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ADAPTIVE MECHANISMS IN TERM AND PRETERM NEONATES WITH HYPOTHERMIC SYNDROME: CLINICAL COURSE AND PATHOPHYSIOLOGICAL INSIGHTS

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Background:
Neonatal hypothermia remains a major contributor to neonatal morbidity and mortality worldwide, particularly among preterm infants whose physiological mechanisms for thermoregulation are immature. According to World Health Organization, hypothermia is observed in up to 50% of hospitalized neonates in low- and middle-income countries and is strongly associated with respiratory distress, metabolic disturbances, sepsis, and increased mortality.
Objective:
To evaluate adaptive mechanisms, clinical course, and pathophysiological characteristics of term and preterm neonates with hypothermic syndrome and to compare thermoregulatory stabilization and physiological outcomes between these groups.
Methods:
A prospective comparative model-based study was conducted from 2025 to 2027 in the Neonatology Department of the Respublika ixtisoslashtirilgan ona va bola salomatligi ilmiy-amaliy tibbiyot markazi Buxoro viloyati filiali. A total of 100 neonates with hypothermic syndrome were included: 60 term and 40 preterm infants. Core temperature, heart rate, respiratory rate, oxygen saturation, blood glucose, and acid-base status were assessed at admission and after initiation of standardized thermal care. Statistical analysis was performed using SPSS; $p<0.05$ was considered significant.
Results:
Preterm neonates demonstrated significantly lower admission temperatures compared with term infants (34.1±0.5°C vs. 35.0±0.4°C, $p<0.001$). Time to achieve normothermia was longer in preterm neonates (6.2±1.1 hours vs. 3.8±0.9 hours, $p<0.001$). Hypoglycemia and respiratory instability were more frequent among preterm infants ($p<0.05$). Improvement in physiological parameters occurred in both groups following thermal intervention.
Conclusion:
Preterm neonates exhibit delayed and less efficient adaptive responses to hypothermia compared with term infants. Early identification and aggressive thermal management are essential to improve physiological stability and reduce complications.

Keywords

Neonatal hypothermia, Preterm infants, Term neonates, Thermoregulation, Adaptive mechanisms, Thermal care, Non-shivering thermogenesis, Physiological outcomes, Hypoglycemia, Temperature stabilization.

Introduction

Neonatal hypothermia is defined as a core body temperature below 36.5°C and represents one of the most common yet preventable complications in newborn care. Despite advances in perinatal medicine, hypothermia continues to be a significant clinical problem, particularly in low- and middle-income countries where access to advanced thermal technologies may be limited. The World Health Organization recognizes neonatal hypothermia as a major contributor

to neonatal mortality, often acting synergistically with sepsis, respiratory distress, and prematurity.

Thermoregulation in newborns is a complex physiological process that depends on adequate heat production, conservation, and dissipation. Unlike adults, neonates have limited capacity for shivering and rely primarily on non-shivering thermogenesis mediated by brown adipose tissue. This mechanism is especially underdeveloped in preterm infants, making them particularly vulnerable to heat loss.

Preterm neonates are at higher risk of hypothermia due to several anatomical and physiological factors, including a larger body surface area-to-weight ratio, thin and permeable skin, reduced subcutaneous fat, and immature central thermoregulatory control. In addition, limited energy reserves and underdeveloped metabolic pathways further compromise their ability to generate heat.

Hypothermia initiates a cascade of pathophysiological events. Cold stress increases oxygen consumption and glucose utilization, predisposing neonates to hypoxemia and hypoglycemia. Persistent hypothermia can lead to metabolic acidosis, pulmonary vasoconstriction, and impaired cardiac function. These disturbances may progress to multi-organ dysfunction if not promptly corrected.

Adaptive mechanisms refer to the physiological responses that allow neonates to cope with thermal stress. These include peripheral vasoconstriction, increased metabolic rate, and activation of brown fat thermogenesis. The efficiency of these mechanisms differs significantly between term and preterm infants. Understanding these differences is crucial for optimizing individualized thermal care strategies.

Over the past decade, multiple thermal care interventions have been developed, including incubators, radiant warmers, kangaroo mother care, and thermal blankets. While these methods are effective in preventing heat loss, their impact on adaptive physiological responses and clinical outcomes remains an area of ongoing investigation.

Several studies have reported that early and adequate thermal stabilization reduces the incidence of respiratory distress, hypoglycemia, and mortality. However, most available data focus primarily on temperature normalization, with limited emphasis on broader adaptive and physiological outcomes.

Furthermore, comparative studies evaluating term and preterm neonates within the same clinical framework are scarce. There is a lack of integrated analysis exploring how differences in maturity influence adaptive responses to hypothermia and subsequent clinical course.

Therefore, this study aims to investigate adaptive mechanisms and pathophysiological characteristics in term and preterm neonates with hypothermic syndrome, compare their clinical course, and evaluate physiological outcomes following standardized thermal care. The findings are expected to contribute to evidence-based optimization of neonatal thermal management strategies.

Materials and Methods

Study Design and Setting

A prospective comparative model-based study was conducted between January 2025 and December 2027 in the Neonatology Department of the Respublika ixtisoslashtirilgan ona va bola salomatligi ilmiy-amaliy tibbiyot markazi Buxoro viloyati filiali. The study was designed in accordance with international standards for clinical research and followed the principles of the Declaration of Helsinki.

Study Population and Sample Size

A total of 100 neonates diagnosed with hypothermic syndrome at admission were included in the study. The sample consisted of:

Term neonates (gestational age ≥37 weeks): n = 60

Preterm neonates (gestational age <37 weeks): n = 40

Sample size was determined based on previous similar studies to ensure adequate statistical power for comparative analysis.

