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Review

Maintaining normothermia immediately after birth in preterm infants <34 weeks' gestation: A systematic review and meta-analysis



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Abstract

Aim: To evaluate delivery room (DR) interventions to prevent hypothermia and improve outcomes in preterm newborn infants <34 weeks' gestation.

Methods: Medline, Embase, CINAHL and CENTRAL were searched till 22nd July 2022. Randomized controlled trials (RCTs), non-RCTs and quality improvement studies were considered. A random effects meta-analysis was performed, and the certainty of evidence was evaluated using GRADE guidelines.

Results: DR temperature of ≥ 23 °C compared to standard care improved temperature outcomes without an increased risk of hyperthermia (low certainty), whereas radiant warmer in servo mode compared to manual mode decreased mean body temperature (MBT) (moderate certainty). Use of a plastic bag or wrap (PBW) improved normothermia (low certainty), but with an increased risk of hyperthermia (moderate certainty). Plastic cap improved normothermia (moderate certainty) and when combined with PBW improved MBT (low certainty). Use of a cloth cap decreased moderate hypothermia (low certainty). Though thermal mattress (TM) improved MBT, it increased risk of hyperthermia (low certainty). Heated-humidified gases (HHG) for resuscitation decreased the risk of moderate hypothermia and severe intraventricular hemorrhage (very low to low certainty). None of the interventions was shown to improve survival, but sample sizes were insufficient.

Conclusions: DR temperature of ≥ 23 °C, radiant warmer in manual mode, use of a PBW and a head covering is suggested for preterm newborn infants <34 weeks' gestation. HHG and TM could be considered in addition to PBW provided resources allow, in settings where hypothermia incidence is high. Careful monitoring to avoid hyperthermia is needed.

Keywords: Preterm newborn infants, Hypothermia, Delivery room, Plastic bag, Hyperthermia

Introduction

Neonatal resuscitation has advanced substantially in recent decades.¹ However, hypothermia immediately after birth remains a common problem in preterm infants.^{2,3} The Vermont Oxford Network reported that despite many initiatives, the rate of hypothermia in very low birth weight infants on admission to a neonatal intensive care unit (NICU) decreased from 52.6% to only 38.2% over 7 years.⁴ The UK Royal College of Paediatrics and Child Health National Neonatal

Audit Programme 2021 reported that only 73.2% of the very preterm (VPT) infants admitted to NICU were in the normothermic range and 12.2% were hyperthermic.⁵ There is insufficient high-quality data for low- and middle-income countries (LMICs).³

Though a Cochrane review concluded that hypothermia prevention may not translate to better clinical outcomes, a network meta-analysis indicated that using a plastic bag or wrap (PBW) in preterm infants improves survival.^{6,7} The International Liaison Committee on Resuscitation Neonatal Life Support Task Force (ILCOR NLS TF) 2020 Consensus on Science with Treatment Recommendations

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(CoSTR) suggested using combined interventions to prevent hypothermia on NICU admission in VPT infants as a weak recommendation based on very low certainty evidence (CoE).⁸ Surveillance of the literature suggested that the evidence base was increasing. Hence, the ILCOR NLS TF undertook an updated systematic review to comprehensively evaluate various interventions in the delivery room (DR) to prevent hypothermia immediately after birth in preterm newborn infants. The cutoff of <34 weeks was chosen for this review because a companion review addressed infants ≥ 34 weeks' gestation.⁹

Methods

The protocol was registered in PROSPERO (2021 CRD42021267301).¹⁰ Reporting was in accordance with PRISMA.¹¹

Inclusion criteria

Population: Preterm newborn infants <34 weeks' gestation.

Interventions / comparator: Increased DR temperature, thermal mattress (TM), PBW, plastic cap, heated and humidified gases (HHG) for resuscitation, radiant warmer (RW), early monitoring of temperature, warm bags of fluid, swaddling with or without a cap, skin-to-skin care (SSC) or combinations of these interventions.

Outcomes: Primary outcomes were survival until discharge and rate of normothermia (axillary, skin or rectal temperature between 36.5 °C and 37.5 °C) on admission to a neonatal unit.¹² If admission temperature was not available, temperature at 30–60 minutes after birth was analysed. Secondary outcomes were mean body temperature (MBT), mild hypothermia (36.0 °C–36.4 °C), moderate hypothermia (<36.0 °C), hypothermia <36.5 °C, hyperthermia (>37.5 °C),¹² receipt of positive pressure ventilation (PPV) in the DR, respiratory distress syndrome (RDS) requiring surfactant and other major morbidities.

Eligible studies: Randomised controlled trials (RCTs), quasi-RCTs, retrospective and prospective observational studies, and quality improvement (QI) studies were included. Exclusion criteria included conference abstracts and study protocols. No language restrictions were applied if an English abstract was available.

Title and abstract screening, article selection, risk of bias assessment and data extraction were performed by two authors independently. Discrepancies were resolved by a third author or by consensus of all authors.

Literature search strategy

Medline, Embase, CINAHL, CENTRAL and other international Clinical trials registries were searched from their inception to 22nd July 2022 (Supplement Table 1). Screening of titles and abstracts, selection of full-texts articles for eligibility assessment and data extraction were each conducted using Covidence systematic review software (Melbourne, Australia). Reference lists of included studies or other similar systematic reviews and publications from trial registries were also searched.

Data extraction and synthesis

Two authors extracted data using a proforma. Data synthesis was done using R software (version 3.6.2).¹³ A random effects model was utilised for reporting of the effect estimates of various outcomes as significant clinical heterogeneity was anticipated. Heterogeneity was evaluated by Cochran's Q, I^2 and τ^2 values. Publication bias was assessed by funnel plots and Egger's test if there was an adequate number of studies.

Risk of bias (RoB) assessment

RoB assessment was performed using the Cochrane RoB tool 2.0 for RCTs¹⁴ and Risk Of Bias in Non-randomized Studies-of Intervention (ROBINS-I) for non-RCTs.¹⁵

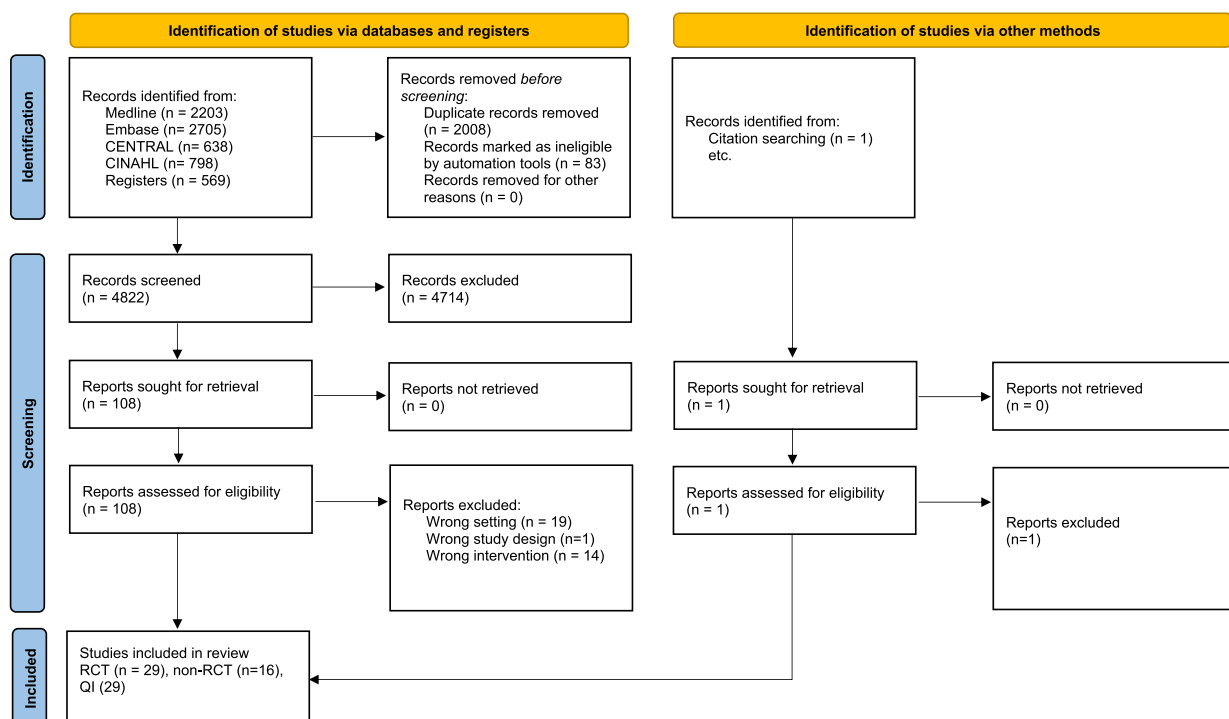


Fig. 1 – PRISMA diagram of article selection.

CoE assessment

CoE was assessed using GRADE recommendations.¹⁶ The findings of the systematic review were communicated using a modified GRADE approach (Supplement Table 2).¹⁷

Sub-group analyses

Sub-group analyses of RCTs were planned based on; gestational age (<28 weeks' gestation versus ≥ 28 weeks), high resource versus low resource setting, inborn (in a healthcare facility) versus outborn, and early versus later cord clamping.

Results

Of 4,822 unique records retrieved, 109 full-text articles were evaluated, and 74 studies were included in the systematic review; 29 RCTs,^{18–45} 16 observational studies^{46–60} and 29 QI studies.^{61–89} (Fig. 1) The characteristics of the RCTs and non-RCTs are presented (by intervention) in Tables 1–7 and QI studies in Supplement Table 3. Additional data was provided by 4 authors, on request.

RoB

Of the RCTs, 10 had overall low RoB^{22,23,25,32,33,35,38,44,45,90}, seven had some concerns^{20,27,28,30,34,37,41} and 12 had high RoB.^{18,19,21,24,26,29,31,36,39,40,42,43} (Supplement Table 4) Issues in the domains of randomisation and deviation from intended interventions were the predominant reasons for judgements of high RoB. Amongst the 16 observational studies, four studies had moderate RoB,^{48,53,54,60} 11 had serious RoB^{47,49–52,55–59,91} and one had critical RoB.⁴⁶ (Supplement Table 5) Deficiencies in the domains of confounding and classification of interventions were the predominant reasons.

Meta-analyses

RCTs comparing different DR temperatures

DR temperature 24–26 °C versus 20–23 °C. A higher DR temperature possibly resulted in higher MBT (MD 0.50 °C, 95% CI: 0.15–0.85 °C) (CoE: very low) and a lower rate of moderate hypothermia (RR 0.51, 95% CI: 0.32–0.82) (CoE: very low).²⁹ (Supplement Fig. 1, Supplement Table 6).

DR temperature 23 °C versus 20 °C. One cluster-randomised trial examined operating room temperatures for infants born by caesarean section. For the included subset of preterm infants, estimates of effect were not significant and CoE was very low, so clinical benefit or harm could not be excluded.²⁶ (Supplement Fig. 2, Supplement Table 7).

Non-RCTs comparing different DR temperatures

DR temperature 34 °C versus 28 °C. A higher DR temperature possibly increased MBT (MD 0.40 °C, 95% CI: 0.24–0.56 °C) (CoE: very low) and risk of hyperthermia (RR 11.48, 95% CI: 1.54–85.54) (CoE: very low).⁵² (Supplement Fig. 3, Supplement Table 8).

DR temperature >25 °C versus 20 °C. Clinical benefit or harm could not be excluded for survival. A higher DR temperature possibly decreased the risk of any hypothermia <36.5 °C (RR 0.69, 95% CI: 0.51–0.94) (CoE: very low) and probably moderate hypothermia

(RR 0.78, 95% CI: 0.72–0.86) (CoE: moderate).⁵³ (Supplement Fig. 4, Supplement Table 9).

DR temperature ≥ 25 °C versus <25 °C. A large prospective study enrolling 1764 preterm infants showed that hypothermic infants were more likely to have been exposed to a DR temperature of <25 °C than to a higher DR temperature [adjusted odds ratio (aOR) 1.44 (1.10–1.88)] (CoE: moderate).⁴⁹

Servo-controlled RW versus manual-mode RW. No studies were found that compared use of a radiant warmer to no radiant warmer, but one study compared use of a radiant warmer in servo-controlled mode with manual mode (which was considered the control group for this study). Servo-controlled RW probably had no effect on survival (RR 1.05, 95% CI: 0.99–1.11) and normothermia (RR 0.94, 95% CI: 0.75–1.17), but probably decreased MBT (MD 0.20 °C, 95% CI: 0.07–0.33 °C) and increased risk of hypothermia <36.5 °C (RR 1.20, 95% CI: 1.01–1.42) and mild hypothermia (RR, 95% CI: 1.48, 1.09–2.01) (CoE: moderate).²² The requirement for invasive PPV in the DR was probably lower in the servo-controlled RW group (RR 0.67, 95% CI: 0.46–0.97) (CoE: moderate) but there was probably no effect on moderate hypothermia, intraventricular haemorrhage (IVH), late-onset neonatal sepsis (LONS), necrotising enterocolitis (NEC), bronchopulmonary dysplasia (BPD) and requirement for nasal PPV. Clinical benefit or harm could not be excluded for hyperthermia (Supplement Fig. 5, Supplement Table 10).

RCTs comparing various other interventions

PBW versus no PBW. Use of a PBW did not affect survival (RR 1.05, 95% CI: 1.00–1.10) (CoE: high).^{18,23,27,30,37–39,42,44,45,90} However, use of a PBW possibly improved normothermia (RR 2.86, 95% CI: 1.66–4.91),^{23,30,36,39,45} decreased the risk of moderate hypothermia (RR 0.40, 95% CI: 0.19–0.81),^{18,20,37,39} increased MBT: axillary (MD 0.65 °C, 95% CI: 0.42–0.87 °C)^{18,20,27,28,36,38,39,42–44} and rectal (MD 0.77 °C, 95% CI: 0.50–1.04 °C) (CoE: low for each outcome).^{18,23,28,30,45,90} Use of a PBW probably decreased the risk of hypothermia <36.5 °C (RR 0.64, 95% CI: 0.50–0.82; 6 RCTs).^{23,30,36,39,44} Use of a plastic bag probably increased the risk of hyperthermia (RR 3.67, 95% CI: 1.77–7.61) (CoE: moderate).^{20,27,28,36,37,39,42,44,45} For IVH > grade 2,^{30,37–39} NEC^{30,37–39} and LONS^{37,38,42} clinical benefit or harm could not be excluded (CoE: low to moderate) (Fig. 2, Table 8). Post-hoc sensitivity analyses found no differences for prior drying versus no drying.^{18,20,23,27,28,30,36,38,39,42–45,90} (Supplement File 2) Funnel plots and Egger's test suggested the possibility of publication bias for the outcomes of survival and MBT.

Thermal mattress versus no thermal mattress. Four RCTs were identified. Because of critical differences in the intervention, they were analysed in two pairs: TM plus PBW versus PBW alone,^{24,33} and TM versus PBW.^{32,41}

For TM plus PBW compared to PBW, for survival, clinical benefit or harm could not be excluded (RR 1.02, 95% CI: 0.98–1.06) (CoE: low)^{24,33} TM plus PBW probably decreased the proportion of normothermic preterm newborn infants at admission (RR 0.53, 95% CI: 0.34–0.81) (CoE: low).³³ (Fig. 3) The MBT was possibly 0.46 °C higher (95% CI: 0.22–0.69) in the TM plus PBW group compared to the PBW group.^{23,32} The reason for fewer normothermic infants was partly because the risk of hyperthermia was higher in the TM

Table 1 – Characteristics of the randomised and non-randomised trials of ambient temperature in delivery room or operating room.

