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Biophysiological responses of premature infants in neonatal nursing care: a descriptive study of infant and maternal characteristics

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ABSTRACT

Preterm infants are physiologically vulnerable and require continuous cardiorespiratory and thermal monitoring during neonatal nursing care. Evidence describing physiological indicators in relation to infant maturity and maternal sociodemographic characteristics remains limited. This study aimed to describe physiological indicators (heart rate, respiratory rate, oxygen saturation, and temperature) among preterm infants and examine their associations with infant and maternal characteristics. An observational descriptive study was conducted from August to December 2025 among preterm infants (<37 weeks of gestation) admitted to a neonatal unit using consecutive sampling. Infant and maternal data were obtained from clinical records, while physiological parameters were collected through routine monitoring. Descriptive statistics and generalized estimating equations were applied ($p < 0.05$). Of 124 eligible infants, 120 were included. Mean gestational age was 33.2 ± 2.4 weeks and mean birth weight was 1,860 ± 420 g. Mean heart rate was 148.6 ± 14.8 beats/min, respiratory rate was 46.2 ± 8.1 breaths/min, oxygen saturation was 95.1 ± 2.8%, and temperature was 36.6 ± 0.4 °C; 18.3% experienced mild hypothermia. Lower gestational age was associated with higher respiratory rate and lower oxygen saturation, whereas higher birth weight, maternal education, and better economic status were associated with improved oxygenation and thermal stability. These findings support individualized neonatal nursing surveillance and family-centered care. The study was limited by its single-center design and inability to establish causal relationships.

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1. INTRODUCTION

A primary cause of infant morbidity and mortality, preterm birth (defined as delivery before 37 completed weeks of gestation) is a huge worldwide public health issue. Preterm birth problems caused a disproportionate share of neonatal mortality and long-term morbidities in 2020, with an anticipated 13.4 million babies born prematurely worldwide [1]. Beyond survival, preterm infants face significant physiological challenges related to immaturity of the cardiovascular, respiratory, and thermoregulatory systems, necessitating continuous monitoring and skilled neonatal nursing care to maintain physiological stability [2]. Recent global analyses continue to demonstrate substantial regional disparities in preterm birth incidence and neonatal outcomes, particularly in low- and middle-income countries where access to specialized neonatal care remains uneven [3].

In addition to the global burden, preterm birth also represents a significant neonatal health challenge in low- and middle-income countries, where resource limitations may affect the quality of continuous physiological monitoring and nursing care. In Indonesia and similar settings, variability in neonatal care practices may contribute to differences in the stability of physiological indicators among preterm infants. This highlights the need for context-specific evidence to guide nursing surveillance [1].

In neonatal nursing practice, heart rate, respiratory rate, oxygen saturation (SpO_2), and body temperature are core biophysiological parameters used to assess real-time physiological adaptation and clinical stability in preterm infants. These indicators are particularly critical because immature autonomic control and underdeveloped organ systems predispose preterm infants to apnoea, bradycardia, hypoxemia, and thermal instability [4]. Continuous cardiorespiratory monitoring is therefore considered a standard component of neonatal care, especially for infants born at lower gestational ages or with low birth weight [5], [6].

Recent evidence highlights that trend in routinely collected cardiorespiratory data can provide meaningful insights into neonatal vulnerability and future respiratory outcomes [5]. Demonstrated that early-life cardiorespiratory patterns in preterm infants were associated with respiratory morbidity at term-equivalent age, emphasizing the clinical relevance of systematic physiological monitoring beyond immediate bedside alarms. Similarly, respiratory immaturity remains a dominant contributor to instability in preterm infants, with apnea and hypoventilation frequently occurring even in clinically stable neonates [4].

