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Nutritional status of Vietnamese infants assessed by Fenton growth chart and related factors: A cross-sectional study

Lieu Thu Thi Nguyen[1,2]* | Cuong Danh Tran[3]* | Ha Thu Thi Nguyen[1] | Hai Thanh Phan[1] | Linh Thuy Nguyen[1,4] | Huong Lan Thi Nguyen[3] | Anh Hoai Thi Ta[3] | Chau Quynh Thi Pho[3] | Khanh Nam Do[1] | Anh Kim Dang[1,5] | Huong Thi Le[1,4]

[1]School of Preventive Medicine and Public Health, Hanoi Medical University, Hanoi, Vietnam
[2]Department of Nutrition, National Hospital of Obstetrics and Gynecology, Hanoi, Vietnam
[3]Department of General Obstetrics, National Hospital of Obstetrics and Gynecology, Hanoi, Vietnam
[4]Department of Nutrition and Dietetics, Hanoi Medical University Hospital, Hanoi, Vietnam
[5]Queensland Alliance for Environmental Health Sciences (QAEHS), The University of Queensland, Brisbane, Australia

Correspondence
Hai Thanh Phan, School of Preventive Medicine and Public Health, Hanoi Medical University, Hanoi 100000, Vietnam
Email: phanthanhhai@hmu.edu.vn

*These authors contributed equally to this study.

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ABSTRACT

Importance: Nutritional status of infants, measured by birth weight and length, is an essential factor in neonatal development. Malnutrition in newborns may lead to a higher risk of mortality, neurological and cognitive impairment, and poor language development.

Objective: This study aims to assess the nutritional status of infants and related factors regarding maternal anthropometric characteristics and medical history.

Methods: A cross-sectional study was conducted at the National Hospital of Obstetrics and Gynecology, Vietnam from May 2021 to May 2022 on 340 infants and mothers. Low birth weight was defined following the Intergrowth-21 standards. Stunting was evaluated using the Fenton growth chart when the length was below the 10% percentile line of the gestational week. Multivariate regression models were applied to identify factors associated with the nutritional status of infants.

Results: We found that 12.4% and 14.1% of infants in our study fell into stunted and underweight categories, respectively. Infants of mothers over 35 years old, having a height lower than 150 cm or experiencing anemia during pregnancy were more likely to be stunted or have low birth weight. Serum albumin deficiency during pregnancy was strongly associated with the infant being underweight (odds ratio [OR] = 2.8, 95% confidence interval [95%CI] 1.1–7.3). Newborns were more likely to be stunted if their mothers had a history of preterm birth (OR = 3.3, 95%CI 1.1–10.2).

Interpretation: Maternal nutritional status is closely related to infant malnutrition, particularly in preterm infants. Improving the understanding of mothers regarding prenatal care, reproductive healthcare, adequate nutritional diet, and multi-micronutrient supplements during pregnancy is therefore important.

KEYWORDS
Fenton chart, Infant, Low birth weight, Stunting, Underweight

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INTRODUCTION

Birth weight and length are crucial indicators of children's nutritional status and predictors of their future health.[1] Globally, the rate of low-birth-weight infants is 15.5%, equivalent to about 20 million newborns each year, and 96.5% of them reside in developing countries.[2] Low birth weight ranks second in the ten leading causes of neonatal death in the United States and accounts for 53.6% of all premature birth deaths in low- and middle-income countries.[3,4] The risk of mortality of low birth weight newborns is over 20 times higher compared to infants weighing more than 2500 g at birth.[5,6] While low birth weight reduces immunity, subsequent malnutrition can impair the cognitive ability and intelligence index of children.[7,8] Low birth weight links to long-term neurological impairment, poor language development, poor academic performance, and an increased risk of chronic illnesses, such as cardiovascular diseases and diabetes, in adulthood.[9]

Stunting at birth is characterized by short length for gestational age.[10] It is a syndrome of severe physiological, physical, and cognitive damage that cannot be reversed due to inadequate nutrition and repeated episodes of infection beginning at conception.[11] Globally, approximately 144 million children under five years old suffer from stunting. Over 92% of them reside in low- and middle-income countries and sub-Saharan countries, accounting for more than a third of the total burden.[12] A study performed in urban areas in Brazil, China, India, Italy, Kenya, Oman, the UK, and the USA from April 27, 2009, to March 2, 2014, on 60 206 infants showed a stunting rate of 3.8%.[13] A report from the General Statistics Office in Vietnam in 2014 revealed that 94.3% of children were weighed at birth and 5.7% of them weighed less than 2500 g.[14] According to the publication of the Nutrition Census for the 2019–2020 period, the stunting rate was 19.6% among children under the age of five.[15]