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Jia 2013 China ²⁹	RCT	DR/OR set at 24–26 °C(43)	DR/OR set at 20–23 °C (48)	I: 29.7 ± 2.0 C: 30.2 ± 1.5 GA <28 weeks I: 10% C: 10%	I: 1330 ± 300 C: 1320 ± 270 BW <1000 g I: 10% C: 10%	Rectal temperature at NICU admission	Hypothermia <36.0 °C, Hypothermia <35.0 °C	Inclusion criteria: GA ≤ 32 weeks, inborn; Exclusion: major congenital anomalies, maternal temperature ≥38 °C DR temperature - I: 25.1 ± 0.6 °C; C: 22.5 °C ± 0.6 °C Mode of delivery: NR Cord management: NR I: OR room set at 24–26 °C; C: DR in regular room set at 20–23 °C I and C: radiant warmer, immediately drying the infant; wet linens removed quickly; no plastic bag/wrap or cap; heated transport incubator to NICU Transfer time DR to NICU - NR
Duryea 2016 USA ²⁶	Cluster RCT	OR set at 23 °C (14)	OR set at 20 °C (8)	GA <28 weeks I: 50% C: 13%	NR	Axillary temperature at NICU admission	MBT, Hypothermia <36.5 °C, Hypothermia < 36.0 °C, Cold stress 36.0–36.4 °C, Hyperthermia >38.0 °C, IVH (any, grade 3 or 4), IPPV in DR	Inclusion criteria: GA <32 weeks, inborn; Exclusion: congenital anomalies Maternal temperature: I: 36.2 ± 0.6 °C; C: 36.4 ± 0.6 °C Caesarean delivery: 100%; Cord management: NR I: OR temperature set at 23 °C; C: OR temperature set at 20 °C I and C: radiant warmer, drying, plastic poncho and cap; plus, TM in NB <28 weeks gestation; transport incubator to NICU set at 38 °C Transfer time DR to NICU – NR Note; study included infants of all gestations. Results in this table are additional data supplied by authors for <32 week-gestation infants.
Johannsen 2017 Germany ⁵²	Retrospective cohort	DR set at 34 °C (111)	DR set at 28 °C (91)	I: 29.1 ± 2.96 C: 29.2 ± 3.48	I: 1075 ± 302 C: 1091 ± 317	Rectal temperature at NICU admission	MBT, Hypothermia <36 °C, Hyperthermia >37.5 °C	Inclusion: BW <1500 g, inborn; Exclusion: palliative care in DR Caesarean I: 86%, C: 100%; Cord management: NR I: DR at 34 °C C: DR at 28 °C I and C: preheated towel, TM at 37 °C if BW <1000 g, radiant heater, cap, humidified and heated gas at 37 °C, transport on the first aid unit with lid on to the NICU Transfer time DR to NICU - NR

Table 1 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Kent 2008 Australia ⁵³	Retrospective cohort	Ia: DR at 25- 28 °C (35) Ib: DR at 25- 28 °C plus polyethylene wrap (48)	DR at 20 °C (73)	Ia: 28.4 \pm 2.5 Ib: 28.9 \pm 1.8 C: 28.9 \pm 2.4	Ia: 1097 \pm 494 Ib: 1194 \pm 297 C: 1235 \pm 397	Axillary temperature at NICU admission	Survival at discharge, MBT, Temp. <36.5 °C, Temp. >37.5 °C, NEC, LONS, IVH grade 3 or 4	Inclusion: GA \leq 31 weeks, inborn; Exclusion: NR Caesarean – 100%; Cord management: NR Ia: DR at 26–28 °C for GA <27 wks; DR at 25 °C for GA 28–31 wks Ib: as Ia plus polyethylene wrap C: DR at 20 °C I and C: radiant warmer, drying and wrapping with warm blankets Transfer time DR to NICU - NR
De Almeida 2014 Brazil ⁴⁹	Prospective cohort	DR set at \geq 25 °C (409)	DR set at 25 °C (571)	I: 28.2 \pm 2.2 C: 28.8 \pm 2.2	I: 1045 \pm 321 C: 1225 \pm 386	Axillary temperature at 5 minutes after birth and at NICU admission	Survival at 7 days, Normothermia, Temp. 36.0–36.4 °C, Hypothermia <36 °C, Temp. >37.5 °C, RDS, NEC, LONS, IVH (any, grade 3 or 4), IPPV in DR	Inclusion: GA 23–31 weeks, inborn; Exclusion: malformations DR temperature - I: \geq 25 °C; C: <25 °C Caesarean I: 73%, C: 60%; Cord management: NR I: plastic bag/wrap, linen or woolen cap, transport incubator \geq 35 °C to NICU I and C: radiant warmer Transfer time DR to NICU - I: 28 \pm 12 min; C: 35 \pm 18 min

BW: Birthweight; **C:** comparator group; **DR:** delivery room; **GA:** gestational age, **g:** grams **I:** intervention group; **IPPV:** intermittent positive pressure ventilation; **IVH** intraventricular haemorrhage; **LONS:** late onset neonatal sepsis; **NEC:** necrotising Enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **OR:** Operating Room; **RCT:** randomised controlled trial; **SD:** standard deviation; **TM:** thermal mattress; **Wks:** weeks; °C: degrees Celsius.

Table 2 – Characteristics of the randomised controlled trial comparing radiant warmer in manual mode to a radiant warmer with servo-control.

Author Year Country	Study design (number of participants)	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD	BW (g) Mean ± SD	Temperature used for analysis	Outcomes reported	Other comments
Cavallin 2021 Italy ²²	RCT	Radiant warmer with servo- controlled system (225)	Radiant warmer without servo- controlled system (225)	I: 29 ± 3 C: 29 ± 3 GA <28 weeks I: 29% C: 36%	I: 1089 ± 313 C: 1066 ± 327 BW <1000 g I: 40% C: 43%	Axillary temperature before leaving the DR, at NICU admission	Survival at discharge, Normothermia 36.5–37.5 °C, Cold stress 36.0–36.4 °C, Hypothermia <36.5 °C, Hypothermia <36 °C, Hyperthermia >38 °C, IVH grade 3 or 4, BPD, LONS, CPAP, IPPV at birth	Inclusion criteria: GA <31 wks and/or BW <1500 g, inborn; Exclusion: major congenital malformations 15 centres DR/OR temperature - I: 24.4 ± 2.0 °C; C: 24.4 ± 1.8 °C Caesarean delivery - I: 84%; C: 84%; Immediate cord clamping - I: 78%, C: 76% I: probe of the servo-controlled system on abdomen and set at 37 °C. At the end of stabilisation, the probe for the servo-controlled system was removed C: radiant warmer set to manual control with maximum output I and C: without drying at birth, PBW; cap (95% of NB), TM (24% of NB), heated humidified gases (26% of NB); transport incubator to NICU set at 37 °C Transfer time DR to NICU - NR

BPD: bronchopulmonary dysplasia; **BW:** birthweight; **C:** comparator group; **CPAP:** continuous positive airway pressure, **DR:** delivery room; **GA:** gestational age; **I:** intervention group; **IQR:** interquartile range; **IPPV:** intermittent positive pressure ventilation; **IVH:** intraventricular haemorrhage, **LONS:** late onset neonatal sepsis; **NEC:** necrotising enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **PBW:** plastic bag or wrap; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SD:** standard deviation; **TM:** thermal mattress; **wks:** weeks; °C: degrees Celsius.

Table 3 – Characteristics of the randomised controlled trials and non-randomised controlled trials of plastic bag or wrap.

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD or Median (range)	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Ahmed 2013 Egypt ¹⁸	RCT	Vinyl bag (25)	Standard thermal care (25)	I: 29.5 ± 1.00 C: 30.0 ± 1.75	I: 1190 ± 200 C: 1250 ± 040	Axillary and rectal temperature at NICU admission	Survival at 30 days , MBT, Hypothermia <35.0 °C	Inclusion criteria: GA <32 weeks and BW <1500 g, inborn; Exclusion: major congenital malformations DR/OR temperature: NR; Caesarean - I: 12%, C: 28%; Cord management: NR I: without drying bag up to the neck immediately after delivery C: drying and placement under a radiant warmer I and C: pre-warmed transport incubator set at 35 °C to NICU Transfer time DR to NICU - NR
Bhavsar 2015 India ²⁰	RCT	Polyethene wrap (49)	Standard thermal care (47)	I: 32.6 ± 2.4 C: 1686 ± 446	I: 31.9 ± 2.8 C: 1471 ± 446	Axillary temperature at birth and at NICU admission	MBT, Hypothermia <35.0°C, Hyperthermia >37.5 °C	Inclusion criteria: GA <37 weeks and BW <2500 g; Exclusion: major congenital malformations DR/OR temperature: NR; Caesarean - I: 88%, C: 81%; Cord management: NR I and C: All NB resuscitated under a radiant warmer and then allocated to I or C I: polythene wrap plus a sterile cloth C: prewarmed sterile cloth only. Infants were born in basic birthing facilities and received intervention there, but were then transferred to another hospital with a NICU. Transfer time - I: 76 ± 35 min; C: 66 ± 29 min
Chantaroj 2011 Thailand ²³	RCT	Polyethylene plastic bag (19)	Standard thermal care (19)	I: 29 (25–33) C: 29 (24–32)	I: 1300 (685–1570) C: 1230 (675–1615)	Rectal temperature on admission to neonatal unit	Survival at hospital discharge , Normothermia 36.5–37.5 °C, Hypothermia <36.5 °C, MBT	Inclusion criteria: GA <32 weeks or BW <1500 g, inborn; Exclusion: congenital anomalies with open lesions (e.g., gastroschisis, meningomyelocele) DR temperature - I and C: 25 °C (25–26 °C) Caesarean delivery - I: 58%, C: 84%; Cord management: NR I: without drying except the head polyethylene bag immediately after birth, under a radiant warmer C: dried and placed under a radiant warmer; after stabilisation, infants covered polyvinyl wrap before transfer to NICU I and C: warm blankets and transport incubator to neonatal unit set at 37 °C Transfer time DR to neonatal unit - I: 15 min (range 5–25); C: 21 min (7–40)

(continued on next page)

Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Farhadi 2012 Iran ²⁷	RCT	Plastic bag (20)	Standard thermal care (20)	I: 28.8 \pm 2.8 C: 29.2 \pm 2.3 GA 24-27w I: 45% C: 45%	I: 1278 \pm 518 C: 1190 \pm 492	Axillary temperature at NICU admission	Survival at 3 days, MBT, Hypothermia <36.5 °C, Hyperthermia >37.5 °C, IVH all grades	Inclusion criteria: GA 24–32 weeks, BW \geq 400 g, inborn; Exclusion: congenital anomalies with open lesions DR temperature: 20–21 °C Caesarean delivery - I: 75%, C: 75%; Immediate cord clamping: 100% I: body placed in plastic bag immediately after birth; head dried and cap applied C: dried with warmed blanket I and C: portable incubator to neonatal unit set at 35 °C Transfer time DR to NICU - NR
Gathwala 2010 India ²⁸	RCT	Vinyl bag (30)	Standard thermal care (30)	I: 29.9 \pm 1.1 C: 29.5 \pm 1.3	I: 1120 \pm 190C: 1110 \pm 230	Axillary and rectal temperature at NICU admission	MBT	Inclusion criteria: GA \leq 32 weeks and BW \leq 1500 g, inborn; Exclusion: congenital malformation, skin blisters DR/OR temperature: NR; Caesarean - I: 16%, C: 23%; Cord management: NR I: vinyl bags up to neck plus cap after drying immediately following delivery; radiant warmer; C: drying under radiant warmer I and C: transport incubator to NICU set at 35 °C; Transfer time DR to NICU - NR
Knobel 2005 USA ³⁰	RCT	Polyurethane bag (41)	Standard thermal care (47)	I: 26.5 \pm 1.4 C: 26.1 \pm 1.4	I: 918 \pm 259 C: 850 \pm 253	Rectal temperature at NICU admission	Survival at hospital discharge, MBT, Hypothermia <36.5 °C, Hyperthermia >38.0 °C, IVH grades 3 or 4	Inclusion criteria: GA <29 weeks, inborn; Exclusion: congenital anomalies (gastroschisis, meningomyelocele) DR temperature - I: 23.9 \pm 2.6 °C; C: 24.5 \pm 2.3 °C Mode of delivery - NR; Cord management - NR I: without drying polyurethane bags up to the neck immediately after delivery, head and face dried, under radiant warmer C: immediately drying the infant, under radiant warmer I and C: covered with warm blankets and transported to NICU Transfer time DR to NICU - I: 16 min \pm 6.6; C: 15.9 min \pm 5.1
Nimbalkar 2019 India ³⁶	RCT	Occlusive wrap (404)	Standard thermal care (397)	I: 25.6 C: 26.0	I: 800 \pm 205 C: 821 \pm 199	Axillary temperature at NICU admission	Survival at discharge or 6 months' corrected age, MBT, Hypothermia <36.5 °C,	Inclusion criteria: GA 24–27 weeks, inborn; 35 centres DR temperature - I: 23.5 °C (16–36 °C), C: 23.3 °C (15–32 °C) Caesarean delivery - I: 70%, C: 67%; Cord management: NR

Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Reilly 2015 Canada ³⁷	RCT	Occlusive wrap (14)	Standard thermal care (14)	Mean (range) I: 22.8 C: 22.7	I: 565 C: 553	Axillary temperature at 25–27 minutes (mean) after birth	Hyperthermia ≥ 37.5 °C, RDS, BPD, NEC, LONS, IVH (any, grade 3 or 4) Survival at discharge or 6 months' corrected age, MBT, RDS, NEC, BPD, LONS, IVH grade 3 or 4	I: occlusive wrap applied immediately after birth (mean 24 seconds) C: drying, no occlusive wrap I and C: NR Transfer time DR to NICU - I: 16 min, C: 16 min Inclusion criteria: GA <24 weeks, inborn; 13 centres DR temperature - I: 24 °C, C: 23.9 °C Caesarean delivery - I: 64%, C: 43%; Cord management: NR I: occlusive wrap applied immediately after birth C: no wrap applied I and C: NR Transfer time DR to NICU - NR
Reilly 2019 Canada ³⁸	RCT	Polyethylene plastic wrap (50)	Standard thermal care (60)	I: 29.7 \pm 2.9 C: 29.8 \pm 2.7 GA <29 weeks I: 32% C: 35%	I: 1277 \pm 462 C: 1328 \pm 459	Axillary temperature at NICU admission	Survival at discharge, MBT, Hypothermia <36.5 °C, Temp. 36.0–36.5 °C, Hypothermia <36.0 °C, Hyperthermia >37.5 °C, RDS, NEC, IVH grade 3 or 4, IPPV	Inclusion criteria: GA 24–33 weeks, inborn. Exclusion: major congenital anomalies (gastroschisis, meningomyelocele) DR temperature - I: 21.9 \pm 2.3 °C; C: 22.0 \pm 2.1 °C Caesarean delivery - I: 72%, C: 73% Cord management: NR I: polyethylene plastic sheets from neck down within the first min after birth C: dried immediately after birth with warmed towels, wet linens removed I and C: radiant warmer, cap; servo-controlled probe placed 15 min after birth and set to maintain a skin temperature of 36.5 °C; preheated transport incubator to NICU Transfer time DR to NICU – NR
Rohana 2011 Malaysia ³⁹	RCT	Occlusive wrap (404)	Standard thermal care (397)	I: 25.6 C: 26.0	I: 800 \pm 205 C: 821 \pm 199	Axillary temperature at NICU admission	Survival at discharge or 6 months' corrected age, MBT, Hypothermia <36.5 °C, Hyperthermia ≥ 37.5 °C, RDS, BPD, NEC, LONS, IVH (any, grade 3 or 4)	Inclusion criteria: GA 24–27 weeks, inborn; 35 centres DR temperature - I: 23.5 °C (16–36 °C), C: 23.3 °C (15–32 °C) Caesarean delivery - I: 70%, C: 67%; Cord management: NR I: occlusive wrap applied immediately after birth (mean 24 seconds) C: drying, no occlusive wrap I and C: NR Transfer time DR to NICU - I: 16 min, C: 16 min
Smith 2013	RCT	Occlusive wrap (43)	Standard thermal care	GA <27 weeks	I: 991 \pm 299 C: 985 \pm 262	Axillary temperature at NICU admission	Survival at discharge, MBT,	Inclusion criteria: GA <30 weeks, inborn. Exclusion: congenital anomalies with open lesions

