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RESEARCH

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Comparative evaluation of axillary and rectal temperatures across different gestational ages in newborns admitted to the neonatal intensive care unit: a cross-sectional study

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Abstract

Objective Maintaining normothermia is crucial for neonatal survival, especially in preterm infants prone to temperature instability. This study evaluates the correlation and variability between axillary and rectal temperatures at Neonatal Intensive Care (NICU) admission across gestational age ranges of 23–28, 29–32, 33–36, and ≥ 37 weeks, aiming to inform improved neonatal thermal management strategies.

Methods This cross-sectional study was conducted at King Abdulaziz Medical City, Riyadh, from October 2023 to April 2024, involving 160 infants. Admission temperatures were measured using digital thermometers. Data analysis included ANOVA/Kruskal-Wallis for continuous variables, Chi-square tests for categorical data, Bland-Altman method for agreement assessment, and Pearson correlation coefficients to evaluate temperature correlations.

Results Mean axillary temperature increased from 36.4 °C in the 23–28 weeks gestational group, to 36.5 °C in the 29–32 weeks group, and to 36.7 °C in the 33–36 weeks and ≥ 37 weeks groups, ($p = 0.033$). Rectal temperature increased from 36.5 °C in the 23–28 weeks group, to 36.6 °C in the 29–32 weeks group, and reached 36.8 °C in both the 33–36 weeks and ≥ 37 weeks groups ($p = 0.006$). Notable differences between measurement methods were observed in the 33–36 and ≥ 37 weeks groups ($p < 0.001$), with less pronounced differences in the 23–28 and 29–32 weeks groups. While temperature differences between rectal and axillary measurements remained consistent across all groups at 0.1 °C ($p = 0.779$), neonatal outcomes varied significantly across gestational age groups, with younger infants exhibiting lower survival rates ($p < 0.001$), higher incidences of hypoglycemia ($p < 0.001$) and sepsis ($p < 0.001$), and extended durations of ventilation ($p < 0.001$) and hospital stay ($p < 0.001$). Strong correlations between rectal and axillary temperature were found across all age ranges (Pearson coefficients: 0.953 for 23–28 weeks, 0.762 for 29–32 weeks, 0.910 for 33–36 weeks, and 0.761 for ≥ 37 weeks; all $p < 0.001$). Bland-Altman analysis indicated higher variability in agreement for younger preterm groups, showing limits of agreement ranging from – 0.5 to 0.65 °C for

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23–28 weeks and −0.5 to 0.69 °C for 29–32 weeks, improving in older groups with −0.2 to 0.4 °C for 33–36 weeks and similarly narrow ranges for ≥37 weeks.

Conclusion Both rectal and axillary temperatures showed variation across different age groups, exhibiting a substantial overall correlation. Notable differences between the two methods were observed in the 33–36 weeks and ≥37 weeks groups. Younger preterm infants demonstrated greater variability, with enhanced agreement observed in older infants.

Keywords Newborn, Temperature, Rectal, Axillary, Agreement

Introduction

The accurate measurement of body temperature in neonates is crucial as it plays an essential role in assessing newborn health, guiding clinical decisions, and ensuring optimal care. According to the World Health Organization's (WHO) practical guide on the thermal protection of newborns, published in 1997, neonatal temperature ranges are categorized as follows: Normothermia is defined as a temperature between 36.5 °C and 37.5 °C. Hypothermia is classified into three categories: mild hypothermia with a temperature range of 36.0 to 36.4 °C; moderate hypothermia with a temperature falling between 32.0 °C and 35.9 °C; and severe hypothermia, indicated by a temperature below 32.0 °C. Notably, newborns, particularly preterm infants, are highly subject to temperature instability, making temperature monitoring a critical aspect of neonatal care.

Admission hypothermia (AH) in newborns, especially those with very low birth weight (VLBW), is linked to heightened mortality and morbidity risks [1–3]. A recent meta-analysis has revealed that a higher mortality risk is faced by hypothermic VLBW infants compared to their normothermic counterparts [2]. The collective odds ratio (OR) for mortality among hypothermic infants was significantly raised, almost doubling the death risk [2]. The meta-analysis also highlighted an increased risk of certain adverse neonatal outcomes like bronchopulmonary dysplasia (BPD), intra-ventricular haemorrhage (IVH), and neonatal sepsis [2]. Reinforcing these findings, a study carried out across multiple centres in China indicated that hypothermic VLBW infants had substantially higher rates of major neonatal morbidities, including respiratory distress syndrome (RDS), IVH, and early onset sepsis [3].

Axillary temperature (AT) measurement is favoured in newborn care because of its non-invasive nature, making it safer and more comfortable for infants. This method avoids the discomfort associated with rectal thermometry and reduces the risk of potential injury [4]. However, it is worth noting that, while axillary temperature is widely used for its convenience and safety, it does not accurately represent the core body temperature. Rectal temperature (RT) is often considered a representative measure of the core body temperature [5].

A comprehensive review of the literature comparing axillary and rectal temperature measurements in neonates has revealed conflicting results [6]. A systematic review highlighted two studies with opposing findings, underlining the considerable variability in this area [6]. In addition to this, seven more studies provided mixed outcomes [7–13]. Four studies that utilized the Bland-Altman method [14] identified a low level of agreement between rectal and axillary measurements [8–10, 12], whereas two other studies demonstrated strong correlations [7, 13]. Interestingly, one study found that temperature readings taken from the back had a closer correlation with rectal temperatures than those taken from the abdomen [11]. These diverse findings from the various studies emphasize the difficulties in obtaining consistent temperature measurements in neonates due to the inherent variability in physiological conditions across different gestational ages. Preterm infants, specifically, are more susceptible to temperature instability which further complicates the accuracy of temperature measurements. Factors such as the type of thermometer, the measurement technique, and external conditions further influence the results.