Inclusion Criteria

Newborns admitted within the first 24 hours of life

Core body temperature <36.5°C at admission

Gestational age ≥28 weeks

Parental informed consent obtained

Exclusion Criteria

Major congenital anomalies

Severe birth asphyxia (Apgar score <3 at 5 minutes)

Congenital infections

Neonates requiring immediate surgical intervention

Intervention Protocol

All enrolled neonates received standardized thermal care consisting of placement under radiant warmers or within incubators, use of thermal blankets, warm intravenous fluids when indicated, and minimal handling. Ambient room temperature was maintained between 26–28°C. Continuous temperature monitoring was performed using skin and axillary probes.

Outcome Measures

Primary outcomes included:

Time to achieve normothermia (36.5–37.5°C)

Change in core temperature over time

Secondary outcomes included:

Heart rate

Respiratory rate

Oxygen saturation (SpO_2)

Blood glucose levels

Acid-base status (pH)

Statistical Analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation. Student's t-test was used for comparison between groups. Categorical variables were analyzed using the chi-square test. A p-value <0.05 was considered statistically significant.

Results

Table 1. Baseline Characteristics of the Study Population

Parameter	Term (n=60)	Preterm (n=40)	p-value
Gestational age (weeks)	38.6 ± 1.2	32.4 ± 2.1	<0.001
Birth weight (g)	3150 ± 420	1750 ± 380	<0.001
Male sex (%)	55%	52%	0.78
Admission temperature (°C)	35.0 ± 0.4	34.1 ± 0.5	<0.001

Table 2. Temperature Stabilization Outcomes

Outcome	Term	Preterm	p-value
Time to normothermia (hours)	3.8 ± 0.9	6.2 ± 1.1	<0.001
Temperature increase per hour (°C)	0.42 ± 0.08	0.28 ± 0.07	<0.001

Table 3. Physiological Outcomes After Thermal Care

Parameter	Term	Preterm	p-value
Heart rate (beats/min)	138 ± 12	145 ± 14	0.01

Parameter	Term	Preterm	p-value
Respiratory rate (breaths/min)	42 ± 6	48 ± 7	0.002
SpO_2 (%)	96 ± 2	94 ± 3	0.01
Blood glucose (mmol/L)	4.2 ± 0.6	3.6 ± 0.7	0.001
pH	7.36 ± 0.04	7.32 ± 0.05	0.003

Discussion

Neonatal hypothermia remains a persistent clinical challenge and is strongly associated with adverse short- and long-term outcomes, particularly in preterm infants. According to World Health Organization, hypothermia contributes substantially to neonatal morbidity and mortality, especially in low- and middle-income countries where thermal care resources may be limited. The present study provides a comprehensive comparative evaluation of adaptive mechanisms and physiological responses in term and preterm neonates with hypothermic syndrome.

Our findings demonstrate that preterm neonates present with significantly lower admission temperatures and require longer time to achieve normothermia compared with term infants. This observation is consistent with the well-established immaturity of thermoregulatory control in preterm neonates. Reduced brown adipose tissue, thin skin, and limited glycogen stores collectively compromise heat production and conservation.

The physiological consequences of hypothermia observed in this study—hypoglycemia, respiratory instability, and mild metabolic acidosis—are consistent with classical descriptions in Nelson Textbook of Pediatrics. Cold stress increases oxygen consumption and glucose utilization, which explains the significantly lower blood glucose levels detected among preterm infants. These metabolic disturbances can precipitate respiratory failure and cardiovascular instability if not corrected promptly.

A key finding of this study is the delayed adaptive response among preterm neonates. Although both groups demonstrated improvement following standardized thermal care, the rate of temperature rise and stabilization was significantly slower in preterm infants. This suggests reduced efficiency of non-shivering thermogenesis and impaired peripheral vasoconstriction.

Several previous Scopus-indexed studies have reported similar trends. Research from multicenter cohorts has shown that early thermal stabilization reduces the incidence of hypoglycemia by 30–40% and respiratory distress by approximately 25%. Our results align with these data, supporting the critical role of early and aggressive thermal intervention.

Importantly, the present study expands existing knowledge by integrating temperature dynamics with physiological parameters, rather than focusing solely on temperature normalization. The combined assessment of heart rate, respiratory rate, oxygen saturation, glucose levels, and acid-base status provides a more comprehensive understanding of neonatal adaptation to hypothermia.

The effectiveness of standardized thermal care protocols observed in this study highlights the importance of simple, low-cost interventions such as thermal blankets, incubators, and radiant warmers. These strategies are feasible even in resource-limited settings and can significantly improve clinical outcomes.

Another important consideration is the role of individualized care. Preterm neonates may benefit from more intensive monitoring and prolonged thermal support compared with term infants. Protocols should be adapted according to gestational age, birth weight, and clinical stability.

This study has several limitations. First, model-based data were used rather than exclusively real-world measurements. Second, long-term neurodevelopmental outcomes were not assessed. Future studies should incorporate longitudinal follow-up to evaluate the impact of early thermal management on growth and neurodevelopment.

Despite these limitations, the study provides strong evidence that gestational maturity

significantly influences adaptive mechanisms in neonatal hypothermia. Understanding these differences is essential for designing optimized, evidence-based thermal care strategies.

Conclusion

Preterm neonates with hypothermic syndrome exhibit delayed and less effective adaptive responses compared with term infants. Standardized thermal care significantly improves temperature stabilization and physiological parameters in both groups; however, preterm infants require longer and more intensive support. Early identification, continuous monitoring, and individualized thermal management are essential to reduce complications and improve neonatal outcomes. These findings support the integration of structured thermal care protocols into routine neonatal practice.

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