





PAPER

Anthropometry, Heart Rate Variability, and Maternal Nutrition: Exploring Full-Term Infant Development and Public Health Implications

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ABSTRACT

This study examined the influence of socioeconomic factors, maternal diet, and heart rate variability (HRV) on the development of full-term newborns (NBs) during their first four months. Data were collected from 49 mother-infant pairs in a maternity hospital in northern Brazil. Infant anthropometric measurements (weight, length, and head circumference) and HRV parameters were assessed at birth, 30, 60, and 120 days. Maternal diet was categorized into protein, carbohydrate, and fruit intake, along with socioeconomic and parental characteristics. Results showed consistent growth across all anthropometric parameters, with differences between boys and girls. HRV analysis indicated autonomic nervous system maturation, with significant changes in linear and nonlinear parameters, especially at 120 days. Maternal diet did not significantly affect infant growth, but trends in red meat and fish consumption reflected regional socioeconomic patterns. These findings highlight the need for policies supporting maternal nutrition and socioeconomic conditions during pregnancy and early childhood, promoting healthier growth and long-term well-being in vulnerable populations.

KEYWORDS

infant development, heart rate variability (HRV), neonatal anthropometry, maternal diet

1 INTRODUCTION

The significance of assessing anthropometric data within a specific population has long been recognized. These measurements are critical for understanding the emergence and progression of various diseases, many of which are preventable or manageable. Anthropometric measurements play a vital role in evaluating nutritional status and disease risks [1]. For newborns (NBs), these assessments are particularly significant, as their health and development are shaped by a combination of genetic, environmental, obstetric, and behavioral factors influenced by their parents.

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Factors such as parental smoking and dietary habits have a profound impact on the growth and development of infants [2].

Key anthropometric indices, including weight, head circumference, and chest circumference, are utilized to classify NBs as small, normal, or large for their age. These measurements can also indicate syndromic conditions or other factors that affect neonatal survival and prognosis [3]. Among these, weight is especially critical, as low birth weight is one of the leading contributors to neonatal mortality. Such data can inform strategies and public policies aimed at reducing infant morbidity and mortality, especially in regions where these rates exceed the national average, such as Brazil's northern region [4].

In addition, the electrocardiogram (ECG) is a widely used diagnostic tool due to its non-invasive nature and its essential role in evaluating the electrical activity of the heart. The ECG provides information about rhythm, rate, and other key parameters necessary for assessing heart rate variability (HRV). HRV, defined as fluctuations in the intervals between successive R-waves (RR intervals), serves as a powerful tool for various analyses, including the physiological maturation of NBs [5,6], the assessment of acute pain [7], and clinical practices [8].

Motivated by this evidence, the study aimed to gain a deeper understanding of the children's development by investigating the socioeconomic conditions of parents at conception, maternal gestational conditions, delivery circumstances, birth anthropometric data, and the growth and development of children during their first 120 days of life. The research sought to identify regional birth patterns, their unique characteristics, and their potential impact on national statistical indices. These findings underscore the need for region-specific public policies designed to address the distinct demands of the studied population.

Although anthropometry, HRV, and maternal nutrition have each been independently studied, there remains a significant gap in research that integrates these three dimensions within the same cohort, particularly in early infancy. Existing studies typically examine growth, autonomic maturation, or maternal dietary factors separately, which limits understanding of how biological and environmental determinants interact during this critical developmental period. Furthermore, populations from the Brazilian Amazon remain underrepresented in neonatal research, despite displaying distinct socioeconomic, cultural, and nutritional contexts that may influence infant development.

Another important gap relates to the use of biomedical engineering tools to monitor neonatal physiology. While HRV analysis is well established [1], few studies have applied a wearable biosensor-based HRV acquisition system combined with cloud-based data transfer and nonlinear computational processing in the context of newborn monitoring. This integrated technological workflow is particularly relevant for regions with limited healthcare resources, where digital tools can enhance longitudinal monitoring and early detection of developmental risks.

