ORIGINAL ARTICLE

Temperature variation in newborn babies: importance of physical contact with the mother

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Background: Hypothermia is a major cause of deterioration and death in the neonatal period. Temperature deviations are key signs of illness.
Objective: To determine normal patterns of temperature variation in newborn babies and the influence of external factors.
Methods: Abdominal and foot skin temperature were continuously recorded in 27 healthy full term babies during the first two days of life and related to the care situation—that is, whether the baby was with the mother or in its cot. The recordings were made using no wires to avoid interference with the care of the neonate. Ambient temperature was close to 23°C during the study period.
Results: Mean rectal and abdominal and foot skin temperature were lower on day 1 than day 2. The foot skin temperature was directly related to the care situation, being significantly higher when the baby was with the mother. The abdominal skin temperature was much less influenced by external factors. When the neonates were with their mothers, the mean difference between rectal temperature and abdominal skin temperature was 0.2°C compared with a mean difference between rectal temperature and foot skin temperature of 1.5°C, indicating a positive heat balance. In the cot the corresponding temperature differences were 0.7°C and 7.5°C. A temperature difference between rectal and foot skin temperature of 7–8°C indicates a heat loss close to the maximum for which a neonate can compensate (about 70 W/m^2).
Conclusion: This study emphasises the importance of close physical contact with the mothers for temperature regulation during the first few postnatal days.

After delivery, in addition to breathing and circulatory adaptation, the newborn must take control of body temperature. World wide, hypothermia is probably the most common associated cause of death during the first weeks of life.[1] The care offered by the mother during this period has a decisive effect on survival.

Temperature control in healthy newborns has been evaluated by surface and core temperature, usually under standardised conditions with the child separated from its normal environment.[2–5] This study is descriptive, aiming to define temperature variations of the neonate during normal care in the first two days of life in a maternity ward of a western European country. The following were recorded.

- Mean skin temperature of the abdomen and foot in relation to ambient temperature and rectal temperature
- Highest and lowest mean foot skin temperature during a stable period of at least one hour in relation to abdominal and ambient temperature with the neonate lying in its cot or close to the mother
- The magnitude and duration of the difference between abdomen and foot skin temperature during periods of low foot skin temperature (>2℃ below the mean) and high foot skin temperature (>2℃ above the mean)
- The maximal rate of increase in the abdominal and foot skin temperature

MATERIALS AND METHODS

After approval from the medical ethics committee of the medical faculty and parental informed consent, abdominal and peripheral skin temperatures of 27 newborn healthy babies were measured continuously during the first two days of life. Measurements started four to eight hours after birth. To obtain the longest possible measurement period, babies born during the night were selected. The mean recording period was 19 hours and 22 hours on the first and second day respectively.

The infants wore disposable nappies (heat insulation 0.44 m^2 ℃/W measured by a TOG meter; ISO11092) and were dressed similarly; they wore a vest (0.04 m^2 ℃/W), underpants (0.03 m^2 ℃/W), and rompers (0.08 m^2 ℃/W). All clothes were made of cotton fabric. In the cot, neonates were covered by a cotton blanket (0.39m^2 ℃/W).

Central skin temperature was measured laterally below the umbilicus under the nappy. Peripheral skin temperature was measured on the sole of the foot. Skin temperature was recorded once a minute with thermistors, and the values stored continuously on a PC. The thermistors (Novametric AB, Göteborg, Sweden) measured 40 × 35 × 6 mm and were made of polymer with an approximate specific conductivity of 0.03 W m/℃ corresponding to a heat insulation of 0.02 m^2 ℃/W. They were attached to the skin using a thin adhesive tape (Micropore 3M). Recordings of skin temperature were transmitted wirelessly to a battery back up receiver located under the neonate's mobile bed. The transmitter range was about 10 m, allowing unrestricted care within the room and in the hospital, as the mobile cot was normally taken with the neonate when parents moved around with their baby. Total loss of measurements from the skin thermometers was 10–11% of possible recordings as a result of external interference or because a child was not within reach of the receiver. The thermistors were calibrated in a temperature certified water bath. A maximum variation of ± 0.2℃ within the 27–40℃ measurement range was recorded. $T_{1/2}$ was one minute.