Furthermore, newborn birth weight and length are closely related to maternal nutrition before and during pregnancy. Low body mass index or insufficient weight gain during pregnancy of expectant mothers may result in poor fetal growth.[13,16] Factors such as the child's sex, weight, maternal height, gestational age, number of births, and maternal comorbidities have been identified as factors associated with low birth weight and neonatal stunting.[3,13,17] In addition, socioeconomic factors of the mothers, including education, occupation, income, alcohol intake, and experience of domestic violence, were also associated with low birth weight.[18] A study conducted in Mexico found that the most significant risk factor for low birth weight was low socioeconomic status.[19] In Bangladesh, various factors, including maternal age, geographic location, maternal education level, wealth index, height, age at first birth, and the child's survival status at the time of the survey, were significantly associated with the incidence of low birth weight.[20]

In Vietnam, there is a scarcity of studies assessing malnutrition in infants after birth using update-to-date measurements. Thus, this study aims to evaluate the nutritional status and related factors, including stunting and low birth weight, of full-term and preterm infants by applying the Fenton growth chart. Findings from the study will generate evidence for policymakers and relevant stakeholders to take appropriate actions to reduce the rate of undernutrition in infants, as well as improve the quality of reproductive health care for women of childbearing age.

METHODS

Ethical approval

The ethics of the study was approved by the ethics committee of the Hanoi Medical University, Vietnam (No. 1661/QD-DHYHN). Informed consent forms were obtained from all parents and/or legal guardians. All data were anonymized and used for research purposes only.

Study setting and participants

We conducted a cross-sectional study at the Department of Obstetrics, National Hospital of Obstetrics and Gynecology, Vietnam from May 2021 to May 2022. We selected infants who a) were born at the National Hospital of Obstetrics and Gynecology from August 2021 onwards with complete medical records, and b) whose mothers consented to involve in the study.

The exclusion criteria were a) children had physical disabilities, such as leg and spine deformities that affected the length; b) children had other comorbidities, such as respiratory failure, which could not be measured length and weight one day after birth; c) mothers had mental and/or linguistic abnormalities and were unable to communicate with data collectors.

The sample size for children and their mothers was calculated by the formula for the sample size to estimate a proportion.

$$n = Z^2_{(1-\alpha/2)} \frac{p(1-p)}{(\varepsilon p)^2}$$

For the above sample size formula, we applied a confidence level of 95% (equivalent to $\alpha = 0.05$ and $Z = 1.96$), relative precision $\varepsilon = 0.32$, and estimated prevalence of underweight infants $p = 0.105$ (referenced from a study in National Hospital of Obstetrics and Gynecology, Vietnam in 2012.[21]) The calculated sample size was 320. We anticipated a refusal rate of 5% and aimed for a sample size of 336 participants. We applied convenience sampling and a total of 340 infants and mothers took part in the study.

Measurements and instruments

We interviewed the participants using a 15-min interviewer-administered questionnaire within the infants' birthdays. The following information was included in the study:

Mothers self-reported information about their age, educational level, occupation, and living areas (rural/urban). Regarding infants' characteristics, we collected data on gestational age (weeks) and sex.

The weight of children was measured in grams within the first hour after birth. We used an electronic scale with an accuracy of 0.1 kg, and the calibration was done prior to measurement. The type of scale used in this study was the Tanita BC 1584 scale. We used a SECA 417 ruler with an accuracy of 0.1 cm to measure the length of infants within 1 day after birth. Both length and weight measurements were performed twice, and the mean was recorded.

Birth weight was divided into low birth weight according to the Intergrowth-21 standards. An infant was defined as stunted when the length was below the 10% percentile line of the gestational week using the Fenton growth chart. While several charts have been established, the majority of which are based on intra-uterine development and are seldom applied to premature neonates. When being measured using standard growth charts, these neonates remain below the 10th percentile for an extended period of time and are usually unable to catch up with normal growth until the age of two to three years.[22] Therefore, the Fenton chart is the best growth chart to examine longitudinal growth in preterm newborns between 36 and 50 weeks of corrected age (10 weeks post-term). This chart was created based on data from 4 million preterm infants born in six countries and combined with the growth standards of the World Health Organization (WHO).

Maternal anthropometric characteristics of height, weight before pregnancy, and weight gain during pregnancy were self-reported and based on hospital records for evaluation. History of giving preterm birth, abortion/miscarriage, low birth weight, and medical history were also collected. Maternal blood tests were taken at the time of admission to the hospital for childbirth. Test results were extracted from medical records, including hemoglobin, serum albumin, and total protein. The serum albumin level was assessed and classified as low (<35 g/L) and normal (35–48 g/L). Total protein was determined and categorized as low (<60 g/L) and normal (60–80 g/L). Mothers with Hemoglobin ≤110 g/L were classified as having anemia.[23] The blood formula indices were measured using the Beckman Coulter, Unicel DXH 600 cell analyzer machine from the United States. The blood biochemical indices were measured using the AU680 machine from Beckman Coulter Mishima K.K. of Japan.