The primary aim of this study is to evaluate the correlation and variability between axillary and rectal temperatures at NICU admission across distinct gestational age groups: 23–28 weeks (Extremely Preterm), 29–32 weeks (Very Preterm), 33–36 weeks (Moderate to Late Preterm), and ≥37 weeks (Term). This research addresses the critical factor of initial temperature measurements at NICU admission, a vital aspect in the management of neonatal hypothermia. Our study fills a significant gap in the current literature by providing a detailed analysis of temperature variability at admission, categorized by gestational age groups. By offering insights into how initial temperatures vary across the spectrum from preterm to term infants, our research contributes to the development of more precise and effective thermal management strategies, thereby enhancing clinical protocols and potentially improving neonatal care outcomes.

Methodology

This cross-sectional study was conducted from the 1st of October 2023 to the 30th of April 2024 at the Neonatal Intensive Care Unit (NICU) of King Abdulaziz Medical City (KAMC) in Riyadh, Kingdom of Saudi Arabia (KSA). The NICU is a 50-bed level IIIc critical care unit and a 36-bed Neonatal High Dependency Unit (NHDU) with an average of 2300 admissions per annum. The study was granted ethical approval by the King Abdullah International Medical Research Centre (KAIMRC), with an IRB number of NRC23R/336/04. Parental consent was obtained for each participant. In instances of emergency deliveries where antenatal consent could not be acquired, consent was retrospectively obtained. This deferred consent process allowed us to enrol patients and collect data, ensuring that parents were approached for consent at the earliest appropriate opportunity.

Inclusion criteria accounted for newborns admitted to either the NICU or NHDU within the study timeframe. The study excluded infants born outside the hospital and those with birth defects that impeded temperature measurement via the axillary or rectal routes. Data collected encompassed demographic and clinical details like gestational age (established by obstetric ultrasound or the date of the last menstrual period), gender, birth weight, and mode of delivery (vaginal delivery or caesarean section). The maternal health information recorded involved conditions such as hypertension (pre-pregnancy and pregnancy-induced), maternal diabetes (gestational diabetes and pre-pregnancy diabetes), prolonged membrane rupture (over 18 h), chorioamnionitis, and maternal axillary temperature at the time of delivery. In our study, chorioamnionitis was clinically defined based on maternal fever (≥38.0 °C) presence and one or more criteria such as uterine tenderness, maternal or fetal tachycardia, foul-smelling amniotic fluid, or purulent vaginal discharge, following the American College of Obstetricians and Gynecologists guidelines [15]. Maternal tachycardia was defined as a heart rate exceeding 100 beats per minute, and fetal tachycardia as a heart rate above 160 beats per minute, aligning with those same guidelines. As for premature rupture of membranes (PROM), it was considered in chorioamnionitis diagnosis only when accompanied by other infection signs, like maternal fever, uterine tenderness, or foul-smelling amniotic fluid. Moreover, Apgar scores at 1 and 5 min, and the need for intubation in the delivery room, were also documented. The following morbidities were evaluated: Major intraventricular hemorrhage (IVH) (grade III & IV) based on the Papile classification, Necrotizing Enterocolitis (NEC) on the Bell's classification that needed surgical intervention with insertion of intraabdominal drain or laparotomy, and culture positive sepsis of the blood, CSF or urine. In addition, the duration of mechanical ventilation to the successful extubation in days and the length of hospital stay to the point of home discharge were also determined.

Upon entering the NICU and having received initial medical attention and size measurements, the infants' admission temperatures were logged within the first-hour post-birth. The temperature was captured using the "Safety 1st 3-in-1 Nursery Thermometer", a digital thermometer specifically designed for neonatal and Pediatric usage, produced by Dorel Juvenile. The thermometer has a measure extent of 32.2–43.2 °C, with a precision of ±0.1 °C for temperatures between 35 and 42 °C, and ±0.2 °C for temperatures below 35 °C and above 42 °C. The thermometer operates within a 10–40 °C environment and is capable of being stored from −25 to 60 °C. The device comes pre-calibrated and features a flexible tip for rectal measurements to increase comfort and an over-insertion guard for safety. The thermometer, also equipped with a last-temperature recall function, can deliver results within just 30 s.

Eight members of the medical staff underwent training for accurate usage of this thermometer and hence carried out the measurements. Rectal temperatures were recorded first by gently inserting the thermometer tip up to 1 cm into the rectum until the signal for stable reading was received. Axillary temperatures were gauged by placing the thermometer tip under the infant's arm, ensuring direct skin contact. The same thermometer was used for all measurements and sanitized with alcohol wipes between uses. As part of our study, immediate hypothermia prevention measures were implemented for all enrolled infants in line with the Newborn Resuscitation Program (NRP) guidelines [15]. In addition, it is essential to mention that all medical personnel involved in neonatal care in our unit are NRP certified, guaranteeing high care standards and adherence to best practices for temperature management [15].

Statistical analysis

Data analysis was conducted using SPSS software, version 26. We calculated the sample size of 160 infants, divided equally across four gestational age groups, to achieve 80% power and detect significant temperature differences of at least 0.1 °C at a 5% significance level. This calculation was based on expected differences and standard deviations from existing literature concerning neonatal temperature variations. We employed power analysis, assuming a normal distribution of temperatures, and utilized two-tailed t-tests for our calculations. This sample size allows us to address potential variability and ensure the robustness of our findings across each gestational group [9].