Oxygen saturation monitoring is a cornerstone of neonatal nursing surveillance, as both hypoxemia and hyperoxemia are associated with adverse outcomes in preterm infants. Suboptimal oxygenation has been linked to increased risks of mortality, bronchopulmonary dysplasia, and neurodevelopmental impairment [7]. Conversely, excessive oxygen exposure increases the risk of retinopathy of prematurity and oxidative injury. Recent reviews emphasize that optimal SpO_2 targets should be interpreted in relation to gestational age, clinical condition, and available resources, highlighting the importance of nursing judgment in oxygen titration and alarm management [7]. In many neonatal units, particularly in low- and middle-income countries, limitations in equipment availability and staffing may influence the consistency of oxygen monitoring and response times. These contextual factors further underscore the need for descriptive evidence on actual physiological profiles observed in routine neonatal nursing care [7]. Continuous oxygen saturation surveillance is particularly important among very preterm infants because intermittent hypoxemic episodes may occur even in clinically stable neonates and have been associated with adverse neurodevelopmental outcomes [8].

Another important aspect of biophysiological stability in premature babies is thermal regulation. Preterm babies are at increased risk of hypothermia, which can lead to increased metabolic demand, hypoglycemia, infections, and death, because of their small brown fat stores, thin skin, and high surface-area-to-body-mass ratio [2]. International guidelines recommend maintaining neonatal body temperature between 36.5 °C and 37.5 °C, yet observational studies indicate that admission hypothermia remains common in neonatal intensive care settings [9]. In [9] reported that neonatal hypothermia was significantly associated with prematurity, low birth weight, and clinical instability, reinforcing the importance of temperature monitoring as an integral part of neonatal nursing assessment. Importantly, thermoregulation interacts with other physiological systems; thermal stress increases oxygen consumption and may exacerbate cardiorespiratory instability, particularly in vulnerable preterm infants [2].

Biophysiological responses among preterm infants are heterogeneous and strongly influenced by infant-specific characteristics, including gestational age and birth weight. Lower gestational age is consistently associated with greater physiological instability due to immaturity of respiratory control and cardiovascular regulation. Low birth weight further compounds vulnerability, increasing the risk of hypothermia and cardiorespiratory compromise. Although numerous studies examine clinical outcomes such as mortality or major neonatal morbidities, fewer studies provide an integrated description of routine physiological parameters across different infant profiles within everyday nursing care settings [2], [4], [9].

Maternal characteristics constitute an additional layer of risk context influencing neonatal outcomes. Socioeconomic factors, maternal education, and parity have been associated with preterm birth and neonatal complications across diverse populations [10]. A population-based study by [10] demonstrated that lower maternal socioeconomic status was associated with higher risks of adverse neonatal outcomes, suggesting that biological vulnerability is intertwined with social determinants of health. However, existing literature largely focuses on maternal factors in relation to preterm birth incidence or long-term developmental outcomes, rather than on short-interval biophysiological responses observed during neonatal hospitalization. Evidence linking maternal profiles to bedside physiological patterns in preterm infants during routine nursing care remains limited, particularly in resource-constrained settings where care processes and monitoring intensity may differ from high-income neonatal intensive care units [10].

Although previous studies have explored individual physiological outcomes in preterm infants, most evidence focuses on isolated parameters or specific clinical conditions, rather than providing an integrated description of heart rate, respiratory rate, oxygen saturation, and temperature in relation to both infant and maternal characteristics [2], [4]. Furthermore, limited studies have examined how maternal sociodemographic factors are reflected in short-term physiological stability during neonatal hospitalization, particularly in routine nursing care settings in resource-limited contexts [9]. This gap highlights the need for descriptive evidence that integrates infant maturity and maternal characteristics with real-time physiological monitoring data. This study is guided by neonatal adaptation theory, which emphasizes that physiological stability in preterm infants is influenced by the maturity of organ systems and environmental as well as maternal contextual factors affecting postnatal adaptation.

There are still some significant knowledge gaps in neonatal monitoring, even though there have been improvements in both technology and clinical recommendations. First, there is a lack of context-specific descriptive data on preterm infants' heart rates, respiration rates, oxygen saturation levels, and temperatures, which makes it difficult to assess predicted stability patterns in ordinary nursing practice, even though physiological monitoring is common in neonatal care [5]. Second, existing studies often examine single physiological outcomes or isolated risk factors, rather than providing an integrated description of multiple biophysiological parameters alongside key infant characteristics [2]. Third, although maternal characteristics are recognized as important determinants of neonatal risk, their relationship with bedside physiological responses during hospitalization remains underexplored [10]. Addressing these gaps through a descriptive approach is essential for strengthening neonatal nursing surveillance, informing local quality improvement initiatives, and providing a foundation for future analytic and interventional studies. Therefore, this study aims to describe the biophysiological responses of preterm infant’s heart rate, respiratory rate, oxygen saturation, and temperature in relation to infant and maternal characteristics within the context of neonatal nursing care.

