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# Early Skin-to-Skin Care in Extremely Preterm Infants: Thermal Balance and Care Environment

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**Objective** To evaluate infant thermal balance and the physical environment in extremely preterm infants during skin-to-skin care (SSC).

**Study design** Measurements were performed in 26 extremely preterm infants (gestational age 22-26 weeks; postnatal age, 2-9 days) during pretest (in incubator), test (during SSC), and posttest (in incubator) periods. Infants' skin temperature and body temperature, ambient temperature, and relative humidity were measured. Evaporimetry was used to determine transepidermal water loss, and insensible water loss through the skin was calculated.

**Results** The infants maintained a normal body temperature during SSC. Transfer to and from SSC was associated with a drop in skin temperature, which increased during SSC. Ambient humidity and temperature were lower during SSC than during incubator care. Insensible water loss through the skin was higher during SSC.

**Conclusion** SSC can be safely used in extremely preterm infants. SSC can be initiated during the first week of life and is feasible in infants requiring neonatal intensive care, including ventilator treatment. During SSC, the conduction of heat from parent to infant is sufficiently high to compensate for the increase in evaporative and convective heat loss. The increased water loss through the skin during SSC is small and should not affect the infant's fluid balance. *(J Pediatr 2012;161:422-6)*.

Maintenance of a normal body temperature ($T_{body}$) is of vital importance to the preterm neonate. The first studies revealing increased morbidity and mortality in infants exposed to hypothermia and cold stress were published more than half a century ago,[1] and temperature control remains a cornerstone of neonatology. Many advances in neonatal care, including measures to improve thermal balance and care environment, have contributed to the increased survival of preterm infants.[2] One such measure is the kangaroo mother care technique, which features early initiated and continuous skin-to-skin care (SSC).[3,4] The kangaroo position reduces infant heat loss by minimizing the skin surface area exposed to the cooler environment, and allows conductive heat gain through skin-to-skin contact between infant and parent. Kangaroo mother care is recommended for use in stabile low birth weight (BW) infants.[5]

Infants born extremely preterm are at particular risk for hypothermia and require a strictly controlled care environment to maintain thermal homeostasis. In these infants, evaporative heat loss because of poor skin barrier function is the dominant mechanism of heat loss early after birth.[6] Because the loss of fluid from the skin is inversely related to ambient relative humidity,[7] creating a high–relative humidity microenvironment close to the skin will reduce fluid loss and improve thermal balance.[8] Furthermore, the high body surface-to-mass ratio and poor capacity for thermogenesis of extremely preterm infants implies that they need to gain heat from the environment to avoid hypothermia and cold stress.[9] In modern neonatal intensive care, such an environment is most often created by maintaining the infants in intensive care incubators with high air temperature ($T_{air}$), leading to convective heat gain,[10] in combination with high humidification and/or plastic dressing to minimize evaporative loss of water and heat.[11] Data are limited regarding the care environment during SSC in extremely preterm infants requiring neonatal intensive care, including respiratory support. We hypothesized that SSC would provide a thermally adequate care environment for the early postnatal care of these infants. To test this hypothesis, we studied a group of extremely preterm infants who received SSC early after birth. We monitored and evaluated these infants' thermal balance and care environment during SSC and conventional incubator care.

| | |
|---|---|
| BSA | Body surface area |
| BW | Birth weight |
| GA | Gestational age |
| IWL | Insensible water loss |
| SSC | Skin-to-skin care |
| $T_{air}$ | Air temperature |
| $T_{body}$ | Body temperature |
| TEWL | Transepidermal water loss |
| $T_{skin}$ | Skin temperature |

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Supported by the Gillbergska Foundation, Uppsala, Sweden. The authors declare no conflicts of interest.

 10.1016/j.jpeds.2012.02.034

## Methods

Infants were eligible for the study who were inborn or admitted after transfer within the first day after birth and born at a gestational age (GA) of <27 weeks. During the 2-year study period, 75 eligible infants were admitted. Twenty-seven infants (GA, 22-26 weeks) were included after parental consent was obtained. Reasons for noninclusion were a parent was unavailable for SSC (n = 4) or an investigator was unavailable for monitoring (n = 44). To verify that our sample was representative, patient data on GA, BW, and SSC (duration and $T_{body}$) from all eligible infants was collected retrospectively. The mean GA of all eligible infants was 25 + 0 weeks, and the mean BW was 688 g, compared with 24 + 4 weeks and 600 g in the sample (Table I).

