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Normal range and risk factors for deviating body temperatures during the first 24 hours in term-born infants under standardised care: an observational study

Lars Tveiten [1], Lien My Diep [2,3], Thomas Halvorsen [4,5], Trond Markestad [4,6]

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[1]Department of Pediatrics - Elverum, Innlandet Hospital Trust, Elverum, Norway
[2]Oslo Centre for Biostatistics and Epidemiology, Research Support Services, Oslo University Hospital, Oslo, Norway
[3]University of Oslo, Oslo, Norway
[4]Faculty of Medicine, Department of Clinical Science, University of Bergen, Bergen, Norway
[5]Department of Pediatrics and Adolescent Medicine, Haukeland University Hospital, Bergen, Norway
[6]Department of Research, Innlandet Hospital Trust, Brumunddal, Norway

Correspondence to
Dr Lars Tveiten; lars.tveiten@sykehuset-innlandet.no

ABSTRACT

Objective Body temperature for a known ambient temperature is not known for infants born at term. We aimed to determine the normal range and the incidences of hypothermia and hyperthermia during the first 24 hours of life in healthy term-born infants nursed according to WHO recommendations.

Design Prospective observational study.

Setting Norwegian single centre district hospital. Infants were observed during skin-to-skin care or when dressed in cots.

Participants Convenience sample of 951 healthy infants born at term.

Methods Delivery room temperature was aimed at 26–30°C and rooming-in temperature at 24°C. We measured rectal and room temperatures at 2, 4, 8, 16 and 24 hours of age.

Main outcome measures Percentile curves for rectal temperature. Proportions and risk factors for hypothermia and hyperthermia.

Results The mean (SD) room temperature was 24.0°C (1.1), 23.8°C (1.0), 23.8°C (1.0)., 23.7°C (0.9) and 23.8°C (0.9). The median (2.5, 97.5 percentile) rectal temperature was 36.9°C (35.7–37.9), 36.8°C (35.9–37.5), 36.9°C (36.1–37.5), 37.0°C (36.4–37.7) and 37.1°C (36.5–37.7). Hypothermia (<36.5°C) occurred in 28% of the infants, 82% of incidents during the first 8 hours. Risk factors for hypothermia were low birth weight (OR 3.1 (95% CI, 2.0 to 4.6), per kg), male sex, being born at night and nursed in a cot versus skin to skin. Hyperthermia (>37.5°C) occurred in 12% and most commonly in large infants after 8 hours of life. Risk factors for hyperthermia were high birth weight (OR 2.2 (95% CI, 1.4 to 3.5), per kg), being awake, nursed skin to skin and being born through heavily stained amniotic fluid.

Conclusions Term-born infants were at risk of hypothermia during the first hours after birth even when nursed in an assumed adequate thermal environment and at risk of hyperthermia after 8 hours of age.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ It is commonly accepted that the normal range of body temperature in the newborn is 36.5–37.5°C, and research has mainly addressed protection against hypothermia.

WHAT THIS STUDY ADDS

⇒ We created rectal temperature-for-age percentiles in healthy term-born infants during the first 24 hours after birth while nursed close to what is recommended by WHO. We also describe the risk factors for hypothermia and hyperthermia in this setting.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The data may contribute to a better understanding and an evidence-based assessment of body temperature.

INTRODUCTION

The incidence of hypothermia is quite high in preterm infants and is associated with severe morbidities and mortality.[1] Systematic reviews have shown that the incidence of hypothermia in term infants is also high.[2] However, this is often underrecognised. Hypothermia in term infants has been shown to be associated with mortality and morbidities such as acid/base disturbances and hypoglycaemia.[3–7] Hyperthermia and temperature instability may be due to overheating but cause concern as they are common symptoms of infection.[8 9] In recognising high rates and severe consequences of hypothermia in newborns, the WHO published a guide for thermal protection in 1997,[5] and many strategies and procedures have been evaluated, especially during the immediate newborn period.[10] WHO defined the normal body temperature to be 36.5–37.5°C, but normal ranges for a given thermal environment have not been scientifically established for newborn infants born at term gestation.[11–13]

