001).

In addition, infants exposed to skin-to-skin contact have been shown to be calm and prone not to cry, compared to infants placed in a cot (Christensson et al, 1992; 1995). Interestingly, newborn infants allowed 15-minutes skin-to-skin contact and suckling during the first half-hour following birth, exhibited less crying behavior 36 hours later (De Chateau, Wiberg, 1977a) than did infants who did not receive the skin-to-skin contact, and at three months they smiled and laughed more and cried less as well (De Chateau, Wiberg, 1977b). It was also shown that infants allowed early skin-to-skin contact with the mother, together with early suckling, recognized own mother's milk odor already at day 4 (Mizuno et al, 2004).

Effects of skin-to-skin contact in the mothers

Mothers, who were allowed skin-to-skin contact with their infant 15 to 60 minutes after birth, exhibited more positive maternal-infant interaction during the following four days if the infant also touched or licked the areola and nipple, compared to mothers, who had only skin-to-skin contact with the infant (Widström et al, 1990). Maternal affectionate behavior (kissing, smiling, talking and looking at the baby) one to three months postpartum was also increased after additional sensory stimulation such as skin-to-skin contact and suckling, compared to the mothers, who were not allowed that (De Chateau, Wiberg, 1977b; Hales et al, 1977; Lozoff et al, 1977). Also, the studies referred to above by Klaus and Kennell point in the same direction.

Role of oxytocin

It is well known that maternal oxytocin is released in response to suckling (Nissen et al, 1996). Oxytocin levels have also been shown to rise during the postpartal period (Nissen et al, 1995). In addition, newborns have been observed to “massage” their mothers’ breast with their hands before suckling, resulting in a rise of maternal oxytocin level during this period. Interestingly, the amount of oxytocin released in the mother is strongly related to the amount of hand movements performed by the baby, which supports the assumption that the release of oxytocin is triggered by the baby’s hand movements (Matthiesen et al, 2001).

Animal experiments demonstrate parallel release of oxytocin into the circulation and into the brain from the PVN. Oxytocin released into the brain is responsible for behavioral adaptation during lactation. In support of this, in a recent animal study it was shown that according to functional magnetic resonance imaging (fMRI), suckling activates brain regions, which are rich in oxytocin receptors (Febo et al, 2005).

Suckling has been shown to decrease anxiety in women and to enhance their tolerance to monotony, and also to increase social desirability after a few days of breastfeeding (Uvnäs-Moberg et al, 1990). These responses correlate with the number of oxytocin pulses in blood samples collected during breastfeeding sessions, probably reflecting oxytocin release in the brain (Nissen et al, 1998). Breastfeeding also induces a significant fall in cortisol level and in blood pressure (Nissen et al, 1996). In addition, breastfeeding has been demonstrated to exert suppression of the cortisol response either to physical, or to mental stress in lactating women (Altemus et al, 1995; Heinrichs et al, 2001).

Women having had a cesarean section have a blunted breastfeeding-related personality profile (Nissen et al, 1998). In addition, their oxytocin release in response to breastfeeding exhibited less pulsatility than in vaginally delivered women (Nissen et al, 1996).

Women having had an elective cesarean section have no labor and, consequently, no release of labor-related oxytocin. Compared to vaginally delivered mothers, these women exhibit significantly lower levels of epinephrine, norepinephrine,

adrenocorticotrophic hormone, cortisol, prolactin and beta-endorphin (Vogl et al, 2006), hormones, which are possibly involved in shaping the maternal adaptations. In women having had an elective cesarean section one hour of early mother-infant skin-to-skin contact (without early suckling) following the completion of surgery, resulted in significantly more caretaking maternal behavior during the first or second postpartal day and when the infant was 1 month old compared to mothers having no skin-to-skin contact (Mc Clellan and Cabianga, 1980). Possibly, early skin-to-skin contact between mother and infant compensated for the lack of hormone release during labor and restored maternal-infant interaction.

Effects of rooming-in

The care practice of rooming-in has been shown to decrease the rate of child neglect and abuse even if there was no early post-birth contact between mother and infant (O'Connor et al, 1980; Siegel et al, 1980). The combination of certain maternity home practices like skin-to-skin mother-infant contact with early suckling after birth, and rooming-in has been shown to result in a significant decrease in such a serious phenomenon as infant abandonment (Lvoff et al, 2000).

1.5 Interventions/design variables

1.5.1 Kangaroo Care

Kangaroo Care (KC) is a form of skin-to-skin practice, initially introduced for care of premature infants. It is a practice mimicking the maternal kangaroo behaviors of keeping the baby kangaroo in her pouch. In KC for human infants, there is close physical skin-to-skin contact between an infant and one of the parents, and the infant is often placed under the parent's clothes.

Many studies have shown the positive effects of KC on both pre-term and full-term infants.

Kangaroo Care has been found to improve thermal regulation, respiration and oxygen saturation, to reduce apnea and bradycardia as well as to accelerate weight gain in premature infants (Fohe et al, 2000; Feldman, 2004). Interestingly, pre-term infants demonstrated increased levels of cholecystokinin (CCK) after nasogastric tube-feeding if it was combined with KC, which indicates vagal nerve activation (Tornhage et al, 1998).

In full-term infants KC has been shown to reduce stress associated with birth and to facilitate self-regulation (Ferber and Makhoul, 2004). Kangaroo Care has been shown to increase pain threshold in both pre-term and full-term infants if it was introduced prior to heel stick as measured by diminished crying behavior and reduced heart rate (Ludington-Hoe et al, 2005; Gray et al, 2000). Interestingly, KC with the fathers caused similar increases in skin temperature of premature babies as did KC with the mothers (Bayer et al, 1996). In addition, infants having skin-to-skin contact with their fathers after cesarean birth exhibited less crying behavior than infants who were placed in a cot (Erlandsson et al, 2007).

In the mothers of the pre-term babies KC during the first days following delivery produced a sense of competence toward the infants, which was stronger if KC started soon after the infant's birth (Tessier et al, 1998).

Massage therapy, also known as tactile/kinesthetic stimulation (Field et al, 1986), has also been demonstrated to induce positive effects on mothers and infants. Thus, it was shown that massage can promote infant mental and physical health (Underdown et al, 2006; Diego et al, 2005), and also to decrease levels of depression in depressed mothers (Field, 1998).

1.5.2 Separation

Separation during early post-birth hours leads to excessive infant crying behavior (Christensson et al, 1992; 1995), associated with increased heart and respiratory rate, which deplete energy reserves (Ludington-Hoe, 1990), and causes higher salivary cortisol, which indicates a stress response (Anderson et al, 1995).

Separation of the mother from her infant in the early postpartum days (nursery care) has been shown to negatively affect milk production and reduce duration of breastfeeding (Elander and Lindberg, 1984).

Long-term separation of infants, e.g., institutionalization in orphanages, resulted in increased incidences of serious infections, delayed neurobehavioral development, and markedly impaired growth due to loss of growth hormone secretion (Kuhn and Shanberg, 1998).

1.5.3 Swaddling

The custom of swaddling is an old one and may have originated in nomadic tribes (Lipton et al, 1965). The technique of swaddling includes wrapping the infant in bands or tightly folding blankets or sheets around the child. The type and tightness of swaddling as well as its duration vary widely. The common belief is that swaddling protects babies from environmental challenges and keeps the baby warm and calm.

Swaddling was an almost universal child-care practice before the 18th century. In the 19th and 20th centuries more "liberal" ideas concerning child rearing started to dominate. Still swaddling is traditional in certain parts of the Middle East and countries of the former Soviet Union including Russia. Nowadays swaddling is regaining popularity in some Western countries, e.g., the Netherlands, mainly because it is presumed that swaddling curbs excessive crying in infants (Van Sleuwen et al, 2007).

Furthermore, it has been found that healthy infants at the age of 24 to 180 days, who are swaddled during sleep have less startles, arouse less, and sleep longer (Gerard et al, 2002). Preterm infants have showed improved neuromuscular development when swaddled (Short et al, 1996), and less physiologic distress, better motor organization, and more self-regulatory ability when swaddled during weighing (Neu and Browne, 1997). In excessively crying infants with cerebral damage, swaddling significantly decreased the

amount of crying compared with massage (Ohgi et al, 2004). Swaddling during heel sticks allowed premature infants to return to their baseline heart rate and oxygen saturation measures more quickly (Huang et al, 2004) and could sooth them after pain (Campos, 1989).

Detrimental effects of swaddling have been shown in respect to the development of hip dysplasia, when the child is swaddled in extension and adduction (Kutlu et al, 1992); for the increased risk of overheating (Manaseki, 1993); and of sudden infant death syndrome, if the swaddled infant is placed prone (Ponsonby et al, 1993). A four times higher incidence of respiratory infections (radiologically confirmed pneumonia and upper respiratory airway infections) was related to swaddling of infants if they were swaddled for at least 3 months (Yardakok et al, 1990). Kahn et al (1992) have found indications for cardiorespiratory compromise associated with swaddling, especially tight swaddling.

2 AIMS

This thesis aims to explore the role of closeness versus separation on infant and maternal temperature adaptation, breastfeeding outcome and mother-child interaction. In addition, we aimed to study a potential influence of swaddling on all outcomes measured.

The specific aims are:

- To explore the development of skin temperature in infants and their mothers and their relation to different labor ward practices (skin-to-skin mother-infant contact, contact of dressed infant with the mother or short-term mother-infant separation) during the immediate postpartal period.
- To investigate how the above mentioned labor ward practices, maternity ward practices (rooming-in or nursery care), and type of infants' apparel (swaddling or clothes) affect breastfeeding parameters (amount of ingested milk, frequency of feeds, duration of feeds, volume of supplements) and influence recovery of neonatal weight loss.
- To study how early suckling, mother's perception of physiological breast engorgement and maternal mood (feeling of being "low/blue") affect milk production in primi- and multiparous mothers.
- To study the influence of mother-infant closeness versus separation after birth and of swaddling on maternal-infant interaction one year later as measured by Parent-Child Early Relational Assessment (PCERA).

3 MATERIAL AND METHODS

The present study was performed in St. Petersburg, data collection began in January 1995 and was completed at the end of 1998. The mother-infant dyads were recruited from Maternity Home 13, which is a freestanding maternity home with approximately 2100-2300 deliveries per year.

This study has a randomized design and a longitudinal approach. At the delivery ward data collection started 30 minutes after birth and went on for 90 minutes. During the following four days at the maternity ward data were collected daily. After discharge mothers and babies came back to the maternity home for seven follow-up visits during the children's first year of life. When the children were one year of age, the data collection ended with videotaped maternal-child interactions at the *Lecotec* in St. Petersburg.

3.1 Participants

Recruitment of participants took place on regular weekdays during daytime hours.

One hundred seventy-six (176) mother-infant dyads were included in the study.

Inclusion criteria were: healthy mothers, free of chronic diseases, with full-term uncomplicated pregnancies and a singleton baby born normally in head presentation. The mothers should intend to breastfeed their babies and be willing to be assigned to any of the suggested post-birth practices according to the randomization, described to them during recruitment.

The infant should be healthy, have no congenital malformations, not be "small for date" and have an Apgar score of eight or more at five minutes after birth.

Exclusion criteria were: oxytocin infusion during labor and analgesia like epidural, paracervical or pudendal block.

3.2 Design

The experimental design used in this study was a "*Factorial design*" with two factors. The first factor was "*Baby's location*," which considered where the baby was located according to one of four location combinations (*Location I-IV*) specified below. The second factor was "*Apparel*" and assessed whether the baby was swaddled (*Apparel 1*) or dressed in clothes (*Apparel 2*). The two factors combined gave in total 4 x 2 treatment combinations (Table 1).

Location I – the "Skin-to-skin group" – comprised of babies lying skin-to-skin on their mother's chest 25-120 minutes after birth, while still at the delivery ward. After this period they were swaddled (*Apparel 1*) or dressed in clothes (*Apparel 2*) and taken to the maternity ward for rooming-in with their mothers. These infants breastfed on demand.

Location II – the "Mother's arms group" – comprised of babies who were swaddled (*Apparel 1*) or dressed in clothes (*Apparel 2*) prior to being placed on the mother's chest

25-120 minutes after birth. These infants were then taken to the maternity ward for rooming-in with their mothers and breastfed on demand.

Location III – the “Nursery group” – comprised of babies who were swaddled (*Apparel 1*) or dressed in clothes (*Apparel 2*) but kept in a cot in the labor ward nursery 25-120 minutes after birth. These infants were also kept in a cot in the nursery at the maternity ward except for when they were taken into the mother’s room for breastfeeding seven times per day.