Data analysis

Data were entered in Epidata 3.1 by two researchers. We analyzed data using SPSS 20.0. Descriptive analyses were conducted to summarize the characteristics of the study participants. Factors related to the nutritional status of infants were analyzed by single and multi-variable regression models. Variables with significant differences between groups were further considered in the regression models. Both crude odds ratio (cOR) and adjusted odds ratio (aOR) with the corresponding 95% confidence intervals (CI) were reported to show the magnitude of the association. A P-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 340 infants were included in our study. Infants classified as stunted accounted for 12.4% and 14.1% of infants fell into the underweight category. Table 1 shows the demographic characteristics of infants and mothers. Mothers aged higher than 35 years old and having low educational levels were significantly associated with having stunted and underweight infants. The number of male infants accounted for 56.5%. Regarding characteristics of infants, there were significant differences in the percentage of stunting and underweight regarding gestational age ($P < 0.001$). The mean infant height was 49.5 cm (standard deviation = 2.0), and the mean infant weight was 3102 g (standard deviation = 459). The average gestational age was 38.5 weeks (standard deviation = 1.6), ranging from 32 weeks 4 days to 41 weeks 5 days.

Characteristics of maternal obstetric history are depicted in Table 2. A higher percentage of stunting and low birth weight of infants was observed in mothers with a history of giving preterm birth, a height under 150 cm, and weight gain during pregnancy less than 10 kg. Regarding sub-clinical features, there were significant differences in the prevalence of stunting and underweight according to levels of hemoglobin and serum albumin. Besides, a higher proportion of low birth weight was seen among mothers having a low level of total protein during pregnancy (36.4% and 12.6%, respectively). All mothers in this study did not smoke or consume alcohol during pregnancy.

Table 3 reveals factors related to the low birth weight of infants. The multivariable regression model showed

TABLE 1 Demographic characteristics of infants and mothers (n = 340)

Variables	Underweight infants			Stunted infants		
	Underweight n (%)	Normal n (%)	P	Stunted n (%)	Normal n (%)	P
Characteristics of mothers						
Age of mother (years)			<0.001†			<0.001†
≥ 35	30 (28.6)	75 (71.4)		26 (24.8)	79 (75.2)	
< 35	18 (7.7)	217 (92.3)		16 (6.8)	219 (93.2)	
Educational level			<0.001‡			0.047‡
Secondary school	2 (22.2)	7 (77.8)		1 (11.1)	8 (88.9)	
High school	30 (23.3)	99 (76.7)		23 (17.8)	106 (82.2)	
University and above university	16 (7.9)	186 (92.1)		18 (8.9)	184 (91.1)	
Occupation			0.191‡			0.218‡
Farmer/worker	12 (18.8)	52 (81.2)		9 (14.1)	55 (85.9)	
Officer	17 (11.9)	126 (88.1)		15 (10.5)	128 (89.5)	
Family business	7 (24.1)	22 (75.9)		7 (24.1)	22 (75.9)	
Freelancer	12 (11.5)	92 (88.5)		11 (10.6)	93 (89.4)	
Living area			0.909			0.719
Urban	30 (14.3)	180 (85.7)		27 (12.9)	183 (87.1)	
Rural	18 (13.8)	112 (86.2)		15 (11.5)	115 (88.5)	
Characteristics of children						
Gestational age (weeks)			<0.001†			<0.001†
< 37	35 (71.4)	14 (28.6)		27 (55.1)	22 (44.9)	
≥ 37	13 (4.5)	278 (95.5)		15 (5.2)	276 (94.9)	
Sex			0.161			0.036‡
Male	32 (16.7)	160 (83.3)		30 (15.6)	162 (84.9)	
Female	16 (10.8)	132 (89.2)		12 (8.1)	136 (91.9)	
Birth order			0.951			0.467
First child	20 (14.4)	119 (85.6)		12 (10.8)	124 (89.2)	
Second child and above	28 (13.9)	173 (86.1)		27 (13.4)	174 (86.6)	

†Chi-squared test.
‡Fisher exact test.

that mothers aged ≥ 35 years old and having a height lower than 150 cm were more likely to give birth to low-birth-weight infants (aOR = 4.7, 95%CI: 1.9–11.2; aOR = 6.1, 95%CI: 2.3–15.8, respectively). Hemoglobin and serum albumin deficiency of mothers were also strongly associated with infant underweight (aOR = 16.1, 95%CI: 6.3–41.3; aOR = 2.9, 95%CI 1.1–7.6, respectively). Regarding newborn wasting, only 6 infants were classified as wasting when using the waste classification according to the Intergrowth-21 standards, equivalent to a rate of 1.76%.