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Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Australia ⁴²			(49)	I: 51% C: 53%			Hypothermia <36.5 °C, Temp. 36–36.4 °C, Hypothermia <36.0 °C, Hyperthermia >37.5°C, LONS, IVH any grade	DR temperature: NR; Caesarean delivery - I: 51%, C: 67%; Cord management: NR I: without drying, wrapped with occlusive wrap from the neck down C: dried with a prewarmed towel I and C: radiant warmer; prewarmed towels; soft-woven cap; transport with radiant warmer to NICU Transfer time DR to NICU - NR
Talakoub 2015 Iran ⁴³	RCT (3-armed)	Polyethylene bag (32)	Standard thermal care (32)	NR	NR	Axillary temperature at NICU admission	MBT	Inclusion criteria: GA 28–32 weeks, inborn. Exclusion: congenital anomalies with open lesions, abdominal wall defects, maternal fever DR temperature: NR; Mode of delivery: NR; Cord management: NR I: without drying, polyethylene plastic bag covering up to the neck, head covered by a cotton cap after drying C: dried using a cloth I and C: placed under a warmer; transport with incubator at 35 °C to NICU Transfer time DR to NICU - NR
Trevisanuto 2010 Italy ⁴⁴	RCT (3-armed)	Polyethylene occlusive wrap (32)	Standard thermal care (with no cap) (32)	I: 25.8 \pm 1.5 C: 26.3 \pm 1.0	I: 800 \pm 223 C: 813 \pm 225	Axillary temperature at NICU admission	Survival at discharge. MBT. Hypothermia <36.4 °C. Hyperthermia >37.5 °C.	Inclusion criteria: GA <29 weeks, inborn. Exclusion: congenital anomalies with open lesions DR temperature: approximately 24 °C Caesarean delivery - Ia: 78%, Ib: 75%, C: 75%; Cord management: NR I: without drying polyethylene occlusive wrap to the neck; head was dried C: pre-warmed towels after drying I and C: pre-heated radiant warmer; transport with incubator to NICU Transfer time DR to NICU - Ia: 18 min \pm 9, Ib: 21 min \pm 7, C: 16 min \pm 5
Vohra 1999 Canada ⁹⁰	RCT	Polyethylene occlusive wrap (27)	Standard thermal care (20)	23– 27 weeks I: 30% C: 50%	23–27 weeks I: 914 \pm 163 C: 742 \pm 206 28–31 weeks I: 1251 \pm 282 C: 1265 \pm 206	Rectal temperature at NICU admission	Survival at discharge, MBT, Hyperthermia	Inclusion criteria: GA 23–31 wks, inborn. Exclusion: congenital anomalies with open lesions DR: 23–27 wks - I: 22.9 \pm 1.3 °C, C: 24.4 \pm 3.1 °C; 28–31 wks - I: 23.0 \pm 1.3 °C, C: 23.4 \pm 3.1 °C Mode of delivery: NR; Cord management: NR I: without drying, polyethylene bag from the shoulders down, only head was dried C: dried under the radiant warmer I and C: radiant warmer; transport with incubator to NICU at 37 °C

Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD or Median (range)	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Vohra 2004 Canada ⁴⁵	RCT	Polyethylene occlusive wrap (27)	Standard thermal care (26)	I: 26 ± 1.5 C: 26 ± 1.4	I: 858 ± 199 C: 825 ± 270	Rectal temperature at NICU admission	Survival at discharge , MBT, Hyperthermia	Time DR to NICU (min): 23–27 wks - I: 16 ± 5, C: 18 ± 3; 28–31 wks - I: 15 ± 5, C: 17 ± 3 Inclusion criteria: GA <28 weeks, inborn. Exclusion: congenital anomalies with open lesions DR temperature: NR; Caesarean delivery - I: 61%, C: 41%; Cord management: NR I: placed in polyethylene bag from the neck down, only the head was dried C: dried completely I and C: radiant warmer; transport with incubator to NICU Transfer time DR to NICU - NR
Çaglar 2014 Turkey ²¹	RCT	Vinyl bag (22)	Polyethylene skin wrapping (37)	I: 29.3 (26–32) C: 28.6 (23–32) GA 23–27wks I: 18% C: 24%	I: 1183 (450–2300) C: 1079 (540–1760) BW <1000 g I: 59% C: 41%	Axillary temperature immediately after birth, and at 20, 40, and 60 minutes	Survival at hospital discharge , MBT, Temp. ≥36.5 °C, Hypothermia <36.0 °C, Temp. 36.0–36.4° C, RDS	Inclusion criteria: GA ≤ 32 weeks, inborn; Exclusion: major congenital malformations, infant's initial axillary temperature ≥36.4 °C, mother's body temperature ≥38 °C DR temperature: 21–22 °C; Caesarean I: 96%, C: 86%; Cord management: NR I and C: head dried and covered immediately after delivery I: entire body was covered up to the neck with sterile vinyl bag C: non-sterile polyethylene covered the entire body up to the neck I and C: transport incubator to NICU set at 35 °C Transfer time DR to NICU - I: 16 min (range 6–30), C: 21 min (5–60)
Abd-El Hamid 2012 Egypt ⁴⁶	Quasi experimental non- randomised	Polyethylene wrap (50)	Standard thermal care (50)	I: 30.8 ± 1.5 C: 30.9 ± 2.0	I: 1171 ± 196 C: 1164 ± 207	Axillary temperature at NICU admission	Survival at hospital discharge , MBT, RDS, NEC, IVH	Inclusion: preterm with BW <1500 g, inborn; Exclusion: maternal temperature >38 °C; major malformations DR temperature, delivery mode and cord management: NR I: without drying, polyethylene wrap up to the neck C: drying I and C: radiant warmer, pre-warmed transport incubator to NICU Transfer time DR to NICU - NR
Bredemeyer 2005 Australia ⁴⁷	Retrospective and prospective cohort	Polyethylene wrap (57)	Standard thermal care (84)	I: 27 (23–29) C: 27 (23–29)	Median I: 1004 C: 920	Axillary temperature at NICU admission	Survival at hospital discharge , Temp. <35.6 °C, Temp. >37.2°C, IPPV in DR	Inclusion: GA <30 weeks, inborn; Exclusion: abdominal wall defects; death ≤ 12 h of postnatal life. DR temperature, delivery mode and cord management: NR I: without drying, polyethylene wrap up to the neck

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Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Carroll 2010 USA ⁹¹	Retrospective cohort	Polyethylene bag (70)	Standard thermal care (70)	I: 25 \pm 2 C: 25 \pm 2	I: 723 \pm 151 C: 727 \pm 149	Axillary temperature at NICU admission	Survival at hospital discharge, Temp. <35 °C, Temp. 35–36.9 °C, Temp. >37 °C, NEC, LONS, IVH (any, grade 3 or 4)	C: drying with warm towels I and C: radiant warmer, pre-warmed pre- humidified transport incubator to NICU Transfer time DR to NICU - I: 16 min; C: 17 min (median) Inclusion: BW <1000; inborn. Exclusion: major malformations DR temperature \geq 25 °C Caesarean I: 86%, C: 73%; Cord management: NR I: without drying, polyethylene bag up to the neck C: drying I and C: radiant warmer, linen cap, warm blankets, heated-humidified transport incubator to NICU Transfer time DR to NICU - I: 19 \pm 7 min; C: 22 \pm 7 min
Castro 2007 Uruguay ⁴⁸	Prospective cohort	Polyethylene bag (39)	Standard thermal care (38)	I: 26 \pm 2.4 C: 26 \pm 2.0	I: 818 \pm 134 C: 830 \pm 129	Axillary temperature at NICU admission	Survival at 7 days, MBT, Hypothermia <36 °C, IVH (any, grade 3 or 4)	Inclusion: BW <1000 g, inborn; Exclusion: major malformations DR temperature 26–28 °C; Delivery and cord management: NR I: without drying polyethylene bag up to the neck, radiant warmer without servo control; woolen cap; transport incubator set at 37 °C to NICU C: No details specified other than that no plastic bag was used Transfer time DR to NICU - NR
De Almeida 2014 Brazil ⁴⁹	Prospective cohort	Plastic bag (409)	Standard thermal care (571)	I: 28.2 \pm 2.2 C: 28.8 \pm 2.2	I: 1045 \pm 321 C: 1225 \pm 386	Axillary temperature at 5 minutes after birth and at NICU admission	Survival at 7 days, Normothermia Temp. 36.0–36.4 °C, Hypothermia <36 °C, Temp. >37.5 °C, RDS, NEC, LONS, IVH (any, grade 3 or 4), IPPV in DR	Inclusion: GA 23–31 weeks, inborn; Exclusion: malformations DR temperature - I: \geq 23 °C; C: <23 °C Caesarean I: 73%, C: 60%; Cord management: NR I: plastic bag/wrap, linen or woolen cap, transport incubator \geq 35 °C to NICU I and C: radiant warmer Transfer time DR to NICU - I: 28 \pm 12 min; C: 35 \pm 18 min
Ibrahim 2009 UK ⁵⁰	Retrospective cohort	Polythene bag (181)	Standard thermal care (72)	I: 27 (23– 29) C: 27 (24– 29)	I: 952 (522–1760) C: 1070 (484– 1565)	Axillary temperature at NICU admission	MBT, Hypothermia <36 °C, Hyperthermia	Inclusion: GA <30 weeks, inborn; Exclusion: NR DR temperature: NR Caesarean I: 55%, C: 62.5%; I: without drying polythene bag up to neck, radiant

Table 3 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
							>37.5 °C	warmer, woolen cap, pre-warmed towel during transport to the neonatal unit on the radiant warmer C: No details specified other than that no plastic bag was used Transfer time DR to NICU - NR
Lenclen 2002 France ⁵⁴	Retrospective cohort	Polyethylene wrap (60)	Standard thermal care (60)	I: 29.5 \pm 2.0 C: 29.7 \pm 2.2	I: 1240 \pm 380 C: 1200 \pm 360	Rectal temperature at NICU admission	MBT, Temp. <35.5 °C, Hyperthermia, IVH (any, grade 3 or 4)	Inclusion: BW <1500 g, inborn; DR temperature: NR Caesarean I: 82%, C: 83%; cord management: NR I: after rapid drying, polyethylene bag I and C: radiant heater, transport to NICU in incubator set at 39 °C Transfer time DR to NICU - I: 23 \pm 8 min; C: 25 \pm 10 min
Lewis 2011 USA ⁵⁵	Quasi- experimental non- randomised	Ia: Plastic wrap (67) Ib: Plastic wrap + thermal mattress (29) Ic: Plastic wrap + thermal mattress + \uparrow DR temp (37)	Standard thermal care (295)	NR	BW <1000 g Ia: 25; Ib: 10; Ic: 9; C: 74 Ia: 42; Ib: 19; Ic: 28; C: 221	Temperature at NICU admission. Site of measurement: NR	Normothermia, MBT	Inclusion: GA <32 wks, BW <1500 g, inborn; Exclusion: NR Delivery mode and cord management: NR DR temperature: Ia, Ib, C: 15.5°-18.3 °C; Ic: 21.1°-23.8 °C Ia, Ib, and Ic: without drying, plastic wrap Ib and Ic: TM for GA <30 wks C: drying with warm blankets, cap and head covering I and C: preheated radiant warmer Mode of transport: NR; Transfer time DR to NICU - NR
Mathew 2007 USA ⁵⁶	Retrospective cohort	Vinyl bag (14)	Standard thermal care (13)	I: 26.3 \pm 0.5 C: 26.3 \pm 0.4	I: 842 \pm 55 C: 838 \pm 42	Axillary temperature at NICU admission	Survival at 30 days, MBT, Hypothermia <35 °C, Hyperthermia >38°C, IVH grade 3 or 4	Inclusion: GA \leq 28 wks, BW <1500 g, inborn; Exclusion: open neural tube defects, abdominal wall defects DR temperature: 20–21 °C; Caesarean I: 79%, C: 85%; cord management: NR I: without drying, vinyl bag up to the neck, head dried, cap C: drying I and C: radiant warmer; transport incubator to NICU at 35 °C Transfer time DR to NICU - I: 22.6 \pm 1.9 min; C: 18.8 \pm 2.4 min

BPD: bronchopulmonary dysplasia; **BW:** birthweight; **C:** comparator group; **DR:** delivery room; **GA:** gestational Age; **I:** intervention group; **IQR:** interquartile range; **IPPV:** intermittent positive pressure ventilation; **IVH:** intraventricular haemorrhage; **LONS:** late onset neonatal sepsis; **MBT:** mean body temperature; **min:** minutes; **NEC:** necrotising enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **OR:** operating room; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SD:** standard deviation; **Wks:** weeks, **°C:** degrees Celsius.

Table 4 – Characteristics of the randomised controlled trials and non-randomised controlled trials of thermal mattress.