Location IV – the “Reunion group” – comprised of babies who were swaddled (*Apparel 1*) or dressed in clothes (*Apparel 2*) and kept in a cot in the labor ward nursery 25-120 minutes after birth. These infants were then taken to the maternity ward for rooming-in with their mothers and breastfed on demand.

Table 1. *Experimental design.*

Groups	Delivery ward		Maternity ward	
	<i>Location</i>	<i>Apparel</i>	<i>Location</i>	<i>Apparel</i>
I “Skin-to-skin group”	Skin-to-skin	-	Rooming-in	Swaddling
	Skin-to-skin	-	Rooming-in	Clothes
II “Mother’s arms group”	Mother’s arms	Swaddling	Rooming-in	Swaddling
	Mother’s arms	Clothes	Rooming-in	Clothes
III “Nursery group”	Nursery	Swaddling	Nursery	Swaddling
	Nursery	Clothes	Nursery	Clothes
IV “Reunion group”	Nursery	Swaddling	Rooming-in	Swaddling
	Nursery	Clothes	Rooming-in	Clothes

3.2.1 Pre-prepared randomization table

A table of allocation sequence was conducted in advance of the trial. For the purpose of balancing the probable influence of time and parity, the future mother-infant pairs were grouped in sets of eight consecutive dyads, separately for primiparas and multiparas. The randomization to the eight treatment combinations was performed in blocks of eight mothers independently of the other blocks. In total there were 11 blocks of eight primiparas and 11 blocks of eight multiparas. Opaque envelopes containing the information on group assignment were sealed and numbered in the order they should be used: primi- 1, 2, 3... 88, and multi- 1, 2, 3... 88. Both the researchers and the recruited women were blind to the task.

3.2.2 Some comments to the design and randomization

The balanced and randomized design of this study allowed data to be analyzed as comprising different numbers of treatment groups. Since the randomization was stratified by parity, separate analyses for primiparas and multiparas were also possible.

Since early suckling could occur in the groups where mothers and infants were kept together after birth, it was possible to discriminate the effect of the combination of location and early suckling from the effect of location *per se*, i.e., in those babies who did not suckle.

Thus, in the *Skin-to-skin group* we were able to study the pure effects of skin-to-skin contact on different parameters measured, as well as the effect of skin-to-skin contact in combination with early suckling.

In the *Mother's arms group*, where the infants were dressed, it was possible to study the effects of early suckling *per se*, i.e., without skin-to-skin contact.

The *Nursery group* allowed us to study the effects of separation of mother and infant in both the first two hours after birth and later, since the infants were not rooming-in with their mothers during the maternity stay.

The *Reunion group* made it possible to understand whether reuniting of mothers and infants can compensate for effects of their separation from each other during the first two hours after birth.

3.3 Ethical considerations

We met some ethical dilemmas during the preparation of the study design. One of them was the question of whether to include two more groups, where mothers and babies would be close to each other for two hours after birth either in skin-to-skin contact or with the baby dressed in the mother's arms and then be separated at the maternity ward. It could give us more knowledge about the potency of immediate mother-infant contact after birth in respect of a stable positive impact, thus, to understand if separation later during the maternity stay would reverse the anticipated positive effect of closeness between mother and baby. However, we considered this tempting addition to the study design to be unethical, and the groups were not included in the final version.

Another example of our "ethical hesitations" was to have a subgroup of swaddled babies after their skin-to-skin contact with their mothers, i.e., first to give the baby the highest level of freedom, and then to take it away. Thus, we tested this procedure on mothers and babies in a pilot study, and we found out that mothers accepted it easily. Accordingly, this subgroup was included in the design.

Prior to conducting the study, approval was granted by the Ethics Committee of the Karolinska Institutet, Stockholm, Sweden and the Health Care Division of the Mayor-Council of St. Petersburg, Russia. All mothers were informed about the study and gave their signed consent.

3.4 Background variables

All study infants were from two-parent families. All pregnancies were wished for, but not a single one was planned. All multiparous mothers had previous breastfeeding experience. Some more background information is presented in Table 2. Smoking habits were also assessed but not reported in the Table since only six mothers, evenly distributed between the four experimental groups, smoked (3-10 cigarettes per day).

Table 2. *Clinical characteristics of the mothers and their infants in the four experimental groups, means and (SD).*

Group	Mother's age (years)	Mother's education (years)	Duration of labor (hours)	Gestational age (weeks)	Infants' birth weight (grams)	Gender, girls (number)
I (n=44)	26.4 (5.7)	14.1 (2.3)	8.7 (2.9)	39.4 (1.0)	3549.4 (417.7)	19
II (n=44)	27.3 (6.1)	13.7 (2.6)	8.4 (3.3)	39.5 (0.9)	3551.8 (427.8)	23
III (n=44)	27.6 (5.1)	13.9 (2.8)	7.5 (3.1)	39.5 (0.8)	3483.9 (370.6)	19
IV (n=44)	26.9 (5.4)	13.9 (2.2)	8.4 (3.5)	39.9 (1.0)	3470.7 (598.0)	17

3.5 Procedure

Five minutes after the infant was born and the second Apgar scoring was taken, and the condition of the baby and mother was assessed as normal, the envelope (with the lowest number) coinciding with parity and with information on group assignment was opened. During the approximate first 20 minutes after birth, all infants were subjected to identical compulsory Russian labor ward routines (see description below). After that the infants were treated according to the randomization grouping.

3.5.1 Routines at the delivery and maternity wards

According to the Russian routines at the time of the study, both a midwife and an obstetrician assisted the mothers in labor. The presence of a pediatrician at the last labor stage was also compulsory. All mothers received intravenous administration of methylegometrin in connection with birth of the babies' head, and all mothers were lying on their backs during the first two hours after giving birth. The umbilical cord was clamped 10 to 15 seconds after birth and all babies were immediately put on an examination table with a radiant heater above. The infants were carefully dried, wrapped in a dry sheet and left on the examination table while the attending midwife took care of the mother. The infants were then washed under tap water, dried and cared for by a midwife according to hospital routines which included weighing, taking anthropometrical measurements and dripping of 30% Sulfacyl Natrium into the babies conjunctivae for prophylaxis of gonococcal ophthalmia. To prevent infection Xeroform powder was applied on the umbilical cord stump and 1% Iodine solution was applied on the baby's skin folds. Babies randomized to the Skin-to-skin group were then left on the examination table covered with a blanket. The babies in experimental groups II-IV were dressed

according to the randomization and left on the examination table. After a mean time of 22 minutes (range 20-25 minutes) after birth the babies were brought to their mothers or to the labour ward nursery. Babies dressed in baby clothes or those who were naked were put between the mothers' breasts in a prone position. Swaddled babies were put between the mothers' breasts on their side to secure free airways.

The hospital routine to put packages of ice on the mother's abdomen in order to contract uterus to minimize maternal bleeding was substituted with manually induced contraction of the uterus because in a pilot study ice packages had been observed to disturb a baby and to jeopardize measurements of the baby's skin temperature.

Provided there was no bleeding the suturing of vaginal ruptures and/or episiotomies was postponed in the mothers until two hours after delivery.

After that the mothers were brought to the maternity ward, where they shared rooms with one, two or three mothers. A usual duration of the stay at the maternity ward was on average five days.

Before the infants were brought to the maternity ward a pediatrician examined them.

After that, according to the randomization, infants were brought either to their mother's room for 24-hour rooming-in, or to the maternity ward nursery to be kept there for the rest of the maternity stay, except for breastfeeds. Breastfeeds were scheduled to seven per 24 hours, were limited in time to 30 minutes each, and took place in the mother's rooms, to which infants were transported on small gurneys. Number of infants per room in the nursery did not exceed ten.

In addition, it should be noted that the Ministry of Health in Moscow sets rules for some treatments in maternity homes in Russia. For instance, to avoid hospital infections all babies were subjected to different antiseptic treatments immediately after birth (see above), pacifiers were forbidden during the maternity stay, and fathers or visitors were not allowed in the maternity homes at the time of the study.

3.5.2 Infant clothes

Infants who were randomized to wear clothes were dressed in identical sets of clothes that were specially brought from Sweden for the purpose of the study. Each set consisted of a loose cotton shirt with long sleeves and leggings, woollen socks and cap. Disposable diapers were used.

3.5.3 Swaddling

According to the traditional Russian hospital practice of swaddling, six cotton cloths were used for each infant. Two cloths were used as diapers, and one to bandage the infant's legs. The next cloth was used to wrap the infant's arms close to the body and to serve as an extra layer over the infant's body and legs. After this, one more cloth was drawn from behind the head in order to cover the forehead and ended with a crosswise fold over the thorax. The last cloth was used as an inner layer under a blanket and together these were tightly wrapped around the body of the infant (Fig. 1).

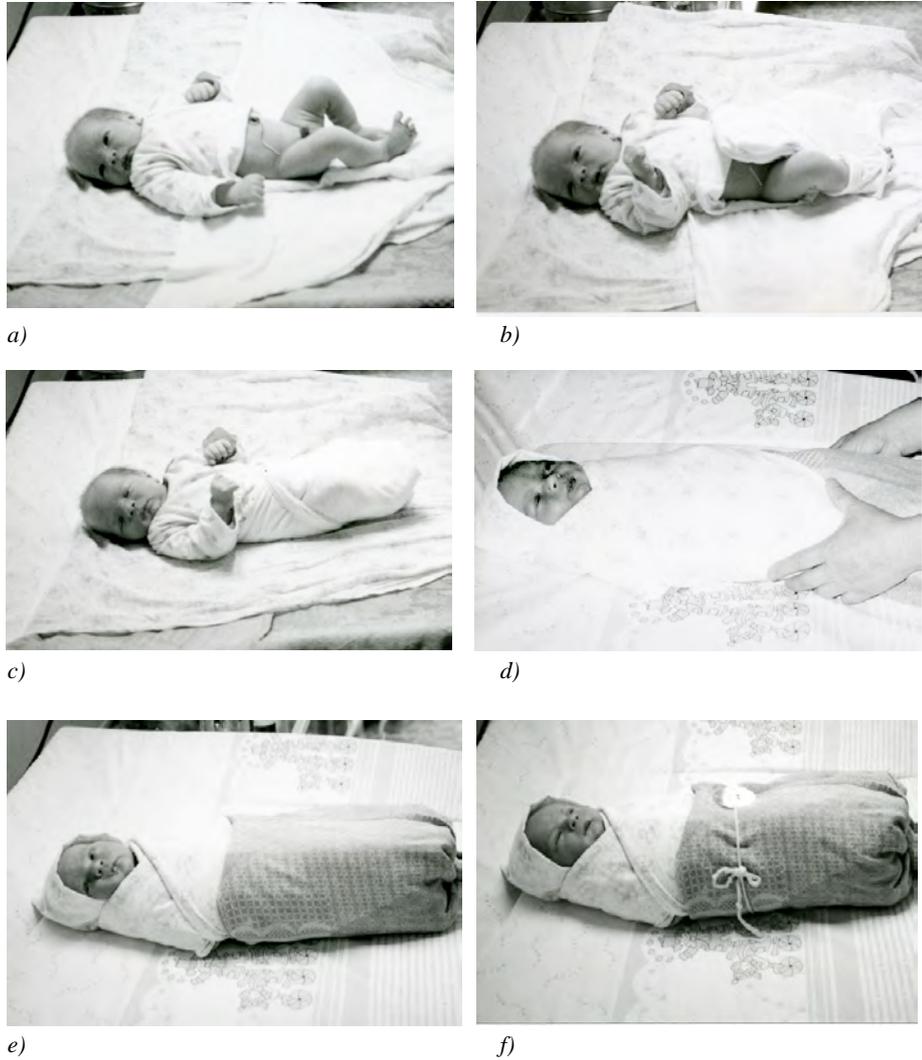


Fig. 1. Stages of swaddling (a-f). At the maternity- but not at a labor ward a loose cotton shirt is put on a baby. Note, that after swaddling of a head, baby can follow an objects only by eyes.

3.6 Final number of participants and dropouts

A certain number of participants withdrew or was excluded from the study during its different stages. A detailed description is presented in Fig. 2.