During the monitoring period, 1 infant became hypothermic due to failure of the ventilator gas humidifier/warmer. The infant's temperature was stabilized once the ventilator was replaced and the infant was returned to the incubator. This adverse event was judged to be unrelated to the SSC period, and the related data were excluded from further analysis. Six infants were from multiple pregnancies, and all but 2 infants had received antenatal corticosteroid treatment at least 24 hours before birth. All but 2 infants had been intubated at birth for surfactant administration and ventilator treatment. GA was estimated from prenatal ultrasound investigations performed routinely at 17-18 weeks gestation and confirmed by postnatal clinical examination.

Most measurements were performed during the first week of life (Table I). The SSC technique followed our neonatal intensive care unit standard care guidelines for extremely preterm infants. In brief, these include care in closed intensive care incubators interrupted by periods of SSC commencing within a few days after birth when the attending neonatologist deems the infant to be in respiratory, hemodynamic, and thermal balance. SSC also is routinely performed in infants who are receiving mechanical ventilation and who have an umbilical catheter in place. During the first postnatal week, the incubator is set at a high relative humidity (85%) and the $T_{air}$ is adjusted manually to maintain a $T_{body}$ between 36.5 and 37.5°C as determined by intermittent measurements of axillary temperature. SSC is performed for a minimum duration of 60 minutes and for as long as the parent feels comfortable. During SSC, the infant is diapered and held in the kangaroo position while wearing a cap and covered by blankets. If an umbilical catheter is in place, the infant may be placed on his or her side. No skin ointments are used. Total fluid volumes are started at 80-90 mL/kg/day (for infants born at GA 25-26 weeks) and 90-100 mL/kg/day (for those born at GA 22-24 weeks) and subsequently increased by approximately 10 mL/kg/day. Fluid management is guided mainly by serial determinations of body weight to allow a weight loss of <3%-4% per day and a total maximum weight loss of 10%-15%.

Data were collected on each infant's clinical course, routine monitoring parameters, daily weight change, and fluid