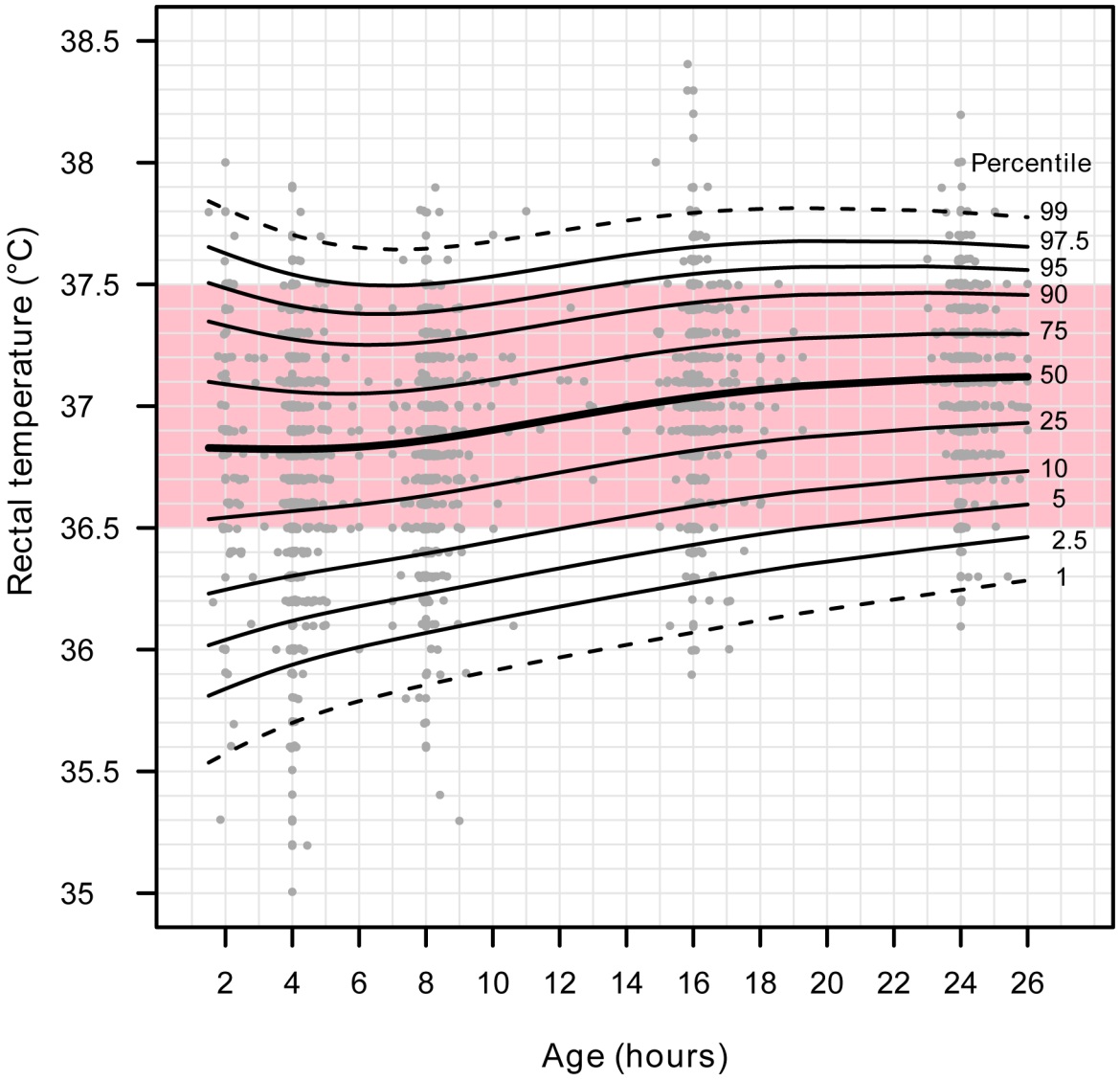

Figure 1 Smoothed percentiles of rectal body temperature from 2 to 24 hours of age. Grey markers represent individual rectal temperature readings. The rectangular pink or shadowed area corresponds to the WHO normal range of body temperature.

Our aims were to obtain normal ranges for rectal temperature and the incidences of hypothermia and hyperthermia during the first 24 hours after birth in infants born at term, when adhering to thermal protection close to the recommendations of WHO, and to determine significant risk factors for hypothermia and hyperthermia.

METHODS

Subjects

The study was conducted at the obstetric unit at Innlandet Hospital Trust, Elverum, Norway, from February 2008 to March 2010 and from December 2010 to January 2012.

Details on recruitment and patient characteristics of these healthy term-born infants were published earlier,[14] and we documented that the sample was representative of the whole birth cohort. We defined infants as being born small for gestational age (SGA) if their birth weight was below the 10th percentile for gestational age.[15]

The attending midwives, gynaecologists and paediatricians were responsible for the immediate handling of the newborns. We obtained arterial and venous blood gases from the umbilical cord[16] and assessed Apgar scores at 1 and 5 min after birth. 20 nurse assistants and midwives who were trained for the study measured the temperatures and collected the relevant clinical data. One of the authors (LT) extracted relevant clinical and laboratory data from the hospital medical records. Written informed consent was obtained from the parents.

Patient and public involvement statement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Table 1 Rectal temperature* in newborn infants at 2–24 hours of age

Temperature percentile	Rectal temperature (°C)				
	Age (hours)				
	2	4	8	16	24
	n=109	n=920	n=918	n=906	n=887
99th	38.0	37.6	37.7	37.9	37.8
98th	38.0	37.5	37.6	37.7	37.7
97.5th	37.9	37.5	37.5	37.7	37.7
(95% CI†)	(37.6 to 38.0)	(37.4 to 37.5)	(37.4 to 37.6)	(37.6 to 37.8)	(37.6 to 37.8)
95th	37.8	37.3	37.4	37.6	37.6
75th	37.2	37.1	37.1	37.2	37.3
50th	36.9	36.8	36.9	37.0	37.1
(95% CI)	(36.8 to 37.1)	(36.8 to 36.8)	(36.8 to 36.9)	(37.0 to 37.1)	(37.1 to 37.1)
25th	36.5	36.6	36.6	36.8	36.9
5th	36.0	36.1	36.2	36.5	36.6
2.5th	35.7	35.9	36.1	36.4	36.5
(95% CI)	(35.3 to 36.0)	(35.7 to 36.0)	(35.9 to 36.2)	(36.2 to 36.4)	(36.4 to 36.5)
2nd	35.6	35.8	36.0	36.3	36.4
1st	35.3	35.5	35.8	36.1	36.3
Other parameters					
Mean (SD), °C	36.9 (0.51)	36.8 (0.40)	36.8 (0.36)	37.0 (0.35)	37.1 (0.30)
CV	0.012	0.011	0.010	0.009	0.008
Range, °C	35.3–38.0	34.7–37.9	35.3–37.9	34.4–38.4	36.1–38.2

Percentiles with 95% CIs.
*Raw data, unsmoothed.
†Confidence intervals (for the 2.5th, 50th and 97.5th percentiles).
CV, Coefficient of variation; SD, Standard deviation.