After each completed period, data were transferred to a PC for processing. Figure 1 shows a complete recording from one child. Environmental air temperature was recorded at the

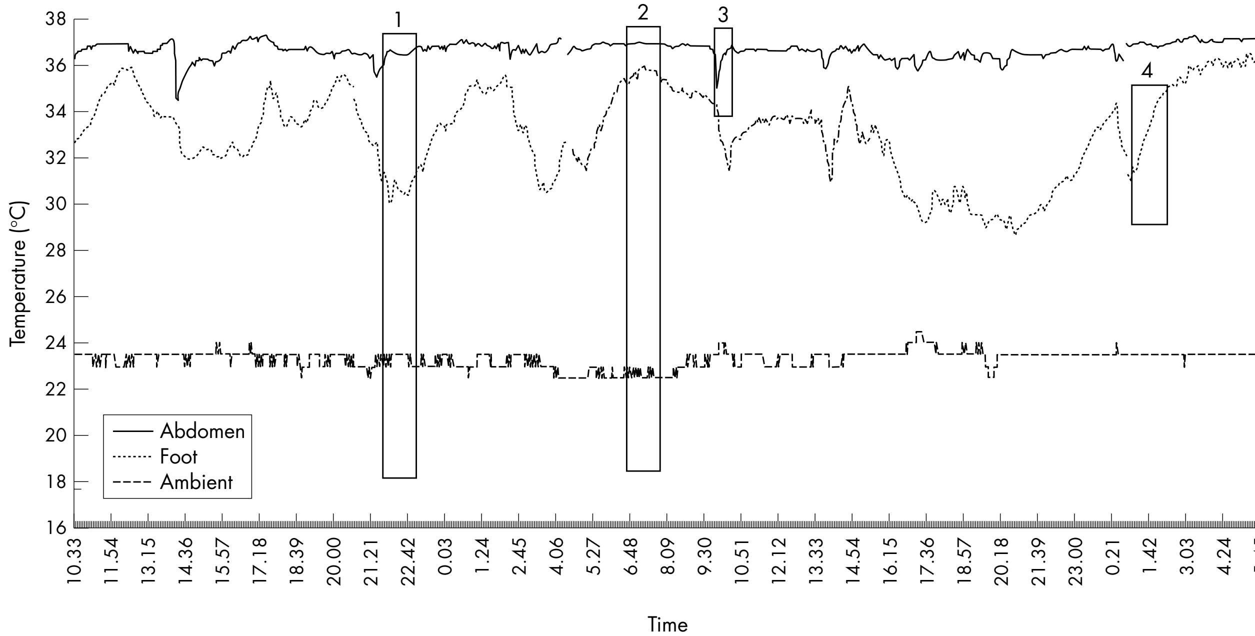

Figure 1 A 48 hour recording of the temperature of the skin on the abdomen and foot, as well as the ambient temperature. Rectangle 1 is a stable period (lasting one hour) when the foot skin temperature was lowest. The baby was in its cot. Temperature recordings within the rectangle were analysed statistically. Rectangle 2 shows the corresponding interval when the foot skin temperature was highest. The baby was with its mother. Rectangle 3 shows an increase in temperature of the abdomen during a period of 30 minutes. Rectangle 4 shows an increase in the temperature of the foot during a period of one hour.

same time as the skin temperature and stored in the same way as the skin temperature. The rectal temperature was recorded morning and evening.

The relative air humidity was recorded using a hair hygrometer with an accuracy of $\pm$ 5%.

The mothers were given a log sheet to record the times of specific activities: feeding; nappy changes; whether the child was in its cot or with the mother; changes of clothing. Completion of the log sheet was voluntary. To avoid interference with normal bonding, no pressure was put on the mothers with regard to precision, intervals, or description of the events.

Mean rectal and abdominal and foot skin temperature were calculated for days 1 and 2. Periods of one hour or more when the foot skin temperature was highest or lowest were identified on the first and second day. Simultaneous abdominal skin temperatures were used for calculation of peripheral to central skin temperature difference during these periods and related to the care situation—that is, whether the baby was with the mother or in its cot (fig 1). The results for one neonate were excluded because of an incomplete diary.