**Table I. Individual infant characteristics at birth and at day of measurement**

| | Birth | | | | | Study day | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infant | Prenatal steroids | Cesarean delivery | GA, weeks | BW, g | Surfactant at birth | PNA, days | Weight, g | Weight change, % | Respiratory support | $FiO_2$, % | SSC duration, minutes | SSC position | BSA, $m^2$ |
| 1 | Yes | - | 26 + 2 | 924 | Yes | 3 | 840 | −9 | Ventilator | 23 | 60 | K | 0.09 |
| 2 | Yes | - | 26 + 2 | 774 | Yes | 5 | 696 | −10 | CPAP | 21 | 90 | K | 0.09 |
| 3 | Yes | Yes | 24 + 6 | 437 | Yes | 3 | 447 | 2 | Ventilator | 40 | 60 | K | 0.07 |
| 4 | Yes | - | 22 + 5 | 532 | Yes | 9 | 508 | −5 | Ventilator | 30 | 60 | K | 0.07 |
| 5 | Yes | - | 22 + 4 | 614 | Yes | 3 | 593 | −3 | CPAP | 44 | 60 | S | 0.08 |
| 6 | Yes | Yes | 24 + 2 | 683 | Yes | 4 | 565 | −17 | CPAP | 69 | 90 | S | 0.08 |
| 7 | Yes | - | 22 + 4 | 510 | Yes | 7 | 504 | −1 | Ventilator | 27 | 120 | K | 0.07 |
| 8 | Yes | - | 25 + 0 | 943 | Yes | 4 | 844 | −10 | CPAP | 25 | 170 | K | 0.09 |
| 9 | Yes | - | 23 + 1 | 595 | Yes | 5 | 557 | −6 | Ventilator | 30 | 60 | K | 0.08 |
| 10 | Yes | Yes | 24 + 3 | 538 | Yes | 7 | 525 | −2 | Ventilator | 28 | 60 | K | 0.07 |
| 11 | Yes | Yes | 23 + 6 | 400 | Yes | 8 | 406 | 2 | Ventilator | 32 | 90 | K | 0.07 |
| 12 | - | - | 26 + 1 | 1000 | Yes | 5 | 900 | −10 | Ventilator | 29 | 90 | S | 0.10 |
| 13 | Yes | Yes | 26 + 1 | 747 | - | 2 | 657 | −12 | CPAP | 25 | 60 | K | 0.09 |
| 14 | Yes | - | 25 + 4 | 695 | - | 5 | 600 | −14 | CPAP | 21 | 60 | S | 0.08 |
| 15 | Yes | Yes | 25 + 0 | 917 | Yes | 3 | 763 | −17 | CPAP | 57 | 90 | K | 0.09 |
| 16 | Yes | Yes | 24 + 5 | 689 | Yes | 5 | 637 | −8 | CPAP | 46 | 120 | S | 0.08 |
| 17 | Yes | Yes | 24 + 5 | 450 | Yes | 7 | 448 | 0 | CPAP | 36 | 120 | K | 0.07 |
| 18 | Yes | Yes | 23 + 1 | 545 | Yes | 6 | 508 | −7 | Ventilator | 24 | 60 | K | 0.07 |
| 19 | Yes | - | 25 + 4 | 688 | Yes | 4 | 650 | −6 | CPAP | 21 | 120 | K | 0.08 |
| 20 | Yes | Yes | 25 + 0 | 820 | Yes | 5 | 751 | −8 | CPAP | 21 | 115 | K | 0.09 |
| 21 | Yes | - | 23 + 4 | 541 | Yes | 4 | 486 | −10 | CPAP | 47 | 120 | K | 0.07 |
| 22 | Yes | - | 26 + 5 | 822 | Yes | 3 | 760 | −8 | CPAP | 21 | 110 | K | 0.09 |
| 23 | Yes | - | 26 + 5 | 1064 | Yes | 4 | 965 | −9 | CPAP | 21 | 180 | K | 0.10 |
| 24 | Yes | - | 23 + 1 | 503 | Yes | 7 | 499 | −1 | Ventilator | 24 | 80 | K | 0.07 |
| 25 | - | - | 22 + 4 | 435 | Yes | 5 | 365 | −16 | Ventilator | 24 | 120 | K | 0.07 |
| 26 | Yes | - | 25 + 4 | 448 | Yes | 7 | 429 | −4 | CPAP | 21 | 120 | K | 0.07 |
| Mean | | | 24 + 4 | 666 | | 5 | 600 | −7 | | 31 | 95 | | 0.08 |

*CPAP*, nasal continuous positive airway pressure; *$FiO_2$*, fraction inspired oxygen; *K*, kangaroo position; *PNA*, postnatal age; *S*, side-lying position.

intake. The Ethics Committee of the Medical Faculty at Uppsala University approved this study.

The study design included measurements made during pretest (in incubator), test (during SSC), and posttest (in incubator) periods, allowing individual comparisons of the different modes of care and their effect on thermal homeostasis. Relative humidy (%) and $T_{air}$ (in °C) in the incubator and during SSC were measured with a combined instrument (Vaisala HMI 41; Vaisala, Helsinki, Finland). To enable continuous monitoring of relative humidity and temperature during SSC, a specifically designed vapor-impermeable blanket (KAM Care Design, Uppsala, Sweden) was developed that fit the measurement probe (**Figure 1**). The measurement setup was evaluated in pilot experiments and found to provide stable relative humidity and temperature data indicating a low level of convective air movement during SSC (data not shown).

Skin temperature ($T_{skin}$; °C) was measured from the lower back of the infant with a YSI 43 TA telethermometer (sensitivity, 0.1°C) and probes (YSI, Yellow Springs, Ohio), secured with adhesive tape. $T_{body}$ (°C) was measured intermittently in the axilla according to standard clinical care procedures.