'The warm chain'

As far as possible, infants and parents were handled according to the 10 steps of the WHO guide for thermal protection of the newborn.[5] Delivery room temperature was aimed at 26–30°C. We did not document room temperature until 2 hours of age but have later checked that standard delivery room temperatures reached nearly 30°C. Infants were immediately dried and placed prone or on the side, on the mothers chest, provided with a cotton hat and covered with clean prewarmed towels, and the infant and mother were covered with a shared duvet. After general anaesthesia, the infants were dried under an overhead heater, dressed with warm clothes and placed in a cot before skin-to-skin contact. The infant and mother/parents usually stayed in the same room facilitating on-demand breastfeeding and keeping the baby warm. If not being nursed skin to skin, we placed the infant on a 7–9 cm thick foam rubber mattress with a cotton cover in an unheated transparent plastic cot. The infants were dressed in one or two cotton T-shirts and trousers or a long nightgown, a disposable diaper and a cotton hat and draped (not swaddled) in a cotton blanket or a thick duvet. We did not bathe the infants.

We routinely monitored glucose levels in newborns at risk of hypoglycaemia, which included those whose birth weight was >5000 g or <2500 g, or maternal or gestational diabetes.

Measurements

We obtained rectal and room temperatures at 2, 4, 8, 16 and 24 hours. Rectal temperature was obtained by inserting a low-reading rectal thermometer (Digitemp MT 1671, Microlife AG, Widnau, Switzerland), pretreated with Vaseline, 2–3 cm (usually 2 cm) into the rectum according to the thermometer manual. The thermometer fulfilled the ASTME-1112 reference standard for electronic thermometers, the EN12470-3: 2000 reference standard for clinical thermometers for hospital use, and was CE 0044 marked. The measurement accuracy was 0.1°C. An internal check at startup at a test value of 37°C gave an error message if a temperature deviation of more than 0.1°C occurred. We used the same thermometer for all rectal temperatures in an infant and read the

Table 2 Associations between clinical characteristics and mean rectal temperature

Characteristics	Measurements*	Regression coefficients (95% CI)					
		Unadjusted		P value	Adjusted†		P value
Infant							
Decreasing BW (kg)	3740	−0.16	(−0.19 to −0.13)	<0.001	−0.16	(−0.19 to −0.13)	<0.001
Male sex	3740	−0.03	(−0.06 to −0.003)	0.03	−0.06	(−0.09 to −0.03)	<0.001
Asleep (vs awake)	3655	−0.10	(−0.12 to −0.08)	<0.001	−0.07	(−0.10 to −0.05)	<0.001
Twins	3740	−0.30	(−0.47 to −0.14)	<0.001	−0.20	(−0.36 to −0.04)	0.015
SGA (10 percentile)	3740	−0.14	(−0.20 to −0.08)	<0.001	0.02	(−0.05 to 0.08)	0.6
Non-Caucasian‡	3740	0.002	(−0.06 to 0.06)	0.9	0.03	(−0.03 to 0.09)	0.3
Environmental							
Cot (vs skin to skin)	3640	−0.04	(−0.08 to −0.001)	0.06	−0.07	(−0.11 to −0.03)	0.001
Room temperature (°C)	3644	−0.0004	(−0.01 to 0.01	0.96	−0.0007	(−0.01 to 0.01)	0.9
Delivery							
Caesarean delivery	3740	−0.006	(−0.05 to 0.03)	0.8	−0.05	(−0.12 to 0.02)	0.2
Epidural anaesthesia	3740	−0.008	(−0.04 to 0.03)	0.4	−0.002	(−0.04 to 0.03)	0.9
Spinal anaesthesia	3740	−0.02	(−0.06 to 0.03)	0.4	0.05	(−0.03 to 0.13)	0.2
General anaesthesia	3740	0.06	(−0.02 to 0.14)	0.1	0.05	(−0.03 to 0.14)	0.2
Amniotic fluid							
Clear¶			1				
Slightly stained§	3721	0.02	(−0.02 to 0.07)	0.3	0.006	(−0.03 to 0.05)	0.8
Heavily stained	3721	0.08	(0.02 to 0.15)	0.016	0.07	(0.01 to 0.14)	0.018
Time of birth							
3 PM to 9:59 PM	3740	0.01	(−0.02 to 0.05	0.6	0.004	(−0.03 to 0.04)	0.8
10 PM to 6:59 AM	3740	−0.06	(−0.10 to −0.02)	0.002	−0.05	(−0.09 to −0.02)	0.005
7 AM to 2:59 PM	3740		1				
Age (hours)							
2	3740	−0.25	(−0.31 to −0.18	<0.001	−0.23	(−0.32 to −0.15)	<0.001
4	3740	−0.31	(−0.34 to −0.28)	<0.001	−0.31	(−0.34 to −0.27)	<0.001
8	3740	−0.26	(−0.29 to −0.23)	<0.001	−0.26	(−0.29 to −0.23)	<0.001
16	3740	−0.07	(−0.10 to −0.05)	<0.001	−0.07	(−0.10 to −0.04)	<0.001
24	3740		1				

*Number of measurements for the unadjusted model.
†Based on 3513 measurements for the adjusted model.
‡Maternal origin.
§Meconium-stained
¶Clear or very light yellow
BW, birth weight; CI, confidence interval; SGA, small for gestational age.

temperature display at approximately 60 s, when the thermometer had given an audible signal that indicated a temperature rise of <0.1°C in 16 s.