Motivated by these gaps, this study aimed to gain a deeper understanding of infant development by examining the socioeconomic conditions of parents, maternal gestational characteristics, birth anthropometry, and the evolution of anthropometric and HRV parameters during the first 120 days of life. By investigating these factors concurrently, the study seeks to clarify how physiological maturation interacts with environmental exposures in an underserved population.

To guide this investigation, the following research questions were formulated: How do the anthropometric parameters of full-term infants evolve during the first 120 days of life in the studied population? How do HRV parameters—measured using a wearable biosensor and a digital acquisition system—reflect autonomic nervous system maturation during this period? This study also contributes to the biomedical engineering

field by highlighting the use of integrated technological tools—combining wearable cardiac sensing, cloud-based digital data acquisition, and linear and nonlinear computational HRV analysis—to support neonatal monitoring. The integration of an adaptive artifact-filtering algorithm specifically suited for newborn movement, together with advanced HRV metrics, underscores the novelty of the methodological approach and its potential application in digital health and remote neonatal assessment.

2 MATERIALS AND METHODS

This study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Ethics Review Board of Brazil University (under protocol CAAE 20711619.0.0000.5494 and opinion number 3.825.367), in accordance with the ethical principles outlined in Resolution 466/2012 of the Brazilian National Health Council. All procedures complied with national and international guidelines for research involving human subjects. Informed consent was obtained from all parents of the NBs who participated in the research. The study employed a descriptive-analytical approach, utilizing quantitative, comparative, and prospective data extracted from the medical records of NBs admitted to the rooming-in and nursery units at the Municipal Hospital of Santarém (HMS) in Pará, Brazil.

The study followed a 120-day monitoring period during which the cardiac function of the NBs was assessed using the Polar V800 device. Measurements were taken at birth (P0) and during follow-up appointments at 30 days (P1), 60 days (P2), and 120 days (P3). Maternal and paternal data collected included age, average income, and profession, dietary habits, and anthropometrics: weight, and height. Data for NBs included anthropometric details: sex, birth weight, length, head circumference, and chest circumference; clinical observations: Apgar score at birth, presence of jaundice, and feeding type, monitored monthly during the study.

Maternal dietary habits were assessed using a weekly frequency food checklist developed for this study. Mothers were asked to report how many times per week they consumed the most common foods within each food group. For proteins, the checklist included red meat, poultry, and fish; for carbohydrates, items included rice, pasta, potatoes, and cassava-based foods; and for fruits, the most frequently available options in the region (e.g., banana, orange, and apple). Responses were recorded in weekly frequency categories (e.g., never, 1 time per week, 2–3 times per week, 4 or more times per week). This approach enabled identification of general dietary patterns while reducing participant burden during clinical consultations. Since portion sizes and total nutrient intake were not assessed, the dietary analysis reflects relative consumption frequency rather than quantitative nutritional values. This instrument was used for exploratory purposes and allowed comparison of broad dietary tendencies across the study periods.

2.1 HRV analysis

During each medical appointment, RR interval time series (1000 RR intervals) were recorded using the Polar V800 monitoring system, a validated wearable device widely used in biomedical research. The V800 operates together with the Polar H10 chest-strap sensor, which captures cardiac depolarization with high precision. The system provides a sampling frequency of 1000 Hz, enabling accurate R-peak detection and ensuring signal quality suitable for neonatal HRV analysis. The Polar H10 detects cardiac depolarizations using chest-surface electrodes and provides inter-beat intervals with timing accuracy compatible with HRV research. Data were

sampled and stored with precision sufficient to derive 1000 consecutive RR intervals per recording session from each infant, as required for robust time-, frequency-, and nonlinear-domain analyses.