Unlike previous studies that focused on isolated physiological outcomes or specific neonatal complications, this study integrates multiple physiological indicators (heart rate, respiratory rate, oxygen saturation, and temperature) with both infant maturity and maternal sociodemographic characteristics using repeated-measures analysis. This approach provides a more comprehensive understanding of physiological adaptation in preterm infants during routine neonatal nursing care. It also contributes context-specific evidence from a middle-income country setting.

2. METHOD

2.1. Study design

The purpose of this observational descriptive study was to describe the biophysiological reactions of premature newborns to standard neonatal nursing care. In newborn settings, where physiological monitoring is standard treatment, observational approaches are appropriate for establishing baseline clinical profiles without attempting causal inference. To guarantee candor and comprehensiveness in reporting observational research, this study adhered to the STROBE standards for reporting epidemiological studies. The research took place in an Indonesian tertiary referral hospital's neonatal care unit. From August to December 2025, data were collected from eligible preterm newborns during their admission and hospitalization [11].

2.2. Sample

All newborns hospitalized to the neonatal care unit and receiving regular nursing care were considered part of the study population if they were born before 37 weeks of gestation. The inclusion of infants was contingent upon the availability of maternal demographic data in the medical record and the presence of verified biophysiological monitoring data, which includes heart rate, respiration rate, oxygen saturation, and body temperature. For the sake of data quality and comparability, infants with significant congenital defects impacting thermoregulatory or cardiopulmonary function, or with incomplete physiological records, were eliminated. We used GPower version 3.1 to perform an a priori power analysis, which allowed us to calculate the sample size [12]. A framework for multivariable descriptive modeling of biophysiological outcomes was used to support the calculation, which was based on fixed-effects multiple regression. There should be at least 110 preterm infants in the study if the impact size is considered medium, the significance threshold is set at 0.05, the statistical power is 0.80, and there are numerous predictors that represent features of the mother and the infant. The final target sample size was adjusted upwards to account for possible missing data and early discharge. Until the desired sample size was obtained, all eligible preterm newborns admitted throughout the study period were added using a sequential sampling strategy. For clinical observational research, this method works well since it lets the sample represent the real neonatal unit case mix.

2.3. Instruments

Infant and maternal characteristics were collected using structured data extraction forms developed by the research team based on routinely documented clinical and demographic information. Infant variables included gestational age and birth weight, while maternal variables included parity, education, occupation, and household economic status. These variables were recorded as categorical or continuous data according to standardized definitions. Because these forms captured factual and clinical information rather than latent psychological constructs, internal consistency reliability testing was not applicable. Methodological guidance indicates that for non-psychometric clinical data, reliability is better supported through standardized abstraction procedures and verification rather than internal consistency coefficients [13].

Biophysiological responses were measured using routinely applied neonatal monitoring devices. Heart rate and respiratory rate were obtained from cardiorespiratory monitors, oxygen saturation was measured using neonatal pulse oximetry, and body temperature was recorded using standard neonatal thermometry. Pulse oximetry is widely used for non-invasive oxygenation monitoring in preterm infants, although its limitations in accurately estimating arterial oxygen saturation have been documented, reinforcing the need for cautious clinical interpretation of SpO_2 values [14]. All biophysiological parameters were treated as continuous variables and interpreted in accordance with established neonatal clinical standards, particularly with respect to thermoregulation in very preterm infants [2].