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD or Median (range)	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Chawla 2011 USA ²⁴	RCT	Warming gel mattress (53)	Standard thermal care (49)	I: 28.7 ± 3 C: 28.7 ± 2.4 GA <28 weeks I: 40% C: 45%	I: 1151 ± 407 C: 1175 ± 413	Axillary temperature in DR before transport to NICU, and at admission to NICU	Survival at discharge, MBT, Hypothermia <36.0 °C, Hypothermia <35.0 °C, Hyperthermia >37.5 °C, IVH grade 3 or 4, BPD, NEC, LONS	Inclusion criteria: GA <32 wks, inborn; Exclusion: major congenital anomalies, maternal temperature >38.2 °C DR temperature - I: 21.8 ± 2.4 °C; C: 21.2 ± 2.6 ° C Caesarean delivery - I: 42%, C: 41%; Cord management: NR I: resuscitated and transported to NICU on a TM I and C: cap, radiant warmer; plus for NB<28 Wks GA; without drying, plastic bag below the neck; transport in incubator to NICU set at 37 °C Transfer time DR to NICU - I: 34 min, C: 38 min
McCarthy 2013 Ireland ³³	RCT	Gel thermal mattress + polyethylene bag (37)	Polyethylene bag (35)	I: 28 ± 2 C: 28 ± 2 GA <28 weeks I: 41% C: 40%	I: 1085 ± 360 C: 1194 ± 386	Rectal and axillary temperature at NICU admission	Survival at discharge, Normothermia, MBT, Hypothermia <36.5 °C, Hyperthermia >37.5 °C, RDS, BPD, IVH grades 3 or 4, IPPV in DR	Inclusion criteria: GA <31 wks, inborn. Exclusion: congenital anomalies Maternal temperature: I: 36.7 ± 0.5 °C; C: 36.8 ± 0.6 °C DR temperature - I: 22.9 ± 1.8 °C; C: 22.4 ± 1.3 ° C Caesarean delivery - I: 60%; C: 60%; Immediate cord clamping: 100% I: placed on TM C: placed on warm towel I and C: without drying, placed into plastic bag up to the neck, head and face dried, cotton knit cap, radiant warmer, wrapped in 3 warm blankets; transport incubator to NICU set at 35–37 °C Transfer time DR to NICU - I: 24 min ± 7; C: 19 min ± 7
Mathew 2013 USA ³²	RCT	Gel thermal mattress (20)	Polyvinyl bag (21)	I: 26 ± 1.2 C: 26 ± 1.3	I: 766 ± 186 C: 768 ± 162	Axillary temperature at NICU admission	Survival at discharge, MBT, NEC, IVH grades 3 or 4	Inclusion criteria: GA 23–28 wks, inborn. Exclusion: major congenital anomalies with open lesions DR/OR temp: 21–22 °C; Caesarean - I: 75%; C: 81%; Cord management: NR I: dried and placed on the TM C: without drying, polyvinyl bag below the neckline immediately following delivery; head dried and covered with a cap I and C: radiant warmer during resuscitation and stabilisation Transfer time DR to NICU - I: 23 min ± 7; C: 23 min ± 7

Table 4 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Simon 2011 USA ⁴¹	RCT	Thermal mattress (17)	Polyethylene wrap (19)	I: 26.0 \pm 1.2 C: 25.9 \pm 1.3	I: 812 \pm 176 C: 901 \pm 248	Axillary temperature at NICU admission	Survival at discharge, MBT, Hypothermia <36.5 °C, Hyperthermia >37.5 °C, BPD, NEC, IVH (any, grade 3 or 4)	Inclusion criteria: GA 24–28 weeks and BW \leq 1250 g. Exclusion: major congenital anomalies with open skin lesions DR temperature - I: 22.2 \pm 2.9 °C, C: 22.7 \pm 2.8 ° C Mode of delivery: vaginal or caesarean section; Cord management: NR I: placed on TM, routinely dried under the radiant warmer C: polyethylene wrap, head of the patient was dried before being wrapped I and C: radiant warmer; warmed cotton/polyester knit cap, preheated transport incubator to NICU Transfer time DR to NICU - I: 22 min \pm 5; C: 22 min \pm 5
Ibrahim 2010 UK ⁵¹	Retrospective cohort	Thermal mattress + polyethylene bag (124)	Polyethylene bag (105)	I: 26 (23– 27) C: 25 (23– 27)	I: 847 (490–1360) C: 790 (522–1240)	Axillary temperature at NICU admission	Median temperature, Hypothermia <36 °C, Hyperthermia >37 °C	Inclusion: GA \leq 28 weeks, inborn; Exclusion: NR DR temperature: NR Caesarean I: 31%, C: 40%; Cord management: NR I: self-heating acetate gel mattresses (TM) I and C: without drying, polythene bag up to neck, radiant warmer; woolen cap, pre-warmed towel during transport to the NICU on radiant warmer Transfer time DR to NICU - NR
Lewis 2011 USA ⁵⁵	Quasi- experimental non- randomized	Ia: Plastic wrap (67) Ib: Plastic wrap + thermal mattress (29) Ic: Plastic wrap + thermal mattress + \uparrow DR temp (37)	Standard thermal care (295)	NR	BW <1000 g Ia: 25; Ib: 10; Ic: 9; C: 74 Ia: 42; Ib: 19; Ic: 28; C: 221	Temperature at NICU admission, Site of measurement: NR	Normothermia, MBT	Inclusion: GA <32 wks, BW <1500 g, inborn; Exclusion: NR Delivery mode and cord management: NR DR temperature: Ia, Ib, C: 15.5°–18.3 °C; Ic: 21.1°–23.8 °C Ia, Ib, and Ic: without drying, plastic wrap Ib and Ic: TM for GA <30 wks C: drying with warm blankets, cap and head covering I and C: preheated radiant warmer Mode of transport: NR; Transfer time DR to NICU - NR

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Table 4 (continued)

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean \pm SD or Median (range)	BW (g) Mean \pm SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
McCarthy 2011 Ireland ⁵⁷	Prospective cohort	Thermal mattress + polyethylene bag (28)	Polyethylene bag (15)	I: 28 \pm 2 C: 29 \pm 1	I: 1041 \pm 350 C: 1293 \pm 286	Axillary temperature at NICU admission	Normothermia , MBT, Hypothermia <36.5 °C and <36 °C, Hyperthermia >37.5°C, IPPV in DR	Inclusion: GA <31 wks, inborn; Exclusion: congenital anomalies with open lesions DR temperature: NR Caesarean I: 67%, C: 79%; cord management: NR I: TM under a dry towel I and C: Immediately after birth, without drying polyethylene bag, on warm towel, radiant warmer, head and face dried and warm cap; transport incubator to NICU at 36–37 °C Transfer time DR to NICU - I: 23 \pm 8 min; C: 18 \pm 6 min
Pinheiro 2011 USA ⁵⁸	Retrospective cohort	Thermal mattress + plastic wrap (183)	Plastic wrap (103)	I: 28.0 \pm 2.6 C: 28.5 \pm 3.1	I: 1060 \pm 299 C: 1072 \pm 308	Axillary temperature at NICU admission	Normothermia , MBT, Hypothermia <36.5 °C, Hyperthermia >38 °C, IPPV in DR	Inclusion: BW <1500 g, inborn Temperature: DR 21–23 °C; OR 17–21 °C Delivery mode and cord management: NR I: TM covered with a warm dry towel I and C: briefly dried, head and body wrapped in polyvinylidene chloride plastic, transferred in radiant warmer to NICU Transfer time DR to NICU: NR
Singh 2010 UK ⁵⁹	Retrospective cohort	Ia: Polythene bag (48) Ib: Thermal mattress and polythene bag (97)	Standard thermal care (230)	Median (IQR) Ia: 28 (26– 29) Ib: 27 (26– 29) C: 28 (26– 29)	Median (IQR) Ia: 1037 (755–1180) Ib: 1035 (835– 1220) C: 1020 (770–1219)	Axillary temperature at NICU admission	Normothermia , MBT, Hypothermia <36.5 °C, Hyperthermia >37.5 °C	Inclusion: GA <30 wks, inborn DR temperature, delivery mode and cord management: NR Ia: without drying polyethene bag Ib: without drying, polythene bag, and TM covered with a warm dry towel C: drying and wrapping I and C: radiant warmer, woolen cap, transport incubator to NICU Transfer time DR to NICU (median (IQR): Ia – 20 min (17–27 min), Ib – 23 min (17–29 min), C – 18 min (12–25 min))

BPD: bronchopulmonary dysplasia; **BW:** birthweight; **C:** comparator group; **DR:** delivery room; **g:** gram; **GA:** gestational age; **I:** intervention group; **IQR:** interquartile range; **IPPV:** intermittent positive pressure ventilation; **IVH:** intraventricular haemorrhage; **LONS:** late onset neonatal sepsis; **MBT:** mean body temperature, **min.:** minutes; **NEC:** necrotising enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **OR:** operating room; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SD:** standard deviation; **TM:** thermal mattress; **Wks:** weeks, °C: degrees Celsius.

Table 5 – Characteristics of the randomised controlled trials and non-randomised controlled trial of heated and humidified gases for resuscitation.

Author Country	Year Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD or Median (range)	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
McGrory 2018 Australia ³⁴	RCT	Heated humidified gas (132)	Non-heated non- humidified gas (141)	I: 27 ± 1.8 C: 27 ± 1.8 GA <26 wks I: 26% C: 25%	I: 973 ± 288 C: 930 ± 272	Rectal temperature at NICU admission	Survival at discharge, Normothermia, MBT, Cold stress 36.0–36.4 °C, Hypothermia <36.0 °C, Hyperthermia >37.5 °C, Hyperthermia >38 °C, RDS, BPD, LONS, IVH grades 3 or 4, IPPV in DR	Inclusion criteria: GA <30 wks, inborn; Exclusion: mother temperature >38 °C, major congenital anomalies DR Temperature: 24.2 °C (median in both groups) Caesarean delivery - I: 52%, C: 52%; Cord management: NR I: heated-humidified gas set at 37 °C during respiratory support C: Non-heated non-humidified gas during respiratory support I and C: radiant warmer; plus polyethylene bags and woolen caps in NB <28 wks gestation; respiratory support with T-piece resuscitator (gas flow rate of 8–10 L/min); transport to NICU with incubator or resuscitation trolley Transfer time DR to NICU - I: 27 min ± 8; C: 25 min ± 9
Meyer 2015 New Zealand ³⁵	RCT	Heated humidified gas (100)	Non-heated non- humidified gas (103)	Mean (range) I: 29 (26–30) C: 29 (27–30)	I: 1158 (890–1460) C: 1190 (954–1396)	Axillary temperature at NICU admission	Normothermia, MBT, Hypothermia <36.5 °C, BPD, NEC, IVH grades 3 or 4	Inclusion criteria: GA <32 wks, inborn; Exclusion: mechanical ventilation for transport, maternal temperature >38 °C, major congenital abnormality; 2 hospitals DR temperature: 25–26 °C Cesarean delivery - I: 54%, C: 49%; Cord management: delayed clamping for 40 seconds in hospital 1 but was not standard procedure in hospital 2 I: Heated humidified gas during CPAP or PPV C: Non-heated non-humidified gas during CPAP or PPV I and C: radiant warmer with servo control in hospital 1 and without manual control in hospital 2; At hospital 1, all infants were wrapped without drying; at hospital 2, NB <30 weeks' were wrapped; cap; respiratory support with T-piece resuscitator (gas flow rate of 8 L/min); transport with radiant warmer or incubator at 35 °C Transfer time DR to NICU - I: 18 min (IQR 14–23), C: 19 min (15–25)
te Pas 2010 Netherlands ⁶⁰	Prospective cohort	Heated humidified gas (54)	Non-heated non- humidified gas (58)	I: 28.4 ± 1.6 C: 28.8 ± 1.9	I: 1206 ± 332 C: 1190 ± 337	Rectal temperature at NICU admission	Survival at hospital discharge, Normothermia, MBT, Temp. 36.0–36.4 °C, Temp. <36.0 °C, Temp. >38 °C, RDS, NEC, LONS, IVH (any, grade 3 or 4), IPPV in DR	Inclusion: GA ≤ 32 wks with respiratory support at birth, inborn. Exclusion: maternal temp >38 °C DR temperature: 25 °C Caesarean I: 71%, C: 56%; cord management: NR I: Heated and humidified gas C: Non-heated non-humidified I and C: radiant warmer, pre-heated mattress, dried, cap, transport incubator to NICU at 35 °C; GA <30 wks - without drying, plastic wrap up to the neck Transfer time DR to NICU - I: 19 ± 5 min; C: 20 ± 5 min

BPD: bronchopulmonary dysplasia; **BW:** birthweight; **C:** comparator group; **DR:** delivery room; **g:** gram; **GA:** gestational age; **I:** intervention group; **IQR:** interquartile range; **IPPV:** intermittent positive pressure ventilation; **LONS:** late onset neonatal sepsis; **MBT:** mean body temperature, **min.:** minutes; **NEC:** necrotising enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SD:** standard deviation; **wks:** week, **°C:** degrees Celsius.

Table 6 – Characteristics of the randomised controlled trials of plastic bag / wrap with plastic caps versus plastic bag / wrap with cotton caps and plastic cap versus standard care.

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD	BW (g) Mean ± SD or Mean (range)	Temperature used for analysis	Outcomes reported	Other comments
Doglioni 2014 Italy ²⁵	RCT	Polyethylene bag, body and head (50)	Polyethylene bag only up to the shoulders (50)	I: 25.7 ± 1.7 C: 25.8 ± 1.7	I: 789 ± 214 C: 770 ± 245	Axillary temperature at NICU admission immediately after wrap removal	Survival at discharge, Hypothermia <36.5 °C, Hypothermia <36.0 °C, Hyperthermia >37.5 °C, Hyperthermia >38.0° C, IVH grades 3 or 4, BPD, NEC, IPPV in DR	Inclusion criteria: GA <29 wks, inborn; Exclusion: congenital anomalies with open lesions DR/OR temperature - I: 23.9 ± 0.7 °C; C: 24.1 ± 0.7 °C; 3 centers Caesarean delivery - I: 86%, C: 88%; Immediate cord clamping: 100% I: body and head (except face) covered with polyethylene bag immediately after birth C: without drying, polyethylene bag up to shoulders; head dried and uncovered I and C: radiant warmer in DR; transport incubator to NICU set at 35–37 °C Transfer time DR to NICU median (IQR) - I: 20 (14–22) min, C: 20 (18–26) min
Shafie 2017 Malaysia ⁴⁰	RCT	Polyethylene cap with a polyethylene wrap (40)	Cotton cap with a polyethylene wrap (40)	I: 30.9 ± 2.0 C: 31.3 ± 2.0	I: 1410 (1170–1605) C: 1642 (1260–1756)	Axillary temperature immediately prior to transfer, at NICU admission	Survival at discharge, MBT, Hypothermia <36.5 °C, Temp. 36–36.4 °C, Hypothermia <36.0 °C, RDS, NEC, IVH grade ≥2	Inclusion criteria: GA 24–33 wks, inborn. Exclusion: congenital anomalies not covered by skin, blistering skin conditions DR temperature - I: 23.3 °C ± 1.9, C: 23.4 °C ± 1.9 Caesarean delivery - I: 68%, C: 70%; Cord management: NR I: without drying, polyethylene cap C: Head dried and covered with cotton cap plus polyethylene wrap I and C: radiant warmer; without drying polyethylene sheet from the neck downwards immediately after birth; preheated transport incubator to NICU Transfer time DR to NICU - I: 46 (IQR 33–48) min; C: 45 (30–64)min
Talakoub 2015 Iran ⁴³	RCT (3-armed)	Plastic hat with a polyethylene bag (32)	Cotton hat with a polyethylene bag (32)	NR	NR	Axillary temperature at NICU admission	MBT	Inclusion criteria: GA 28–32 weeks, inborn. Exclusion: congenital anomalies with open lesions, abdominal wall defects, maternal fever DR temperature: NR; Mode of delivery: NR; Cord management: NR I - without drying, polyethylene plastic bag up to the neck, head covered by a cotton cap after drying C - without drying, polyethylene plastic bag up to the neck, head covered by a polyethylene cap without drying I and C: placed under a warmer; transport with incubator at 35 °C to NICU Transfer time DR to NICU - NR

Table 6 (continued)

Author Year Country	Study design (number of participants)	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD	BW (g) Mean ± SD or Mean (range)	Temperature used for analysis	Outcomes reported	Other comments
Trevisan ⁴⁴ 2010 Italy	(3-armed)	Polyethylene cap (32)	Standard thermal care with no cap (32)	I: 26.1 ± 1.4 C: 26.3 ± 1.0	I: 834 ± 246 C: 813 ± 225	Axillary temperature at NICU admission	Survival at discharge, MBT, Hypothermia <36.4 °C, Hyperthermia >37.5 °C	Inclusion criteria: GA <29 weeks, inborn. Exclusion: congenital anomalies with open lesions DR temperature: approximately 24 °C Caesarean delivery - Ia: 78%, Ib: 75%, C: 75%; Cord management: NR I: body was dried, head covered with polyethylene cap without drying head C: pre-warmed towels after drying I and C: pre-heated radiant warmer; transport with incubator to NICU Transfer time DR to NICU - Ia: 18 min ± 9, Ib: 21 min ± 7, C: 16 min ± 5

BPD: bronchopulmonary dysplasia; **BW:** birthweight; **C:** comparator group; **DR:** delivery room; **GA:** gestational age; **I:** intervention group; **IQR:** interquartile range; **IVH:** intraventricular haemorrhage; **IPPV:** intermittent positive pressure ventilation; **MBT:** mean body temperature **min.:** minutes; **NEC:** necrotising enterocolitis; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **OR:** operating room; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SD:** standard deviation; **Wks:** weeks, °C: degrees Celsius.

plus PBW group (RR 0.46, 95% CI: 0.22–0.69).^{24,33} Clinical benefit or harm could not be excluded for other outcomes (Fig. 3, Supplement Table 11). Clinical benefit or harm could not be excluded for any outcomes for the comparison TM versus PBW^{32,41} (Fig. 3, Supplement Table 11).