Transepidermal water loss (TEWL, in g $m^{-2}$ $h^{-1}$), the rate of water evaporation from the skin, was determined from an interscapular skin area using an Evaporimeter Ep 1 (Servo Med, Stockholm, Sweden) as described previously.[12] In contrast to the relative humidity measurement, TEWL reflects water transport during free evaporation, precluding measurement of TEWL under the covering blanket. Accordingly, TEWL was measured only during incubator care, and not under the blanket. To estimate the difference in water loss between incubator and SSC care, we then recalculated the TEWL values obtained in the incubator using the relative humidity values obtained during SSC care (see Treatment of Data and Statistical Analysis).

## Measurement Procedure

Measurements were performed during routine neonatal intensive care and monitoring. At the start of measurement, the infant was nursed in an incubator (Omnibed; GE Healthcare, Madison, Wisconsin) and any ongoing phototherapy was discontinued. $T_{air}$ was recorded, and the blanket with measurement probe was transferred to the incubator to equilibrate for a minimum of 30 minutes, after which monitoring of $T_{skin}$ was initiated. Data were recorded every 15 minutes for the duration of measurement, except for the $T_{body}$ measurements during SSC.

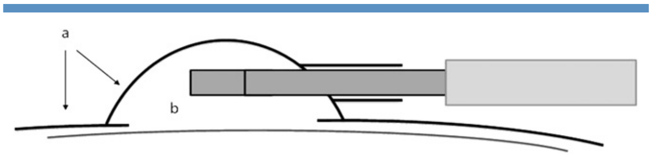


**Figure 1.** Measurement setup during SSC. The infant is placed skin-to-skin and covered by a vapor-impermeable blanket with a relative humidity and temperature measurement probe in place. In this schematic, a represents the blanket and b represents the air above the infant's skin. $T_{skin}$ is measured below b.

After the 30-minute equilibration time and the 30-minute recording period in the incubator, the infant was transferred to SSC and positioned as shown in **Figure 1**. The infant was covered and wrapped in the blanket and placed in position on the parent's chest, making sure to maximize SSC and avoid leakage of air between the blanket and the parent. After the ventilator and monitoring devices were reconnected, the parent's shirt was buttoned over the blanket, and an additional insulating blanket was added on top. At the end of SSC, the infant was transferred back to the incubator in a similar manner. Measurements were terminated after another 30 minutes of recording in the incubator, after which phototherapy (if needed) was restarted.

## Treatment of Data and Statistical Analysis

Because TEWL is inversely and strongly related to ambient relative humidity,[7] any change in relative humidity will result in a change in TEWL. As described previously,[13,14] the difference in relative humidity between the incubator and SSC was used to estimate TEWL during SSC ($TEWL_{SSC}$), using the following equation:

$$TEWL_{ssc} = TEWL_{inc} \times ((100\ \text{relative humidity}_{ssc}) / (100\ \text{relative humidity}_{inc})),$$

where $TEWL_{inc}$ is the TEWL measured during care in the incubator and relative $\text{humidity}_{SSC}$ and relative $\text{humidity}_{inc}$ are the relative humidity measured during SSC and incubator care, respectively.

To further evaluate the possible effect of SSC care on fluid and heat balance, the insensible water loss (IWL) through the skin ($IWL_{skin}$, in g $kg^{-1}$ $h^{-1}$) was calculated as described previously[13] using the following equation:

$$IWL_{skin} = TEWL_{ssc} \times BSA,$$

body surface area (BSA) (in square meters), calculated as

$$BSA = 0.25157 \times W^{0.425} \times H^{0.725}$$

where $H$ is the height (in meters) and $W$ the weight of the infant (in kilograms).

Values are presented as mean ± SE and/or mean (range), as stated. The paired-sample Student $t$ test was used to test for statistical significance ($P < .05$).