All series were filtered using an adaptive artifact-removal algorithm, as described by [2], which automatically detects and corrects artifacts exceeding 20% deviation from local RR trends. This ensures high-quality physiological data even in NBs, who often exhibit movement-related noise. Data from the P0 period were excluded due to excessive noise caused by newborn movements (more than 10% of RR intervals in those recordings were altered during preprocessing). Recordings were initiated preferentially when the infant was calm. If the infant was crying or highly active, the recording was paused and resumed when the infant became calmer. Body position was maintained as supine during the acquisition. Because the study was conducted during routine clinical visits.

Filtered RR interval time series were analyzed using both linear and nonlinear methods. Linear methods include statistical parameters from time domain: the mean RR interval, standard deviation (SDRR), root mean square of successive differences (RMSSD), and the percentage of adjacent intervals differing by more than 50 ms (pNN50) were calculated to characterize cardiac cycle length and instantaneous heart rate [3]. Frequency domain: very low frequency (VLF), low frequency (LF), and high frequency (HF) parameters were analyzed to assess autonomic modulation of heart period [4]. Conventional linear parameters provide some information related to the periodic oscillations of the RR intervals [5].

Nonlinear methods include the Poincaré plot, Approximate (ApEn) and Sample (SampEn) entropies, and Detrended Fluctuation Analysis (DFA). These methods offer a valuable alternative for analyzing RR interval time series, as certain characteristics of physiological systems and their interactions are not linear when evaluating properties such as nonlinear correlation and complexity of the time series [6], [7]. The Poincaré plot is a significant tool that enables visual inspection and quantitative information on instantaneous short-term RR variability (SD1) and continuous long-term RR variability (SD2) [2]. Entropy-based analyses (ApEn and SampEn) are employed to investigate disorder, predictability, and regularity of clinical time series [8]. DFA (α_1 and α_2 indexes) can establish individual physiological thresholds [9] and assess autonomic nervous system impairment [10].

Overall, the integration of wearable biosensing technology, digital signal acquisition, and computational HRV analysis underscores the technological relevance of this study and its alignment with biomedical engineering applications in early-life physiological monitoring.

2.2 Statistical analysis

Statistical analysis was performed using a combination of parametric and non-parametric techniques, depending on the distributional characteristics of the variables. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was examined using Levene’s test. For variables that met normality assumptions, ANOVA with repeated measures was applied; otherwise, the Friedman test and Kruskal–Wallis test were used. When significant differences were detected, appropriate post-hoc analyses (Tukey or Dunn’s test) were performed.

Correlations were assessed using Pearson or Spearman coefficients (ρ), according to variable distribution. All tests were conducted at a 5% significance level ($p < 0.05$) with 95% confidence intervals. This statistical approach is appropriate for physiological datasets characterized by natural variability and non-Gaussian distributions, such as neonatal HRV recordings.

3 RESULTS

3.1 Characterization of the parents' study participants

This study focused on children aged 0 to 4 months, analyzing anthropometric parameters such as head circumference, height, weight, and heart rate variability. Additionally, we evaluated their development by considering the socioeconomic and anthropometric characteristics of their parents, including age, race, family income, dietary habits, and body mass index (BMI) (refer to Table 1). A total of 49 full-term NBs and their mothers participated in this study, resulting in 196 appointments. This final sample is consistent with sample sizes commonly reported in neonatal HRV studies, where data acquisition is challenging due to motion artifacts, clinical scheduling constraints, and the need for long RR interval recordings.