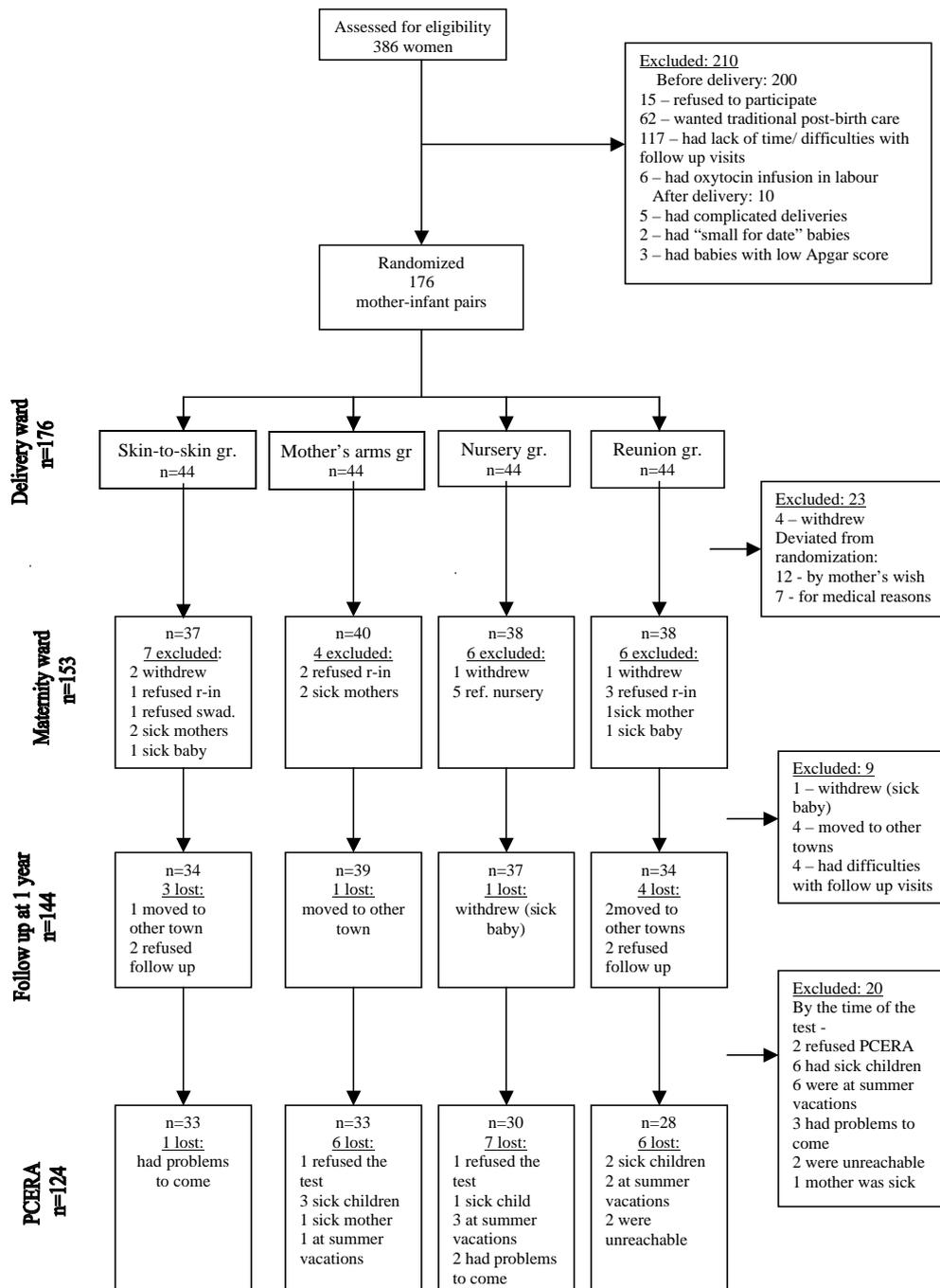


Fig. 2. Flow diagram

3.7 Data collection and methods

3.7.1 Research teams

Prior to the start of the data collection in Maternity Home 13 in St. Petersburg, members of the Russian and Swedish research teams met both in Sweden and in Russia to decide on research methods and tools. The teams later tested the suggested methods on newly delivered mothers in a pilot study in Russia and made revisions if necessary.

A local research team was created in St. Petersburg especially for the purpose of data collection. It consisted of six persons: one pediatrician from Maternity Home 13, three pediatricians from the St. Petersburg Pediatric Medical Academy and two psychologists from the Psychological Faculty of the St. Petersburg State University. One of the pediatricians, the study coordinator (KB), was responsible for finding members of the team, for organizing the whole practical research process, and for writing a short manual to describe how data should be collected. She trained the members of the local team accordingly and participated in each step of the data collection herself.

Two of the pediatricians were responsible for recruiting mothers-to-be, for data collection at the delivery ward during the first two hours after birth as well as later on at the maternity ward. They also assisted with practical details during the follow-up visits. To increase the reliability in data collection at the delivery ward, one of these two pediatricians was assigned to always collect maternal data and the other one to always collect infant data. They had separate protocols to fill in, even if mother and infant were kept together. To synchronize the time of measurements, both persons were equipped with a stopwatch, which were switched on simultaneously in connection with the birth of the infant.

The fourth pediatrician (neonatologist-neurologist) was responsible for the infant's daily examination during the maternity stay and for the examinations during the follow-up visits as well as for assessing psycho-neurological status and anthropometrical measurements (data not described in the papers of this thesis).

The coordinator was also the person who telephoned the mothers after their discharge to ask them to come for follow-ups, and to fix the closest to exact date day and time of the visit (at 1, 2, 3, 4, 6, 9 and 12 months after birth, totalling seven times during the following year).

One of the two involved psychologists was responsible for performing a video filming of mothers and children according to the Parent-Child Early Relational Assessment (PCERA) when the children were one year old.

3.7.2 Registration of temperature

Maternal temperature (Paper I)

During the 30 to 120 minutes after delivery, the mother's axillar and breast temperature was measured repeatedly every 15 minutes for 90 minutes (seven times). Axillar temperature was measured with a digital clinical thermometer (model C31, Terumo Corporation, Tokyo, Japan, accuracy $\pm 0.1^\circ \text{C}$) and the breast temperature was measured with an electronic thermometer THERM 2283-2 (AHLBORN Mess – und

Regulungstechnik, Holzkirchen, Germany, accuracy $\pm 0.1^\circ\text{C}$). The probe for recording of the breast temperature was 3 mm in diameter and was attached with one layer of thick plaster (woven material) exactly above the areola in a 12-o'clock position to the breast, which was assumed not to be suckled. The assumption was based on the observation of the baby's preference for positioning his/her head when put prone to the mother's chest. In a few cases when the baby unexpectedly chose that breast for suckling, the probe was moved to the other breast.

Infant temperature (Papers I and II)

After the baby had been subjected to the compulsory labor ward routines, approximately at 15 minutes after birth four sensors, connected to an electronic thermometer (Exacon 8700, probe SW-4, Exacon Scientific Instrument, Taastrup, Denmark, accuracy $\pm 0.1^\circ\text{C}$) were attached to the infant, one in the left axilla, one interscapular, one on the outside of the left thigh and one on the inner part of the left foot. The sensors had a diameter of 8 mm and were attached to the skin by two layers of thick plaster (woven material). Following this, according to the randomized group assignment, infants were tightly swaddled or dressed in clothes, or covered with a sheet and blanket for later skin-to-skin contact with their mothers. All infants then remained on the examination table under the radiant heater for a short period of time (approximately five minutes or less) before being placed according to the randomization.

At a mean time of 22 minutes after birth the infants were either placed on their mothers' chest or brought to the nursery and put in a cot. Mothers of the babies who were kept on their chest either in skin-to-skin contact or dressed, had no shirt on, but were covered with a blanket together with the baby. Mothers of the babies who were kept in the nursery had their shirt on and were also covered with a blanket. The temperature equipment was tested at 25 minutes postpartum, and the first temperature registration to be included in the study was performed at 30 minutes after birth. The measurements were then repeated every 15 minutes for 90 minutes (seven times) at the same time points as the mother's temperature was measured.

In addition, the baby's foot temperature was measured when the baby was three hours of age and at a mean age of 23 hours (range 17-28 hours), and then each morning between 11 and 12 a.m. (n=73) during the remaining days of the maternity stay.

Air temperature (Papers I and II)

The air temperature in the delivery room and in the nursery was registered by an electronic thermometer THERM 2283-2 (AHLBORN Mess – und Regelungstechnik, Holzkirchen, Germany, accuracy $\pm 0.1^\circ\text{C}$). During the following days at the maternity ward the air temperature was measured by the same thermometer both in the mother's room and in the nursery in connection with the examination of the babies' foot temperature.

	30	60	90	120min	3h	1	2	3	4days
T ^o mother:									
- axilla	x	x	x	x	x	x	x		
- breast	x	x	x	x	x	x	x		
T ^o infant									
- axilla	x	x	x	x	x	x	x		
- back	x	x	x	x	x	x	x		
- thigh	x	x	x	x	x	x	x		
- foot	x	x	x	x	x	x	x	x	x

Fig. 3. The figure shows time after delivery and site of temperature measurements in mothers and infants.

3.7.3 Early suckling

Early suckling (*Papers II, III, IV, V*). In the Skin-to-skin and Mother’s arms groups where the babies stayed with their mothers at the delivery ward, all mothers wished to breastfeed and were supported by the staff so that babies could start suckling. Suckling was noted if the baby attached to the breast and suckled with distinct sucking movements.

3.7.4 Breastfeeding variables

At the maternity ward the mothers filled in a diary for each day (if the baby was born after noon, this day was defined as “day 0” and, accordingly, no measurements were performed).

Breast engorgement (*Paper IV*) was estimated by the mothers in the evening each day (at day one to four) as their perception of tension/hardness in the breasts as “none,” “slight” or “marked.”

Number of breastfeeds (*Papers III, IV*) were marked per 24 hours at day one to four.

Amount of milk ingested (*Papers III, IV*). On day 4 (i.e., in the interval between 72 and 96 hours after delivery) the amount of breast milk ingested by the baby was measured as the difference in weight before and after each feeding. The time of the beginning of measuring of milk intake (corresponding to 72 hours after delivery) was marked in a special protocol. Accordingly, the measuring should be finished round the clock, that corresponded to 96 hours after delivery. If the breastfeeding session began before 72 hours postpartum and was finished after 72 hours, the breastfeed was not taken into consideration. In case a suckling episode started before 96 hours postpartum, but finished after this time, it was included in the calculation. Several scales of the model Electronic scales, Tanita 1581, Tanita Corporation, Japan (accuracy ± 1 g), were specially purchased for the study. Each mother who was rooming-in with her baby was educated by the staff about how to weigh the baby on the scales brought to her room and was once checked for precision when weighing the baby. The mothers filled in the infant’s weight before and

after every breastfeed in the protocol. In advance of the weighing they received a filled-in example of such a protocol.

The nurses weighed the babies kept in the nursery on scales of the same model.

The volume of supplemental formula and/or glucose (*Papers III, IV*) was measured on day 4 and noted. The rooming-in infants were supplemented by their mothers if the mothers wished to. The infants from the Nursery group were supplemented by the nurses only in cases when the infants seemed to be crying of hunger.

Duration of each breastfeed (*Paper III*) on day 4 was also estimated and noted.

3.7.5 Maternity blues

Feeling “low/blue” (*Paper IV*). The English expression feeling “low/blue” was translated into Russian. In order to check the accuracy of the terminology, later on it was retranslated by another person into English, and it was found out that there was no misunderstanding.

Each evening during the maternity stay the mothers had to fill in their perception of “feeling low/blue” during day time by a mark on a 100 mm long horizontal Visual Analogue Scale (VAS) with the end points “not at all” and “as much as I can imagine.”

A pediatrician from the research team visited the mothers daily to offer them help if something was unclear about how to fill in the diary and protocols.

3.7.6 Anthropometrical measurements

Baby’s birth weight (*Paper III*) was measured at the delivery ward.

Baby’s weight during the hospital stay (*Paper III*) was measured daily during the baby’s examination by the pediatrician from the research team at 11-12 a.m.

3.7.7. “Nearly exclusive” breastfeeding

“Nearly exclusive” breastfeeding (*Papers IV, V*) was assessed over a year-long period at specific follow-up times at the Maternity Home (at 1, 2, 3, 4, 6, 9 and 12 months after birth). During the follow-up visits the same pediatrician examined the babies, and health and anthropometrical measurements were taken (data not shown in this thesis). Mothers were asked about breastfeeding and whether or not they used any supplementation. Exclusive breastfeeding, i.e., breastfeeding without any supplementation, is not a common practice in Russia, and thus could not be registered in this study. Instead, the expression used in this study was “*nearly exclusive*” *breastfeeding* which was defined as breastfeeding including *irregular* supplementation of juices or solids in a daily volume of 30 ml or less or formula in a daily volume of 100 ml or less (Vorontsov et al, 1998).