# Results

## Infant Temperature

Measurements were performed for a mean SSC duration of 95 minutes (range, 60-180 minutes), at a mean postnatal age of 5 days (range, 2-9 days) (**Table I**). There was a slight drop in $T_{body}$ from pretest to posttest ($P < .05$; **Table II**). $T_{skin}$ displayed several changes during the measurements,

**Table II.** $T_{body}$, $T_{air}$, relative humidity, and $IWL_{skin}$ during incubator and SSC care

| | Incubator (pre-SSC) | SSC | Incubator (post-SSC) |
|---|---|---|---|
| $T_{body}$, °C | 36.8 ± 0.0 | - | 36.7 ± 0.1* |
| $T_{air}$, °C | 32.9 ± 0.3 | 32.1 ± 0.3 | - |
| Relative humidity, % | 68 ± 2 | 42 ± 1* | - |
| $IWL_{skin}$, g/kg/hour | 2.3 ± 0.2 | 4.7 ± 0.5* | - |

Data are mean ± SE.
*$P < .05$ versus pretest.

including a drop in $T_{skin}$ when the infant was transferred from the incubator to SSC ($P < .001$), an increase during SSC ($P < .001$), and again a slight drop after transfer back to the incubator ($P < .05$) (**Figure 2**). However, no significant differences ($P = .32$) in $T_{skin}$ were seen between pretest (36.1°C) and the end of SSC (36.10°C) or between pretest and posttest (36°C) (**Figure 2**). The mean difference in $T_{body}$ and $T_{skin}$ was 0.7°C (−0.3 to 1.6°C). The highest temperatures recorded during and after SSC were 37.2°C for $T_{body}$ and 37.4°C for $T_{skin}$. Changes in $T_{skin}$ and $T_{body}$ during SSC were similar regardless of whether the infants was in the kangaroo position or side-lying during SSC (data not shown).

Retrospective analysis of the entire group of eligible infants revealed no differences from the study sample in mean age at first SSC (5 days), mean duration of SSC (92 minutes), or mean $T_{body}$ before SSC (37.0°C) and after SSC (36.6°C).

### Care Environment

The mean room $T_{air}$ at the time of measurement was 24.0°C (range, 23.0-25.5°C). No relationship was seen between $T_{air}$ and the changes in $T_{body}$ or $T_{skin}$ (data not shown). The care environment during SSC differs from that in the incubator, with a lower relative humidity (42% vs 68%; $P < .001$) (**Table II**). $T_{air}$ was 32.1°C during SSC and 32.9°C during incubator care ($P = .11$) (**Table II**).

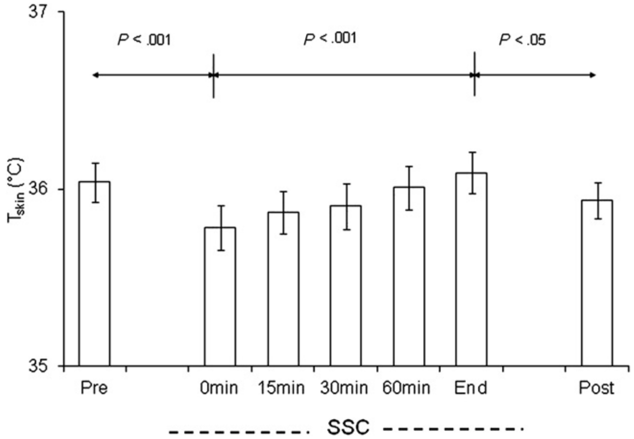


**Figure 2.** $T_{skin}$ measured in the incubator before SSC (Pre), during SSC, and after return to the incubator (Post). $T_{skin}$ dropped when the infants were transferred to and from the incubator but increased during SSC.

### IWL through the Skin

During incubator care, measurement of TEWL and the BSA calculated from body weight and length yielded an estimated $IWL_{skin}$ of 2.3 ± 0.2 g $kg^{-1}$ $h^{-1}$. By recalculating $IWL_{skin}$ using the 2-point formula for TEWL in relation to relative humidity, a higher $IWL_{skin}$ value was obtained for SSC (4.7 ± 0.5 g $kg^{-1}$ $h^{-1}$; $P < .001$) (**Table II**).

## Discussion

We present detailed data on thermal balance and physical care environment during early postnatal SSC of extremely preterm infants receiving neonatal intensive care, including mechanical ventilation. After SSC, the infants maintained their $T_{body}$ within the normal range. Transfer of the infant to and from SSC resulted in a drop in infant $T_{skin}$, which increased during SSC. The physical environment during SSC is characterized by a lower $T_{air}$ and relative humidity than during incubator care.