Table 4 depicts maternal factors associated with stunting status among infants. Similarly, the age ≥ 35 years old and the height of mothers lower than 150 cm were strongly associated with infants being stunted category. In addition, the children were more likely to be classified as stunted if their mothers had a history of preterm birth (aOR = 3.5, 95%CI: 1.1–10.6). Maternal anemia during pregnancy was also a factor that increased the likelihood of stunting in infants (aOR = 7.6, 95%CI: 3.2–18.2).

DISCUSSION

To our knowledge, this study is one of a handful of studies in Vietnam that investigated stunted and underweight infants using the Fenton chart and the first study to publish. Previous studies examining birth weight in Vietnam mainly followed WHO guidelines.[24–26] Our results found that a moderate percentage of infants experienced malnutrition.

TABLE 2 Maternal obstetric history characteristics ($n = 340$)

	Underweight infants			Stunted infants		
Variables	**Underweight** ***n* (%)**	**Normal** ***n* (%)**	***P***	**Stunted** ***n* (%)**	**Normal** ***n* (%)**	***P***
History of preterm birth			0.004†			0.002†
Yes	8 (38.1)	13 (61.9)		8 (38.1)	13 (61.9)	
No	40 (12.5)	279 (87.5)		34 (10.7)	285 (89.3)	
History of abortion/miscarriage			0.769‡			0.852‡
Yes	18 (13.4)	116 (86.6)		16 (11.9)	118 (88.1)	
No	30 (14.6)	176 (85.4)		26 (12.6)	180 (87.4)	
History of having children with low birth weight			0.038†			0.011†
Yes	5 (33.3)	10 (66.7)		5 (33.3)	10 (66.7)	
No	43 (13.2)	282 (86.8)		37 (11.2)	288 (88.6)	
Medical history			0.584‡			0.973‡
Yes	8 (16.7)	40 (83.3)		6 (12.5)	42 (87.5)	
No	40 (13.7)	252 (86.3)		36 (12.3)	256 (87.8)	
Height (cm)			<0.001‡			<0.001‡
< 150	21 (55.3)	17 (44.7)		18 (47.4)	20 (52.6)	
≥ 150	27 (8.9)	275 (91.1)		24 (7.9)	278 (92.1)	
Body mass index before pregnancy (kg/m^2)			0.971†			0.980†
< 18.5	7 (14.3)	42 (85.7)		6 (12.5)	43 (87.5)	
≥ 18.5	41 (14.1)	250 (85.9)		36 (12.4)	255 (87.6)	
Weight gain during pregnancy (kg)			0.014‡			0.006‡
< 10	18 (22.5)	62 (77.5)		17 (21.3)	63 (78.8)	
≥ 10	30 (11.5)	230 (88.5)		25 (9.6)	235 (90.4)	
Hemoglobin during pregnancy (g/L)			<0.001‡			<0.001‡
< 110	26 (56.5)	20 (43.5)		20 (43.5)	26 (56.5)	
≥ 110	22 (7.5)	272 (92.5)		22 (7.5)	272 (92.5)	
Serum albumin during pregnancy			<0.001‡			<0.001‡
Low	39 (22.5)	134 (77.5)		33 (19.1)	140 (80.9)	
Normal	9 (5.4)	158 (94.6)		9 (5.4)	158 (94.6)	
Total protein during pregnancy			0.006†			0.390†
Low	8 (36.4)	14 (63.6)		4 (18.2)	18 (81.8)	
Normal	40 (12.6)	278 (87.4)		38 (11.9)	280 (88.1)	

†Fisher exact test.
‡Chi-squared test.

In addition, several maternal factors, such as anthropometry, anemia, and serum albumin deficiency during pregnancy, were positively associated with stunting and low birth weight in infants.