HHG versus non-HHG. Clinical benefit or harm could not be excluded for either survival or normothermia. Use of HHG probably increased MBT (MD 0.15, 95% CI: 0.03–0.26) (CoE: moderate) and possibly decreased moderate hypothermia (RR 0.58, 95% CI: 0.36–0.94) and IVH > grade 2 (RR 0.39, 95% CI: 0.17–0.91) (CoE: very low).^{34,35} (Fig. 4, Supplement Fig. 13, Supplement Table 12).

PBW with a plastic cap versus PBW alone. Clinical benefit or harm could not be excluded for survival or for normothermia.^{25,40} Adding a plastic cap to a PBW possibly improved MBT (MD 0.20 °C, 95% CI: 0.02–0.37 °C) (24,39,42) and decreased the risk of DR intubation (RR 0.67, 95% CI: 0.49–0.90) (CoE: moderate).²⁵ (Supplement Fig. 6, Supplement Table 13).

Plastic bag versus plastic wrap. Use of a plastic bag possibly increased MBT when compared to a plastic wrap (MD 0.40 °C, 95% CI: 0.34–0.46 °C) (CoE: very low).²¹ (Supplement Fig. 7, Supplement Table 14).

Plastic cap versus no plastic cap. A plastic cap when compared to no plastic cap probably did not affect survival (RR 0.97, 95% CI: 0.84–1.12), but probably improved the rate of normothermia (RR 6.00, 95% CI: 1.96–18.38) and MBT (MD 0.80 °C, 95% CI: 0.41–1.19 °C), and had no effect on hypothermia <36.5 °C or DR intubation (CoE: moderate).⁴³ Clinical benefit or harm could not be ruled out for hyperthermia.⁴³ (Supplement Fig. 8, Supplement Table 15).

PBW versus plastic cap. PBW compared to plastic cap probably did not affect the outcomes of survival, normothermia, hypothermia <36.5 °C or endotracheal intubation in the DR (CoE: moderate).⁴⁴ (Supplement Fig. 9, Supplement Table 16).

SSC versus standard care. Clinical benefit or harm could not be ruled out for MBT^{19,31} and RDS requiring surfactant.³¹ (Supplement Fig. 10, Supplement Table 17).

Outcomes for various other comparisons from non-RCTs (Tables 1, 3, 4 and 5).

For the comparisons: PBW versus no PBW,^{46–50,54–56,59,91} TM versus no TM^{51,55,57,58} and HHG versus non-HHG,^{49,60} the CoE for the meta-analyses of RCTs was higher than that from non-RCTs. Therefore, the evidence from non-RCTs is not presented (Supplement Fig. 11–13, Supplement Tables 18–20). The various other interventions that were evaluated from observational studies included:

Cloth cap versus no cloth cap. One prospective observational study showed that normothermic infants 22–33 weeks' gestation were more likely to have had a cloth cap applied [aOR 1.44 (1.10–1.88)] (CoE: low).⁴⁹

PBW plus TM plus increased DR temperature versus versus PBW plus TM versus PBW versus none of the above (four-arm cohort study). Clinical benefit or harm could not be ruled out for normothermia or for MBT.⁵⁵ (Supplement Table 21–22).

Table 7 – Characteristics of the randomised controlled trials of skin-to-skin care.

Author Year Country	Study design	Intervention (number of participants)	Comparator (number of participants)	GA (wks) Mean ± SD or Median (range)	BW (g) Mean ± SD or Median (range)	Temperature used for analysis	Outcomes reported	Other comments
Bergman 2004 South Africa ¹⁹	RCT	SSC (21)	Servo- controlled incubator (13)	I: 34.2 ± 1.9 C: 35.3 ± 1.9	I: 1813 ± 260 C: 1866 ± 258	Skin temperature at 5-min intervals in the first hour after birth	MBT, Hypothermia <35.5 °C	Inclusion criteria: BW 1200–2199 g, inborn; Exclusion: Apgar 5 min <6, congenital malformations DR/OR temperature: NR; Vaginal delivery 100%; Cord management: NR I and C: cloth on the mother's abdomen/chest, dried before cord clamping I: SSC with mother ≥60 min C: pre-warmed servo-controlled incubator ≥60 min; if <36 °C, cap, booties, and heat shield Transfer time DR to NICU - NR
Linner 2020 Sweden ³¹	RCT	SSC (26)	Standard thermal care (29)	I: 31 ± 10 (range 28-33) C: 32 ± 10 (29-33)	I: 1646 ± 439 (976-2822) C: 1864 ± 439 (885-2815)	Rectal temperature at NICU admission and 1 hour later	MBT, RDS, IPPV in DR	Inclusion criteria: GA 28–33 wks, BW 1000-2500 g, inborn. Exclusion: congenital anomalies DR temperature: 23 °C ± 1.4; Caesarean - I: 62%; C: 45% Cord management: delayed as per protocol in SSC group I: SSC immediately after birth on the chest of the parent/partner, dried and covered with preheated wool cape and blanket during the first postnatal hour; transported with parent to the neonatal unit C: stabilisation on resuscitation trolley or incubator; for NB 32-33 weeks gestation and vaginal birth - ~2 minutes on the mother's chest; transport incubator or bed to the neonatal unit Transfer time DR to NICU - I: 31 min ± 10; C: 30 min ± 9

BW: birthweight; **C:** comparator group; **DR:** delivery room; **g:** gram **GA:** gestational age; **I:** intervention group; **IPPV:** intermittent positive pressure ventilation; **MBT:** mean body temperature, **min.:** minutes; **NICU:** neonatal intensive care unit; **NB:** newborn; **NR:** not reported; **OR:** operating room; **RCT:** randomised controlled trial; **RDS:** respiratory distress syndrome; **SSC** skin to skin care, **SD:** standard deviation; **wks:** weeks, **°C:** degrees Celsius.

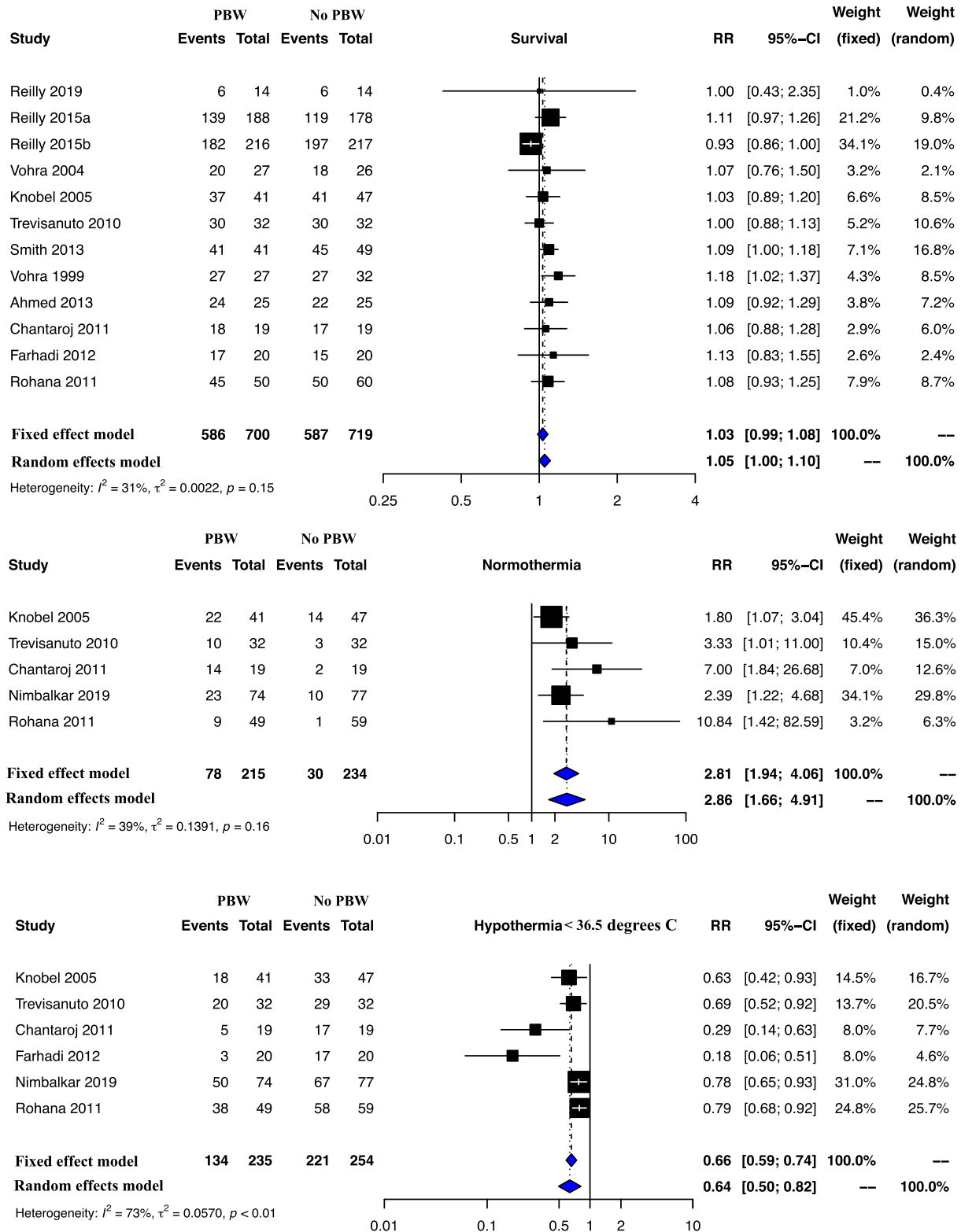


Fig. 2 – A: Forest plots for different outcomes for the comparison plastic bag or wrap versus no plastic bag or wrap. For studies that provided subgroup analyses by gestation, these are indicated as ‘a’ and ‘b’ for the same study, with explanation of the subgroups in footnotes. Abbreviations; CI: confidence intervals; DR: delivery room; IVH: intraventricular haemorrhage; LONS; late onset neonatal sepsis; MD: mean difference; NEC: necrotising enterocolitis; PBW: plastic bag or wrap; RR: relative risk. Fig. 2B: Funnel plots assessing for publication bias for the outcomes of survival and mean body temperature for the comparison plastic bag or wrap versus no plastic bag or wrap.

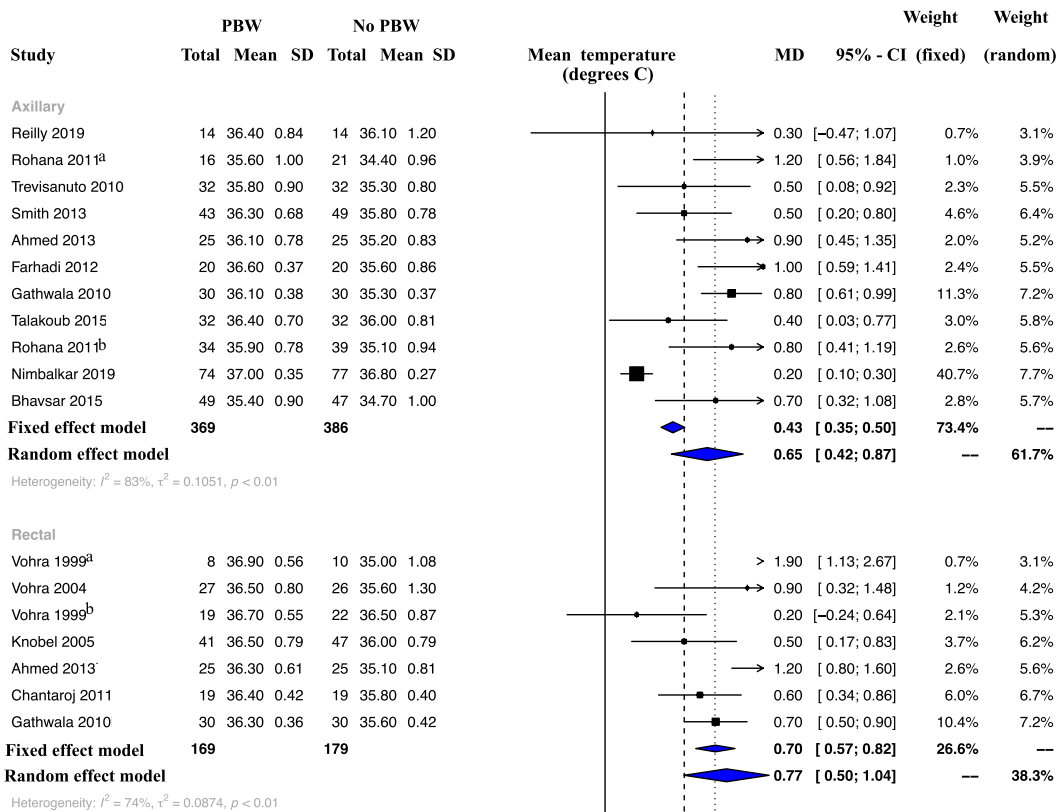
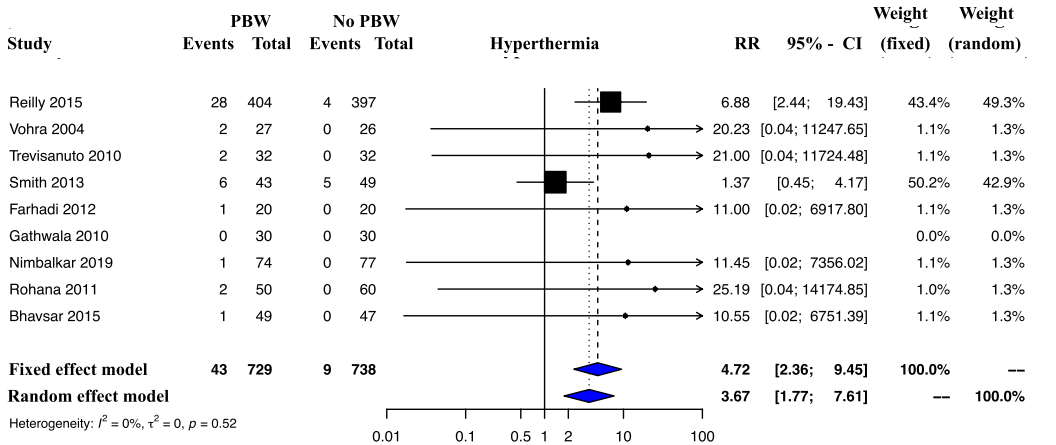
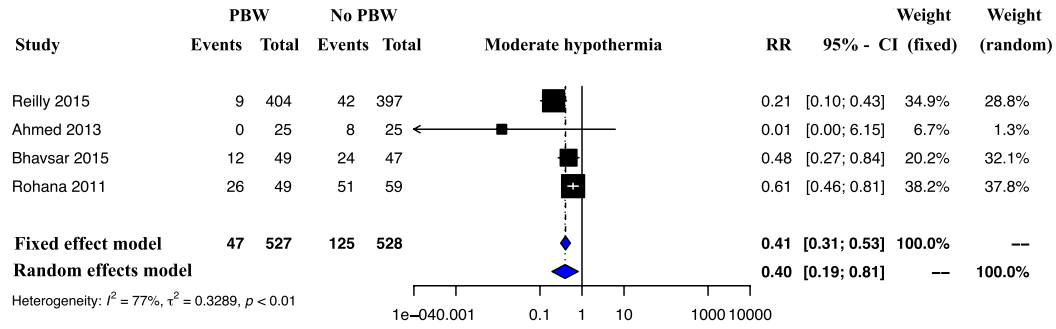