We disinfected the thermometer in 'Alkotip' (isopropyl alcohol 70%) after each measurement and fully submerged it in 'Perasafe' (Antec International Limited, Windham Road, Chilton Industrial Estate, Sudbury, Suffolk, UK) for 10 min before using it on another infant.

We obtained room temperature with a Duotemp TM101 (Fisher & Paykel Electronics Ltd, Auckland, New Zealand) thermometer with Fisher & Paykel DuoSense sensor. The room temperature could be adjusted for individual preferences.

Statistical analysis

We estimated the required sample size to be 300 infants to create percentile curves[17] but included 1000 for increased precision. To create the curves (figure 1), we applied Johnson's SU distribution of the GAMLSS package[18] in R software V.4.2.2 (the R Foundation, Vienna, Austria[19]). The mean and SD of

Table 3 Predictors for hypothermia (<36.5 °C) in 951 healthy infants

Characteristics	Measure-ments*	OR (95% CI†)			
		Unadjusted	P value	Adjusted††	P value
Infant					
Decreasing BW (kg)	3740	2.8 (2.1 to 3.8)	<0.001	3.1 (2.0 to 4.6)	<0.001
Male sex	3740	1.4 (1.1 to 1.8)	0.02	1.9 (1.4 to 2.5)	<0.001
Asleep (vs awake)	3655	1.7 (1.3 to 2.2)	<0.001	1.3 (1.0 to 1.7)	0.07
Twins	3740	5.4 (1.8 to 16.3)	0.003	4.6 (1.3 to 16.1)	0.02
SGA (10-percentile)	3740	3.1 (2.0 to 4.9)	<0.001	1.3 (1.7 to 2.2)	0.4
Non-Caucasian‡	3740	1.5 (0.9 to 2.5)	0.1	1.2 (0.7 to 2.1)	0.6
Environmental					
Cot (vs skin to skin)	3640	1.3 (0.8 to 2.2)	0.3	1.8 (1.04 to 3.0)	0.04
Room temperature (°C)	3644	0.9 (0.8 to 1.1)	0.5	0.9 (0.8 to 1.1)	0.2
Delivery					
Caesarean delivery	3740	1.0 (0.7 to 1.4)	0.9	1.5 (0.7 to 3.4)	0.3
Epidural anaesthesia	3740	0.8 (0.6 to 1.1)	0.2	0.7 (0.5 to 1.1)	0.1
Spinal anaesthesia	3740	1.1 (0.7 to 1.6)	0.7	0.7 (0.3 to 1.6)	0.4
General anaesthesia	3740	0.8 (0.4 to 1.7)	0.6	0.7 (0.3 to 1.7)	0.4
Amniotic fluid					
Clear	3721	1			
Slightly meconium-stained	3721	1.1 (0.8 to 1.7)	0.4	1.3 (0.9 to 2.0)	0.2
Heavily meconium-stained	3721	1.0 (0.6 to 1.9)	0.9	1.1 (0.6 to 2.2)	0.8
Time of birth					
3 PM to 9:59 PM	3740	0.9 (0.6 to 1.3)	0.6	1.1 (0.7 to 1.6)	0.6
10 PM to 6:59 AM	3740	1.7 (1.2 to 2.3)	<0.001	1.8 (1.2 to 2.6)	0.002
7 AM to 2:59 PM	3740	1			
Age (hours)					
2	3740	13.7 (6.3 to 29.7)	<0.001	13.1 (4.8 to 36.0)	<0.001
4	3740	11.9 (7.1 to 20.1)	<0.001	14.5 (8.2 to 25.9)	<0.001
8	3740	8.8 (5.2 to 14.8)	<0.001	10.4 (5.8 to 18.5)	<0.001
16	3740	2.4 (1.4 to 4.3)	0.001	2.9 (1.6 to 5.4)	0.001
24	3740	1			

*Number of measurements for the unadjusted model.
†Based on 3532 measurements for the adjusted model.
‡Maternal origin.
BW, birth weight; CI, confidence interval; OR, odds ratio; SGA, small for gestational age.

rectal temperature were allowed to change with age as a p-spline with two degrees of freedom. For raw percentiles (table 1), we applied the centile function in Stata SE 18.0 (StataCorp LLC, Texas, USA[20]), and for percentile confidence intervals (table 1), we used quantile regression.

To estimate the effects of covariates (table 2), we used linear mixed effects models with rectal temperature as the dependent variable. Infant and age were specified as random intercepts and slope variables with unstructured variance-covariance matrix to fit five measurements per infant. Intraclass correlation coefficients (ICCs) were calculated using the Stata icc function for a two-way mixed effects model. ICC describes how strongly the rectal temperatures of the same infant resemble each other, while allowing for systematic differences between different points in time (consistency).