In line with our finding, a prior study conducted in the United States which used the Fenton chart[27] revealed that the percentage of infants being small for gestational age was 10.9%. According to global figures from the WHO in 2017, the rate of stunting of children under 5 years old was 9.6%.[28] In this study, we applied the Fenton growth chart to evaluate the nutritional status of stunting and low birth weight in infants. To enhance preterm baby growth monitoring, the Fenton growth chart for preterm newborns has been established to fit the WHO Growth Standard and to represent actual age rather than completed weeks. The new growth chart's features are based on the suggested development target for preterm newborns, such as the fetus and the term infant.[29] At 50-week-gestation, this corresponds to the WHO growth charts (10 weeks post-term age). The curve of the Fenton chart can measure the growth of preterm infants under 36 weeks, while the WHO chart can only assess

TABLE 3 Factors associated with low birth weight of infants

Variables	cOR (95% CI)	aOR (95% CI)	$P^{\dagger}$
Age of mother (years)			
≥ 35	4.8 (2.4–9.7)	4.7 (1.9–11.2)	0.001
< 35	Reference	Reference	
Education level of the mother			
Secondary school	3.5 (1.8–6.9)	3.8 (0.5–30.8)	0.211
High school	3.3 (0.6–17.5)	1.7 (0.7–4.2)	0.242
University and above university	Reference	Reference	
History of preterm birth			
Yes	4.3 (1.4–11.9)	2.2 (0.7–7.3)	0.179
No	Reference	Reference	
Height of mother (cm)			
< 150	12.6 (5.5–28.5)	6.1 (2.3–15.8)	<0.001
≥ 150	Reference	Reference	
Weight gain during pregnancy (kg)			
< 10	2.2 (1.1–4.4)	1.1 (0.4–2.6)	0.901
≥ 10	Reference	Reference	
Hemoglobin during pregnancy (g/L)			
< 110	16.1 (7.3–35.4)	16.1 (6.3–41.3)	<0.001
≥ 110	Reference	Reference	
Serum albumin during pregnancy			
Low	5.1 (2.3–12.4)	2.9 (1.1–7.6)	0.032
Normal	Reference	Reference	

Abbreviations: aOR, adjusted odd ratio; CI, confidence interval; cOR, crude odd ratio.
†Chi-squared test.

full-term infants.[29] As a result, utilizing the Fenton growth chart in this study helps measure the nutritional status of premature infants precisely.

Maternal height has been used as a marker to evaluate relationships between a mother and her children through generations. Previous research had indicated that children of short-stature mothers could face several adverse health-related effects, including nutritional outcomes.[30,31] This finding is similar to our study, which found that children whose moms were short-statured (height < 150 cm) were more likely to be stunted and underweight.[32] Therefore, developing measures to reduce the malnutrition of infants and the mother's nutritional status for better growth and development of children should be taken into consideration.[33] In many low-income countries, focusing on adolescent female reproductive health is now seen as a critical goal, especially for increasing nutrition for children under the age of five.[33,34]

In many nations, advanced maternal age, defined as the mother being 35 years old or older at the time of delivery, is regarded as a significant risk factor for adverse pregnancy and postpartum outcomes.[35] Our finding is consistent with the results from other studies, which found a positive correlation between the age of mothers and the nutrition of infants.[35,36] We also pointed out that mothers' history of giving preterm birth was related to the stunting of infants. It is in line with the results of Scolowitz's study (2013), in which mothers who delivered at least a preterm birth had a four-fold increased risk of having children with low birth weight in subsequent pregnancies.[37]

Anemia is an adverse issue during pregnancy and negatively impacts the outcomes for the newborn, including fetal anemia, stillbirth, and low and very low birth weights.[38,39] On the other hand, obstructed fetal growth brought on by maternal anemia raises the possibility of birth stunting.[40] Our results on the impact of maternal anemia on infants are consistent with earlier studies.[40,41] Strategies to prevent maternal anemia should be incorporated into intervention programs to reduce undernutrition. In addition, the deficiency of albumin increased the odds of having low birth weight in infants. Similar findings conducted in different parts of the world were also reported.[42,43] Besides, the study by Wada et al.[42] in 2018 showed that the percentage

TABLE 4 Factors associated with the stunting status of infants

Variables	cOR (95% CI)	aOR (95% CI)	$P^{\dagger}$
Age of mother (years)			
≥ 35	4.5 (2.1–9.4)	3.6 (1.6–8.1)	0.002
< 35	Reference	Reference	
Educational level of the mother			
Secondary school	1.3 (0.2–10.9)	0.6 (0.0–10.5)	0.726
High school	2.2 (1.1–4.3)	0.94 (0.4–2.2)	0.891
University and above university	Reference	Reference	
History of preterm birth			
Yes	5.2 (1.7–14.5)	3.5 (1.1–10.6)	0.029
No	Reference	Reference	
Height of mother (cm)			
< 150	10.4 (4.5–23.8)	4.8 (1.9–11.8)	0.001
≥ 150	Reference	Reference	
Weight gain during pregnancy (kg)			
<10	2.5 (1.2–5.2)	1.5 (0.7–3.6)	0.321
≥ 10	Reference	Reference	
Hemoglobin during pregnancy (g/L)			
< 110	4.1 (1.8–10.1)	7.6 (3.2–18.0)	<0.001
≥ 110	Reference	Reference	
Serum albumin during pregnancy			
Low	1.6 (0.4–5.3)	2.1 (0.9–5.3)	0.123
Normal	Reference	Reference	