Two previous studies investigated infant temperatures in extremely preterm infants during SSC; however, our cohort was of lower GA, body weight, and postnatal age and had a higher proportion of infants receiving mechanical ventilation. In contrast to our study, Bauer et al[15] reported a net heat loss during early (first week) SSC in preterm infants (median GA, 27 weeks; median BW, 930 g), and SSC during the second week resulted in an increase in $T_{body}$. In that study, the infants' heads were exposed to room air, and SSC was limited to 60 minutes. Interestingly, the drop in $T_{body}$ during early SSC was not related to any increase in oxygen consumption, indicating the absence of a metabolic response to cold stress. The authors concluded that SSC should be postponed until the second week in infants born at GA <27 weeks.

Maastrup and Greisen[16] found that preterm infants (mean GA, 25 + 4 weeks; mean BW, 735 g) maintained their $T_{body}$ during SSC. The infants in that study exhibited a less pronounced drop in $T_{skin}$ during transfer to/from SSC compared with our cohort, possibly related to that study's larger and more mature infants.

The magnitude and direction of heat flux indeed differ between different care environments and modes of care. Our data clearly demonstrate that SSC results in higher evaporative heat losses due to lower relative humidity compared with incubator care. In addition, convective heat loss is higher during SSC than in the incubator, due to a lower ambient $T_{air}$. Despite the higher evaporative and convective heat losses, conductive heat transfer to the infant during SSC is apparently sufficient to result in a net heat gain. It is also clear that periods of SSC should be long enough to allow the infant's temperature to return to normal after the transfer. Although the kangaroo position is widely accepted for SSC, we could not discern any association between infant position and temperature, possibly related to our relatively small sample size. Optimizing routines for the transfer to/from SSC might further improve the performance of SSC.

We used data for measurements of water loss from the skin surface in the incubator and the relative humidity to estimate $IWL_{skin}$ during SSC. Given that water loss from the immature skin surface is linearly related to ambient humidity,[7] we consider the IWL estimates during SSC to be reasonably accurate. Clearly, real-time measurements of water flux during SSC from multiple skin areas would be preferable, but because the gradient method relies on free evaporation, this is not technically feasible. The estimated $IWL_{skin}$ was twice as high during SSC than during incubator care. Assuming that approximately one-third of the infant's skin surface (upper back, face, and posterior parts of arms/legs) would be exposed to the lower relative humidity during SSC, every hour of SSC would correspond to a 1-g/kg increase in IWL. Thus, we consider it most unlikely that a few hours of SSC would have any significant impact on fluid balance and fluid management. Indeed, we discerned no such effect in our group of infants (data not shown), although a detailed analysis of any augmented changes in, for example, sodium levels or increased weight loss would require both a control group and a much larger sample size. Under normal care conditions including SSC, changes in core $T_{body}$ are slow, and peripheral temperature (ie, $T_{skin}$) changes can be more rapid. Accordingly, the observed drop in $T_{skin}$ during transfer to and from SSC might have been slightly more pronounced than what could be detected by measurements every 15 minutes.

The $T_{body}$ measurements during incubator care were in the lower normal range, and the $T_{body}$ to $T_{skin}$ gradient was larger than expected. This might represent a slight cold stress in this population of very tiny infants whose care requires frequent opening of incubator portholes. In our experience, the need (and/or staff urge) for such disturbances in the infant's immediate care environment is reduced (and limited by access) during SSC. We consider our sample representative for the population of extremely preterm infants admitted to our neonatal intensive care unit and to our present practice. The outcome data of our cohort was evaluated as part of an ongoing investigation and shown to be no different (G. Sjörs, personal communication, January 5, 2012) from those recently reported in a national cohort.[2]

In conclusion, our data indicate that early-initiated SSC allows infant temperature control in even the tiniest extremely preterm infants receiving intensive care, including mechanical ventilation. IWL is higher during SSC than during incubator care, but the difference is of marginal clinical importance if the duration of SSC is limited to a few hours a day. We consider SSC an important mode of care for extremely preterm infants. ■

Submitted for publication Nov 14, 2011; last revision received Jan 17, 2012; accepted Feb 21, 2012.

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