The rate of increase in abdominal and foot skin temperatures (℃/h) after a period of low temperature was calculated. For the recordings of foot skin temperature, a stable temperature increase over one hour was required. For the abdominal skin temperature, a stable increase over 30 minutes was accepted, as the preceding reduction in temperature was usually small (fig 1).

Table 1 Temperatures (℃) on days 1 and 2

	Day 1	Day 2
Rectal	37.07 (0.31)	37.22 (0.26)*
Abdomen	36.52 (0.59)	36.80 (0.57)***
Foot	31.85 (1.73)	32.47 (1.19)*
Ambient	23.06 (0.75)	22.93 (0.90)

Values are mean (SD).
*p<0.05, ***p<0.001 compared with day 1.

Data processing

The mean abdominal, foot, and ambient temperatures were calculated and related to rectal temperatures for the whole period and separately for days 1 and 2. All results are presented as mean (SD).

Statistical analysis was carried out using paired Student's *t* test for comparisons of measurements from the same baby on days 1 and 2 and unpaired Student's *t* test for comparisons between different babies on days 1 and 2. $p<0.05$ was taken as significant.

RESULTS

The neonates were treated as one group as no significant differences were found between the 16 boys and 11 girls with

Table 2 Highest and lowest foot skin temperatures (℃) during a stable one hour period on days 1 and 2 in relation to abdominal skin temperature and ambient temperature

	Day 1	Day 2
Highest		
Abdomen	36.88 (0.66)	37.00 (0.69)
Foot	35.50 (1.15)	35.64 (1.23)
Difference	1.38 (0.49)	1.36 (0.95)
Ambient	23.05 (0.99)	22.93 (0.98)
Lowest		
Abdomen	36.19 (0.62)	36.52 (1.05)
Foot	29.37 (1.80)	29.84 (1.47)
Difference	6.77 (1.61)	6.68 (1.46)
Ambient	23.21 (0.77)	22.96 (0.86)**

Values are mean (SD).
**p<0.01 compared with day 1.

regard to gestational age (mean (SD) 40 (1.2) weeks), birth weight (3630 (481) g), length (50.7 (2.1) cm), and mean rectal or skin temperatures.

Mean rectal and abdominal and foot skin temperature on days 1 and 2

Abdominal skin temperature was always higher than foot skin temperature ($p<0.001$).

The mean abdominal skin, foot skin, and rectal temperatures for the 27 children were significantly lower on day 1 than day 2 (table 1).

The relative air humidity during the measurement periods was 40 (10)% with no significant difference between days 1 and 2.

Periods of highest and lowest foot skin temperature on days 1 and 2

Mean foot skin and abdominal skin temperatures for periods of more than one hour when the foot skin temperature was highest and lowest were calculated for the whole group (n = 26; recordings from one neonate were incomplete). There were no significant differences between days 1 and 2.

The difference between abdominal skin temperature and the highest foot skin temperature was 1.38 (0.49)℃ and 1.36 (0.95)℃ on days 1 and 2 respectively. The corresponding differences for the lowest foot skin temperature were 6.77 (1.61)℃ and 6.68 (1.46)℃ (table 2).

Foot skin temperature when the baby was with the mother and in the cot

Log sheets that were sufficiently detailed were used to compare skin temperatures when the neonates were in close contact with the mothers and when lying alone in their cots. Six protocols, with periods between notes of less than three hours, were selected. Periods with a foot skin temperature >2.0℃ above or below the mean of the whole measurement period were studied. A total of 26 episodes of high foot skin temperature and 22 episodes of low foot skin temperature could be defined. During all episodes of high foot skin temperature, the neonates were with their mothers, whereas they were in their cots during all the episodes of low foot skin temperature. This observation was, with few exceptions, consistent for the remaining 21 neonates for whom notes were less precise.