Abbreviations: aOR, adjusted odd ratio; CI, confidence interval; cOR, crude odd ratio.
†Chi-squared test.

of albumin in serum in the third trimester of pregnancy is positively and significantly correlated with the birth weight of the newborn. The low-protein diet is likely involved in the association between maternal serum albumin redox state and the birth weight of the offspring.[42] Malnourished mothers are more likely to have low albumin levels and give birth to underweight children.[44]

The findings of this study can be the basis for developing effective nutrition programs that target malnutrition infants to alleviate the double burden of malnutrition in Vietnam. We suggest that the Fenton growth chart should be used for further studies to assess the nutritional status of infants, especially preterm infants. Intervention strategies geared toward enhancing mothers' knowledge about prenatal care, reproductive health care, adequate nutritional diet, and multi-micronutrient supplements should be implemented. Evidence from across the globe indicates that interventions to prevent stunting and facilitate children's growth are effective if relevant sectors join in these programs. Therefore, it is necessary to establish "intersectoral actions" to reduce the risk of stunting during the first 1000 days of life.[28]

Our study has several strengths. First, to our knowledge, this study was one of the first studies in Vietnam that investigated low birth weight in infants using the Fenton growth chart. Thus, it may increase the comparability of the study to other international research in accurately assessing the nutritional status of premature infants. However, the current study has some limitations. Firstly, recall bias may have occurred because information about mothers was collected retrospectively. Secondly, we could not demonstrate a causal relationship between the observed risk factors and the outcomes due to the nature of the cross-sectional study design. In addition, the sample size of the current study is relatively small, which did not support such an analysis that may yield more consolidated results as stratified analysis by the mothers' stature, mothers' weight gain during pregnancy, etc.