Fig 2. (continued)

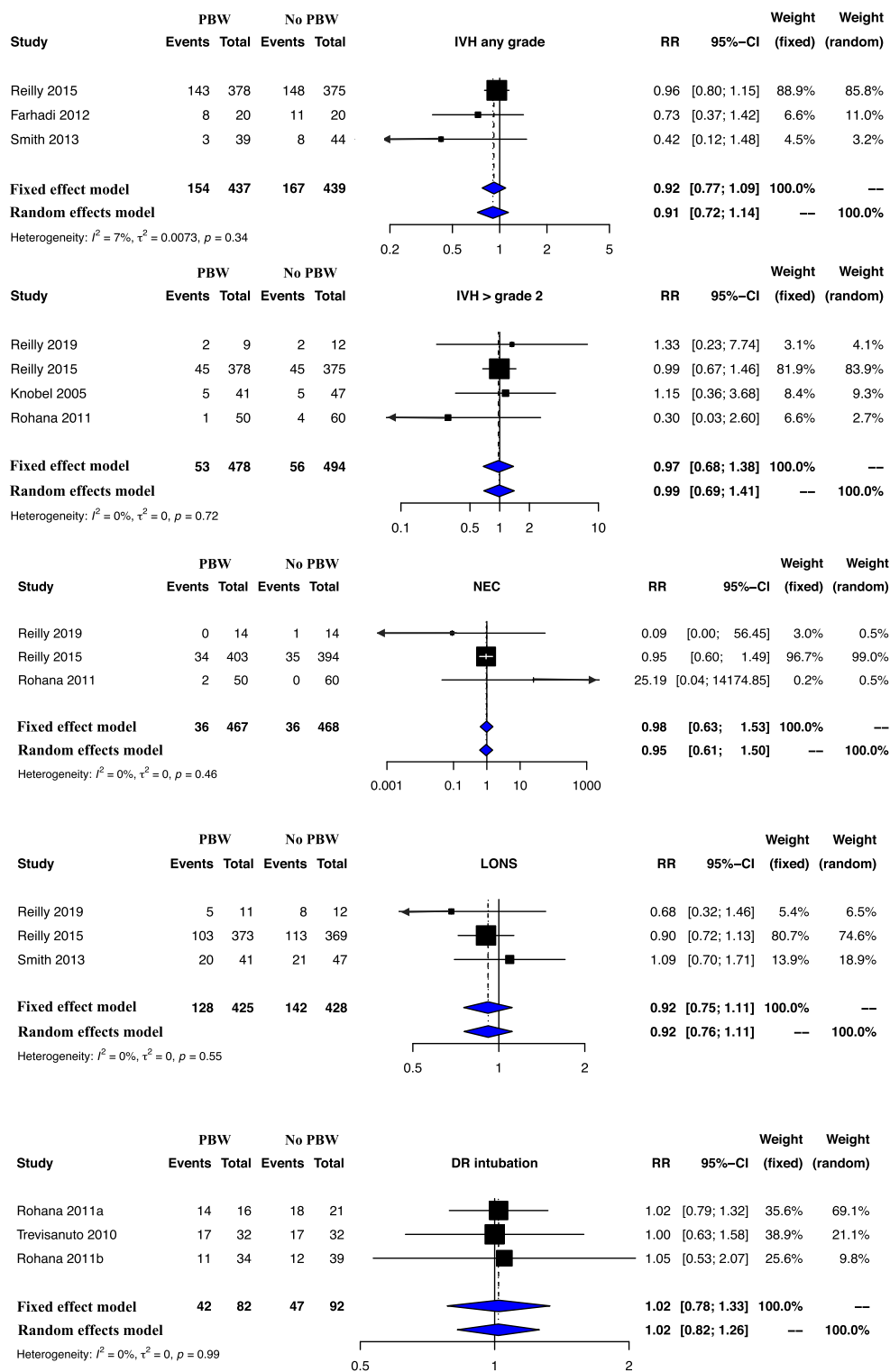


Fig 2. (continued)

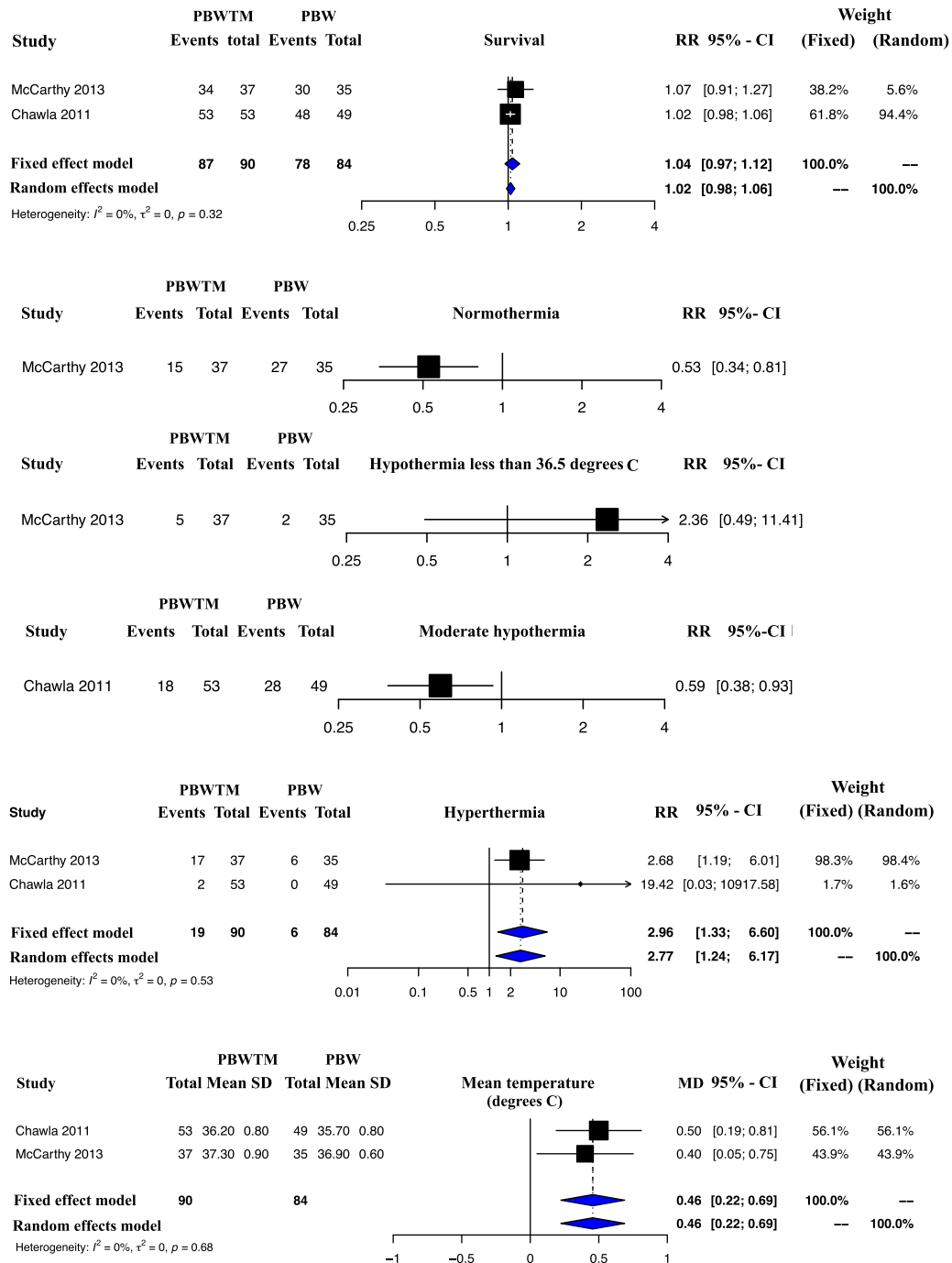


Fig. 3 – Forest plots for different outcomes for the comparison plastic bag or wrap with thermal mattress (PBWTM) versus plastic bag or wrap (PBW) or thermal mattress (TM) versus PBW. Other abbreviations; BPD: bronchopulmonary dysplasia; CI: confidence intervals; DR: delivery room; IPPV: intermittent positive pressure ventilation; IVH: intraventricular haemorrhage; LONS; late onset neonatal sepsis; MD: mean difference; NEC: necrotising enterocolitis; RDS surfactant: respiratory distress syndrome treated with surfactant; RR: relative risk; SD: standard deviation.

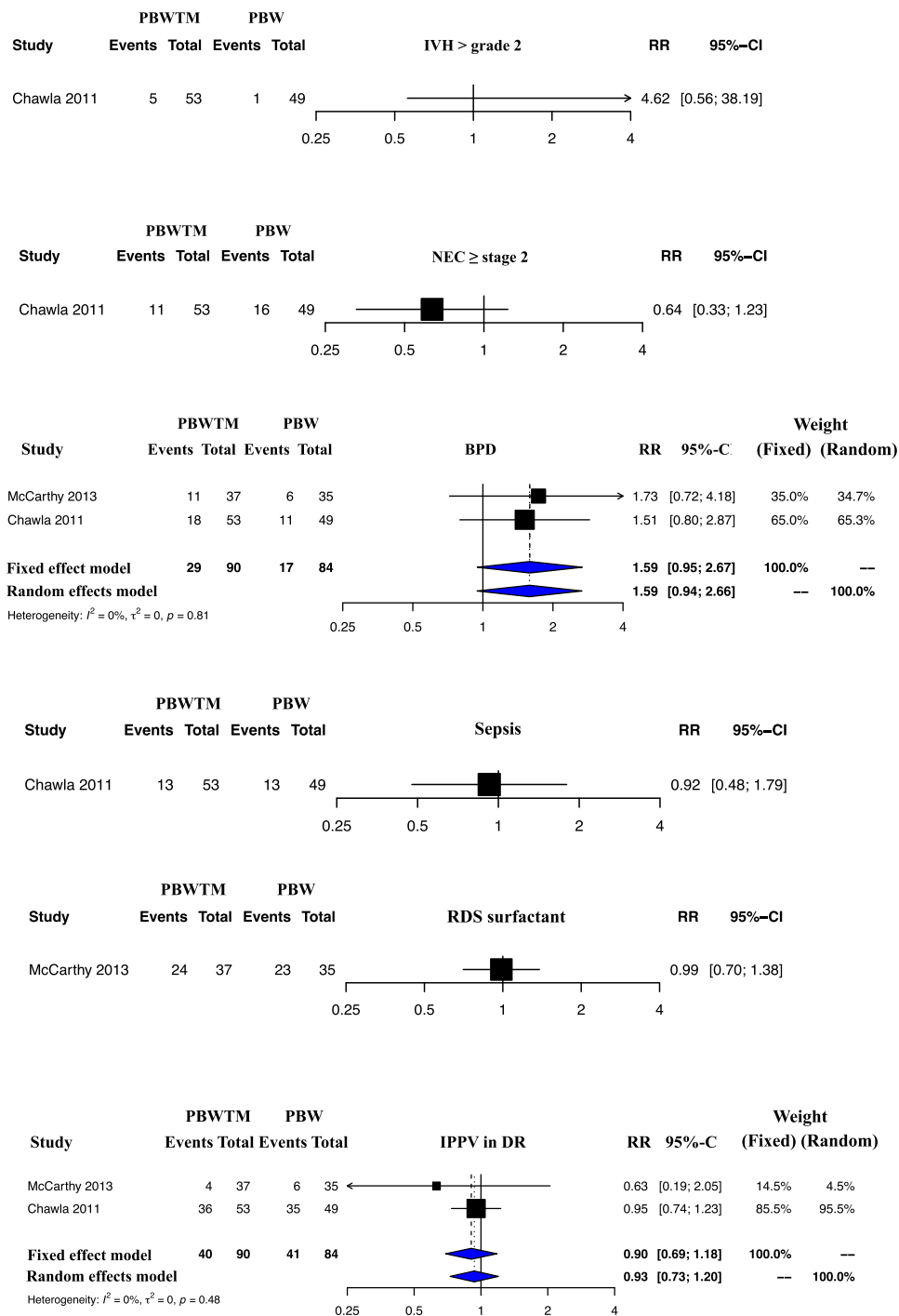


Fig 3. (continued)

PBW plus cap plus increased DR temperature $\geq 23^\circ\text{C}$ versus standard care. The author of a prospective cohort study (980 infants) provided additional data regarding this combination. The combined interventions possibly increased the rate of normothermia (RR, 95% CI: 1.70, 1.30–2.20), increased MBT and possibly decreased moderate hypothermia (RR, 95% CI: 0.78, 0.70–0.80) and hypothermia $<36.5^\circ\text{C}$ (RR, 95% CI: 0.88, 0.82–0.94) (CoE: not assessed because this analysis used unpublished data).⁴⁹ (Supplement Fig. 14, Supplement Table 23).

Other interventions. No comparative trials were found for the following interventions; early monitoring of temperature, warm bags of fluid and swaddling with or without a cap.