We performed mixed effects ordered logistic regression analysis to evaluate the potential risk factors associated with hypothermia (rectal temperature <36.5°C, table 3) and mixed effects logistic regression for hyperthermia (>37.5°C, table 4). In these models, we treated infant as a random intercept variable and used the Stata mvaghermite function as integration method but excluded the random slope variable due to non-convergence.

Table 4 Predictors for hyperthermia (>37.5°C) in 951 healthy infants

Characteristics	Measure-ments*	OR (95% CI†) Unadjusted	P value	Adjusted†	P value
Infant					
Birth weight (kg)	3740	2.0 (1.4 to 3.0)	<0.001	2.2 (1.4 to 3.5)	<0.001
Male sex	3740	0.9 (0.6 to 1.3)	0.4	0.8 (0.5 to 1.1)	0.2
Awake (vs asleep)	3655	2.2 (1.4 to 3.2)	<0.001	1.9 (1.3 to 3.0)	0.002
Twins		N/A		N/A	
SGA (10-percentile)	3740	0.3 (0.1 to 1.1)	0.07	0.8 (0.2 to 2.7)	0.7
Non-Caucasian‡	3740	1.6 (0.8 to 3.1)	0.2	1.7 (0.8 to 3.6)	0.2
Environmental					
Skin to skin (vs cot)	3640	1.7 (0.9 to 3.0)	0.08	2.0 (1.0 to 3.7)	0.04
Room temperature (°C)	3644	1.0 (0.8 to 1.2)	0.9	1.0 (0.8 to 1.3)	0.2
Delivery					
Caesarean delivery	3740	0.7 (0.4 to 1.2)	0.2	0.5 (0.2 to 1.6)	0.2
Epidural anaesthesia	3740	0.3 (0.8 to 1.9)	0.3	1.2 (0.8 to 1.9)	0.4
Spinal anaesthesia	3740	0.8 (0.4 to 1.4)	0.4	1.5 (0.4 to 5.1)	0.5
General anaesthesia	3740	0.8 (0.3 to 2.5)	0.7	0.9 (0.3 to 2.8)	0.8
Amniotic fluid					
Clear	3721	1			
Slightly meconium-stained	3721	1.5 (0.9 to 2.5)	0.09	1.2 (0.7 to 2.1)	0.4
Heavily meconium-stained	3721	2.2 (1.1 to 4.3)	0.02	2.3 (1.1 to 4.6)	0.02
Time of birth					
3 PM to 9:59 PM	3740	1.0 (0.6 to 1.5)	0.9	0.8 (0.5 to 1.4)	0.5
10 PM to 6:59 AM	3740	1.1 (0.7 to 1.7)	0.8	1.2 (0.7 to 1.9)	0.5
7 AM to 2:59 PM	3740	1			
Age (hours)					
2	3740	5.6 (2.1 to 15.1)	0.001	2.9 (0.8 to 11.5)	0.1
4	3740	1			
8	3740	1.5 (0.7 to 3.2)	0.3	1.5 (0.7 to 3.1)	0.1
16	3740	4.1 (2.1 to 8.0)	<0.001	3.8 (2.0 to 7.4)	<0.001
24	3740	4.1 (2.1 to 7.9)	<0.001	3.9 (2.0 to 7.6)	<0.001

*Number of measurements for the unadjusted model.
†Based on 3483 measurements for the adjusted model.
‡Maternal origin.
CI, conficence interval; OR, odds ratio; SGA, small for gestational age.

RESULTS

Of the 951 included infants, 258 (27%) were born during the night shift from 10 PM to 6:59 AM, 422 (44%) during the day shift from 7 AM to 2:59 PM and 271 (28%) from 3 PM to 9:59 PM. All appeared healthy from birth, including 56 infants with a base excess below −10 mmol/L and 14 infants with a pH <7.1. Due to work shifts, each infant was usually assessed by 3–4 different observers. The median (IQR) ages at assessment were 2 (2.0–2.2), 4 (4.0–4.1), 8 (8.0–8.1), 16 (16.0–16.1) and 24 (24.0–24.1) hours.

In accordance with the study protocol to avoid undue family interference, we measured temperatures at 2 hours in only 109 infants, but they did not differ from the others with respect to clinical characteristics or later temperatures (table 5). Temperatures were missing for 5% of planned rectal and room measurements from 4 to 24 hours.

Rectal temperature percentiles and significance of perinatal factors

The median rectal temperature at 2 hours of age was 36.9°C. It decreased to 36.8°C at 4 hours and stabilised at 37.1°C at 24 hours (figure 1, table 1). The 2.5th percentile was 35.7°C at 2 hours and gradually increased to 36.5°C at 24 hours. The 97.5th percentile was 37.9°C at 2 hours, thereafter between 37.5