In summary, a moderate percentage of infants experienced low birth weight, and stunting was found in this study using the Fenton growth chart. In addition, maternal nutritional status is closely related to infant malnutrition, particularly in preterm infants. It is critical to implement interventions that increase the knowledge of mothers on prenatal care, reproductive health care, adequate nutritional diet, and multi-micronutrient supplements during pregnancy.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Khan S, Zaheer S, Safdar NF. Determinants of stunting, underweight and wasting among children < 5 years of age: evidence from 2012-2013 Pakistan demographic and health survey. *BMC Public Health.* 2019;19:358. DOI: 10.1186/s12889-019-6688-2
2. World Health Organization (WHO). Care of the preterm and low-birth-weight newborn. Accessed May 10, 2021. http://www.who.int/maternal_child_adolescent/newborns/prematurity/en/
3. Mahumud RA, Sultana M, Sarker AR. Distribution and determinants of low birth weight in developing countries. *J Prev Med Public Health.* 2017;50:18-28. DOI: 10.3961/jpmph.16.087
4. Dhaded SM, Somannavar MS, Vernekar SS, Goudar SS, Mwenche M, Derman R, et al. Neonatal mortality and coverage of essential newborn interventions 2010 - 2013: a prospective, population-based study from low-middle income countries. *Reprod Health.* 2015;12:S6. DOI: 10.1186/1742-4755-12-S2-S6
5. Badshah S, Mason L, McKelvie K, Payne R, Lisboa PJ. Risk factors for low birthweight in the public-hospitals at Peshawar, NWFP-Pakistan. *BMC Public Health.* 2008;8:197. DOI: 10.1186/1471-2458-8-197
6. Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. *Bull World Health Organ.* 1987;65:663-737.
7. Hjort R, Alfredsson L, Carlsson PO, Groop L, Martinell M, Storm P, et al. Low birthweight is associated with an increased risk of LADA and type 2 diabetes: results from a Swedish case-control study. *Diabetologia.* 2015;58:2525-2532. DOI: 10.1007/s00125-015-3711-8
8. Nair MK, Chacko DS, Paul MK, Nair L, George B, Kumar GS. Low birthweight babies–outcome at 13 years. *Indian Pediatr.* 2009;46:s71-74.
9. Zerbeto AB, Cortelo FM, Filho ÉB C. Association between gestational age and birth weight on the language development of Brazilian children: a systematic review. *J Pediatr (Rio J).* 2015;91:326-332. DOI: 10.1016/j.jped.2014.11.003
10. Gonete AT, Kassahun B, Mekonnen EG, Takele WW. Stunting at birth and associated factors among newborns delivered at the University of Gondar Comprehensive Specialized Referral Hospital. *PLoS One.* 2021;16:e0245528. DOI: 10.1371/journal.pone.0245528
11. Miller AC, Murray MB, Thomson DR, Arbour MC. How consistent are associations between stunting and child development? Evidence from a meta-analysis of associations between stunting and multidimensional child development in fifteen low- and middle-income countries. *Public Health Nutr.* 2016;19:1339-1347. DOI: 10.1017/S136898001500227X
12. UNICEF /WHO / World Bank Group Joint Child Malnutrition Estimates. Levels and trends in child malnutrition. Accessed May 10, 2021. https://apps.who.int/iris/bitstream/handle/10665/331621/9789240003576-eng.pdf
13. Victora CG, Villar J, Barros FC, Ismail LC, Chumlea C, Papageorghiou AT, et al. Anthropometric characterization of impaired fetal growth: risk factors for and prognosis of newborns with stunting or wasting. *JAMA Pediatr.* 2015;169:e151431. DOI: 10.1001/jamapediatrics.2015.1431
14. General Statistics Office of Vietnam. Targeted survey on children and women in Vietnam (2014). Accessed April 12, 2022. https://www.gso.gov.vn/wp-content/uploads/2019/04/6.MICSVIETNAM2014310815.compressed.pdf
15. Portal of the Ministry of Health. The Ministry of Health announces the results of the 2019-2020 Nutrition Census - Highlights. Accessed April 15, 2021. https://moh.gov.vn/tin-noi-bat/-/asset_publisher/3Yst7YhbkA5j/content/bo-y-te-cong-bo-ket-qua-tong-ieu-tra-dinh-duong-nam-2019-2020
16. Khatibi A, Brantsaeter AL, Sengpiel V, Kacerovsky M, Magnus P, Morken NH, et al. Prepregnancy maternal body mass index and preterm delivery. *Am J Obstet Gynecol.* 2012;207:212e1-7. DOI: 10.1016/j.ajog.2012.06.002
17. Noureddine E, Abdellatif B. Prevalence and determinants of low birth weight: a case-control study in Marrakesh (Morocco). *Iran J Public Health.* 2015;44:422-424.
18. Demelash H, Nigatu D, Gashaw K. A case-control study on intimate partner violence during pregnancy and low birth weight, Southeast Ethiopia. *Obstet Gynecol Int.* 2015;2015:394875. DOI: 10.1155/2015/394875
19. Torres-Arreola LP, Constantino-Casas P, Flores-Hernández S, Villa-Barragán JP. Rendón-Macías E. Socioeconomic factors and low birth weight in Mexico. *BMC Public Health.* 2005;5:20. DOI: 10.1186/1471-2458-5-20
20. Moreira AIM, Sousa PRM, Sarno F. Low birth weight and its associated factors. *Einstein.* 2018;16:eAO4251. DOI: 10.31744/einstein_journal/2018AO4251
21. Phan NB. Micronutrient deficiency in mother and child and effectiveness of multi-micronutrient supplementation on fetal malnourished children at the National Hospital of Obstetrics and Gynecology. Doctoral thesis in nutrition-National Institute of Nutrition. 2012.
22. Samarani M, Restom G, Mardini J, Abi Fares G, Hallit S, Fadous Khalife MC. Comparative study between Fenton and intergrowth 21 charts in a sample of Lebanese premature babies. *BMC Pediatr.* 2020;20:74. DOI: 10.1186/s12887-020-1968-7
23. World Health Organization (WHO). Archived: Iron deficiency anaemia: assessment, prevention and control. Accessed September 21, 2022. https://www.who.int/publications/m/item/iron-children-6to23–archived-iron-deficiency-anaemia-assessment-prevention-and-control
24. Thi HN, Khanh DK, Thu Hle T, Thomas EG, Lee KJ, Russell FM. Foot length, chest circumference, and mid upper arm circumference are good predictors of low birth weight and prematurity in ethnic minority newborns in Vietnam: A hospital-based observational study. *PLoS One.* 2015;10:e0142420. DOI: 10.1371/journal.pone.0142420
25. Golding J, Shenton T. Low birth-weight and pre-term delivery in South-east Asia. The WHO International Collaborative