Abdominal and foot skin temperatures and the difference were analysed for the periods when foot skin temperature was >2℃ above and >2℃ below the mean. Mean abdominal skin temperature was significantly higher when the foot skin temperature was high than when foot skin temperature was low. The temperature difference was significantly less during episodes of high (1.62 (0.71)℃) than low (6.86 (0.95)℃) ($p<0.001$) foot skin temperature. There was no significant difference between days 1 and 2 (table 3).

Table 4 Maximum increase in temperature (℃/h) of the abdomen and foot on days 1 and 2

	Day 1	Day 2
Abdomen	2.35 (1.17)	2.07 (0.88)
Foot	4.78 (1.80)***	5.06 (1.40)***

Values are mean (SD).
***p<0.001 compared with the abdomen.

The periods of high foot skin temperature made up 7.8 (3.3) hours of the whole study period of 41 (9.3) hours, and those of low foot skin temperature made up 9.0 (4.5) hours.

Ability to increase skin temperature

The speed of increase in skin temperature was significantly greater for the foot than for the abdomen (table 4). There was no significant difference between days 1 and 2 for either location.

When all periods of increased foot skin temperature (heat saving) were added together, they made up 52% and 55% of the observation period on days 1 and 2 respectively.

DISCUSSION

Peripheral and central skin temperature in 27 healthy newborns during the first two days of life were continuously analysed by wireless temperature sensors. All neonates were cared for by their mothers on the ward. The mothers kept diaries about the care situation, noting when the neonates were in close contact themselves and when lying in the cot.

All mothers reported that the temperature sensors did not interfere with the care of their babies. The local insulation added by the sensors was 2% and 3% of the total for the abdomen (with nappy, underpants, and cotton blanket) and foot (with rompers and cotton blanket) respectively. This may delay changes in skin temperature caused by a rapid change in the environment but only marginally influence

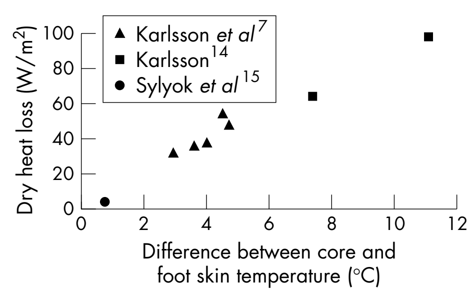

Figure 2 Measured dry heat loss in relation to the difference between core temperature and foot skin temperature as reported in previous studies.

Table 3 Temperature difference (℃) for all abdominal and foot skin temperature periods in which the foot skin temperature was 2°C higher (baby with mother) or 2°C lower (baby in the cot) than mean foot skin temperature for the whole measurement period

	With mother		In cot	
	Abdominal/foot	Difference	Abdominal/foot	Difference
Day 1	36.93/35.36	1.57 (0.62)	36.30**/29.46***	6.84 (0.74)***
Day 2	36.96/35.24	1.72 (0.79)	36.48**/29.57***	6.91 (1.13)***
Total	36.95/35.30	1.62 (0.71)	36.39**/29.52***	6.86 (0.95)***

Differences are mean (SD).
**p<0.01, ***p<0.001 compared with when the baby was with the mother.

What is already known on this topic

- Temperature regulation in newborn babies has been studied during short periods of time and under experimental conditions

What this study adds

- We have studied the natural pattern of temperature variations in newborn babies and the influence of changes in environmental conditions during routine care during the first two days of life

skin surface temperature during a "steady state" (at the most + 0.2℃). As attempts to calculate the effect on skin temperature caused by the sensors contained uncertainties, original temperature measurements are presented. As the added insulation is the same for abdomen and foot, the results and conclusions based on skin temperature differences will not be affected.

All the neonates were regarded as having normal regulation of body temperature. Stable ambient conditions of about 23.0℃ and relative air humidity of 40% were recorded during the two day period.