To test the validity of a five minutes long videotaping according to the PCERA, Kemppinen et al. (2005) compared mother-infant observations one hour/week during one year (40 hours) in the families' homes with a five minutes video recording one year after birth using the PCERA Free play as measure. They found that 40 hours of observations during one year and observations of a five minutes video recordings gave rise to very similar information about mother-infant interactions.

The video recording was carried out at the Lecotec ("Library of Toys") in St. Petersburg. The two Russian psychologists (RM and VI), performing the PCERA in this study, had a vast experience and a common ground in assessing mother-child behavior in general. In addition they were trained *together* in Stockholm by an authorized trainer in the PCERA. The video recording was performed by the same psychologist (VI) who was unaware of the child's group affiliation. In the first task scored in this study, the Structured task, the psychologist requested the mother to invite her child to play with a standard set of toys such as blocks, two cups, a toy lamb and a picture book for five minutes. In the second task, Free play, the mother was offered a wide range of toys to choose from for playing with her child during five minutes.

Scoring of the PCERA

The PCERA consists of 65 variables totally: 29 for the mother, 28 for the child and eight for the dyad. Each variable is scored on a 5-point Likert scale. Values 1 and 2 indicate areas of concern, 3 an area of some concern and 4 and 5 areas of strength. Thus, the PCERA manual gives for each variable a comprehensive description of each value (1-5) in terms of frequency, duration and intensity. The two Russian psychologists showed a high inter-rater reliability score of 0.99 (on 20 cases with 65 items each their score differed on six items). After establishing the high inter-rater reliability, only one of the two psychologists (VI), scored the remaining 104 videos.

Analyses of the PCERA

The selection of variables to be used in the study was based on a report given by R. Clark at the World Association for Infant Mental Health (WAIMH) 7th World Congress in Montreal, 2000. Thus, for the present study we selected 22 variables related to the mother, distributed on three subscales according to the factorial validity of the PCERA (Clark, 1985): Maternal positive affective involvement and responsiveness (11 variables); Maternal negative affect and behavior (five variables) and Maternal insensitivity, inconsistency and anxiety (eight variables). Two variables – amount of verbalization and structuring and mediating the environment – are used in two of the subscales. Related to the child, 20 variables were selected and distributed on three subscales: Child positive affect, communicative and social skills (eight variables), Child dysregulation and irritability (six variables) and Child quality of play, interest and attention skills (10 variables). Three variables – apathetic, withdrawn mood, self-regulation and communicative competence and readability – are used in two of the subscales. The dyadic eight variables were analyzed by two subscales: Dyadic mutuality and reciprocity (four variables) and Dyadic disorganization and tension (five variables). One variable was used in both scales. It is important to note that the variables were scored in such a way that the

higher the score, the better the outcome, even in the negatively formulated composite variables (e.g., “Maternal insensitivity, inconsistency and anxiety”).

3.8 Statistical methods

The statistics were computed using StatView software (SAS Institute Inc., 1998). Analysis of variance (ANOVA or MANOVA) was used to compare the treatment groups, with Fisher’s Protected Least Significant Difference (PLSD) as post hoc analyses. Kruskal-Wallis test was used instead of ANOVA when comparing groups with few observations and/or risk of non-normality in distributions. Repeated measures ANOVA were used to analyze data over time, and two-way ANOVA was used to explore the influence of swaddling.

Simple and multiple linear regressions were also used.

The significance level was set at $p \leq 0.05$.

Data were treated with “per protocol analyses” and not according to “intention to treat” as the present study has an explanatory, rather than a pragmatic aim (Hollis and Campbell, 1999).

3.9 Sample size considerations

Sample size was originally determined by using experiences from previous studies basing power calculations on variation obtained in these studies.

4 Results

In the present study we explored the influence of several types of postpartal mother-infant care practices (“design variables”) on three different outcomes. The first outcome studied was the postpartal temperature development, both in infants and mothers, their potential relations and reciprocal influences. The second outcome was breastfeeding performance, which was evaluated by mother’s milk production (measured as milk amount ingested by infants). The third outcome studied was maternal-infant interaction one year after birth.

The design variables used comprised different combinations of labor- and maternity ward practices: skin-to-skin mother-infant contact, mothers holding dressed babies in their arms or short-term separation after birth – in the labor ward; nursery care of the babies or rooming-in with the mothers – in the maternity ward. Of special interest was to study the effect of tight swaddling, an ancient type of infant’s apparel, still existing in many parts of the world.

In this section only the most important results will be presented. For a more detailed description of the results the reader is advised to read the articles referred to.

4.1 Development of skin temperature in newborn infants and newly-delivered mothers at 30 to 120 minutes postpartum (Papers I and II)

Since only the practices received at the delivery ward were of interest with regard to temperature measurements, the data were analyzed as comprising three groups, Skin-to-skin (I), Mother’s arms (II) and Nursery group. In this case the Nursery group consisted of mother-infant dyads from the original groups III (Nursery group) and IV (Reunion group), as all of them experienced a short-term separation of 120 minutes following birth (see Methods section). In the part of the study, in which infant foot temperature was followed during the entire stay at the maternity ward, the four original experimental groups were used.

Air temperature was measured in connection with post-birth mother-infant care and during the following days at the time of infant’s foot temperature measurement. There was no significant difference between mean air temperature in the delivery room (20.6° C, SD =1.7) and the labor ward nursery (20.8° C, SD =2.3), as well as later on between the mother’s room (19.9° C, SD=1.5) compared to the maternity ward nursery (20.1° C, SD=1.5).

4.1.1 Maternal temperature (Paper I)

Temperature level

In the present study both maternal axillar and breast temperature showed a small but significant rise during the 90-minute long observation period from 30 to 120 minutes postpartum. The rise of temperature was not influenced by group assignment, since it occurred to the same extent in those mothers having their babies in close contact (Skin-to-skin and Mother's arms groups) as in those having their babies in the nursery (Fig. 5).

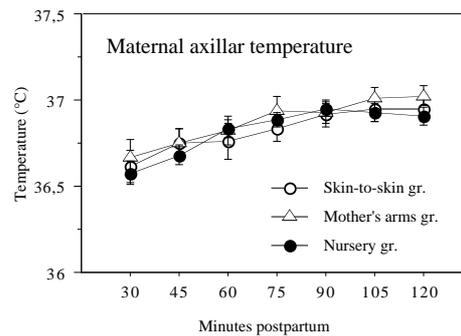


Fig. 5. Maternal axillar temperature in the three experimental groups (means and SE).

In contrast, parity was shown to influence temperature, and both axillar and breast temperature rise was significantly higher in multiparas than in primiparas ($p = 0.0430$ and $p = 0.0143$, respectively).

Temperature variation

Breast temperature varied more in mothers belonging to the Skin-to-skin group and the Mother's arms group than in mothers from the Nursery group despite a similar rise of temperature (Fig. 6).

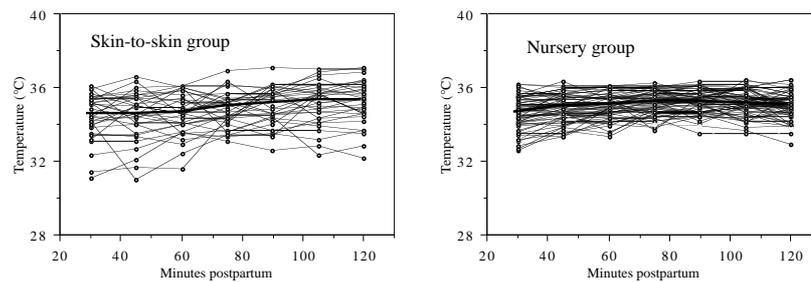


Fig. 6. Individual breast temperature curves for mothers belonging to the Skin-to-skin group and the Nursery group. Curve in bold represents mean temperature in each group.

The mothers in the Skin-to-skin group and the Mother's arms group had a significantly larger variation in their temperature than the mothers in the Nursery group ($p < 0.0001$ and $p = 0.0109$, respectively). Within the Mother's arms group, only those mothers having been exposed to early suckling had significantly increased variation in their temperature compared to the mothers in the Nursery group ($p = 0.0002$) (Fig. 7).

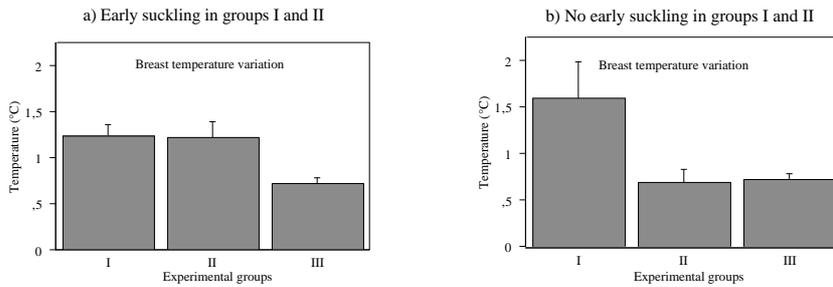


Fig. 7. Bar plots for the variation in the maternal breast temperature from 30 to 120 minutes postpartum, as measured by interquartile ranges (°C) in the three experimental groups (means and SE). (a) Mothers from the Skin-to-skin group (I) and the Mother's arms group (II), whose infants succeeded in suckling and all mothers from the Nursery group (III). (b) Mothers from the Skin-to-skin group (I) and the Mother's arms group (II), whose infants failed in suckling and all mothers from the Nursery group (III).

4.1.2 Infant temperature (Paper II)

Infant skin temperatures developed differently in the three groups exposed to different ward practices. Skin temperature increased the most in the Skin-to-skin group, was intermediate in the Mother's arms group and was the lowest in the Nursery group during the 90 minutes observation period from 30 to 120 minutes after birth.

These differences in skin temperature were much more clearly expressed in distal parts of the body, e.g., in the foot. In the Skin-to-skin group most of the change occurred during the first 30 minutes, while the rise of the foot temperature in the Mother's arms group was delayed and started to increase after 60 minutes of the observation period, which corresponds to 90 minutes after birth (Fig. 8). In contrast, in the Nursery group foot temperature decreased significantly. This effect was more pronounced in the swaddled babies ($p = 0.057$).

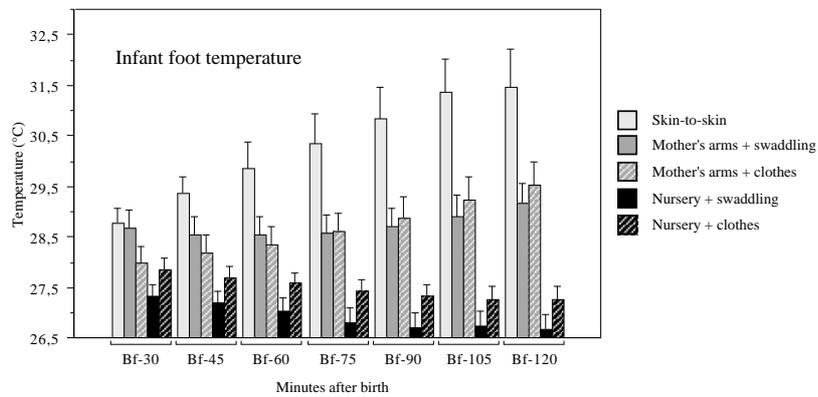


Fig. 8. Bar plot (means and SE) presents development of mean foot temperatures after birth in infants from the Skin-to-skin group and swaddled or dressed infants from the Mother's arms and the Nursery groups.

The foot temperature in the Skin-to-skin group remained constantly high during the entire maternity stay (4-5 days), while the foot temperature in the other groups was still significantly lower than in the Skin-to-skin group at 23 hours after birth ($p = 0.0095$). Thereafter it gradually rose to reach the same level within two days (Fig. 9).

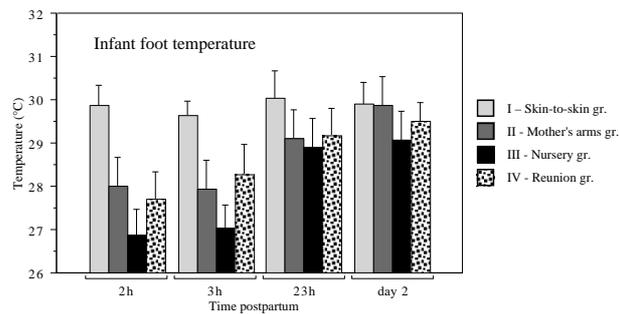


Fig. 9. Bar plot (means and SE) presents development of mean foot temperatures from 2h to 2 days after birth in infants from the four original experimental groups. There was no significant difference over time in overall mean foot temperatures between infants from the Nursery and Reunion groups ($p = 0.31$). The infants from the Nursery group were separated from their mothers for the entire maternity stay, whereas the infants from the Reunion group were separated only for 2h following birth.