Initial normality tests for the temperature data were performed using the Kolmogorov-Smirnov test,

Table 1 Maternal and infant characteristics

	23–28 wks. (*n*=40)	29–32 wks. (*n*=40)	33–36wks. (*n*=40)	≥37 wks. (*n*=40)	*P* value
Birthweight (grams) (Mean ± SD)	875(292)	1566(307)	2294(533)	3064(486)	< 0.001
Gestational age (weeks) (Mean ± SD)	25.8(1.7)	30.8(1.2)	34.7(1.0)	38.4(1.3)	< 0.001
Gender (male)	69%	47.5%	56.4%	59%	0.269
Maternal hypertension	15.4%	10%	15.4%	5%	0.382
Maternal diabetes	25%	27.5%	30.8%	23.1%	0.890
Mode of delivery (cesarean section)	51.3%	70.0%	74.4%	35.9%	0.002
Maternal prolonged rupture of membranes (PROM) > 18 h	38.5%	40%	10%	0%	< 0.001
Maternal chorioamnionitis	7.7%	10%	0%	0%	0.018
Apgar score at 1 min (Mean ± SD)	5(2)	7(2)	8(1)	8(1)	< 0.001
Apgar score at 5 min (Mean ± SD)	7(1)	8(2)	9(1)	9(1)	< 0.001
Need for delivery room intubation	75%	35%	7.5%	2.5%	< 0.001

Table 2 Comparison of temperature data across four gestational ages

	23–28 wks. (*n*=40)	29–32 wks. (*n*=40)	33–36 wks. (*n*=40)	≥37 wks. (*n*=40)	*P*-value
Axillary Temperature °C (Mean ± SD)	36.4(0.9)	36.5(0.4)	36.7(0.3)	36.7(0.2)	0.033
Rectal Temperature °C (Mean ± SD)	36.5(0.8)	36.6(0.4)	36.8(0.3)	36.8(0.2)	0.006
Mean of Rectal and Axillary Temperature °C (Mean ± SD)	36.4(0.9)	36.6(0.4)	36.7(0.3)	36.7(0.2)	0.039
Maternal AxillaryTemperature °C (Mean ± SD)	36.9(0.3)	38.8(0.2)	36.8(0.2)	36.8(0.1)	0.547
Time from birth to admission (min) (Mean ± SD)	17(9)	17(10)	17(4)	20(8)	0.250
Delivery room temperature (°C) (Mean ± SD)	23.2(0.2)	23.1(0.1)	23.1(0.1)	23.3(0.1)	< 0.001

confirming that the data was normally distributed. We analyzed continuous variables, such as temperature measurements, across the four gestational age groups using Analysis of Variance (ANOVA). Non-normally distributed data such as the length of hospital stay and the duration of mechanical ventilation across the four different gestational age groups were analyzed using the Kruskal-Wallis test. Categorical variables were evaluated using the Chi-square test. We calculated the Pearson correlation coefficient (R) to determine the linear relationship between temperatures recorded at the rectal and axillary sites. Additionally, we assessed the statistical differences between rectal and axillary temperatures within each gestational age group using the paired sample t-test.

To assess the concordance between axillary and rectal temperature measurements, the Bland-Altman method was utilized across each of the four gestational age groups. Bias was determined as the average difference between the two measurement methodologies. The agreement limits were defined as the average difference plus or minus 1.96 times the standard deviation of these differences, indicating the range in which 95% of the disparities between the two methods would reside [14].

Results

This cross-sectional study enrolled a total of 160 infants systematically stratified them into four gestational age categories for a detailed analysis. These groups consisted of infants born at less than 28 weeks, 29 to 32 weeks, 33 to 36 weeks, and those at or beyond 37 weeks, with each category uniformly accommodating 40 infants.

Table 1 provides a summary of the demographic and clinical characteristics of infants across four gestational age groups. There were significant differences in birth weight ($p<0.001$), gestational age ($p<0.001$), mode of delivery ($p=0.002$), prolonged rupture of maternal membranes (PROM) > 18 h ($p<0.001$), maternal chorioamnionitis ($p=0.018$), Apgar scores at 1 min ($p<0.001$) and 5 min ($p<0.001$), and necessity for delivery room intubation ($p<0.001$). However, there were no significant differences in gender ($p=0.269$), maternal hypertension ($p=0.382$), maternal diabetes ($p=0.890$), or time from birth to admission ($p=0.250$) (Table 1).

Table 2 presents the comparison of temperature data across four different gestational age groups. Significant differences were identified in both axillary ($p=0.033$) and rectal temperatures ($p=0.006$) across the gestational age groups. This indicates that temperature readings from these sites differ depending on the infant's gestational age. In addition, significant differences were also found in

Table 3 Paired t-test results for rectal and axillary temperatures within each gestational age group

Gestational age group	Axillary Temperature (Mean, SD)	Rectal Temperature (Mean, SD)	*P* value
23–28 weeks' gestation (*n* = 40)	36.4(0.9)	36.5(0.8)	0.090
29–32 weeks' gestation (*n* = 40)	36.5(0.4)	36.6(0.4)	0.068
33–36 weeks' gestation (*n* = 40)	36.7 (0.3)	36.8(0.3)	< 0.001
≥ 37 weeks' gestation (*n* = 40)	36.7(0.2)	36.8(0.2)	< 0.001

Table 4 Correlations of rectal and axillary at different gestational age groups

Gestational Age (Weeks)	*N*	Pearson Correlation	Significance (2-tailed)
23–28 weeks	40	0.953**	< 0.001
29–32 weeks	40	0.762**	< 0.001
33–36 weeks	40	0.910**	< 0.001
≥ 37 weeks	40	0.761**	< 0.001

**. Correlation is significant at the 0.01 level (2-tailed

the means of rectal and axillary temperatures ($p=0.039$), underlining the overall variation in temperature measurements. There were also significant differences in delivery room temperatures ($p<0.001$) across the groups. However, no significant differences were noted in the maternal axillary temperatures ($p=0.547$) and the time from birth to admission ($p=0.250$) (Table 2).