Table 5 Maternal, pregnancy and infant characteristics*

	Participants	
	Total	Subgroup†
	n=951	n=109
Maternal and pregnancy characteristics		
Married/cohabitating, *n (%)*	887 (93.3)	98 (89.9)
Daily smoker (during early pregnancy), *n (%)*	133 (14.8)‡	13 (11.9)§
Nulliparous, *n (%)*	369 (38.8)	38 (34.9)
Age, y (SD)	29.3 (5.3)	28.7 (5.4)
Non-Caucasian origin	62 (6.5)	10 (9.2)
Preeclampsia, *n (%)*	10 (1.0)	2 (1.8)
Delivery characteristics, n (%)		
Caesarean delivery	156 (16.4)	26 (23.9)
Epidural anaesthesia	225 (23.7)	30 (27.5)
Spinal anaesthesia	123 (12.9)	22 (20.2)
General anaesthesia	35 (3.7)	8 (7.3)
Amniotic fluid		
Slightly meconium-stained	147 (15.5)	21 (19.3)
Heavily meconium-stained	56 (5.9)	6 (5.5)
Infant characteristics		
Birth weight, mean (SD), g	3595 (483)	3628 (511)
Male sex, n (%)	487 (51.2)	57 (52.3)
Twins, n (%)	8 (0.8)	2 (1.8)
SGA (<10th percentile), n (%)	62 (6.5)	7 (6.4)
Head circumference, mean (SD), cm	35.1 (1.5)	35.1 (1.5)
Gestational age at birth, mean (SD), d	280 (8.6)	279 (9.1)
Apgar score at 1 min <8, *n* (%)	37 (3.9)	6 (5.5)
Transferred to the neonatal ward, *n* (%)	9 (0.9)	1 (0.9)

*Data from the Medical Birth Registry of Norway.
†Subgroup is the one whose temperatures were measured from 2 hours.
‡Missing for 63 (6.6%).
§Missing for 9 (8.3%).
SD, Standard deviation; SGA, small for gestational age.

and 37.7°C. Median and mean temperatures were nearly identical (table 1).

The mean rectal temperature was 0.06°C (95% CI, 0.03 to 0.09, p<0.001) lower for males than for females after adjusting for birth weight. It decreased by 0.16°C (95% CI, 0.13 to 0.19, p<0.001) per kg lower birth weight. The decrease was largest at 2 hours (0.46°C, 95% CI, 0.29 to 0.63, p<0.001), but the difference remained until 24 hours (figure 2). The mean temperature was lower during sleep than when awake (0.1°C, 95% CI, 0.08 to 0.12, p<0.001, unadjusted) and higher if exposed to heavy meconium-stained amniotic fluid, but without respiratory symptoms (n=56), than with clear fluid (0.07, 95% CI, 0.01 to 0.14°C, p=0.02). There were no differences between infants delivered by caesarean section and vaginally, between deliveries without or following epidural, spinal or general anaesthesia, or between Caucasian and non-Caucasian infants.

A sensitivity analysis showed that limiting the data to non-SGA infants increased the 2.5th percentile by 0.1°C at 2 hours but did not affect the 5th to 97.5th percentiles.

Temperature variation

For 807 infants with 4 measurements, the ICC was 0.28 (95% CI, 0.24 to 0.31). For 95 infants with all 5 observations, the ICC was 0.31 (95% CI, 0.21 to 0.41).

Hypothermia

Of the 3740 measurements, 302 (8.1%) were in the mild (36.0 to <36.5°C) and 48 (1.2%) in the moderate (32.0 to <36.0°C) hypothermic range (table 6A). Of all infants, 270 (28.4%) had at least one hypothermic temperature; 23.8% had mild, and 4.5% had moderate hypothermia. The occurrence of hypothermia decreased from 16.5% at 2 to 2.1% at 24 hours (table 6A). The risk of hypothermia increased with being male as compared with female (OR 1.7 (95% CI, 1.3 to 2.2), p<0.001) after adjusting for birth weight and in the final adjusted model (1.9 (95% CI, 1.4 to 2.5), p<0.001), with decreasing birth weight (OR 3.1 (95% CI, 2.0 to 4.6), p<0.001, per kg), being born at night (OR 1.8 (95% CI, 1.2 to 2.6), p=0.002) or born SGA (OR 3.1 (95% CI, 2.0 to 4.9), p<0.001, unadjusted), and with being nursed in a cot as opposed to skin to skin (OR 1.8 (95% CI, 1.04 to 3.0), p=0.04) (table 3).

Hyperthermia

Of the 951 infants, 115 (12%) had a total of 126 recorded rectal temperatures above 37.5°C (19 measurements at 2–4 hours and 107 at 8–24 hours). Six infants had a temperature above 38°C; five at 16 and one at 24 hours. Their mean (SD) birth weight was 4253 (973) g. The risk of hyperthermia increased with increasing birth weight (OR 2.2 (95% CI, 1.4 to 3.5), p<0.001, per kg), with being awake (OR 1.9 (95% CI, 1.3 to 3.0), p=0.002), being with parents (OR 2.0 (1.0–3.7), p=0.04) and at ages 16–24 hours compared with 4 hours (table 4). Compared with age 24 hours, the risk of hyperthermia was significantly reduced at 4 and 8 hours (data not shown).

Room temperature

The room temperature was close to 24°C during the 22-hour observation (table 6B) but was lower when infants were nursed skin to skin than in a cot (mean difference: −0.14°C (95% CI, −0.23 to −0.04), p=0.005). There was no diurnal variation.