4.1.3 Relation between maternal and infant temperatures (Paper I)

In the Skin-to-skin group and the Mother's arms group there was a significant positive correlation between maternal axillar temperature and the temperature of the axilla and foot in infants 120 minutes after birth. No such significant correlations were found in the Nursery group (Fig. 10 a, b).

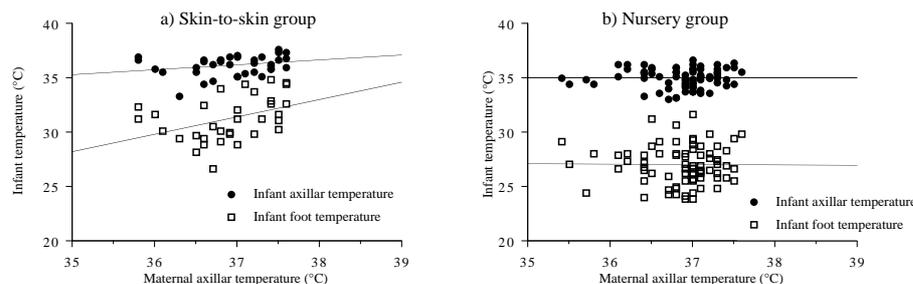


Fig. 10. Bivariate descriptive regression plots for the maternal axillar temperature and the infant axillar and foot temperature 120 minutes postpartum in the Skin-to-skin (a) and the Nursery (b) groups.

An increase of maternal axillar temperature by 1° C corresponded to an increase by 1° C in the infant's axillar temperature, and by 2° C in the infant's foot temperature (Fig. 10 a). In addition, for a given level of maternal axillar temperature, infants belonging to the Skin-to-skin group had on average nearly 2° C higher foot temperature than those belonging to the Mother's arms group.

4.2 Early lactation performance (Papers III and IV)

4.2.1 Influence of labor- and maternity ward practices on breastfeeding outcome

The *labor* ward practices used in the design of the present study (skin-to-skin contact, clothes or swaddling, short term separation of 120 min) did not influence the breastfeeding outcome on day 4 after birth, i.e., amount of ingested milk, number of breastfeeds, time of breastfeeds, and amount of ingested supplements.

The procedure of *early suckling* (suckling within the first two hours postpartum) in the Skin-to-skin and the Mother's arms groups, i.e., the two groups that were not separated at the labor ward, was associated with increased milk ingestion/production in infants succeeded in early suckling compared to those who did not, on the 4th day after birth ($p = 0.0197$ and $p = 0.0148$, respectively) (Fig. 11).

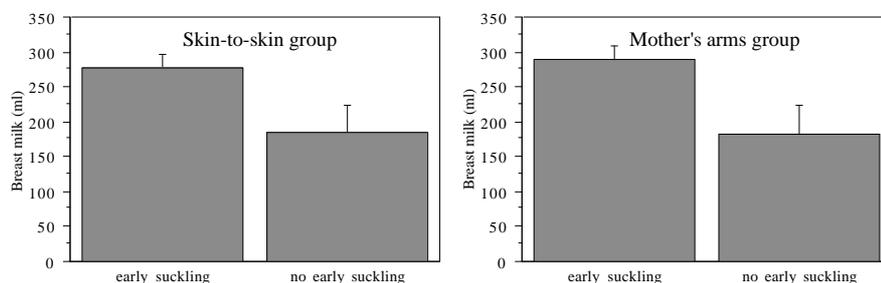


Fig. 11. Bar plots (means and SE) for mean amount of breast-milk on day 4, ingested by infants who succeeded in early suckling within two hours after birth or not. In the Skin-to-skin group the amount of milk was 277 ml (SD=90) and 184 ml (SD=121), respectively, and in the Mother's arms group it was 289 ml (SD=105) and 183 ml (SD=122), respectively.

In addition, infants who succeeded in early suckling at the labor ward demonstrated a quicker recovery of the neonatal weight loss, which reached significance in the Mother's arms group ($p = 0.0148$) (Fig. 12) (unpublished data).

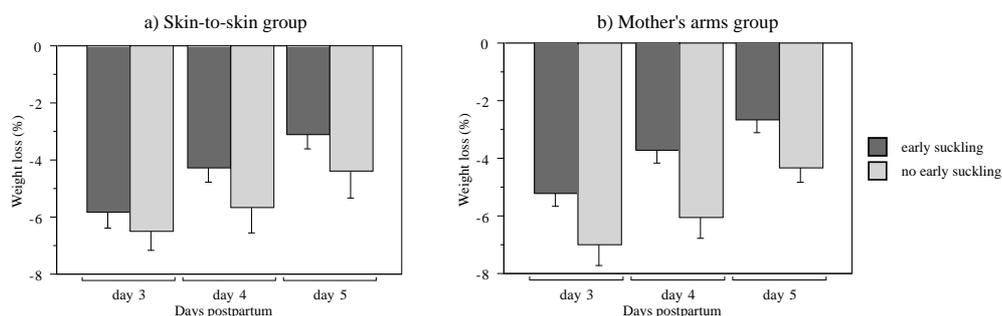


Fig. 12. Bar plots (mean per cent and SE) for infants from the Skin-to-skin and Mother's arms group, who succeeded in early suckling within two hours after birth or not. The bars show the weight loss during days 3 to 5 after birth as per cent of birth weight, e.g., 100 x (weight–birth weight): birth weight.

The *maternity* ward practices, used in the design of the study (rooming-in and nursery care), did influence the outcome of breastfeeding four days after birth. The data show that the Nursery group infants ingested significantly less amounts of breast-milk and higher amounts of formula and glucose on day 4 after birth than did babies in the rooming-in groups (Table 3). However, this difference in milk ingestion reached significance only in infants of multiparous women ($p = 0.0021$). This lower milk intake was not related to more supplementation in infants of multiparas.

Table 3. Breastfeeding parameters on day 4 after birth in the three merged rooming-in groups (Skin-to-skin, Mother's arms, Reunion) and in the Nursery group; means and (SD). Merging of the rooming-in groups was possible as there was no significant difference among them in breastfeeding parameters measured.

	Three rooming-in groups			Nursery group			Significant p-values
	All (n=109)*	Exclusively breastfed infants (n=99)*	Supple-mented infants (n=7)*	All (n=37)*	Exclusively breastfed infants (n=17)*	Supple-mented infants (n=20)*	
	1	2	3	4	5	6	
Number of breastfeeds	8.6 (2.0)	8.7 (1.9)	7.7 (2.6)	7	7	7	$p_{1-4} < 0.0001$ $p_{2-5} = 0.0004$
Total time of breast-feeds (min)	195 (70)	199 (71)	179 (55)	142 (61)	173 (61)	117 (50)	$p_{1-4} = 0.0003$ $p_{3-6} = 0.0169$ $p_{5-6} = 0.0131$
Breast-milk (ml)	256 (119)	266 (114)	121 (106)	162 (102)	212 (100)	120 (85)	$p_{1-4} < 0.0001$ $p_{2-5} = 0.07^{**}$ $p_{2-3} = 0.0015$ $p_{5-6} = 0.0045$
Formula (ml)	6 (24)	0	84 (53)	62 (83)	0	115 (81)	$p_{1-4} < 0.0001$
Glucose (ml)	0	0	0	12 (22)	0	38 (24)	–
Breast-milk + formula (ml)	262 (114)	266 (114)	204 (115)	224 (82)	212 (100)	235 (64)	$p_{1-4} = 0.07^{**}$ $p_{2-5} = 0.07^{**}$
Breast-milk + formula + glucose (ml)	262 (114)	266 (114)	204 (115)	237 (86)	212 (100)	258 (68)	$p_{2-5} = 0.07^{**}$

* number of subjects in the analysis

** strong tendency

Interestingly, the outcome of breastfeeding in infants who were exposed to a short-term (120 minutes) separation period immediately after birth, but then had rooming-in (Reunion group), did not differ significantly from that of infants who were not separated from their mothers after birth (Skin-to-skin and Mother's arms groups), but also had rooming-in.

4.2.2 Influence of swaddling on breastfeeding outcome

Swaddling was not shown to influence, in any of the experimental groups, the breastfeeding parameters studied (e.g., amount of ingested breast-milk).

In spite of this, swaddled infants from the Nursery group, who were also supplemented by formula, demonstrated a significant delay in recovery of the neonatal weight loss ($p = 0.0258$), compared to those swaddled infants receiving only breast-milk.

In addition, swaddled infants in the Reunion group, who experienced a 120-minute short-term separation from their mothers after birth and also swaddling, demonstrated a delayed recovery of neonatal weight loss ($p = 0.0576$) compared to infants from the same group, who were dressed in clothes (note, that infants in the Reunion group did not receive supplementation).

4.2.3 The relative role of variables, affecting milk volume on day 4

In order to explore the influence of different variables on milk production, some regression analyses were performed. The results show, that in the groups of the mothers and infants who stayed together in the labor ward (Skin-to-skin and Mother's arms groups), early suckling, the intensity of breast engorgement and the number of breastfeeds on day 3 after delivery were positively associated, and the intensity of feeling "low/blue" was negatively associated, with the amount of milk ingested/produced four days after birth. These significant relationships were, however, only seen in the primiparous mothers. In multiparous mothers, early suckling was found to be the only significant factor of importance affecting milk volume.

A similar pattern, except for early suckling, was obtained in the groups of mothers and infants that were exposed to a short-term separation after birth (Nursery and Reunion groups). Thus, even in the separated groups, the intensity of breast engorgement was positively associated and the intensity of feeling "low/blue" was negatively associated with the amount of milk ingested/produced four days after birth in the primiparous women, whereas the routine of rooming-in was the only factor of importance for milk ingestion/production in multiparous women (Table 4).

Table 4. A schematic overview of variables affecting milk amount on day 4 postpartum in primiparous and multiparous mothers explanation of symbols: “—” no influence; “*pos*” positive influence; “*neg*” negative influence.

	Primiparas	Multiparas
Mother-infant closeness 2 hours after delivery (Skin-to-skin and Mother’s arms groups)		
Swaddling / clothes	—	—
Skin-to-skin contact	—	—
Early suckling	pos	pos
Number of breastfeeds on day 3	pos	—
Marked engagement on day 3	pos	—
Feeling “low/blue” on day 3	neg	—
Mother-infant separation 2 hours after delivery (Nursery and Reunion groups)		
Swaddling / clothes	—	—
Rooming-in	—	pos
Marked engagement on day 3	pos	—
Feeling “low/blue” on day 3	neg	—

4.2.4 Factors predicting the duration of “nearly exclusive” breastfeeding

The only variable found to significantly predict the duration of “nearly exclusive” breastfeeding was amount of breast-milk ingested on day 4 ($p < 0.0001$). Thus, the more milk produced on day 4, the longer the duration of “nearly exclusive” breastfeeding (Fig. 13).

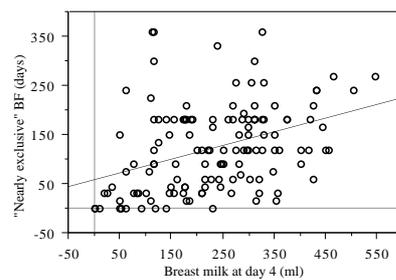


Fig. 13. A descriptive regression plot for the amount of breast-milk ingested by infants on day 4, and duration of “nearly exclusive” breastfeeding.

4.3 Maternal-child interaction one year after birth (Paper V)

Closeness between the mother and infant the first two hours after birth was found to be of significant importance for *maternal* sensitivity, *infant's* self-regulation as well as for mutuality and reciprocity in the *dyad* at the time when the infant was one year old, as measured by the PCERA. The scores of these variables were significantly higher in the Skin-to-skin and Mother's arms groups compared to the Nursery and Reunion groups. Skin-to-skin contact after birth was shown to be the most efficient care practice for developing infant's self-regulation and for optimal mother-child interaction one year later. In the absence of skin-to-skin contact, early suckling seemed to serve for its compensation in the Mother's arms group.

The importance of closeness between the mother and the infant immediately after birth was further emphasized by the findings from the Reunion group (IV). It was shown that in this group mother-child interaction was less developed after 1 year. Thus, the effect of a two-hour separation after birth, was not compensated for by reunion of the mother and infant.

Together the findings support the existence of an early "sensitive" period, during which close contact between mother and infant facilitates future maternal-infant interaction and the development of the infant's self-regulation. Interestingly, the findings mentioned above were disclosed only in the Structured task, a model of a slight stress, while in the Free play no differences between groups were found.