Table 3 presents a comparison of axillary and rectal temperatures within each gestational age group. Notable differences were observed between the mean rectal and axillary temperatures in the 33–36 weeks and ≥37 weeks gestational age groups, with a significance level of $p<0.001$. In contrast, the mean rectal and axillary temperatures showed no statistically significant differences in the 23–28 weeks ($p=0.090$) and 29–32 weeks ($p=0.068$) gestational age groups as indicated in Table 3.

Table 4 displays the Pearson correlation coefficients between axillary and rectal temperatures within each gestational age group. The correlations were strong and highly significant for all groups: 0.953 for 23–28 weeks, 0.762 for 29–32 weeks, 0.910 for 33–36 weeks, and 0.761 for ≥37 weeks, with all p-values being less than 0.001. These findings indicate a robust correlation between axillary and rectal temperatures within each gestational age group (Table 4).

Table 5 presents neonatal outcomes across the four gestational age groups. The mean difference between rectal and axillary temperatures was consistent across groups at 0.1 °C ($p=0.779$). Survival rates were significantly lower in the 23–28 weeks group at 75%, compared to 95% in the 29–32 weeks group, and 100% in both the 33–36 weeks and ≥37 weeks groups ($p<0.001$). Major IVH occurred in 5% of infants in the 23–28 weeks and 29–32 weeks groups, but was absent in the older gestational age groups ($p=0.267$). Surgical NEC was observed in 3% of the 23–28 weeks group and was absent in the other groups ($p=0.393$). Hypoglycemia in the first 24 h was noted in 37% of the 23–28 weeks group, 52% of the 29–32 weeks group, 18% of the 33–36 weeks group, and 8% of the ≥37 weeks group ($p<0.001$). Culture-positive sepsis was present in 28% of the 23–28 weeks group, 10% of the 29–32 weeks group, and absent in the older age groups ($p<0.001$). Duration of ventilation was longest in the 23–28 weeks group at a median of 19 days (IQR: 7–24), compared to 3 days (IQR: 2–5) in the 29–32 weeks group, 1 day (IQR: 1–9) in the 33–36 weeks group, and 1 day (IQR: 1–3) in the ≥37 weeks group ($p<0.001$). Length of hospital stay also decreased with increasing gestational age, with a median of 50 days (IQR: 20–62) in the 23–28 weeks group, 30 days (IQR: 20–37) in the 29–32 weeks group, 8 days (IQR: 6–11) in the 33–36 weeks group, and 3 days (IQR: 2–6) in the ≥37 weeks group ($p<0.001$) (Table 5).

The analysis of Bland-Altman plots in Figs. 1, 2, 3 and 4, for various gestational age groups, offers important

Table 5 Neonatal outcomes and temperature differences across gestational age groups

Outcome	23–28 weeks (*n* = 40)	29–32 weeks (*n* = 40)	33–36 weeks (*n* = 40)	≥ 37 weeks (*n* = 40)	*P*-value
Difference between Rectal and Axillary temperature (Mean ± SD)	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.2	0.1 ± 0.2	0.779
Survival Rate (%)	75	95	100	100	< 0.001
Major Intraventricular Hemorrhage (IVH) (%)	5	5	0	0	0.267
Surgical Necrotizing Enterocolitis (NEC) (%)	3	0	0	0	0.393
Hypoglycemia in First 24 h (%)	37	52	18	8	< 0.001
Culture-positive Sepsis (Blood, Urine, CSF) (%)	28	10	0	0	< 0.001
Duration of Ventilation (Days, Median [IQR])	19 [7–24]	3 [2–5]	1 [1–9]	1 [1–3]	< 0.001
Length of Hospital Stay (Days, Median [IQR])	50 [20–62]	30 [20–37]	8 [6–11]	3 [2–6]	< 0.001