Mean rectal and abdominal and foot skin temperatures on days 1 and 2

As expected, the continuous recordings of abdominal skin temperature were stable and close to core temperature (fig 1). This is in accordance with previous studies.[6 7]

For the environmental conditions studied, skin circulation in this area is minimally affected.[7]

In our study, we only measured peripheral skin temperature at the foot, which, because of clothing and bedclothes, was less exposed to ambient temperature than the hand. Even so, a clear variation in skin temperature was recorded, which is in agreement with previous studies which showed that hands and feet react by decreasing peripheral circulation in heat loosing conditions.[2 3] This vasoconstriction is mediated by the sympathetic system acting on arteriovenous shunts.[8]

A significantly higher mean body temperature, rectal temperature, and abdominal and foot skin temperature was recorded on day 2 than day 1. This also agrees with previous studies which showed a continuously increasing body temperature during day 1.[9 10] This has been attributed to a successive increase in the basal metabolism and thus increased heat producing ability during the first days of life.[2 11 12]

Highest and lowest foot skin temperature

All the one hour periods of highest foot skin temperature were recorded when the neonates were in close contact with the mother. On these occasions the abdominal skin temperature was also higher than average, and the temperature difference between abdominal skin and foot skin was small. Periods of lowest foot skin temperature were always recorded when the neonates were in their cots. During these periods the abdominal skin temperature was lower than average and the temperature difference was large. No differences were found between days 1 and 2.

We interpret the consistent finding of a small temperature difference when the neonate was with the mother as diminished heat loss from the baby when it was next to a warm surface than when lying in the cot, as in previous studies of skin to skin care.[13]

Abdominal skin temperature during periods with the mother was close to the mean rectal temperature for the whole study period (0.2℃ below) compared with 0.7℃ below during periods in the cot.

The mean foot skin temperature was 32℃ for the whole study period. For periods when the neonates were with their mothers, it was 35.3℃ compared with 29.5℃ when they were in the cot.

Ability to increase skin temperature

Decreases in abdominal skin temperature were always associated with a change of nappy. The subsequent maximal abdominal skin temperature increase was 2.1–2.4℃/h (table 4).

The foot skin temperature increased by 4.8–5.1℃/h when a child was taken from the cot to the mother (table 4). Foot skin temperature increased from the lowest to the highest level within two hours.

In a previous study, deep body temperature increased by 0.7℃/h during skin to skin care periods in term, newborn babies with an initial rectal temperature of 36.3°.[13]

Heat losses

Adamson *et al*[5] showed that oxygen consumption correlated with the ambient to mean skin temperature difference (external temperature gradient) but not with the rectal temperature.

Measurement of dry heat losses confirms that heat losses are determined by the external temperature gradient in neonates.[4 5 7] Clothing changes the dimension of the heat loss but not the correlation.

Information from the limited number of studies allowing quantification of dry heat loss from neonates from direct whole body calorimetry[15] or weighted direct calorimetry[7 14] in relation to the difference between core and foot skin temperature can be combined to illustrate heat loss over a range of core-foot skin temperature differences (fig 2). For all these references[7 14 15] values from diagrams of dry heat loss have to be combined with diagrams presenting core temperature and foot skin temperature.

The temperature difference of 7℃ between abdominal and foot skin recorded for the neonates when in the cot corresponds to a heat loss of about 70 W/m^2. A difference of 2℃ recorded when the neonate was kept next to the mother's skin corresponds to a heat loss of 20 W/m^2.

The mean abdominal to foot skin temperature difference of 5℃ for the whole study period corresponds to a mean heat loss of 50 W/m^2. Under optimal environmental conditions (temperature neutral zone) the heat loss from term babies is about 35 W/m^2.[3 4 7 10] Losses of 70 W/m^2 are close to the maximum for which a neonate can compensate.[3] A loss of 20 W/m^2 allows heat storage and compensation for the losses experienced when cared for in the cot.

The maximal measured rectal temperature during the study period was 37.5℃, and sweating was never reported. Sweating has been reported to occur in newborn babies with a core temperature of 37.3℃ or more in combination with a temperature difference between core and mean skin temperature of less than 1℃.[4]

CONCLUSIONS

This study emphasises the importance of close physical contact with the mothers for temperature regulation during the first few postnatal days. In the maternity ward studied, periods of cot care resulted in peripheral skin temperature changes indicating heat losses close to compensatory capacity. During periods of skin to skin care, peripheral and abdominal skin temperature increased indicating a heat gain.

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