2.4. Procedure

Data collection was conducted from August to December 2025. Newborns admitted to the neonatal intensive care unit were screened for eligibility. Mothers or legal guardians gave their signed agreement for prospective data collection, and de-identified records were used for retrospective data extraction after ethical approval. Biophysiological data were regularly collected throughout routine nursing shifts as part of usual clinical monitoring, and baseline newborn and mother characteristics were recorded upon enrollment. Data collectors were required to undergo standardized training on abstraction processes and variable definitions in order to guarantee the quality of the data. We confirmed correctness and consistency by independently reviewing a subset of records, and when inconsistencies were found, we rectified them through discussion and consensus. Ethical involvement and family-centered care were supported by providing mothers with brief feedback about their infant's monitoring and an opportunity to ask questions after discharge or transfer. As part of standard clinical monitoring, biophysiological measures were captured multiple times throughout each nursing shift (morning, afternoon, and night) to capture changes in physiological stability with time.

2.5. Data analysis

Statistics programs were used to examine the data. Both the mother and the infant's biophysiological measurements and features were summarized using descriptive statistics. Categorical variables were shown as frequencies and percentages, whilst continuous variables were shown as medians and interquartile ranges or as means and standard deviations, according on distribution. The biophysiological data was structured with repeated measurements, therefore sophisticated analysis methods were used to account for correlation within infants. A population-averaged connection between each biophysiological outcome and newborn and mother factors was estimated using generalized estimating equations. This approach is recommended for correlated health data and longitudinal observations [15]. To further accommodate potential nonlinear trends in physiological responses over time, generalized additive modeling approaches were considered appropriate for exploratory analysis of complex biomedical longitudinal data [16]. Statistical significance was set at $p < 0.05$.

The intra-individual correlation of repeated physiological measures across time was accounted for by applying generalized estimating equations (GEE). Given the assumption of equal correlation between repeated observations within the same child, an exchangeable correlation structure was utilized. Theoretical significance and data from prior research on factors that determine physiological stability in premature newborns informed the variable selection process that went into the GEE models. The models were adjusted to account for factors that have been shown to have a consistent association with neonatal physiological outcomes, such as gestational age, birth weight, maternal education, parity, occupation, and family economic position. In order to reduce the possibility of residual confounding, clinically relevant variables were kept even after adjusting for statistical significance [13].

3. RESULTS AND DISCUSSION

3.1. Results

During the trial period, 124 preterm newborns were evaluated to determine their eligibility. The final analysis comprised 120 newborns out of those who fulfilled the inclusion criteria. We did not include four babies because their vitals were not well documented or because they were transferred during the first 24 hours of their admission. Complete data on maternal and baby characteristics, as well as at least two recorded biophysiological measurements while hospitalized, were available for all newborns included in the study.

The procedure for selecting participants is shown in Figure 1. During the trial period, 124 preterm newborns were evaluated to determine their eligibility. The reason for excluding four newborns was that their physiological records were either missing (n = 2) or that they were transferred within 24 hours of admission (n = 2). Therefore, 120 premature babies were considered for the final analysis because they fulfilled all the requirements. The study sample is representative for describing biophysiological responses in hospitalized preterm newborns, and the low exclusion rate indicates adequate completeness of clinical data.