*CSF = Cerebrospinal Fluid; *IQR = Interquartile Range

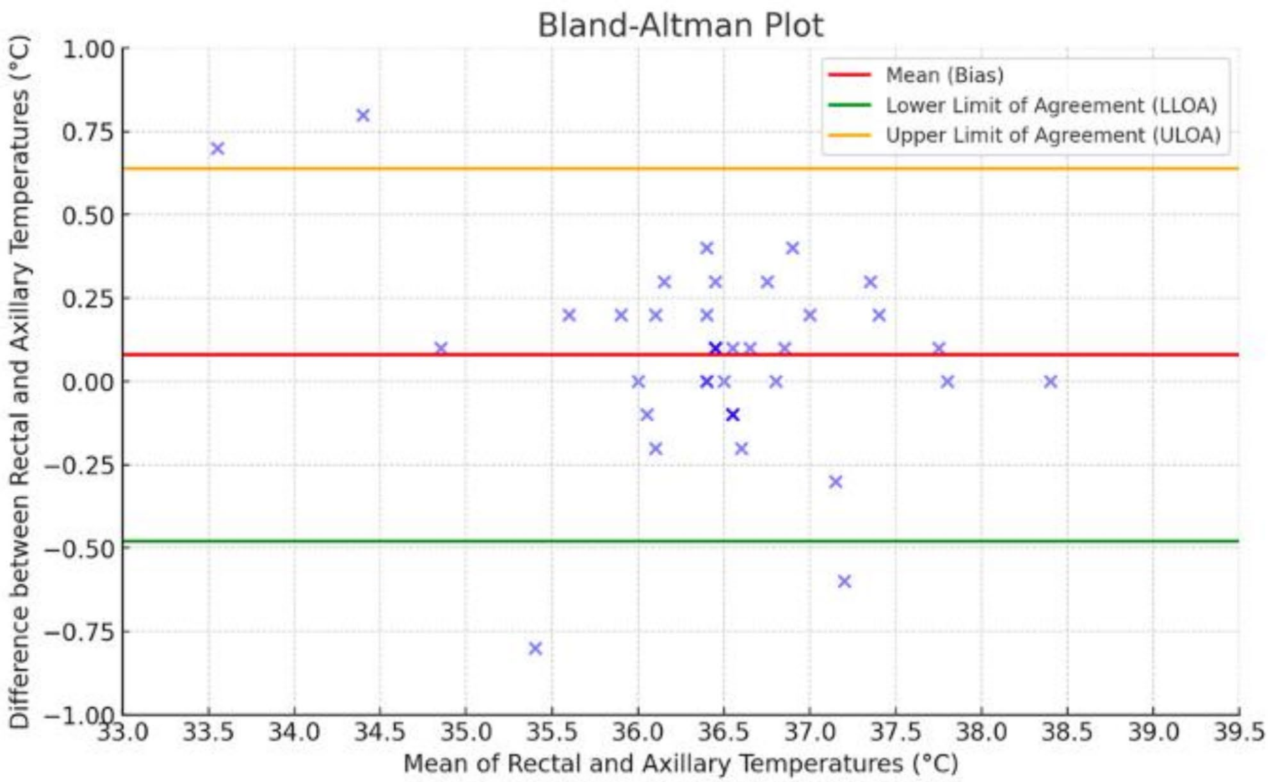

Fig. 1 Bland-Altman plots (23–28 weeks)

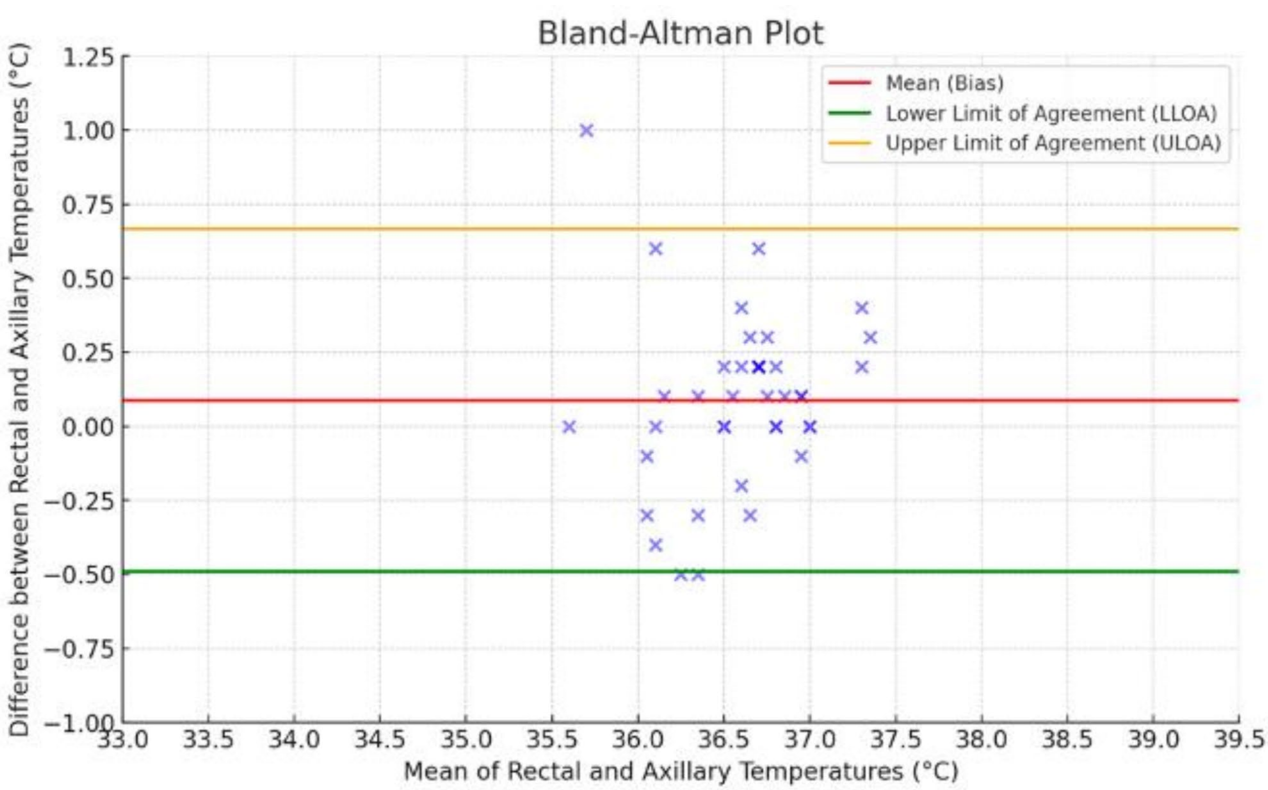

Fig. 2 Bland-Altman plots (29–32 weeks)