Study of Hypertensive Disorders of Pregnancy. *Soc Sci Med.* 1990;30:497-502. DOI: 10.1016/0277-9536(90)90352-s
26. Nguyen HT, Eriksson B, Tran TK, Nguyen CT, Ascher H. Birth weight and delivery practice in a Vietnamese rural district during 12 year of rapid economic development. *BMC Pregnancy Childbirth.* 2013;13:41. DOI: 10.1186/1471-2393-13-41
27. Yitayew M, Chahin N, Rustom S, Thacker LR, Hendricks-Muñoz KD. Fenton vs. intergrowth-21st: postnatal growth assessment and prediction of neurodevelopment in preterm infants. *Nutrients.* 2021;13:2841. DOI: 10.3390/nu13082841
28. Rueda-Guevara P, Botero Tovar N, Trujillo KM, Ramírez A. Worldwide evidence about infant stunting from a public health perspective: a systematic review. *Biomedica.* 2021;41:541-554. DOI: 10.7705/biomedica.6017
29. Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. *BMC Pediatr.* 2013;13:59. DOI: 10.1186/1471-2431-13-59
30. Subramanian SV, Ackerson LK, Davey Smith G, John NA. Association of maternal height with child mortality, anthropometric failure, and anemia in India. *JAMA.* 2009;301:1691-1701. DOI: 10.1001/jama.2009.548
31. Addo OY, Stein AD, Fall CH, Gigante DP, Guntupalli AM, Horta BL, et al. Maternal height and child growth patterns. *J Pediatr.* 2013;163:549-554. DOI: 10.1016/j.jpeds.2013.02.002
32. Felisbino-Mendes MS, Villamor E, Velasquez-Melendez G. Association of maternal and child nutritional status in Brazil: a population based cross-sectional study. *PLoS One.* 2014;9:e87486. DOI: 10.1371/journal.pone.0087486
33. Negash C, Whiting SJ, Henry CJ, Belachew T, Hailemariam TG. Association between maternal and child nutritional status in Hula, rural Southern Ethiopia: A cross sectional study. *PLoS One.* 2015;10:e0142301. DOI: 10.1371/journal.pone.0142301
34. Badruddin SH, Agha A, Peermohamed H, Rafique G, Khan KS, Pappas G. Tawana project-school nutrition program in Pakistan–its success, bottlenecks and lessons learned. *Asia Pac J Clin Nutr.* 2008;17:357-360.
35. Goisis A, Remes H, Barclay K, Martikainen P, Myrskylä M. Advanced maternal age and the risk of low birth weight and preterm delivery: a within-family analysis using Finnish Population Registers. *Am J Epidemiol.* 2017;186:1219-1226. DOI: 10.1093/aje/kwx177
36. Wang S, Yang L, Shang L, Yang W, Qi C, Huang L, et al. Changing trends of birth weight with maternal age: a cross-sectional study in Xi'an city of Northwestern China. *BMC Pregnancy Childbirth.* 2020;20:744. DOI: 10.1186/s12884-020-03445-2
37. Sclowitz IK, Santos IS, Domingues MR, Matijasevich A, Barros AJ. Prognostic factors for low birthweight repetition in successive pregnancies: a cohort study. *BMC Pregnancy Childbirth.* 2013;13:20. DOI: 10.1186/1471-2393-13-20
38. Rahman MM, Abe SK, Rahman MS, Kanda M, Narita S, Bilano V, et al. Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis. *Am J Clin Nutr.* 2016;103:495-504. DOI: 10.3945/ajcn.115.107896
39. Engidaw MT, Eyayu T, Tiruneh T. The effect of maternal anaemia on low birth weight among newborns in Northwest Ethiopia. *Sci Rep.* 2022;12:15280. DOI: 10.1038/s41598-022-19726-z
40. Tampy ST, Nugroho HW, Syuadzah R. Association between maternal anemia with stunting incidence among newborns in Surakarta, Central Java. In: The 7th International Conference on Public Health. 2020. http://theicph.com/wp-content/uploads/2020/12/191-Safitri-Tia-Tampy-Hari-Wahyu-Nugroho-Rahmi-Syuadzah.pdf. DOI: 10.26911/the7thicph.03.11
41. Rahmati S, Delpishe A, Azami M, Hafezi Ahmadi MR, Sayehmiri K. Maternal anemia during pregnancy and infant low birth weight: a systematic review and meta-analysis. *Int J Reprod Biomed.* 2017;15:125-134.
42. Wada Y, Ehara T, Tabata F, Komatsu Y, Izumi H, Kawakami S, et al. Maternal serum albumin redox state is associated with infant birth weight in Japanese pregnant women. *Nutrients.* 2021;13:1764. DOI: 10.3390/nu13061764
43. Chaudhry ER, Chaudhry ZR, Chaudhry SR. Correlation of maternal albumin levels with neonatal birth weight. *J Islam Int Med Coll.* 2017;12:97-100.
44. Ahmadu BU, Ayodele AA-E, Ngadda H, Jungudu U, Mustapha KS. Correlation of maternal albumin and birth weight of babies in a Nigerian Teaching Hospital. *Int J Public Health Epidemiol.* 2012;1:10-13.

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