Table 1. Socioeconomic and anthropometric characteristics of the parents of the NBs

Age (years)	N	Mother %	N	Father %
< 20	7	14	0	0
20 I-I 29	30	61	30	61
30 I-I 39	12	25	14	29
40 I-I 49	0	0	1	2
50 I-I 59	0	0	0	0
60 I-I 69	0	0	1	2
no answer	0	0	3	6
Race/ethnicity (self-declaration)				
Indigenous	3	6	2	4
Black	3	6	4	8
Mixed-race	42	86	37	76
White	1	2	4	8
no answer	0	0	2	4
Class of BMI				
Underweight	4	8	2	4
Healthy weight	20	41	11	22
Overweight	16	33	15	31
Obesity (low-risk)	8	16	6	12
Obesity (moderate-risk)	0	0	1	2
no answer	1	2	14	29
Income (per month*)				
Less than 1 salary	0	0	10	21
1 I-I 2 salaries	0	0	21	43
2 I-I 3 salaries	0	0	8	16
3 I-salaries	0	0	8	16
no answer	0	0	2	4

Note: *One salary is approximately US\$ 300.

Regarding maternal nutrition, we examined the primary foods consumed during pregnancy and their influence on the children’s development up to 120 days of age. These foods were categorized into three groups: 1) proteins: essential for building and maintaining organs and tissues in the human body; 2) carbohydrates: crucial for providing energy required for vital bodily functions; and 3) fruits: vital for regulating bodily functions, rich in vitamins and minerals, and essential for immune system health and digestion, thanks to their fiber and water content. Throughout the study period, we observed an increased consumption of red meat and chicken by the parents, accompanied by a notable reduction in fish consumption. These dietary trends were observed during the pre-pregnancy, pregnancy, and postnatal periods, extending to the fourth month of the child’s life, which constituted the study’s follow-up period (Figure 1a). Additionally, our findings revealed that rice was the primary source of carbohydrates in their diet. Notably, we did not observe significant consumption of other carbohydrate sources, as indicated in Figure 1b. Fruits are sources of carbohydrates and proteins, the latter in smaller proportions. It is observed that the main fruits consumed were bananas, oranges, and apples (see Figure 1c).

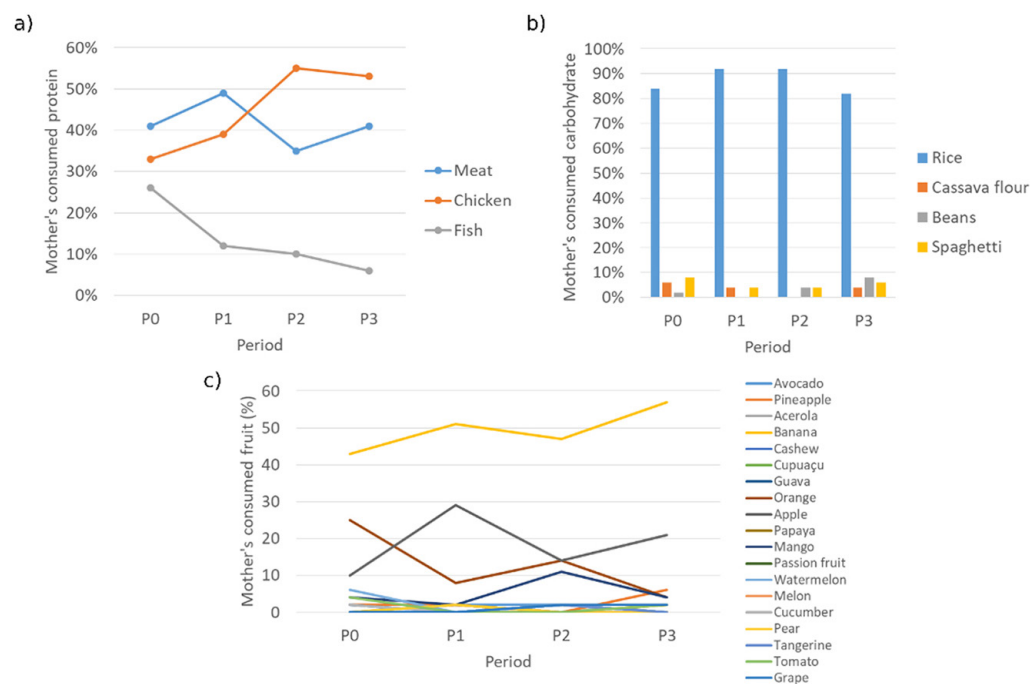


Fig. 1. Percentage of mother’s consumed intake: a) Percentage of mothers’ protein intake evolution during the four data collection periods, b) evolution of carbohydrate intake during the four data collection periods, and c) percentage of fruits consumed by mothers’ NBs. P0: newborn; P1: 30 days of life; P2: 60 days of life; P3: 120 days of life (approx.)