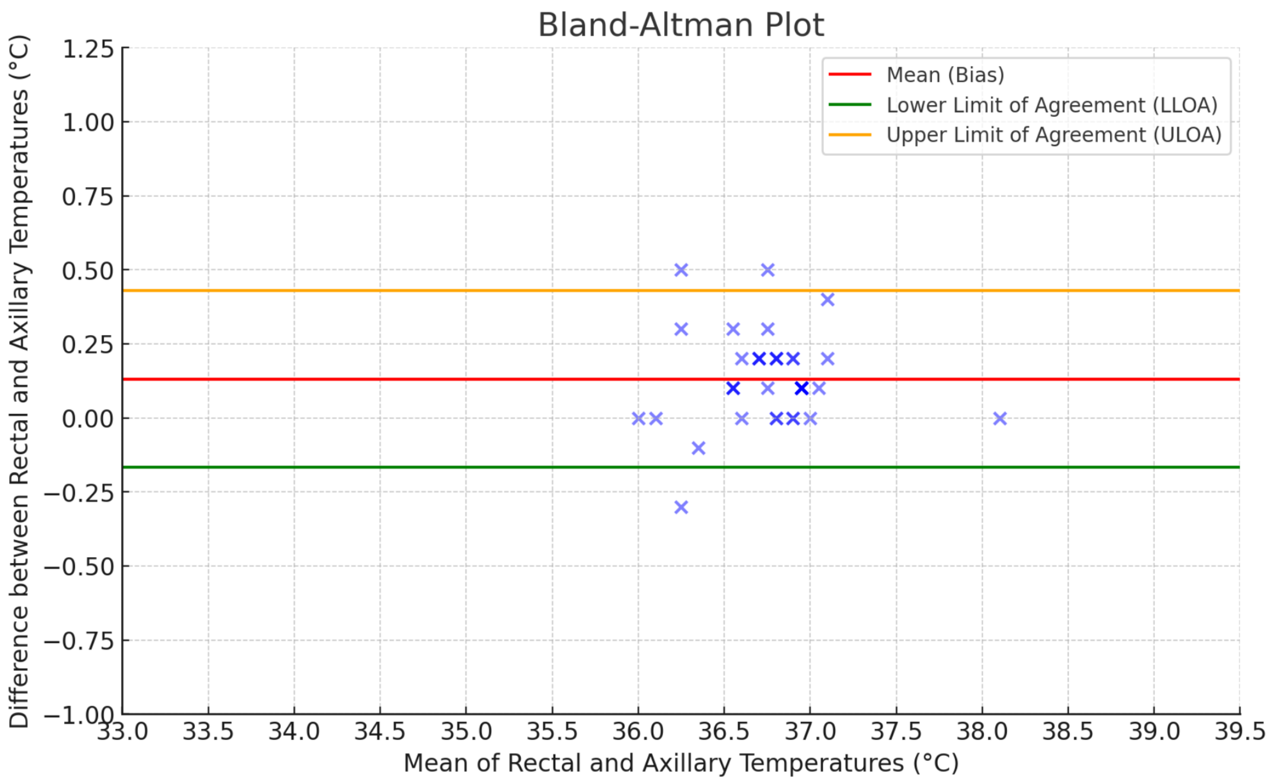

Fig. 3 Bland-Altman plots (33–36 weeks)

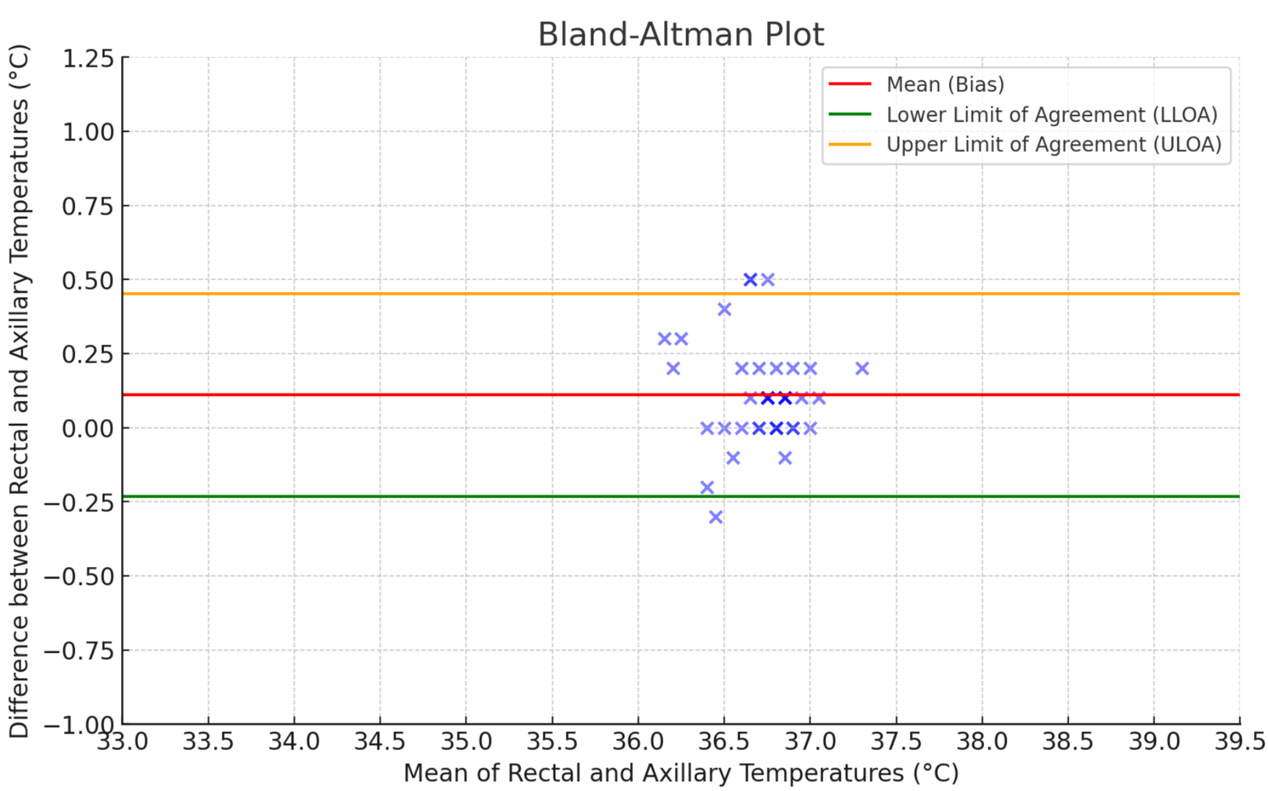

Fig. 4 Bland-Altman plots (≥ 37 weeks)

insights into the agreement between rectal and axillary temperature measurements in neonates.