Influence of swaddling

In contrast, swaddling affected some PCERA variables both in the Structured task and in the Free play, variables related only to *maternal* and *dyadic* behaviors. Thus, swaddling of the infant significantly decreased the *mother's* ability for positive affective involvement in the infant ($p = 0.0227$), and mutuality and reciprocity in the *dyad* ($p = 0.0430$), as measured by the PCERA (Fig. 14).

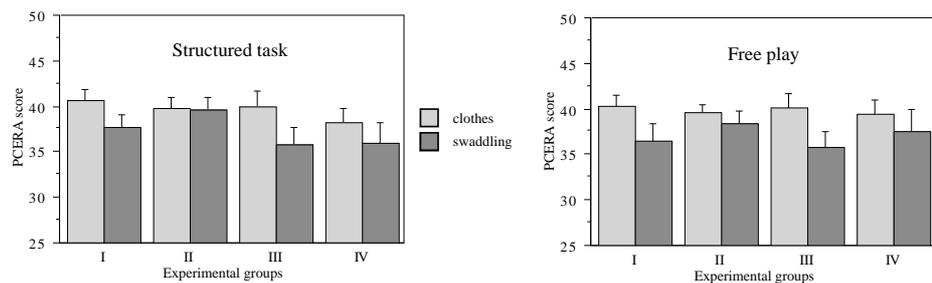


Fig. 14. Bar plots (means and SE) for the effects of swaddling on the composite PCERA variable "Maternal positive involvement and responsiveness" in the Structured task and Free play (note: the higher the score, the better the outcome).

5 DISCUSSION

Summary

A schematic overview of the findings is presented in Table 5, which will be referred to in the following.

The main findings in the present study were that maternal and infant skin temperature rose in the postpartal period, and that the development of skin temperature was related to group assignment. Infant temperature was the highest in the Skin-to-skin group, possibly as a consequence of a pulsating maternal breast temperature in the Skin-to-skin group. Suckling in the Mother's arms group also induced a pulsatile breast temperature. Still the rise of skin temperature was delayed and blunted in infants belonging to the Mother's arms group, suggesting that clothes/swaddling has an insulating effect. Infant foot temperature even decreased in the Nursery group as a consequence of separation. Strong correlations were found between maternal and infant temperatures in the Skin-to-skin and Mother's arms groups. No such correlation was found in the Nursery group.

The rise of temperature was the highest in the foot suggesting that the effect is induced by increased skin circulation as a consequence of decreased sympathetic nervous tone.

Milk production at day four after birth was significantly lower in the Nursery group than in the Skin-to-skin, Mother's arms and Reunion groups. Early suckling significantly increased milk production in both Skin-to-skin and Mother's arms groups, indicating that the suckling stimulus is of greater importance than skin-to-skin contact for milk production. The fact that milk production was not reduced by short-term separation after birth may be related to a compensatory positive effect of rooming-in.

Mother-child interaction ("maternal sensitivity," "child self-regulation," "dyadic mutuality and reciprocity") were positively influenced by skin-to-skin contact in the postpartal period. A similar effect was found in the Mother's arms group, but only in those mother-infant dyads where suckling had occurred. Interestingly, this suckling-related pattern resembles the pattern of one related to the postpartal development of skin temperature.

It is interesting to note that the PCERA item "self-regulation" denotes how well the children can regulate their stress levels. It is tempting to suggest that the experience of the anti-stress effect induced by the skin-to-skin contact during the first hours after birth somehow facilitates the infant's ability to regulate stress levels better also in a long-term perspective. In addition, the close interaction between mother and infant in the Skin-to-skin and Mother's arms groups stimulate the capacity for social interaction in both, mother and child, later in life.

In conclusion, the data suggest that the regulation of skin temperature and of milk production seem to be mediated by different and independent physiological mechanisms. Skin-to-skin contact during the first two hours after birth promotes the development of temperature in mothers and infants, whereas early suckling promotes milk production. In addition, the data show that early skin-to-skin contact influence the development of maternal-infant interaction at the age of one year, suggesting the existence of an early "sensitive period."

Table 5. A schematic overview of influences of group belonging (Skin-to-skin, Mother's arms, Nursery and Reunion group) involving various levels of closeness versus separation, and swaddling (see Method section) on some parameters measured.
Explanation of symbols. Level: **↑** – increased; **↓** – increased to a less extent; **↔** – decreased. (-): not applicable or not measured; « — »: no influence; «**pos**»: positively influenced; «**neg**»: negatively influenced. For infant foot temperature 2 hours – 2 days: the closer the symbol is to the right side of the cell, the more delayed the response is.

Study parameters measured	I. Skin-to-skin group			II. Mother's arms group			III. Nursery group			IV. Reunion group		
	All	Early suckling	Swaddl. after 2 h	All	Early suckling	Swaddl.	All	Swaddl.	Swaddl.+ Supplem	All	Swaddl.	Swaddl.
Temperature in connection with birth (30-120 min p.p.)												
Maternal axillar temperature	↑	—	(-)	↑	pos	(-)	↑	(-)	(-)	↑	(-)	(-)
Maternal breast temp. variation	↑	—	(-)	↑	pos	(-)	↑	(-)	(-)	↑	(-)	(-)
Infant foot temperature	↑	—	(-)	↑	—	—	↔	neg	(-)	↔	(-)	neg
Maternal axillar / infant foot temperature correlation	pos	—	(-)	pos	—	—	—	(-)	(-)	—	(-)	(-)
Infant foot temperature 2hours – 2 days	↑	(-)	—	↑	(-)	—	↑	—	(-)	↑	(-)	—
Breastfeeding variables at day 4												
Amount of breastmilk	↑	pos	—	↑	pos	—	↑	—	neg	↑	—	—
Total time of breastfeeds	↑	—	—	↑	—	—	↑	—	—	↑	—	—
Amount of supplements	≈ 0	(-)	(-)	≈ 0	(-)	(-)	↑	(-)	(-)	≈ 0	(-)	(-)
Infant weight gain day 3 to day 5 after birth*	↑	(pos)	—	↑	pos	—	↑	—	neg	↑	neg	neg
PCERA variables at 1 year												
Maternal positive involvement	↑	—	neg	↑	—	neg	↑	neg	(-)	↑	(-)	neg
Maternal sensitivity**	↑	—	—	↑	pos	—	↑	—	(-)	↑	(-)	—
Child self-regulation***	↑	—	—	↑	pos	—	↑	—	(-)	↑	(-)	—
Dyadic mutuality	↑	—	neg	↑	pos	neg	↑	neg	(-)	↑	(-)	neg

* Infant weight gain day 3 to day 5 after birth as reflected by recovery of the neonatal weight loss.

** "Maternal sensitivity" reflects the PCERA variable "Maternal insensitivity."

*** "Child self-regulation" reflects the PCERA variable "Child dysregulation."

Development of skin temperature after birth

Maternal temperature

Maternal axillar temperature increased after birth. This rise occurred independently of whether the infant was close to the mother or not, suggesting that it is an expression of an inborn physiological pattern aimed at protecting the infant from losing heat. In contrast, closeness between mother and infant (Skin-to-skin group and Mother's arms group) was reflected by an increased pulsatility in maternal breast skin temperature. This pulsatility was almost lacking in the mothers, who were separated from their infants, i.e., mothers in the Nursery and Reunion groups.

Our data are consistent with the results of Goodlin and Chapin (1982), and Harper et al (1991), who demonstrated that maternal skin temperature rose during the first hour after birth after a preceding fall during labor. A similar pattern was found at several sites of determination (Goodlin and Chapin, 1982), and the women having received analgesia during labor did not show this change in temperature.

Infant temperature

In the infant skin temperature increased in the axilla, back and thigh during the observation period from 30 to 120 minutes postpartum in all groups, but the rise was more pronounced in the Skin-to-skin group and in the Mother's arms group. Our data are in line with previous observations by Christensson et al (1992) who showed that axillar, interscapular and thigh temperature was higher in infants being exposed to skin-to-skin contact than in those staying in a cot.

A new finding in the present study was that the effect on skin temperature differed depending on the site of determination of temperature. The rise in foot temperature was, e.g., most pronounced in infants belonging to the Skin-to-skin group. In the Mother's arms group, i.e., in the group, in which the infants were either dressed in clothes or were swaddled during this time period, the response was delayed and much lower. Foot temperature even decreased in the infants that were separated from their mothers (Nursery and Reunion groups). The difference observed in foot temperature between infants in the Skin-to-skin and the Nursery groups persisted for 1 to 2 days.

Some other studies support the findings of variations in temperature responses in different parts of the body and as a consequence of different ward practices. In a study by Carfoot et al (2005) a difference in the postpartal rise of axillar temperature was observed between infants in skin-to-skin contact with their mothers and infants wrapped and held by their mothers. In a study by Fransson et al (2005) large differences between the development of skin temperature responses in the abdomen and the foot of the infant were found during the two first days of life. Interestingly the low foot temperature observed in infants staying in a cot rose by 5 degrees within two hours of renewed skin-to-skin contact.

Maternal influence on infant temperature

These data show that closeness between mothers and infants promotes the increase of infant skin temperature, since infants that were separated from their mothers did not

exhibit a similar sized rise in skin temperature as those infants belonging to the Skin-to-skin and Mother's arms groups. Furthermore, it can be concluded that clothes/swaddling interfere with the effect on infant temperature caused by closeness to the mother, since the temperature response was blunted in the Mother's arms group compared to the Skin-to-skin group. Together these data suggest that it is not only the absence (separation) of the mother that hinders the rise in the infant skin temperature, but that clothes and the swaddling material act like an insulator preventing these effects.

The strong correlation between maternal axillar temperature and infant foot temperature in the Skin-to-skin group and in the Mother's arms group further underpins the strong interdependence between maternal and infant temperature and the sensitivity of the infant to variations in maternal temperature, and infant ability to adapt to maternal temperature.

The observation that skin-to-skin contact did not influence maternal but only the infant's rise in temperature suggests that it is the mother that warms the infant up and that a such "warming up" does not take place if the infant is separated from his/her mother, and that it is reduced by insulating material such as clothes or swaddling material. These data are consistent with data obtained in animal experiments suggesting that the mother acts as a regulator of infant physiology and behavior via, e.g., temperature when they are in close contact (Hofer, 1994).

Even if the level of the mother's skin temperature was not influenced by closeness to the infant, the pattern of breast temperature differed in such a way that the temperature became more pulsatile if mothers were in close contact with their infants, e.g., as in the Skin-to-skin group and in the Mother's arms group. A pulsatile maternal temperature may influence infant temperature more efficiently than does a stable temperature level and may therefore explain the higher skin temperatures of infants belonging to the Skin-to-skin and Mother's arms groups.

The pulsatile pattern was more clearly expressed in mothers within the Mother's arms group whose infants were suckling after birth, but this pattern was not seen in suckling mothers in the Skin-to-skin group. We have interpreted this data as if sensory stimulation caused by skin-to-skin contact after birth triggers this response. In the absence of skin-to-skin contact the sensory stimulation caused by suckling of the infant takes over the role of activating the pulsatility of the breast temperature.

Sequence of events

It is thus possible that the sequence of events is as follows. After birth maternal temperature rises. This rise is not dependent on closeness with the infant, but seems to be a reflection of a spontaneously occurring postpartal program aiming for protection of the newborn infant. In contrast, the pulsatility of the maternal breast temperature increases as a result of close contact with the infant. Perhaps, this pulsatility is sensed by the infant, who is in close contact with the mother, and is then reflected by a rise of infant skin temperature. In addition, the infant's temperature adapts to the maternal temperature. Infants dressed in clothes or being swaddled may have difficulties sensing the subtle

changes in temperature, which leads to a delayed and blunted response in infant temperature.

Decrease of sympathetic nervous tone

Acute changes in skin temperature are reflections of changes in vascular tone in cutaneous blood vessels. The increased skin temperature in response to skin-to-skin contact is, therefore, a consequence of vasodilation due to a decreased level of sympathetic nervous tone.

The effect of skin-to-skin contact and/or suckling on vascular tone seems to be mediated by activation of sensory nerves. It is not known exactly which nerve fibers mediate these effects, but thick myelinated fibers mediating the sense of touch (A-beta), C-fibers mediating the sense of temperature or light pressure, unmyelinated slow-conducting C-fibers, described by Vallbo et al (1999) and Olausson et al (2002), which mediate pleasant feelings in response to slow rhythmic stroking and also a special type of vagal afferents originating in the skin, as described by Eriksson et al (1996, a), could be involved. Important cardiovascular regulatory centers are located in the brain stem and, in particular, in the sensory nucleus of the vagal nerve, the nucleus tractus solitarius (NTS). The sensory nerves activated by skin-to-skin contact or suckling are directly or indirectly connected to the NTS and are, therefore, likely to in part exert their inhibitory effect on sympathetic nervous tone in the NTS.