3.2 Anthropometric data of the study participants

At each study visit (P0 to P3), we measured the head circumference, weight, and height of the children. Table 2 summarizes the mean, standard deviation (SD), minimum (min), and maximum (max) values for each measurement at each visit, both for the entire study group and for each sex. These measurements were collected at four time points to evaluate growth trends over time.

Table 2. Anthropometric data (cephalic perimeter, weight, and height) for the infants in the collected data period

Period	Total (N = 49)		Female		Male	
	mean ± std	min-max	mean ± std	min-max	mean ± std	min-max
Cephalic perimeter (cm)						
P0	34.11 ± 1.37	31.50–37.00	34.02 ± 1.34	31.50–37.00	34.25 ± 1.45	32.00–37.00
P1	37.22 ± 1.50	33.00–41.00	37.13 ± 1.56	33.00–40.00	37.35 ± 1.44	34.00–41.00
P2	39.14 ± 1.34	37.00–43.00	38.88 ± 1.34	37.00–43.00	39.53 ± 1.26	37.00–42.50
P3	41.62 ± 1.28	30.80–44.00	41.12 ± 1.28	38.00–44.00	42.38 ± 0.86	41.00–44.00
Weight (kg)						
P0	3.31 ± 0.47	2.17–4.81	3.29 ± 0.42	2.17–4.13	3.34 ± 0.55	2.17–4.81
P1	4.29 ± 0.65	3.04–6.25	4.25 ± 0.51	3.32–5.32	4.37 ± 0.84	3.04–6.25
P2	5.33 ± 0.64	4.17–6.77	5.19 ± 0.55	4.22–6.77	5.54 ± 0.72	4.17–6.69
P3	6.87 ± 0.72	5.16–8.68	6.60 ± 0.71	5.16–8.68	7.30 ± 0.50	6.40–8.10
Height (cm)						
P0	50.42 ± 2.25	44.00–55.00	50.72 ± 2.13	46.00–55.00	49.95 ± 2.41	44.00–54.00
P1	53.81 ± 1.96	49.00–59.00	53.69 ± 1.62	51.00–56.30	54.00 ± 2.44	49.00–59.00
P2	57.51 ± 2.12	52.00–61.50	57.47 ± 2.07	52.0–61.00	57.58 ± 2.26	53.00–61.50
P3	62.66 ± 2.12	58.00–68.00	62.22 ± 1.85	58.00–66.00	63.37 ± 2.38	59.00–68.00

To assess longitudinal growth patterns, we calculated the percentage change in anthropometric measurements between consecutive visits using the formula $((P_i - P_{i-1})/P_{i-1}) * 100$, where P_i represents the current measurement and P_{i-1} the measurement from the previous visit. The results indicate that girls generally showed smaller percentage increases compared to boys, with the exception of height between visits P2 and P1, as detailed in Table 3.

Table 3. Percentage variance of the anthropometric variables among the collected data period

Difference Period	Percentage Variance (%)		
	Total	Female	Male
Cephalic perimeter (cm)			
P1, P0	9.12	9.14	9.05
P2, P1	5.16	4.71	5.84
P3, P2	6.34	5.76	7.21
Weight (kg)			
P1, P0	29.61	29.18	30.84
P2, P1	24.24	22.12	26.77
P3, P2	28.89	27.17	31.77
Height (cm)			
P1, P0	6.72	5.86	8.11
P2, P1	6.88	7.04	6.63
P3, P2	8.95	8.27	10.06

3.3 Relationship between maternal diets and anthropometric data of the infants

To evaluate the influence of maternal diets on children's development (focusing on protein and carbohydrate intake), we performed statistical hypothesis tests to identify potential differences between children's anthropometric variables and the primary types of maternal diets. A significance level of 5% ($p\text{-value} = 0.05$) was applied for decision-making.