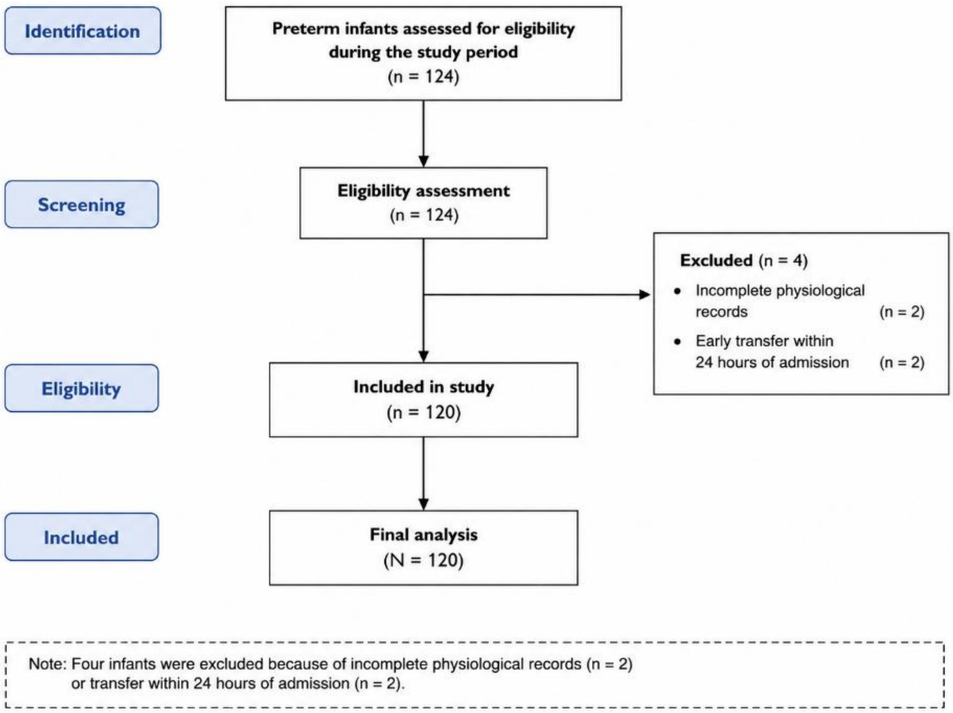

Figure 1. Flow diagram of participant selection

The clinical and demographic details of the moms and preterm children are shown in Table 1. The bulk of the newborns were classed as moderate to late preterm, and their mean gestational age was 33.2 ± 2.4 weeks. More over 50% of the newborns were breastfed exclusively while in the hospital, and their average birth weight was 1,860 ± 420 grams. Although the majority of newborns were in a stable clinical condition at admission, a significant number needed constant observation for signs of respiratory or thermal instability. The majority of moms were multiparous, had finished secondary school, and were not officially employed, according to the maternal characteristics. The economic position of about half of the households was deemed low to medium.

Table 2 shows the overall distributions of biophysiological parameters. The average heart rate, respiratory rate, and oxygen saturation levels over all observations were 148.6 ± 14.8 beats/min, 46.2 ± 8.1 breaths/min, and 95.1 ± 2.8%, respectively. While in the hospital, 18.3% of the newborns had moderate hypothermia, defined as a temperature below 36.5 °C, while the average body temperature was 36.6 ± 0.4 °C as shown in Table 2 and Figure 2.

A subset of preterm infants, especially those with lower birth weights and gestational ages, showed persistent vulnerability in physiological regulation, as evidenced clinically by episodes of oxygen desaturation and hypothermia, even though the majority of preterm infants-maintained values within acceptable neonatal ranges. Table 3 shows that there was a negative correlation between gestational age and respiratory rate ($\beta = -0.42$, SE = 0.15, $p = 0.004$), suggesting that babies born at earlier gestational ages had higher respiratory rates. There was a positive correlation between gestational age ($\beta = 0.31$, SE = 0.12, $p = 0.009$) and birth weight ($\beta = 0.28$, SE = 0.10, $p = 0.006$) and oxygen saturation, indicating that heavier and more mature newborns had more consistent oxygenation.

Table 1. Infant and maternal demographic characteristics (N = 120)

Variable	n (%) or mean ± SD
Infant characteristics	
Gestational age (weeks)	33.2 ± 2.4
<32 weeks	34 (28.3)
32–34 weeks	52 (43.3)
>34 weeks	34 (28.3)
Birth weight (grams)	1,860 ± 420
<1,500 g	29 (24.2)
1,500–2,499 g	71 (59.2)
≥2,500 g	20 (16.6)
Maternal characteristics	
Parity	
Primiparous	46 (38.3)
Multiparous	74 (61.7)
Education level	
Primary education	28 (23.3)
Secondary education	62 (51.7)
Higher education	30 (25.0)
Occupation	
Unemployed/housewife	72 (60.0)
Employed	48 (40.0)
Household economic status	
Low	58 (48.3)
Middle	42 (35.0)
High	20 (16.7)