For infants born between 23 and 28 weeks (Fig. 1), the bias is 0.1 °C with a relatively high standard deviation of 0.29 °C. This results in wide limits of agreement ranging from −0.5 to 0.65 °C, indicating substantial variability in temperature measurements within this extremely preterm group. The high variation implies that, for extremely preterm infants, rectal and axillary temperature measurements may not be reliably interchangeable.

In the 29 to 32 weeks group (Fig. 2), the bias remains consistent at 0.1 °C, but the standard deviation increases to 0.30 °C. This results in limits of agreement ranging from −0.5 to 0.66 °C, reflecting continued high variability. The broader range of limits of agreement, analogous to the 23 to 28-week group, indicates that the variability in temperature measurements remains significant for this very preterm infants' group.

For infants born between 33 and 36 weeks (Fig. 3), there was also a bias of 0.1 °C; however, the standard deviation decreased to 0.13 °C. This refinement narrowed the limits of agreement from −0.2 to 0.4 °C, indicating an increased consistency in measurements. The decreased variability suggests that, for this gestational age group, rectal and axillary temperature measurements are more reliable and can thus be used interchangeably with enhanced confidence.

Finally, for term infants born ≥ 37 weeks (Fig. 4), the bias is steady at 0.1 °C, and the standard deviation is 0.15 °C. The limits of agreement for this gestational age group range from −0.2°to 0.45 °C, suggesting more consistent measurements. These outcomes imply that the consistency in temperature measurements evident in the late preterm group is maintained in term infants, with comparable limits of agreement.

Discussion

In this cross-sectional study involving 160 infants across diverse gestational ages, we discovered a significant correlation between axillary and rectal temperatures at NICU admission within each gestational group. This indicates that both methods are dependable for initial temperature assessment in neonates. Additionally, significant variations in both axillary and rectal temperatures were observed across gestational age groups, indicating that temperature readings are influenced by the infant's gestational maturity. The mean temperatures between these two measurement sites also differed, highlighting an overall variation in temperature assessment based on gestational age.

The Bland-Altman plot analysis across gestational age groups reveals a pattern of diminishing variability and progressively narrowing limits of agreement with increasing gestational age. The analysis notably emphasizes that infants between 33- and 36-weeks gestation and those of ≥37 weeks showcase similar levels of measurement consistency. This implies that the reliability of temperature measurement in later preterm infants approximates that of term infants. This pattern underscores the impact of physiological maturity on the reliability of temperature measurement methods in neonates. Such insights are vital for clinicians when evaluating the appropriateness of temperature measurement techniques based on the gestational age of the newborn, ultimately aiding the betterment of neonatal care practices.

Additionally, we observed broader limits of agreement in infants who appeared clinically unstable in the first hour after birth, as indicated by lower Apgar scores and the need for intensive interventions, including respiratory support. This observation indicates that both gestational age and clinical stability significantly impact the reliability of temperature measurements. In our institution, intubation remains necessary for many extremely preterm infants, particularly those under 26 weeks, due to their immediate stabilization needs. This high rate of intubation is also reflective of the challenges associated with managing admission temperatures particularly among extreme preterm infants. While the Less Invasive Surfactant Administration (LISA) [16] technique has been adopted for infants over 26 weeks and shows promise, its implementation is still in the early stages in our institution. As we gain more experience with LISA, we anticipate a broader application, which may influence future intubation rates and potentially improve admission temperature management.

In this study, we found that neonatal outcomes such as IVH and NEC did not show significant differences across the gestational age groups. However, there were notable variations in the rates of hypoglycemia and culture-positive sepsis. Hypoglycemia was more common in the 29–32 weeks and 23–28 weeks groups, while sepsis was more frequently observed in the 23–28 weeks group, with no cases in the more mature infants. The data also indicated that the duration of ventilation and length of hospital stay (LOS) were considerably longer in infants born at earlier gestations. Importantly, these conditions did not significantly affect the minimal difference observed between rectal and axillary temperatures, suggesting that the temperature variability is independent of these neonatal morbidities. Additionally, no cases of perinatal asphyxia or DIC were recorded, ruling out their potential impact on temperature differences in this cohort. The lack of statistically significant difference in the difference between rectal and axillary temperatures across the four gestational age groups suggests that the observed differences in clinical outcomes are more likely attributable to gestational age rather than variations between rectal and axillary temperature measurements.

To our knowledge, this study is the first to specifically focus on the correlation between rectal and axillary temperatures taken upon admission in newborns of various gestational ages, all within the critical first hour of life. The early neonatal period is vital for temperature regulation, particularly for preterm and clinically unstable infants. As such, accurate temperature assessment is essential for immediate clinical interventions.