The NTS is, however, directly linked to the paraventricular nucleus (PVN) in the hypothalamus, which also plays an important role in cardiovascular regulation.

Oxytocin is produced in the PVN (in addition to several other regulatory peptides, such as CRF and Vasopressin). Oxytocin neurons originating in the PVN project to the posterior pituitary from which oxytocin is released into the circulation, but also to many important regulatory centers in the brain, including the NTS (Buis et al, 1985; Sofroniew, 1983). Administration of oxytocin has been shown to decrease blood pressure and to increase the function of alfa 2-adrenoreceptors (a type of receptors which counteracts Noradrenergic and Adrenergic transmission in the brain) in the NTS, in particular, in response to repeated administration of oxytocin (Pettersson et al, 1998). Therefore, oxytocin, which is produced in the PVN, may be released from nerve terminals in NTS in response to skin-to-skin contact and/or suckling, and may act in concert with brain-stem reflexes to decrease sympathetic nervous tone, which will be followed by increased vasodilation and/or lowered blood pressure. Note that this release of oxytocin, which occurs within the brain may, or may not be reflected by a parallel release of oxytocin into the circulation. A lack of rise of oxytocin levels may, therefore, not be used as an argument against a release of oxytocin in the brain.

Skin-to-skin contact after birth may counteract the “stress of being born”

The fact that skin-to-skin contact during the first two hours after birth was followed by an increased peripheral circulation in infants is not only a sign of decreased sympathetic nerve activity, but in more general terms, of a decreased stress level. We assumed that the function of this effect in connection with birth was to counteract the “stress of being

born". As also discussed in Paper II, vaginal delivery increases stress levels in the infants, a phenomenon, which is of physiological importance for the development of, e.g., lung function in the newborn infant (Lagercrantz and Slotkin, 1986). We also suggested that such a stress level is not positive for a longer period of time. The decreased stress levels caused by skin-to-skin contact, therefore, offers an ideal non-pharmacological way of reducing stress levels in the postpartum period.

The infant lying on the mother's chest also cries less than separated infants, another sign of a calming effect of the skin-to-skin contact (Christensson et al, 1992). This effect might also be due to the oxytocin released during skin-to-skin contact.

Since oxytocin also promotes different kinds of pro-social behaviors (Carter, 1998), it is tempting to suggest that the approach or pre-feeding behavior that the newborn infant displays, if put in skin-to-skin contact with his/her mother immediately after birth, is also facilitated by oxytocin released by the skin-to-skin contact (for a further discussion on this subject see below).

Maternal release of oxytocin in response to skin-to-skin contact

Skin-to-skin contact is accompanied by a release of oxytocin into the maternal circulation, in particular if the infants massage their mother's breasts (Nissen et al, 1995; Matthiesen et al, 2001). In fact, the mothers release oxytocin in a dose- or massage-dependent way in the immediate postpartal period. Skin-to-skin contact, however, does not appear to induce a release of oxytocin with the same type of pulsatility as does suckling. The suckling-related oxytocin release is characterized by a regular pulses occurring with 90-second intervals, whereas the skin-to-skin contact or massage-related release of oxytocin is characterized by longer and irregular intervals (see below) (W. Jonas, personal communication).

As described in the Introduction, oxytocin is known to increase blood flow via a release of locally produced vasodilating peptides in certain parts of the skin, such as on the chest (flushing) (Lindh et al, 1971; Kimura and Matsuoka, 2007). Possibly, one consequence of the oxytocin release is the pulsatile temperature observed in the postpartal period in mothers exposed to skin-to-skin contact or early suckling. If so, the role of circulating oxytocin may not be limited to expulsion of milk from the alveoli, but may also be linked to "giving of warmth." Such an oxytocin-mediated function is of course not limited to mothers, but could, perhaps, also be induced in fathers, thus explaining the positive effects of skin-to-skin contact between infant and father in the neonatal period (Bayer et al, 1996; Christensson, 1996).

Effects of Kangaroo Care (KC)

In studies performed on premature infants during KC, another clinical situation involving skin-to-skin contact, some additional interesting hormonal changes were noted, such as decreased basal levels of the gastrointestinal hormone cholecystokinin (CCK). Cholecystokinin is controlled by vagal nerve activity, and the lowered CCK levels during KC reflect activation of an inhibitory vagal tone. In contrast, the levels of CCK in response to KC combined with feeding were elevated, when compared to controls,

suggesting that the increased vagal tone promoted the release of CCK under these conditions (Tornhage et al, 1998). Kangaroo Care has also been associated with improvement of thermal regulation, respiration and oxygen saturation, reduction of apnea and bradycardia as well as with accelerating of weight gain in premature infants (Fohe et al, 2000; Feldman, 2004). Kangaroo Care has been shown to increase pain threshold in both pre-term and full-term infants if it was introduced prior to heel stick as measured by diminished crying behavior and reduced heart rate (Ludington-Hoe et al, 2005; Gray et al, 2000). In full-term infants KC has been shown to reduce stress associated with birth and to facilitate self-regulation (Ferber and Makhoul, 2004).

Effects of breastfeeding on maternal physiology and behavior

Breastfeeding is not only associated by ejection and production of milk, but also of some physiological and behavioral adaptations in the mother. In connection with a breastfeeding episode, maternal blood pressure and cortisol levels fall, and vagal nerve activity is enhanced (Nissen et al, 1996). In addition, the mother becomes calmer and more social during a breastfeeding session (Uvnäs-Moberg et al, 1990). Interestingly, these changes become sustained in response to repeated breastfeedings as evidenced by a chronically lowered blood pressure and a reduced activity in the HPA axis (Altemus et al, 1995; Heinrichs et al, 2001). Also the personality profile of the mothers is changed and the mothers report themselves to be more social and interactive (Nissen et al, 1998).

Short and long-term effects of oxytocin

Oxytocin is released into circulation from the supraoptic (SON) and paraventricular nuclei (PVN), and also into many important regulatory centers in the brain from oxytocinergic nerves originating in the PVN (Buis et al, 1985; Sofroniew, 1983).

In animals oxytocin has been demonstrated to exert a multitude of central effects, such as to stimulate social interactive behavior, to induce an anxiolytic effect, to cause a reduction in sensitivity to pain, to reduce stress levels as evidenced by reduced cortisol levels, to lower blood pressure and to increase vagal nerve tone (Agren et al, 1995; Kurosawa et al, 1995; Björkstrand et al, 1996; Uvnäs-Moberg et al, 1994, 1997, 1998a, 1998b, 2005a, 2005b; Holst et al, 2002).

It is possible that this entire oxytocin-related effect pattern (the calm and connection pattern) is activated in connection with any type of skin-to-skin contact in both mothers (fathers) and infants (e.g., breastfeeding or KC). As will be mentioned below some effects are more clearly induced by suckling. Given the ability of oxytocin to induce long-term functional changes in other signaling systems, such as the noradrenergic, serotonergic, cholinergic and opioidergic systems and also in glucocorticoid and mineralocorticoid receptors, repeated exposure to skin-to-skin contact might result in long-term effects (Uvnäs-Moberg, 1998b). For a further discussion see below.

Regulation of milk production/milk ingestion 4 days after birth

Influence of labor and maternity ward routines on milk production

Labor ward routines were not found to influence milk production four days after birth. Thus, the mothers, exposed to a two-hour separation period and then having had rooming-in, did not have less milk production/ingestion than the mothers having had close contact with their infants at the labor ward and thereafter rooming-in (Skin-to-skin and Mother's arms groups).

The effect of labor ward practices on milk production therefore appears to be different from the effect on labor ward routines on temperature regulation after birth, since infants that were separated from their mothers had lower skin temperature, in particular in the feet, during the two-hour observation period, and that these differences were not eradicated until 1-2 days later. These results thus indicate that a short-term separation after birth does not reduce milk production or that the sensory contact offered by rooming-in later on compensates for a reduced milk production caused by the loss of close contact immediately after birth.

In contrast, early suckling, which could occur at the infant's/mother's choice in the Skin-to-skin and Mother's arms groups, was related to significantly more milk production in these groups on day four (see Fig. 11 in the Results section). These data suggest that it is the *suckling stimulus per se* that causes the increased milk production and not the skin-to-skin contact.

When total milk amount ingested during breastfeeds at day 4 after birth (from 72 to 96 hours postpartum) was compared between the four experimental groups, i.e., Skin-to-skin, Mother's arms, Nursery and Reunion groups, infants belonging to the Nursery group were found to ingest significantly less breast-milk than those of the other groups (see Paper III).

Mothers of infants having received formula, irrespective of group belonging, produced substantially less milk four days after birth (see Table 3 in the Results section). One possible explanation for this finding is that the infants, having received formula *ad libitum* in addition to breast-milk, were less hungry and therefore had a lower intensity of suckling, which in turn did not stimulate milk production in the same way as in exclusively breastfed infants. In addition, the number of breastfeeds in the Nursery group was set to seven per 24 hours, while the mean frequency of breastfeeds in the rooming-in groups, practicing breastfeeding on demand, was significantly higher. Thus, this regimen probably also contributed to the reduced stimulation of milk production. Our results are in line with the data from other studies, which have demonstrated that nursery care and supplementation of infants by formula, glucose solution, or water decrease milk amount during the first days after birth (Houston et al, 1983; Nylander et al, 1991; Widström et al, 1990).

The effect of early suckling versus skin-to-skin contact on milk production four days after birth

To summarize the data, it seems as if early suckling is of greater importance for milk production than is skin-to-skin contact immediately after birth. These data are consistent

with previous observations indicating that skin-to-skin contact after birth does not increase the duration of exclusive breastfeeding, which is in part dependent on milk production (Carfoot et al, 2003, 2005). The present data clearly show that early suckling, but not skin-to-skin contact, increases milk production on day 4. On the other hand skin-to-skin contact with the mother may increase the chance of early suckling, since it facilitates the inborn breast-seeking behavior in newborn infants (Widström et al, 1987). As discussed in the previous section, we suggest that oxytocin release, in particular in the CNS, is stimulated by skin-to-skin contact in both mothers and infants, and since oxytocin stimulates pro-social behaviors (Uvnäs-Moberg et al, 1990; Nissen et al, 1998), oxytocin may contribute to the activation the breast-seeking behavior induced by skin-to-skin contact (Carter, 1998).

Hormonal control of milk production

Prolactin, a hormone produced in the anterior pituitary, is of great importance for milk production, in particular, during the early phases of breastfeeding and milk production. Prolactin is under inhibitory control by dopamine, produced in the tuberoinfundular system (Ben Jonathan and Hnask, 2001), and is stimulated by oxytocin released from neurons reaching the anterior pituitary from the PVN (McKee et al, 2007).

Oxytocin, which is produced in the SON and PVN, is released into the circulation in response to suckling, and causes milk ejection. As mentioned above, suckling induces a pulsatile release of oxytocin. The pulses occur with regular (90 sec) intervals and are each accompanied by milk ejection. Strong stimuli, such as suckling, even change the morphology in the SON and PVN in such a way that the oxytocin-producing cells come closer to each other and start to fire in synchrony (Belin et al, 1984; Belin and Moos, 1986). These synchronized firings are followed by a pulse shaped release of oxytocin and, consequently, milk ejection (Wakerley et al, 1994).

In recent experiments it has been demonstrated that the suckling-related release of prolactin, in connection with breastfeeding two days after birth, can be augmented by oxytocin infusion during labor (W. Jonas, personal communication). Since oxytocin is released by suckling, early suckling may, via release of endogenous oxytocin during the first hours of life, influence the function or sensitivity of prolactin-secreting cells/receptors in such a way, that the suckling related prolactin release will be enhanced in connection with forthcoming breastfeeding episodes. Accordingly, in the present study early suckling in the Skin-to-skin and Mother's arms groups resulted in significantly higher milk production on day 4. A similar pattern was observed in both primi- and multiparous mothers.

Differences between primiparous and multiparous mothers

In the present study the amount of breast-milk ingested by infants on day 4, did not differ between primi- and multiparous mothers. Moreover, milk amount on day 4, which was found to be lower in the Nursery group than in each of the three rooming-in groups, was significantly lower only in the multiparas. These results differ from previous reports, in

which multiparas were shown to produce more milk compared to primiparas (Zuppa et al, 1988; Chen et al, 1998; Ingram et al, 1999).

Multiple regression analyses of factors affecting milk production in our study also suggest that milk production is differently influenced or even regulated in primi- and multiparous mothers, since in multiparas sensory stimulation from the infant (early suckling and/or rooming-in) was sufficient to initiate milk production, while more factors influenced milk production in primiparas (see Table 4 in the Results section). Thus, we propose, that the “machinery” for milk production might be primed by previous lactations, and can be triggered by closeness to the baby (see Paper IV).