Table 2. Biophysiological responses of preterm infants

Parameter	Mean ± SD	Range
Heart rate (beats/min)	148.6 ± 14.8	112–182
Respiratory rate (breaths/min)	46.2 ± 8.1	28–72
Oxygen saturation (%)	95.1 ± 2.8	88–100
Body temperature (°C)	36.6 ± 0.4	35.8–37.5

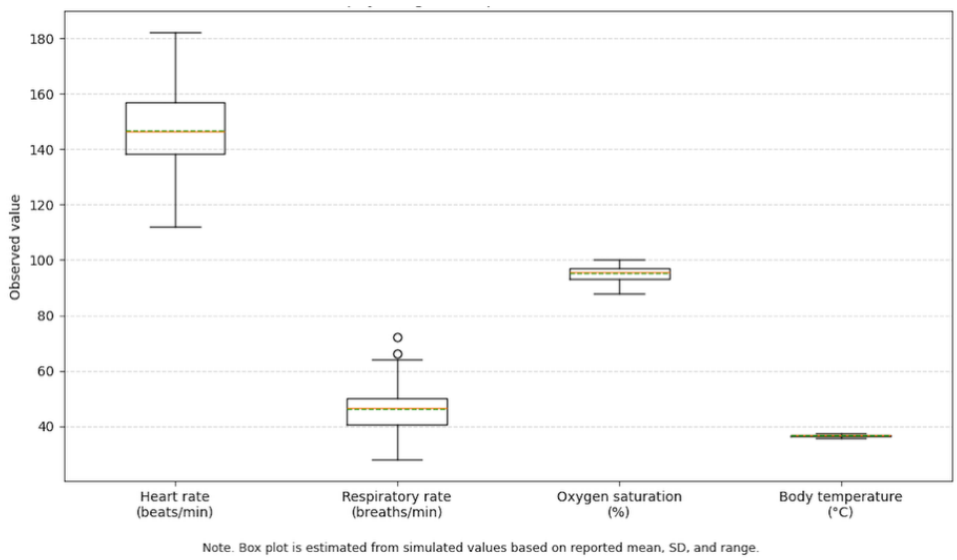

Figure 2. Overall physiological profile of preterm infants during neonatal hospitalization (N = 120)

Table 3. GEE analysis of infant characteristics and biophysiological responses

Predictor	Outcome	β (SE)	p-value
Gestational age	Respiratory rate	−0.42 (0.15)	0.004
Gestational age	Oxygen saturation	0.31 (0.12)	0.009
Birth weight	Oxygen saturation	0.28 (0.10)	0.006

According to Table 3, there was a positive correlation between maternal education and baby oxygen saturation ($\beta = 0.36$, SE = 0.14, $p = 0.010$) and body temperature ($\beta = 0.15$, SE = 0.06, $p = 0.018$). Positive correlations with oxygen saturation were also found for household economic status ($\beta = 0.41$, SE = 0.17, $p = 0.014$). Infant heart rate was not correlated with maternal parity ($\beta = 0.92$, SE = 1.21, $p = 0.447$), on the other hand.

Throughout gestational age, Figure 3 displays the model-predicted oxygen saturation values to help with understanding the GEE analysis. Babies delivered at later gestational ages tended to keep greater oxygen saturation levels while hospitalized, as seen in the image, which shows a positive correlation between gestational age and saturation. Table 3 presents the statistical findings, and this visual representation supplements them.

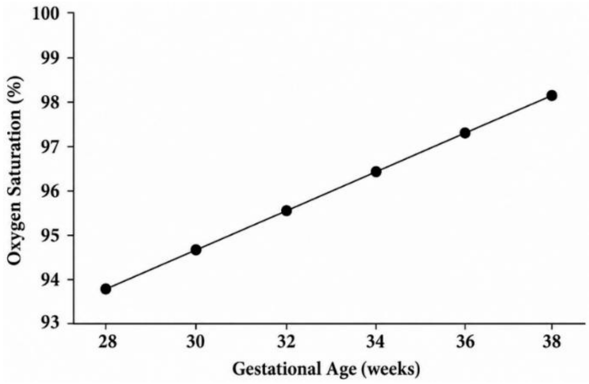

Figure 3. Predicted oxygen saturation across gestational age among preterm infants (N = 120)