There are no significant differences ($p\text{-value} > 0.05$) in mean head circumference across the various maternal diet types during these visits (P0 up to P3). This suggests that the type of maternal diet did not significantly influence head circumference development at these stages. Children's heights and weights remained within normal ranges across all four studied periods. Applying the ANOVA test, we found no significant differences ($p\text{-value} > 0.05$) in average height between the different maternal diet types. Thus, there was no statistical evidence to suggest that maternal diet influenced the height or weight of NBs during the study period.

In summary, statistical analyses demonstrated that maternal diet types (proteins and carbohydrates) did not significantly influence the head circumference, height, or weight of NBs during the studied periods. These findings suggest that other factors, such as genetics or environmental conditions, may play a more decisive role in determining these anthropometric variables.

3.4 Analysis of HRV parameters

In this study, HRV parameters were analyzed using both linear methods (time domain and frequency domain) and non-linear methods. Statistical hypothesis tests were conducted to detect potential variations in the variables of interest across the three study periods. RR interval time series collected during the P0 period (at birth) were excluded from the analysis because more than 10% of the RR intervals were altered during filtering, as per the methodology described by [2].

Table 4 summarizes the mean and SD of RR interval time series analyzed using linear (time and frequency domains) and nonlinear methods. Significant differences were observed in the time domain parameters RMSSD ($p\text{-value} = 0.0047$), NN50 ($p\text{-value} = 0.0002$), and pNN50 ($p\text{-value} = 0.0011$). Multiple comparison tests revealed that RMSSD exhibited differences in periods P1 versus P3 ($p\text{-value} < 0.05$) and P2 versus P3 ($p\text{-value} < 0.01$). The NN50 and pNN50 parameters differed between periods P2 versus P3 ($p\text{-value} < 0.01$). Significant differences were observed in the HF power ($p\text{-value} = 0.0047$) and LF/HF power ($p\text{-value} = 0.0052$) during the study period. A multiple comparison test revealed that there is a statistically significant difference in the HF power between P1 versus P3 ($p\text{-value} < 0.05$) and P2 versus P3 ($p\text{-value} < 0.01$). The LF/HF power shows a difference in P1 versus P3 ($p\text{-value} < 0.05$) P2 versus P3 ($p\text{-value} < 0.05$).

Analysis of non-linear HRV parameters revealed significant differences in several variables: the SD1 parameter ($p\text{-value} = 0.0249$) shows statistical difference between P2 versus P3 ($p\text{-value} < 0.05$). The entropies ApEn ($p\text{-value} = 0.0023$) and SampEn ($p\text{-value} = 0.0055$) present a statistical difference for both between P1 versus P3 ($p\text{-value} < 0.05$) and P2 vs. P3 ($p\text{-value} < 0.01$ for ApEn and $p\text{-value} < 0.05$ for SampEn). DFA α_2 ($p\text{-value} = 0.0275$) shows a statistical difference between P2 versus P3 ($p\text{-value} < 0.05$).