Predictors of duration of breastfeeding

In the present study the only variable found to significantly predict the duration of “nearly exclusive” breastfeeding was the amount of milk ingested by infants at day 4. At the same time, irrespective of significantly lower mean amounts of milk ingested on day 4 by infants from the Nursery group, the median duration of “nearly exclusive” breastfeeding was similar in all four experimental groups. This discrepancy can be explained by the fact that duration of breastfeeding has been shown to depend not only on maternity practices, but also on social factors like support of close surrounding and also of professionals (Sikorski et al, 2003; Ekström et al, 2003b). Perhaps, the mothers in the present study, who visited Maternity Home seven times during the year following delivery, felt cared for and supported, leading to a similar duration of breastfeeding irrespective of group assignment.

Recovery of neonatal weight loss

The importance of early suckling and increased milk production was also pinpointed by the fact that early suckling was associated with a significantly quicker recovery of neonatal weight loss after birth in the Mother’s arms group. Thus, the more milk the infants received, the more quickly they recovered from their weight loss (see Fig. 12 in the Results section). Infants in the Skin-to-skin group demonstrated the same pattern of recovery of neonatal weight loss, but the effect of early suckling did not reach significance. Perhaps, skin-to-skin contact *per se* can increase vagal nerve activity and may, thereby, promote digestion of nutrients through vagally controlled release of GI hormones (Uvnäs-Moberg et al, 1987; Tornhage et al, 1998), and in this way shorten the time of recovery of neonatal weight loss.

In contrast, absence of close contact and, hence, lack of sensory stimulation, can lead to retardation of the infant’s weight gain, but this effect was only observed in situations of several parallel stressors. Thus, infants, that were swaddled, which reduces the amount of close contact, and also received formula or were exposed to early separation, recovered from the weight loss after birth more slowly (see Paper III).

PCERA at the age of one year

Effects on mother and infant

In the present study we could demonstrate that infants exposed to skin-to-skin contact or held in their mother's arms (including suckling) for two hours after birth differed in their PCERA profile from infants that were separated during this period in the variables called "maternal insensitivity," "child dysregulation" and "dyadic mutuality and reciprocity." When analyzing the questions referring to these items it becomes evident that they reflect communicative skills in the mother ("maternal insensitivity") as well as in the mother and the infant ("dyadic mutuality and reciprocity"), as well as the ability to tolerate and regulate stressful stimuli in the child ("child dysregulation").

An important question to be answered is, by what mechanisms the long-term stimulation of social interactive skills and anti-stress effects are induced. The results show that close contact with the mother is necessary for the effects to be induced. In fact it may be the sensory stimulation by skin-to-skin contact itself that promotes the effects in the Skin-to-skin group, and suckling, within the Mother's arms group. Possibly, the clothes or the swaddling material to a certain extent hinders the sensory stimulation induced by close contact. Suckling may offer an alternative way of sensory stimulation.

The particular role of the first hours after birth is further strengthened by the finding that mother-infant dyads that were separated during the first two hours after birth, but then reunited, did not develop the increased communicative skills, and the infants did not increase their ability to regulate their feelings. These data support the existence of the early "sensitive period" during which these effects could be established.

Similarities between temperature and PCERA patterns

When analyzing Table 5, it becomes evident that there are some similarities as to group belongings between the development of temperature patterns at birth and the PCERA pattern recorded one year later. The infants having had skin-to-skin contact during the two-hour observation period after birth increased their skin temperature, in particular the foot temperature. In the Mother's arms groups those who had early suckling had a similar rise albeit somewhat smaller. The same pattern as to group assignment and as to the occurrence of early suckling was observed in the PCERA variable "child dysregulation", which actually describes the children's ability to regulate their behavior and stress levels. As discussed above we have suggested that the increased skin temperature after birth in infants belonging to the Skin-to-skin and Mother's arms group is but one expression of a much more comprehensive anti-stress pattern induced by skin-to-skin contact, perhaps, with the aim of reducing the "stress of being born."

A further characteristic of infants belonging to the Skin-to-skin and Mother's arms groups was that they were allowed to suckle if they managed. Both skin-to-skin contact and suckling are reflections of close interaction between mother and infant, which involves stimulation of sensory nerves. Interestingly, mother-infant dyads belonging to these groups had higher scores in the PCERA variables "maternal sensitivity" and "dyadic mutuality and reciprocity," which actually reflect a more mature and developed form of

mother-infant interaction than the direct sensory contact these mother-infant couples experienced after birth.

The finding of differences between infants, having close contact with their mothers after birth and those who have not in the direction of increased social competence in both mother and infant and, in addition, of reduced stress levels in the infants, suggests that the effects induced immediately after birth somehow becomes transformed into long-lasting effects.

From this point of view it is of particular interest that oxytocin, as described in the Introduction, may induce long-term stimulation of social skills and of an anti-stress pattern, if administered repeatedly via adaptation of the functions in other signaling systems (for references see above). Perhaps, the situation in the postpartal period, characterized by extremely high levels of oxytocin in mother and infant during labor and with sensory stimulation after birth, increasing the release of oxytocin and the function in related neuro-endocrine mechanism even more gives rise to an effect pattern that resembles the long-term effects caused by repeated administration of exogenous oxytocin. In addition, other hormones such as estrogen, CRF and cortisol may enhance the effect of skin-to-skin contact and make it long-lasting. Maternal and, in particular, the infant hormone profiles during labor and some time after birth are unique, and infant hormone profile will never be repeated. Dramatically high levels of catecholamines, noradrenalin in particular, of cortisol and CRF, which are of vital importance for survival during birth, are combined with high levels of estrogens of placental origin (Irested et al, 1982; Lagercrantz and Slotkin, 1987; Marchini et al, 1988; Vogl et al, 2006). In addition, *locus coeruleus*, a cluster of noradrenergic neurons in the pons, innervating vast areas of the CNS, is also strongly activated in response to birth (Lagercrantz, 1996). This highly activated neuro-endocrine system allows the infant to be alert up to 2 hours following birth, “sharpens” all sensory systems, and also provides a quick metabolic cascade of absorbed information in the brain, and neonatal learning (Sullivan et al, 1989). As described above, oxytocin levels are also high, and the sensitivity of oxytocinergic neurons/receptors is potentiated by cortisol and estrogens. It seems plausible, that the balance in the infant neuro-endocrine system after birth will be shaped towards increased social competence and to anti-stress in case of closeness to the mother and repeated release of oxytocin. In contrast, separation from the mother after birth will lead to a prolonged “stress of being born” in the absence of regulators of maternal origin.

It is possible that the early “sensitive period,” described by Klaus and Kennel, corresponds to the period after birth when this unique neuro-endocrine profile is prevailing. Several of the studies performed by Klaus and Kennel show that maternal-infant interaction is increased after several months if the mother-infant dyad were allowed skin-to-skin contact after birth. (Kennel et al, 1975; Klaus and Kennel, 1976, 1982; Kennel and Klaus, 1998).

Some recent studies also link oxytocin to these long-term effects. Thus, oxytocin levels have been shown to correlate with maternal-fetal and mother-infant bonding (Levine et al, 2007; Feldman et al, 2007). Furthermore, administration of oxytocin to adults have been shown to increase social competence and trust, and also to decrease fear and stress

responses (Hollander et al, 2003, 2007; Kosfeld et al, 2005; Kirsch et al, 2005; Domes et al, 2007 a, b).

There are also studies demonstrating a critical role of early experience in the development of brain systems underlying basic aspects of human social behavior. Thus, in the study of Wismer Fries et al (2005), children who began their lives in institutionalized settings, but were then adopted, were compared to a group of children who were raised in a typical family environment. The oxytocin levels of family-reared children were found to increase after physical contact with their mothers, whereas children, who experienced early neglect, did not show this response.

The above data are also in agreement with the animal experiments, presented in the Introduction, demonstrating the importance of the neuro-endocrine mechanisms in the development of maternal-infant interaction and reducing stress levels in the infants.

Swaddling

Some authors have reported some beneficial effects of swaddling (see Introduction). We did not find any effects of that kind for infants to be swaddled versus to be in clothes, according to analyses of the outcomes measured in our study. But the anticipated disadvantages of swaddling appeared to be less pronounced than expected. Moreover, these negative effects were disclosed only in cases when swaddling was combined with some kind of stressors, like separation and/or supplementation by formula. Thus, swaddled infants separated from their mothers during two hours after birth had lower foot temperature compared to separated but dressed infants. As discussed in Paper II, restriction of the movements related to swaddling, could intensify the activation of sympathetic nervous system and, thereby, vasoconstriction in the feet, leading to lower foot temperature.

The second observed example of a negative influence of swaddling was the delayed recovery of neonatal weight loss in swaddled infants when they were separated from their mothers for two hours after birth, or had nursery care and supplementation. As discussed in Paper III, in addition to being exposed to the “stress of being born” for a longer time, these infants experienced lack of tactile interaction with mother/staff. Since vagal nerve activity and GI hormones stimulate digestion and anabolic function, weight gain and growth are secondarily enhanced by such stimulation and may, therefore, contribute to the retardation of weight gain (Uvnäs-Moberg et al, 1987).

In addition to influencing physiological parameters, swaddling can also affect psychological variables, as was shown by the PCERA. Accordingly, swaddling of the infants decreased the mother’s ability for positive affective involvement in the infant, and mutuality and reciprocity in the dyad. As discussed in Paper V, that restriction of movements caused by swaddling, hinders infant’s inborn “body language”. As a result, infants cannot give the feedback to the mother, which she needs for a mutual and joyful dialogue with her infant.

6 CLINICAL IMPLICATIONS

The findings of the study lead us to the following suggestions.

Newborn babies should not be separated from their mothers except for medical reasons; they should be placed skin-to-skin, as soon as possible after birth. Babies should stay skin-to-skin with the mother to counteract the “stress of being born” and to keep warm. In addition, skin-to-skin contact between mother and baby has beneficial effects on their interaction including the infant’s ability to regulate behaviors at the age of one year. Thus, babies should stay skin-to-skin with their mothers irrespective of whether they are able to suckle or not. However, mother-infant couples should have the possibility to initiate breastfeeding, as shown in this study, early suckling by itself enhanced milk production.

Another reason for giving the baby the chance to suckle early is that early suckling by itself has similar beneficial effects on mother-infant interaction as when the baby is staying skin-to-skin with the mother. Thus, in some cases when early skin-to-skin contact cannot be practiced there is a possibility to compensate for the lack of skin-to-skin contact by early suckling.

In this study, although the skin-to-skin contact started approximately 25 minutes after birth due to the hospital infection prevention policy, still 90 minutes of skin-to-skin contact were sufficient to produce the positive effects. However, any delay in skin-to-skin contact after birth is not recommended.

As stated in the “Ten Steps to Successful Breastfeeding” (WHO) babies and mothers should stay together during the maternity stay and breastfeed “on demand” without supplementation. The reason for this is clearly shown in this thesis. If the baby is staying in the nursery and is only taken to the mother at regular times for breastfeeding there is a risk the baby will suckle less time, ingest less milk and be given formula when in the nursery. Consequently, the mother will produce less milk. In addition, it was shown that even those mothers rooming in with their babies had less milk on the fourth day after birth if the baby was supplemented. Less milk on day four was correlated to a shorter time of “nearly exclusive” breastfeeding.

Mothers and fathers should be told that the first two hours after birth seem to be a sensitive time whereby nature provides a window for mother and infant to develop affection for each other. Nevertheless, this time should not be looked upon as the only time when bonds between mother and baby can be shaped. Thus, to protect parents from depression and a sense of guilt in cases when early contact is not possible, it is of great importance that health professionals not only talk about the advantages of early contact, but also give the information that this period is “sensitive, but not critical”. This sensitive period can be compensated for postnatally with repeated episodes of physical closeness between mother and baby. As an example of this Anisfeld et al. (1990) showed that repeated carrying of a baby in a soft baby carrier months after birth, keeping the baby close to the body in a chest-to-chest position enhanced maternal bonding.

Families and staff should consider whether the practice of traditionally tight swaddling should be abandoned as the swaddled baby seemed to stay in a state of stress during the first hours and days after birth when separated from the mother. In addition, if the swaddled baby was staying in the nursery and was given formula, the baby gained weight slower than a baby dressed in baby clothes in the same situation. Another disadvantage of hard traditional swaddling was that it restricted the baby's body movements and thus hindered the baby's inborn "body language," as well as the mother's ability to interpret the baby's cues.

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