Only one previous study has specifically addressed the correlation between rectal and axillary temperatures at NICU admission [17]. While that study mainly focused on preterm infants younger than 31 weeks gestation, our research included a broader range of gestational ages, from 23 weeks to term gestation. Both our data and the earlier study showed similar mean differences between the two methods, as assessed by the Bland-Altman plot. However, the limits of agreement between the two methods in our study were narrower, not only for late preterm and term infants but also for infants younger than 32 weeks gestation. Several factors could account for these observed differences between our study and the earlier one [17]. Our study featured a wider gestational age range, with 160 infants in four groups, potentially providing a more comprehensive representation and resulting in narrower limits of agreement. In contrast, the other study focused solely on preterm infants less than 31 weeks, possibly creating more variability and wider limits of agreement, despite a similar mean difference. Demographic characteristics, such as age, weight, and clinical conditions, may have also influenced the discrepancy between the two populations. Finally, the types of thermometers and measurement techniques used in each study could have contributed to the accuracy and consistency of the results.

In a different study involving 118 newborns with gestational ages ranging from 29 to 41 weeks and a median birth weight of 2980 g, a significant correlation ($r=0.5$, $p=0.001$) was identified between measurements of axillary and rectal temperature [18]. The correlation was observed to increase alongside gestational age, with it being especially notable in term newborns ($r=0.6$, $p<0.001$). Bland-Altman plots from the study indicated good agreement for gestational ages beyond 29 weeks. Factors such as Caesarean delivery increased measurement discrepancies, whereas an increase in chronological and gestational ages reduced these differences [18]. The research concluded that axillary thermometry is reliable in both stable term and preterm infants, emphasizing gestational age, chronological age, and mode of delivery as principal predictors of measurement agreement [18].

Our findings are in line with those of Falzon et al. [8], where a strong correlation was also observed between axillary and rectal temperatures ($r=0.73$, $p<0.0001$). However, despite both studies exhibiting a strong correlation, differences are apparent in the limits of agreement in the Bland-Altman plots. Falzon et al. found that axillary temperatures differed by 2.5–3 °C from rectal readings [8]. A distinguishing feature of their study is the wider age range, from newborns to children of four years, with a lack of specific insights into the neonatal subgroup. This broader scope could explain the discrepancies between their results and our study, which specifically targeted neonates and recorded admission temperatures within 1 h of birth.

The study presents several strengths and noticeable limitations. Our study is pioneering as it reports on admission temperatures across a broad spectrum of gestational age groups, from extremely preterm to full-term. This comprehensive analysis offers crucial insights that are vital for developing and refining age-specific protocols in neonatal care. To our knowledge, there is no previous comparative cross-sectional study on admission hypothermia across different gestational age groups, making our findings particularly significant. By focusing on temperature measurements within the first-hour post-birth, our study ensures the data's accuracy and clinical relevance during this critical period. These factors underscore the study's significant contribution to enhancing neonatal care and facilitating the development of bespoke management strategies based on reliable initial measurements. The large sample size and stratification by gestational age improve the study's statistical strength and generalizability. Furthermore, the inclusion of extensive maternal and neonatal demographic and clinical data enables a more detailed analysis of factors influencing neonatal temperature regulation, which further strengthens the study's contributions to neonatal care practices. However, several limitations need consideration. Firstly, the innate variability in physiological conditions among infants, ranging from 23 weeks gestation to term, combined with the environmental and procedural factors at the time of admission, may impact the generalizability of the findings to other settings or populations. Secondly, the study's focus on the first hour of life, when temperature measurements were taken, could generate variability due to varying clinical conditions and immediate postnatal care practices. This makes attributing temperature differences solely to gestational age complicated, potentially obscuring other contributing clinical or environmental factors. Thirdly, the study does not account for temperature fluctuations after admission, which could significantly impact neonatal outcomes. Lastly, the single-centre design might limit the generalizability of the study findings. Consequently, future research should involve multiple centres to enhance the robustness and applicability of the findings.

Conclusion

The study identified a significant variation in mean axillary and rectal temperature measurements across different gestational age groups. Notable differences were observed between mean rectal and axillary temperature measurements within the 33–36 weeks and ≥37 weeks groups, but not in the 23–28 weeks and 28–32 weeks groups. A substantial correlation between axillary and rectal temperatures was evident across all gestational age groups. Bland-Altman analysis displayed an augmented variability in agreement for the 23–28 weeks and 29–32 weeks groups, but the agreement improved in the 33–36 weeks and ≥37 weeks groups. These observations emphasize the significance of considering gestational age when interpreting temperature measurements in neonates. Moreover, they underline the necessity for accurate and consistent temperature monitoring practices to elevate neonatal care outcomes.

Abbreviations

AH	Admission Hypothermia
AT	Axillary Temperature
BPD	Bronchopulmonary Dysplasia
DR	Delivery Room
IVH	Intraventricular Hemorrhage
KAIMRC	King Abdullah International Medical Research Centre
KAMC	King Abdulaziz Medical City
KSA	Kingdom of Saudi Arabia
NICU	Neonatal Intensive Care Unit
RT	Rectal Temperature
VLBW	Very Low Birth Weight
WHO	World Health Organization

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Author contributions
KA, SH, AH, AA, and SA were involved in the concept and design of the study, supervision, and made significant contributions to the writing and critical review of the manuscript. KA and SH performed the statistical analysis of the data, had full access to all the data in the study, and take responsibility for the integrity and accuracy of the data analysis. KA, SH, AA, RA, MA, AA, MA, and MA were involved in the data acquisition, analysis, interpretation of data, and critical review of the manuscript for important intellectual content. All authors reviewed and approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed in studies involving human participants adhered to the ethical standards of the institutional and/or national research committee. They also complied with the 1964 Helsinki Declaration and its subsequent amendments or comparable ethical standards. King Abdullah International Medical Research Centre (KAIMRC) ethics committee approved the project with IRB number: NRC23R/336/04. Informed written consent was obtained from the parents.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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