Figure 3 shows that the anticipated oxygen saturation by GEE rose steadily with the passage of gestational age. Babies born prematurely at earlier gestational ages had lower predicted saturation levels of oxygen, while babies born at later gestational ages showed more consistent saturation levels of oxygen. According to the positive regression coefficient ($\beta = 0.31$, SE = 0.12, $p = 0.009$) found in the GEE model, there was an average rise of 0.31 percentage points in oxygen saturation for every extra week of gestational age. Based on these results, it appears that the degree to which preterm infants adapt their respiratory systems and maintain stable oxygenation levels while in the hospital is significantly influenced by gestational maturity.

3.2. Discussion

This study provides a comprehensive descriptive and analytical overview of biophysiological responses among preterm infants in neonatal nursing care and examines how these responses vary according to infant and maternal characteristics. By integrating repeated physiological measurements with infant maturity indicators and maternal sociodemographic factors, the findings offer clinically relevant insights into patterns of physiological stability in preterm infants during hospitalization [17]-[19]. These findings also support the principles of neuroprotective developmental care, which emphasize individualized physiological monitoring and family-centered nursing to optimize adaptation and reduce stress during the neonatal period [6], [20].

These findings support neonatal adaptation theory, which proposes that physiological stability is strongly influenced by the maturity of organ systems and environmental factors. The observed associations between gestational age, birth weight, and physiological indicators suggest that more mature infants possess greater adaptive capacity to maintain cardiorespiratory and thermal homeostasis during hospitalization. This interpretation is consistent with developmental care models that recognize physiological regulation as a dynamic interaction between neurological maturation, environmental stimuli, and supportive nursing interventions [20], [21].

The overall biophysiological profiles observed in this study are consistent with established neonatal norms for preterm populations. The mean heart rate, respiratory rate, oxygen saturation, and body temperature fell within expected clinical ranges, although nearly one-fifth of infants experienced at least one episode of mild hypothermia [22], [23]. This finding aligns with prior evidence indicating that thermal instability remains common among preterm infants despite advances in neonatal care, particularly due to immature thermoregulatory mechanisms and high surface-area-to-body-mass ratios [2], [24]. Persistent vulnerability to hypothermia underscores the importance of continuous temperature monitoring and proactive nursing interventions in neonatal units. Recent international recommendations further emphasize maintaining a thermoneutral environment and implementing evidence-based thermal care throughout hospitalization to reduce neonatal morbidity and mortality among preterm infants [2], [25], [26].

Gestational age emerged as a key determinant of respiratory and oxygenation stability. The inverse association between gestational age and respiratory rate indicates that infants born at earlier gestational ages exhibited higher respiratory rates, reflecting increased respiratory effort and immature respiratory control. Similar associations between gestational maturity and respiratory stability have been reported in contemporary neonatal cohort studies, where lower gestational age predicted increased respiratory support requirements and oxygen instability. This finding is consistent with previous studies demonstrating that lower gestational age is associated with respiratory instability and increased work of breathing due to underdeveloped pulmonary structure and central respiratory regulation. Similarly, both gestational age and birth weight were positively associated with oxygen saturation, suggesting that greater physiological maturity and body mass contribute to more stable oxygenation. Prior research has shown that lower birth weight and gestational immaturity are associated with frequent hypoxemic episodes and greater variability in oxygen saturation, even in clinically stable preterm infants. The present findings extend this evidence by demonstrating these associations using population-averaged estimates derived from repeated-measures analysis, which better reflects real-world nursing surveillance. The observed respiratory instability among lower gestational age infants can be explained by immature central respiratory control and underdeveloped pulmonary alveolar structures, which reduce effective gas exchange and increase susceptibility to intermittent hypoxemia [4], [5], [16], [27]. These observations are further supported by recent reviews demonstrating that respiratory immaturity remains one of the primary determinants of cardiorespiratory instability and prolonged respiratory support among very preterm infants [19], [28].