DISCUSSION

By keeping the delivery room temperature at around 26–30°C, the rooming-in temperature at 24°C and nursing the infant skin to skin or dressed and covered

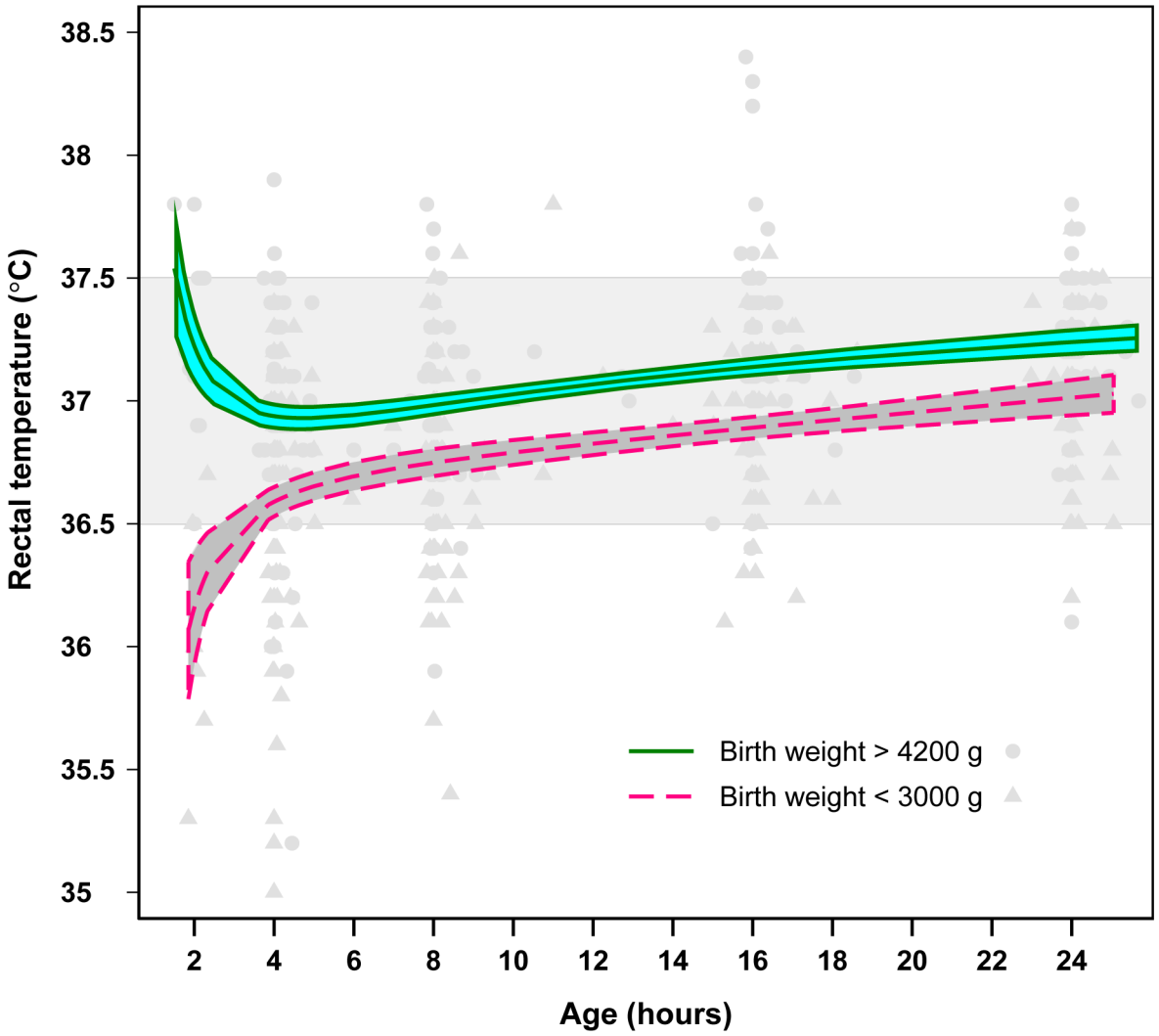

Figure 2 Mean rectal temperatures with 95% CIs in healthy newborns born at term, with lower birth weight (<3000 g, n=95) versus higher birth weight (>4200 g, n=97), from 2 to 24 hours of age. There is a persisting temperature difference between the two groups. Grey markers: individual temperature readings. Shaded rectangular area: the WHO normal range.

in a cot, the median and mean rectal temperatures were close to 37.0°C during the first 24 hours of life in these healthy infants born at term. The 2.5th–97.5th range was close to what has been defined as the normal range of 36.5–37.5°C by WHO, but 28% of the infants experienced hypothermia according to the WHO definition. Hypothermia occurred mainly during the first 8 hours of life and was usually mild. Low birth weight was the major risk factor for hypothermia, while sleeping, male sex or being born at night had a minor impact. Skin-to-skin care had a protective effect, while mode of delivery had no effect on rectal temperature. Hyperthermia occurred in 12% of the infants, usually after 8 hours, and was mainly associated with high birth weights.