Sub-group analysis of RCTs

There were insufficient studies for most comparisons of interventions to perform subgroup analyses, and for most of those that were possible, no significant differences between subgroups were found. For PBW versus no PBW, the pre-planned subgroup analysis by gestation was not

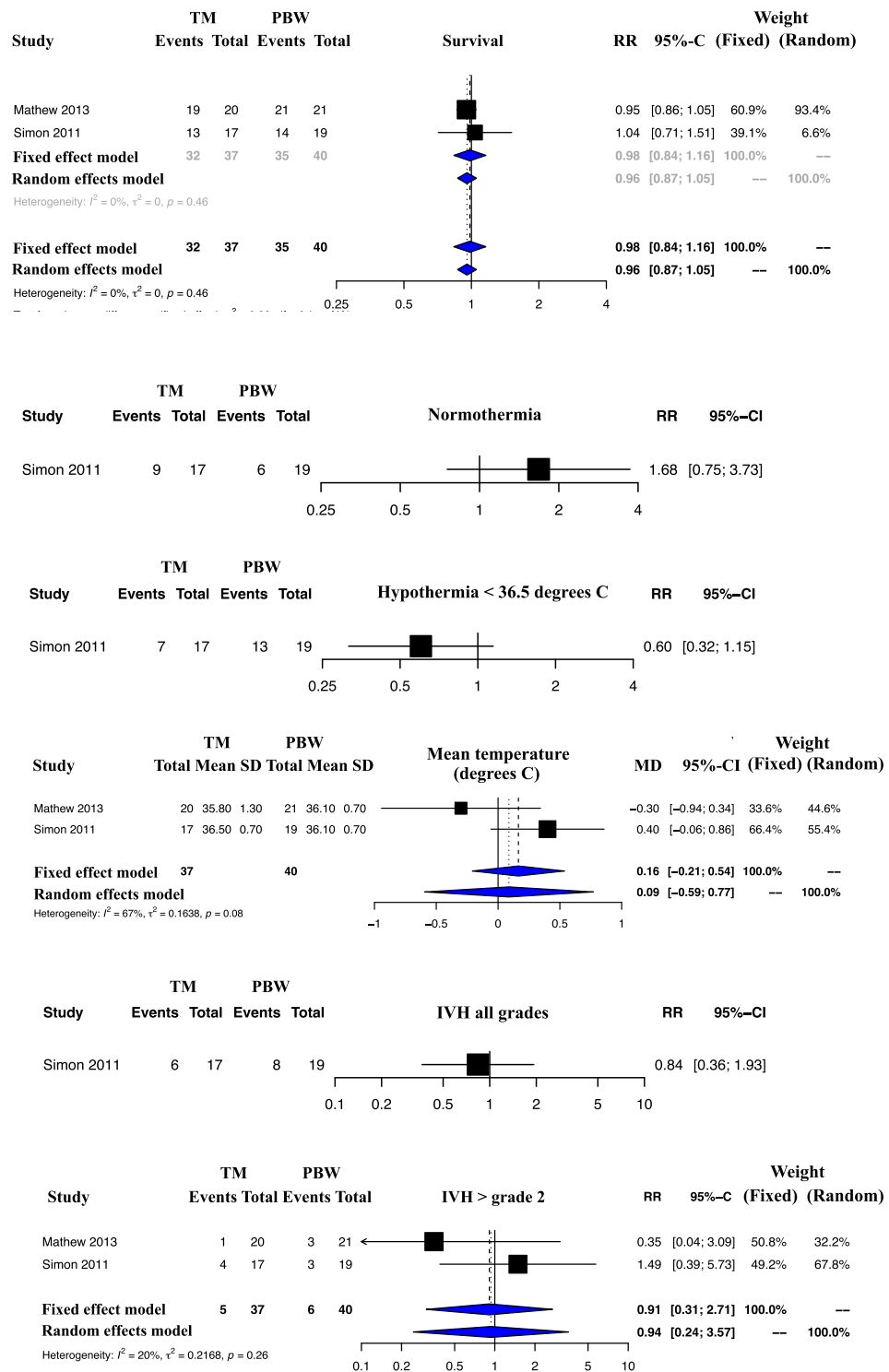


Fig 3. (continued)

possible because insufficient studies provided data separating infants by gestation. However, for PBW, post-hoc analysis by mean gestational age of the included neonates found significant sub-group differences for the outcome of moderate hypothermia ($p = 0.02$); with a lower relative risk in infants <28 weeks' gestation than in infants ≥ 28 weeks.^{23,27,30,36,39,44} The pre-planned subgroup analysis by resources of setting was not possible because studies did not report resource levels of the setting. How-

ever, post-hoc analysis by country income classification showed a lower risk for moderate hypothermia ($p = 0.02$) in HIC than LMIC with the use of a PBW.^{18,20,37,39} There were no significant subgroup differences for any other outcomes. We also performed a post-hoc subgroup analysis by type of plastic used in studies of PBW (vinyl, polyethylene and polyurethane) and found no significant differences between these for any outcome (Supplement File 2).

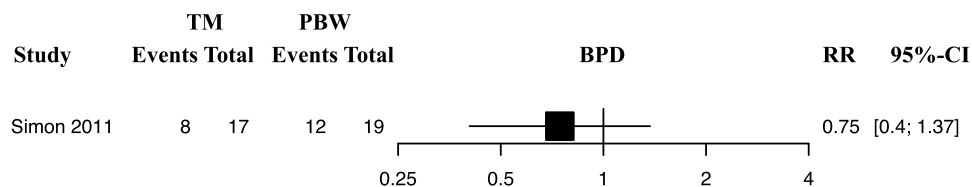
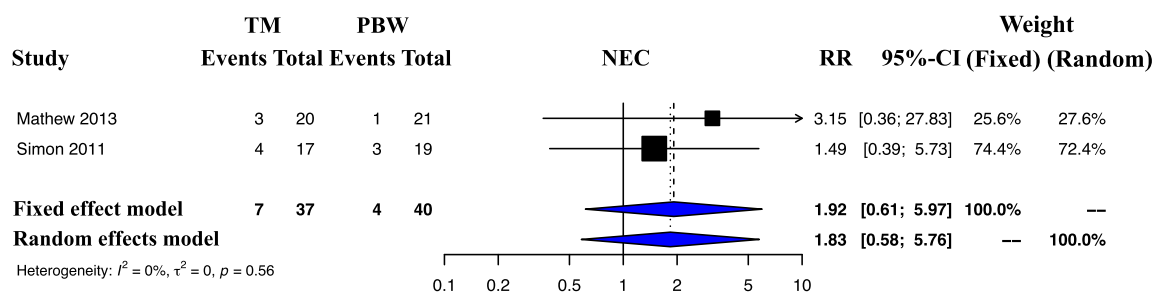


Fig 3. (continued)

Quality improvement initiatives^{61–89}

The 29 QI studies included in this systematic review evaluated the effect of implementing a range of interventions, 14 of them using multiple PDSA (Plan-Do-Study-Act) cycles. However, very few studies reported on sustainability. The most common interventions used were PBW (all studies), caps made of plastic, wool or cotton (22 studies) increased ambient temperature (18 studies) and TM (16 studies). In some studies, the initiative focused on increased use or expanded criteria (to include infants of higher birth weight or gestation) of the study interventions. Eight studies did not report which measures were routinely used in the baseline period. These factors precluded any meta-analysis of results. All studies reported some form of improvement in body temperature. However, nineteen studies reported that some infants became hyperthermic >37.5 °C. This included 10 of 16 studies that used TM, while four reported no difference in the rate of hypothermia and two did not report this outcome. Together, the studies suggested that a tailored approach addressing specific local deficiencies improves temperature outcomes of pre-term infants immediately after birth. However, the studies were sufficiently diverse that no specific bundle of interventions could be identified as likely to be applicable in all settings (Supplement Table 3).

Discussion

This systematic review found evidence for various DR strategies to prevent hypothermia in preterm infants <34 weeks' gestation immediately after birth. None of the interventions improved survival, but several single or combined interventions improved temperature outcomes.

Our review indicated that room temperature ranges of 24 °C to 26 °C, ≥ 23 °C and ≥ 25 °C when compared to lower temperatures may improve infants' temperature outcomes, although heterogeneity of the studies precluded meta-analysis.^{29,49,53} A single study of a high (34 °C) DR temperature increased the risk of hyperthermia

when compared to 28 °C,⁵² whereas in RCTs and observational studies, various DR temperatures between 23 °C and 26 °C improved temperature outcomes without increasing the risk of hyperthermia.^{29,49,53} Hence, we suggest that the DR temperature be at least 23 °C for anticipated delivery of infants <34 weeks' gestation but emphasise that the optimal ambient temperature is not yet well-defined. It may also vary depending on ambient humidity (not recorded in any studies) and the number and type of other measures used for maintaining infants' temperatures. The European Resuscitation Council (ERC) guidelines recommend a DR temperature between 23 °C and 25 °C for infants ≥ 28 weeks' gestation and >25 °C for infants <28 weeks' gestation.⁹²

For use of RW, the only study eligible for inclusion indicated that servo-controlled mode compared to manual-mode might result in lower body temperatures.²² Outcomes could differ depending on specific servo-control settings or manual settings and locations for skin probes.

For head coverings, a large observational study suggested that use of a cloth cap decreased the risk of moderate hypothermia when compared to no cap.⁴⁹ The one eligible RCT compared a plastic cap without a PBW and compared to use of neither improved temperature outcomes, but benefits were less impressive for a plastic cap plus a PBW compared to PBW alone.⁴⁴ Our previous review in term and near term infants suggested that woollen caps were effective, but that cotton caps might be little more effective than no cap.⁹ Further pre-clinical and clinical studies (including studies that address cranial temperatures) are needed to evaluate what type of cap is best for both preterm and term infants.

Other systematic reviews have also found that PBW improves temperature outcomes in preterm infants <34 weeks' gestation.^{6,7,93} None of the reviews has found convincing evidence that PBW improves other major morbidity or mortality. However, very few studies reported morbidity outcomes comprehensively, and even with meta-analysis, sample sizes were often insufficient for them. Increased risk of hyperthermia when using PBW suggests the need

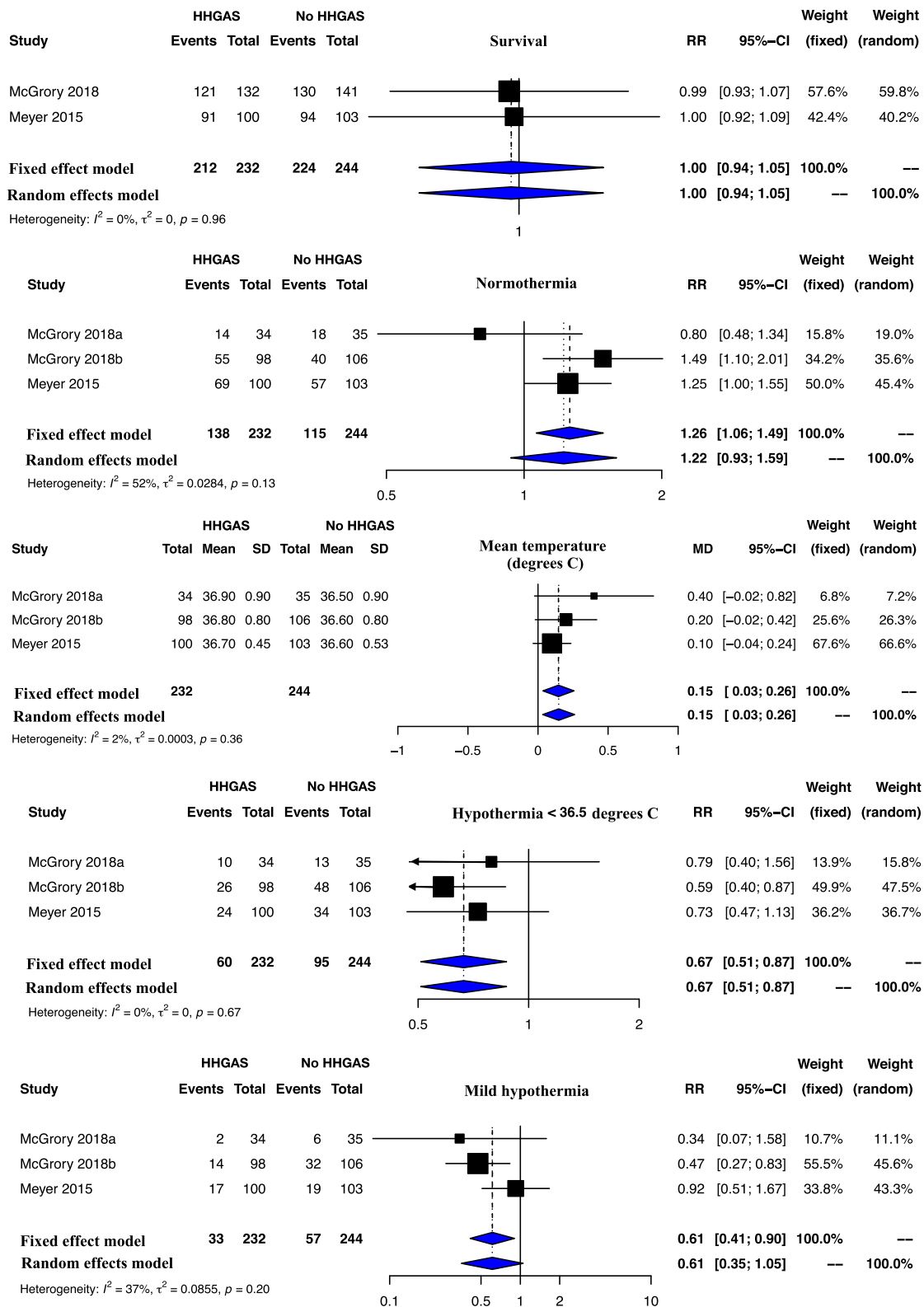
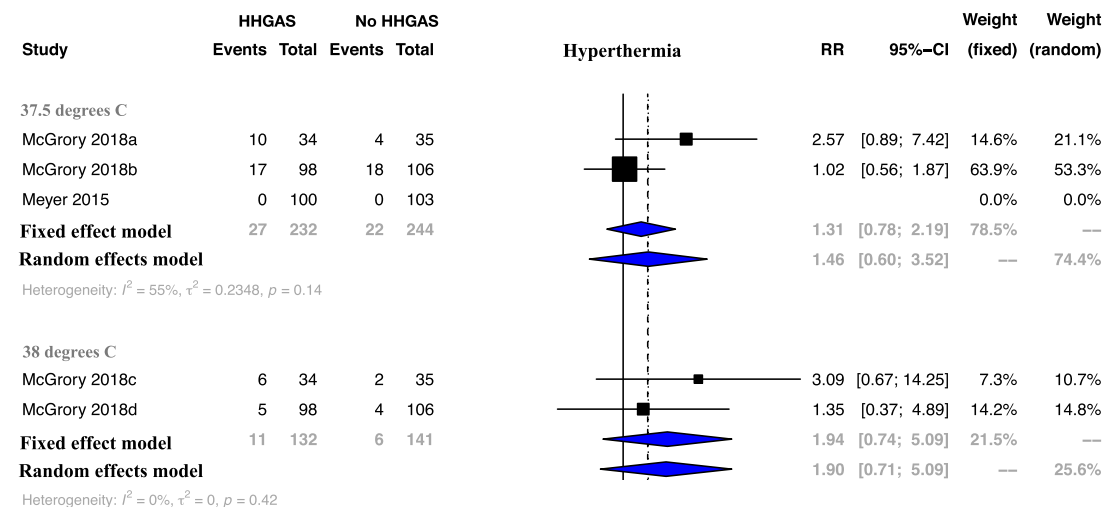
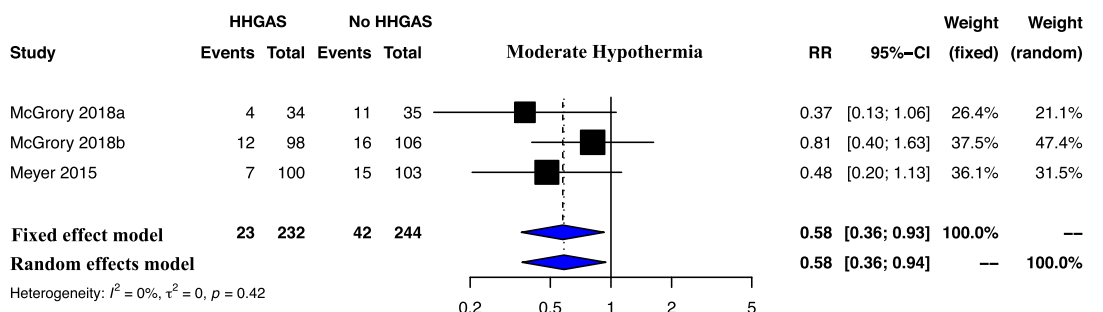


Fig. 4 – Forest plots for different outcomes for the comparison heated and humidified gases (HHGAS) versus non-heated non-humidified gases for stabilisation the delivery room. For studies that provided subgroup analyses by gestation, these are indicated as ‘a’ and ‘b’ for the same study, with explanation of the subgroups in footnotes. Other abbreviations; BPD: bronchopulmonary dysplasia; CI: confidence intervals; DR: delivery room; IVH: intraventricular haemorrhage; LONS; late onset neonatal sepsis; MD: mean difference; NEC: necrotising enterocolitis; RDS surfactant: respiratory distress syndrome treated with surfactant; RR: relative risk; SD: standard deviation.