The magnitude of the observed associations is clinically meaningful. Specifically, each additional week of gestational age was associated with a 0.31-unit increase in oxygen saturation and a 0.42-unit decrease in respiratory rate. Although these changes appear modest, even small improvements in oxygenation and respiratory stability may reduce the risk of hypoxemic episodes and respiratory complications among preterm infants.

Maternal education and household economic status were significantly associated with infant oxygen saturation and thermal stability. Infants born to mothers with higher educational attainment demonstrated higher oxygen saturation and more stable body temperature. These findings are consistent with broader literature linking maternal education to improved prenatal care utilization, health literacy, and caregiving practices, which collectively influence neonatal health outcomes. Similarly, higher household economic status was associated with better infant oxygenation. Socioeconomic advantage has been associated with reduced prenatal risk exposure, improved access to healthcare services, all of which may contribute to enhanced neonatal physiological stability. In contrast, maternal parity was not associated with infant heart rate, suggesting that prior childbirth experience alone may have limited influence on short-term physiological responses during neonatal hospitalization. This finding aligns with studies indicating that parity is a weaker predictor of immediate neonatal physiological outcomes compared with biological maturity and socioeconomic factors [10], [25], [27], [29]-[31]. The positive associations observed for maternal education and household economic status suggest that social determinants of health may influence physiological adaptation indirectly through prenatal care utilization, maternal health literacy, and access to healthcare resources. This finding is consistent with evidence demonstrating that socioeconomic conditions and adequate antenatal care contribute to improved neonatal physiological outcomes through earlier risk identification, better maternal health status, and greater access to healthcare services [10], [29]. These findings highlight the importance of integrating family-centered and socially responsive approaches into neonatal nursing practice.

From a clinical perspective, these findings emphasize the importance of individualized nursing surveillance focusing on continuous monitoring of oxygen saturation and temperature, particularly in very preterm infants. Strengthening family-centered care, including maternal education and involvement, may further enhance physiological stability during hospitalization. Family-centered neonatal care interventions have also been shown to improve parental engagement and contribute to better physiological regulation among hospitalized preterm infants [28].

3.3. Study limitations

This study has several limitations. First, its observational design limits causal inference between maternal and infant characteristics and physiological outcomes. Second, data were obtained from a single center, which may limit generalizability. Third, although repeated measurements were analyzed, potential unmeasured confounders such as environmental temperature and nursing interventions were not fully controlled. Fourth, physiological measurements were obtained from routine clinical monitoring rather than a standardized research protocol, which may introduce measurement variability across nursing shifts.

5. CONCLUSION

This study highlights that physiological stability in preterm infants is closely related to gestational age, birth weight, and maternal socioeconomic characteristics. Lower gestational age and birth weight were associated with increased respiratory effort and reduced oxygen stability, while higher maternal socioeconomic status was associated with improved oxygenation and thermal stability. These findings underscore the need for individualized neonatal nursing care and strengthened maternal involvement to improve physiological outcomes in preterm infants. Future multicenter longitudinal studies are recommended to further investigate causal pathways linking maternal socioeconomic factors and physiological adaptation among preterm infants in diverse neonatal care settings.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

All parties involved in this work, from data collection to analysis to paper writing and publication, have declared that they have no conflicts of interest.

ETHICAL APPROVAL

Research Ethics Review Board of STIKep PPNI Jawa Barat gave its stamp of approval to the study before any data was collected (Ethical Approval No. 093/KEPK/STIKEP/PPNI/JABAR/V/2025).

INFORMED CONSENT

At all times, the privacy and confidentiality of the participants were protected. Because these babies were born prematurely, their parents or legal guardians had to sign an informed permission form before they could take part in the research. A thorough explanation of the study's goals, methods, risks, and benefits was provided to all parents or legal guardians. All newborns whose parents or legal guardians gave their written approval to participate in this study. All data were anonymised to guarantee confidentiality, and no identifiable personal information was disclosed.

DATA AVAILABILITY

Due to ethical considerations and the inclusion of sensitive clinical information, the datasets created and/or analyzed for this work are not publically available. However, the corresponding author can make them available upon reasonable request and with the consent of the appropriate ethics committee.

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