The mean rectal temperature was similar to mean axillary and rectal measurements in similar single centre studies,[11–13 21 22] but no previous attempts have been made to scientifically define a normal range[12 13] or to construct a percentile chart for body temperature for a given thermal environment. Instead, it has been common practice to calculate the percentage of infants with hypothermia or hyperthermia at various points in time and compare results with various normal body temperature standards given in textbooks. Such normal standards were summarised by Li *et al* who concluded that they were not evidence based.[13]

The rectal temperature during the first 24 hours of life in our study was very similar to that of a UK study at 2 and 24 hours of age,[11] and that of 27 Swedish term-born infants monitored for 48 hours after birth,[22] but higher than temperatures at 2 and 24 hours after birth in an intervention study to combat hypothermia in Nepal.[23] In the Nepalese study, the infants received immediate drying under radiant heat, swaddling including the head and nursing on the mother's chest, but 22% of the infants weighed <2500 g, and the mean room temperature was only 17.8°C. In the UK study,[11] routines included swaddling, overhead heaters and incubators, and the mean ambient temperature was

Table 6 Hypothermia incidents by severity classifications and age, and room temperature

		Age (hours)				
		2	4	8	16	24
(A) Hypothermia incidents		**n=109**	**n=920**	**n=918**	**n=906**	**n=887**
Severity classifications						
WHO*	Mullany†					
Mild	Grade 1: <36.5–36.0 °C, *n* (%)	13 (11.9)	124 (13.5)	105 (11.4)	41 (4.5)	19 (2.1)
Moderate	Grade 2: <36.0–35.0 °C, *n* (%)	5 (4.6)	25 (2.7)	15 (1.6)	1 (0.11)	0
Moderate	Grade 3: <35.0–34.0 °C, *n* (%)	0	1 (0.11)	0	1 (0.11)	0
Moderate	Grade 4‡: <34.0 °C, *n*	0	0	0	0	0
Severe: < 32.0 °C		0	0	0	0	0
Hypothermia§ (<36.5°C) total, *n* (%)		18 (16.5)	150 (16.3)	120 (13.1)	43 (4.7)	19 (2.1)
(B) Room temperature						
Mean (SD), °C		24.0 (1.1)	23.8 (1.0)	23.8 (1.0)	23.7 (0.90)	23.8 (0.90)
Median, °C		23.9	23.8	23.8	23.7	23.8
Quartiles (25–75 P), °C		23.4–24.6	23.2–24.4	23.2–24.4	23.1–24.3	23.2–24.4
Range, °C		20.0–29.4	20.0–28.1	21.0–32.0	21.4–27.2	21.3–27.1

*Hypothermia as defined by WHO.[1]
†Hypothermia grades as suggested by Mullany.[7]
‡Mullany hypothermia Grade 4 comprises the lower segment of WHO moderate hypothermia <34.0°C and WHO severe hypothermia (<32.0°C).
§A total of 350 measurements of rectal temperature <36.5°C in 270 infants.
P, Percentile; SD, Standard deviation.

~2°C higher than in our study. Their incidence of hypothermia was lower than in our study, but only 22% of temperature recordings were rectal. In the Swedish study, the ambient temperature was ~1°C lower than in our study.[22] Other relevant studies used axillary temperatures or methods of thermal protection which were not comparable to our study[9 12 13] or did not report ambient temperatures.[1 9 13 24 25]

Our finding that a quarter of the infants had temperatures below 36.5°C during the first 8 hours demonstrated the difficulty of maintaining what is considered a normal body temperature immediately after birth. This finding is in line with research which has demonstrated that infants are unable to fully compensate for heat loss by increasing their metabolism during the first hours after birth, while a gradually increasing basal metabolic rate contributes to the maintenance of a normal body temperature from 8 to 12 hours of age.[26] However, the variation between infants is large, especially during the first day of life,[27] as it was in our study.

The clinical consequences of mild hypothermia are difficult to ascertain, but mild hypothermia has been associated with hypoglycaemia[4] and hyperbilirubinaemia.[6] However, the high incidence of low temperatures despite environmental control near the recommendations of WHO underscores that the risk of hypothermia may be high under less favourable conditions. Further studies are needed, preferably multicentre studies to be able to evaluate local variations in thermoregulatory practices.

We measured rectal temperature because it is traditionally considered the gold standard for assessing the body temperature.[28] Axillary temperature is commonly recommended because of ease and safety if accurate measurement is not essential.[5] Axillary temperature is generally lower than rectal,[29 30] and our percentile values had probably been lower and the rates of temperatures in the hypothermic range higher if we had used axillary instead of rectal temperature. However, there may be no simple correlation between these measurements because they represent different body compartments.[31] Rectal measurement is considered safe if the thermometer is not inserted further than 2–3 cm into the rectum,[32] and WHO recommends 2 cm insertion.[5]

The strengths of this study included the large number of participants and the consistent way of obtaining measurements. The study would have gained from simultaneous measurements of rectal and axillary temperatures since axillary measurement is a common screening procedure, but rectal measurements may be preferred when accuracy is essential.[5 33] WHO recommends a rooming-in temperature of at least 25°C.[5] However, such temperatures are often difficult to maintain because they feel uncomfortable for adults,[5 34] and we suggest that 24°C, as used in our study, is sufficient if other recommended ways of thermoprotection are adhered to.

CONCLUSION

By following the recommendations for thermal protection by WHO, our data supported that 36.5–37.5°C is a reasonable normal range of rectal temperature in the early newborn period, because the rectal temperatures converged

to this range by 24 hours of age. Term-born infants were at risk of hypothermia during the first hours after birth, even when nursed in an assumed adequate thermal environment, which underscores the high risk of hypothermia among more vulnerable infants born under less optimal conditions. Hyperthermia was seen in heavy, awake infants and usually after 8 hours. Potential significances of the deviating body temperatures were not addressed.

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ORCID iDs
Lars Tveiten http://orcid.org/0000-0003-1767-7520
Lien My Diep http://orcid.org/0000-0003-2086-4909
Thomas Halvorsen http://orcid.org/0000-0003-1471-0225
Trond Markestad http://orcid.org/0000-0002-4725-1769

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