* Not pooled

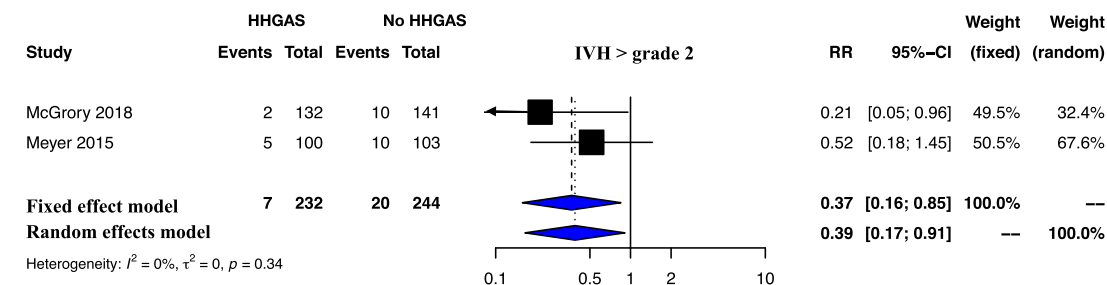


Fig 4. (continued)

for frequent temperature monitoring. The included studies of wraps used simple sheets of various types of plastic. Newer, purpose-designed wraps that include a head covering and a front fastening might improve effectiveness and reduce the need for a cap as well.

Sensitivity analysis by upper gestation limit of each study suggested greater effectiveness of PBW for preventing moderate hypothermia in preterm infants <28 weeks' gestation than ≥28 weeks. This is plausible based on differences in skin maturity, surface-area-to-weight ratio and maturity of homeostatic mecha-

nisms. Nevertheless, the rates of hypothermia were high in the control groups even among infants ≥28 weeks' gestation suggesting that use of PBW is still justified for larger preterm infants. Although subgroup analysis also suggested that the efficacy of PBW was better in HICs than in LMICs, there was only one study performed in a HIC, which was also the sole study that enrolled only infants <28 weeks.³⁷ Therefore, both subgroup analyses should be interpreted with caution.

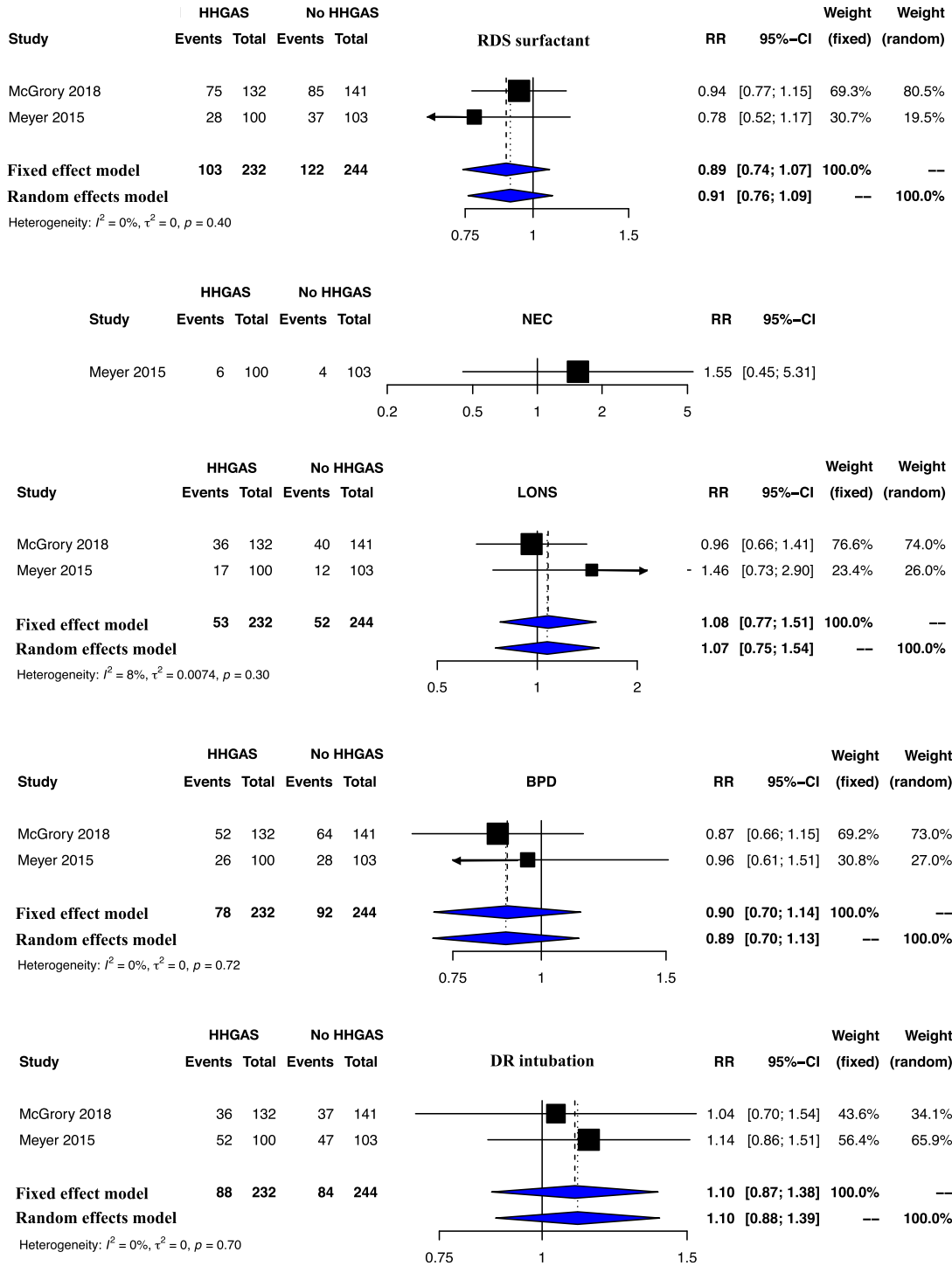


Fig 4. (continued)

Use of PBW with TM increased risk of hyperthermia, suggesting possible harm in combining these methods. However, TM may have application in settings where local audit demonstrates that other methods to maintain normal temperature are insufficiently effective, or where they are unavailable, such as for out-of-hospital births.

Use of HHG plus PBW possibly improved temperature outcomes and decreased the risk of IVH > grade 2.^{34,35} These results deserve

replication in larger trials. Use of HHG may not be feasible in LMICs and other low resource settings.

The quantity and certainty of evidence for SSC for maintaining normal temperature in VPT infants immediately after birth was very low, making it a research priority, especially for low resource settings. A recent RCT that did not meet eligibility criteria for this review evaluated SSC in <33 week-gestation infants within the first 1–2

Table 8 – Summary of findings table for GRADE based evidence rating for the comparison plastic bag or wrap versus no plastic bag or wrap. A plastic bag or wrap compared to no plastic bag or wrap for preterm infants <34 weeks' gestation or equivalent birth weight, immediately after birth.

Certainty assessment						Summary of findings					
Participants (studies) Follow-up	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of evidence	Study event rates (%)		Relative effect (95% CI)	Anticipated absolute effects	
							With standard care	With a plastic bag or wrap		Risk with standard care	Risk difference with a plastic bag or wrap
Survival											
1419 (12 RCTs)	not serious ^a	not serious ^b	not serious ^c	not serious ^d	none	⊕⊕⊕⊕ High	587/719 (81.6%)	586/700 (83.7%)	RR 1.05 (1.00 to 1.10)	816 per 1,000	41 more per 1,000 (from 0 fewer to 82 more)
Normothermia											
449 (5 RCTs)	serious ^e	not serious ^b	not serious ^c	serious ^f	none	⊕⊕○○ Low	30/234 (12.8%)	78/215 (36.3%)	RR 2.86 (1.66 to 4.91)	128 per 1,000	238 more per 1,000 (from 85 more to 501 more)
Mean body temperature (Axillary)											
755 (10 RCTs)	serious ^g	not serious ^h	not serious	not serious ⁱ	publication bias strongly suspected ^j	⊕⊕○○ Low	420	401	-	Control mean body temperature 35.56 Celsius	MD 0.65 Celsius higher (0.42 higher to 0.87 higher)
Mean body temperature (Rectal)											
348 (7 RCTs)	serious ^g	not serious	not serious	not serious	publication bias strongly suspected ^j	⊕⊕○○ Low	179	169	-	Control mean body temperature 35.86 Celsius	MD 0.77 Celsius higher (0.5 higher to 1.04 higher)
Hypothermia <36.5 degree celsius											
489 (6 RCTs)	serious ^e	not serious ^h	not serious ^c	not serious ^k	none	⊕⊕⊕○ Moderate	221/254 (87.0%)	134/235 (57.0%)	RR 0.64 (0.50 to 0.82)	870 per 1,000	313 fewer per 1,000 (from 435 fewer to 157 fewer)
Moderate hypothermia (varied definition)											
1055 (4 RCTs)	serious ^e	not serious ^h	serious ^l	serious ^m	none	⊕○○○ Very low	125/528 (23.7%)	47/527 (8.9%)	RR 0.40 (0.19 to 0.81)	237 per 1,000	142 fewer per 1,000 (from 192 fewer to 45 fewer)
Hyperthermia											
1467 (9 RCTs)	serious ⁿ	not serious ^b	not serious ^c	not serious ^o	none	⊕⊕⊕○ Moderate	9/836 (1.1%)	44/816 (5.4%)	RR 3.67 (1.77 to 7.61)	11 per 1,000	33 more per 1,000 (from 9 more to 81 more)
IVH any grade											
876 (3 RCTs)	not serious ^p	not serious ^b	not serious ^c	serious ^q	none	⊕⊕⊕○ Moderate	167/439 (38.0%)	154/437 (35.2%)	RR 0.91 (0.72 to 1.14)	380 per 1,000	34 fewer per 1,000 (from 107 fewer to 53 more)
IVH > grade 2											
972 (4 RCTs)	not serious ^p	not serious ^b	not serious ^c	serious ⁱ	none	⊕⊕⊕○ Moderate	56/494 (11.3%)	53/478 (11.1%)	RR 0.99 (0.69 to 1.41)	113 per 1,000	1 fewer per 1,000 (from 35 fewer to 46 more)

(continued on next page)

Table 8 (continued)

Certainty assessment						Summary of findings					
Participants (studies) Follow-up	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of evidence	Study event rates (%)		Relative effect (95% CI)	Anticipated absolute effects	
							With standard care	With a plastic bag or wrap		Risk with standard care	Risk difference with a plastic bag or wrap
NEC											
935 (3 RCTs)	not serious ^p	not serious ^b	serious ^r	serious ⁱ	none	⊕⊕○○ Low	36/468 (7.7%)	36/467 (7.7%)	RR 0.95 (0.61 to 1.50)	77 per 1,000	4 fewer per 1,000 (from 30 fewer to 38 more)
Late onset neonatal sepsis											
853 (3 RCTs)	not serious ^p	serious ^b	not serious ^c	serious ^q	none	⊕⊕○○ Low	142/428 (33.2%)	128/425 (30.1%)	RR 0.92 (0.76 to 1.11)	332 per 1,000	27 fewer per 1,000 (from 80 fewer to 36 more)
Intubation in the delivery room											
174 (3 RCTs)	serious ^e	not serious ^b	not serious ^c	serious ^q	none	⊕⊕○○ Low	47/92 (51.1%)	42/82 (51.2%)	RR 1.02 (0.82 to 1.26)	511 per 1,000	10 more per 1,000 (from 92 fewer to 133 more)

CI: confidence interval; MD: mean difference; RR: risk ratio.

Explanations.

- Most of the trials with higher weightage contributing to the meta-analysis had a low bias and a few had some concerns.
- The test for heterogeneity was not significant.
- The PICO was similar across trials.
- Narrow 95% confidence interval with optimal information size criterion (OIS) satisfied for sample size and event rates as calculated for relative risk reduction of 25%.
- Most of the trials with higher weightage in the meta-analysis had a high risk of overall bias.
- With a control group event rate of 12.8%, for a RRR of 25% an approximate sample size of 2500 is required. Hence the OIS criterion was not satisfied.
- Overall, most of the trials had similar weightage in the meta-analysis. Amongst them there were a significant number of trials which either had some concerns or a high risk of overall bias.
- Though I² was high, this was attributed to difference between small and large magnitude of effect estimate.
- 95% confidence interval not crossing the line of no effect and OIS criterion satisfied.
- Egger's test showed a possibility of publication bias with a p-value of 0.002.
- RR 95% not crossing the line of no effect; OIS criterion satisfied for a control group event rate of 87% for RRR of 25%.
- There was indirectness related to the definition of the outcome moderate hypothermia across studies.
- For a control group event rate of 23.7%, the total sample size required is 1500 and hence OIS criterion not met.
- There were two trials that had contributed significant weightage in the meta-analysis. While one had some concerns, the other had a high risk of overall bias.
- Though the event rate is low, this is one of the scenarios where the presence of large sample size overrides the OIS criterion.
- The trial with the highest weightage had low risk of overall bias.
- 95% CI crossing the line of no effect.
- Two studies have not specified the staging of NEC and hence indirectness related to the outcome was adjudged.

hours after birth but did report some improved outcomes compared to care in an incubator or cot.⁹⁴

The optimal methods for maintaining normal temperature during DCC could not be defined, because too few included studies defined the approach to umbilical cord management or reported temperature outcomes immediately after DCC.

For each of the interventions we examined, the protocols of individual studies generally specified other co-interventions (for both study arms) to maintain normal temperature. It is probable that co-interventions affect effect sizes and therefore, the balance of risks and benefits for each comparison. For the comparisons we examined, there were insufficient studies to draw any conclusions on the influence of co-interventions.

Strengths of this systematic review included careful, consensus-driven development of the research protocol, and rigorous methodology using methods specified by ILCOR that included peer review and public consultation regarding the resulting consensus on the scientific results.⁹⁵ Limitations included the difficulties of synthesising evidence from trials that used a variety of different comparisons and outcome measures, and in some cases, excluded infants at highest need of resuscitation. The lack of a standardised method of reporting temperature outcomes also limited the meta-analysis. There were small numbers of studies for most comparisons. Differences in reporting precluded the pre-defined subgroup analyses. Finally, the lack of data for interventions such as early monitoring of temperature, warm bags of fluid and swaddling with or without a cap, which might have particular value in low resource settings suggests the need for future studies.

Conclusions

For maintenance of normal temperature of newborn infants <34 weeks' gestation, the review found some support for using a DR temperature of ≥ 23 °C, a RW in manual mode, a head covering such as a plastic or cloth cap and a PBW. HHG for PPV is also supported where resources allow. TM and SSC may also improve temperature outcomes. A consensus opinion of TF members was that they may have greatest benefit in settings where other measures are unavailable or insufficiently effective. Measures to prevent hypothermia can increase risk of hyperthermia, especially when used in combination. To maintain normothermia, frequent checking of temperature at intervals before admission to the NICU seems justified. The high rates of hypothermia and cold stress shown even in intervention groups in this review demonstrate that the ILCOR recommendation to monitor admission temperatures as a measure of quality of care remains valid.⁹⁶

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V.V. Ramaswamy: Conceptualization, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **J.A. Dawson:** Conceptualization, Formal

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data used in this systematic review and meta-analysis are from published literature. Data may be shared on reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.resuscitation.2023.109934>.

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