Table 4. Mean and SD values for linear and nonlinear parameters considering each collected data period

Variable	P1	P2	P3	p-Value
	Mean \pm SD	Mean \pm SD	Mean \pm SD	
Time domain methods				
Mean RR (ms)	414.68 \pm 36.27	415.00 \pm 29.13	427.23 \pm 31.19	0.1410*
STD RR (ms)	25.09 \pm 10.61	24.67 \pm 9.56	25.67 \pm 9.33	0.5580
Mean HRV (1/min)	146.28 \pm 11.43	145.81 \pm 9.67	141.71 \pm 10.12	0.1059*
STD HRV (1/min)	8.61 \pm 3.25	8.39 \pm 2.71	8.11 \pm 2.52	0.7222*
RMSSD (ms)	10.43 \pm 4.80	10.01 \pm 3.88	13.67 \pm 6.85	0.0047
NN50 (count)	3.94 \pm 8.50	1.97 \pm 4.62	7.56 \pm 10.06	0.0002
pNN50 (%)	0.55 \pm 1.17	0.29 \pm 0.70	1.13 \pm 1.54	0.0011
Frequency domain methods				
VLF peak (Hz)	0.010 \pm 0.009	0.013 \pm 0.011	0.013 \pm 0.011	0.4817
LF peak (Hz)	0.07 \pm 0.02	0.06 \pm 0.02	0.07 \pm 0.02	0.9082
HF peak (Hz)	0.18 \pm 0.03	0.18 \pm 0.03	0.18 \pm 0.02	0.0445
VLF power (ms ²)	374.0 \pm 392.3	338.3 \pm 330.3	321.7 \pm 313.1	0.8233
LF power (ms ²)	195.1 \pm 142.3	249.1 \pm 356.0	256.8 \pm 258.6	0.4594
HF power (ms ²)	40.77 \pm 42.91	34.62 \pm 31.89	63.72 \pm 50.22	0.0047*
LF/HF power (ms ²)	8.04 \pm 6.03	8.32 \pm 5.77	5.00 \pm 4.12	0.0052
Nonlinear methods				
SD1 (ms)	13.63 \pm 21.73	10.27 \pm 19.28	9.15 \pm 4.42	0.0249
SD2 (ms)	41.61 \pm 26.94	37.02 \pm 9.56	37.69 \pm 15.46	0.3578
ApEn	1.02 \pm 0.20	1.01 \pm 9.67	1.13 \pm 0.18	0.0023*
SampEn	0.96 \pm 0.30	0.95 \pm 2.71	1.15 \pm 0.32	0.0055*
DFA: α 1	1.36 \pm 0.20	1.40 \pm 3.88	1.31 \pm 0.19	0.0730*
DFA: α 2	1.12 \pm 0.17	1.14 \pm 4.62	1.06 \pm 0.13	0.0275*

Note: *Non-parametric analysis.

This study highlights significant changes in HRV parameters during the first four months of life, reflecting the maturation of the ANS. These differences were particularly pronounced when comparing data at 120 days (P3) with earlier periods (P1 and P2). For the P1 vs. P3 comparison, variables such as RMSSD, HF, LF/HF, ApEn, and SampEn consistently showed differences. For P2 vs. P3, significant changes were observed in RMSSD, NN50, pNN50, HF, LF/HF, SD1, ApEn, SampEn, and DFA α 2.

Analysis of the correlation coefficient (ρ) between HRV variables and anthropometric measures revealed significant relationships at a 5% significance level: correlations between DFA α 1 and Height ($\rho = 0.8023$, p-value = 0.0433) in P3; DFA α 2 and Weight ($\rho = 0.3682$, p-value = 0.0271) in P1; DFA α 2 and Height ($\rho = 0.03438$, p-value = 0.0401) in P1; DFA α 2 and BMI ($\rho = 0.3444$, p-value = 0.0397) in P1; SDNNi and height ($\rho = 0.3677$, p-value = 0.0274) in P2; and pNN50 and height ($\rho = 0.3677$, p-value = 0.0264) in P2. These significant correlations confirm the presence of linear

relationships between HRV parameters and anthropometric measures, highlighting potential interactions between cardiac autonomic function and physical growth.

4 DISCUSSION

This study contributes to biomedical engineering by demonstrating an integrated technological workflow for neonatal HRV assessment, combining a validated wearable biosensor, a cloud-based digital acquisition platform, and advanced computational processing of RR intervals. Although HRV has been previously studied in neonatal populations, the present work adds an engineering perspective by applying an adaptive artifact-filtering algorithm specifically suited for newborn motion artifacts and incorporating nonlinear HRV metrics, which enhance the interpretation of early autonomic maturation. This approach aligns with current trends in remote monitoring and digital neonatal assessment.

The characterization of parents revealed that most mothers and fathers were young adults, with a predominance of mixed-race self-identification, which reflects the demographic characteristics of the study region. Regarding nutritional status, 41% of mothers and 33% of fathers were classified as overweight, findings that align with national surveillance data such as VIGITEL [11] and previous reports showing high prevalence of excess weight among pregnant women [12]. While parental BMI was described in this study, the association between parental overweight/obesity and child development reported in the literature [13] should be interpreted here as contextual information rather than a direct conclusion from our dataset, as developmental outcomes were not evaluated.

Dietary patterns showed changes across the perinatal period, including increased consumption of red meat and poultry and reduced fish intake. Comparison with national profiles [14], [15] highlights regional differences in protein and carbohydrate consumption, such as the predominance of rice over cassava derivatives despite local production trends [16]. While such patterns may influence maternal-infant nutrition and have been associated with childhood obesity risks [17], the present study did not find statistically significant associations between maternal diet categories and infant anthropometric outcomes.

However, these findings must be interpreted with caution. The dietary assessment relied on a simplified weekly frequency checklist capturing how many times per week foods were consumed within each group (e.g., meat, poultry, fish; rice, pasta, potatoes; bananas, oranges, apples). This method allowed detection of general consumption tendencies but did not quantify portion size, nutrient density, or caloric intake. Additionally, responses depended on maternal recall. Thus, diet-related observations in this study should be viewed as descriptive indicators of regional eating habits rather than determinants of infant outcomes. Anthropometric parameters (head circumference, weight, and height) increased consistently between P0 and P3, with boys showing slightly greater growth in weight and height, in agreement with sex-related differences reported by [18] and growth trajectories described by [19]. These findings suggest expected physical development in the cohort.

HRV parameters demonstrated significant maturation of the autonomic nervous system across the four-month period. Linear and nonlinear metrics—such as RMSSD, NN50, pNN50, HF, LF/HF, ApEn, SampEn, and DFA α_2 —showed progressive increases, especially between P2 and P3, consistent with the physiological shift toward enhanced parasympathetic modulation described in prior studies [20]–[23]. These results reinforce the utility of HRV as a noninvasive indicator

of early neurophysiological development. Taken together, the findings suggest that, within this sample, infant growth patterns and HRV maturation progressed as expected and were not significantly influenced by broad maternal dietary categories as measured. While demographic, socioeconomic, and nutritional factors provide relevant contextual information, conclusions about their causal impact on infant development should be considered exploratory given the study design and measurement limitations.

In summary, this study underscores the importance of monitoring both physical and autonomic development during early infancy while illustrating the feasibility of combining wearable sensing, digital acquisition, and advanced HRV analytics in clinical contexts. Future studies with larger samples, detailed dietary assessment instruments, and standardized evaluation of environmental and behavioral factors will be essential to better elucidate the determinants of neonatal development. Findings may eventually inform public health strategies tailored to regional needs; however, such implications should be explored cautiously and supported by further evidence.

5 CONCLUSIONS

This study demonstrates that socioeconomic conditions, parental weight status, and maternal diet play important roles in shaping infant development during the first months of life. While anthropometric growth and autonomic nervous system maturation followed healthy trajectories, the high prevalence of parental overweight and obesity, along with dietary imbalances, highlight potential risks for future developmental challenges. These findings reinforce the importance of culturally sensitive nutritional guidance and targeted interventions for pregnant and breastfeeding women, particularly in vulnerable contexts, to support healthier outcomes for both mothers and children.

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