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Vitamin D Status in Late Pregnancy Was Related to Pregnancy Outcomes: A Multi-ethnic Cohort Study in Indonesia and Malaysia

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Abstract In Southeast Asian countries, where vitamin D deficiency is common, available data on the association between low 25(OH)D concentrations and adverse pregnancy outcomes are limited. This study aimed to identify the relationship between vitamin D levels of pregnant women and pregnancy outcomes in Indonesia and Malaysia. The study applied a prospective cohort approach, including 775 mother-infant pairs from selected public health facilities in West Sumatra (Indonesia) and Selangor and Kuala Lumpur (Malaysia). Blood samples were collected to evaluate serum 25(OH)D concentrations during the third trimester of pregnancy. Generally, the mean concentration of 25(OH)D throughout pregnancy was 18.04 ± 9.97 ng/ml and the prevalence of the vitamin D deficiency, insufficiency, and sufficiency status were 30.50%, 40.10%, and 29.40%, respectively. Infants born to mothers with higher 25(OH)D concentrations had increased birth weight and head circumference ($p<0.05$), although no significant correlation was found with length at birth. Furthermore, a significant percentage of pregnant women in Indonesia and Malaysia had insufficient vitamin D status. Maternal vitamin D status is associated with newborn anthropometric measurements in birth weight and head circumference. However, additional studies are needed to confirm these results.

Keywords Vitamin D Status, Pregnancy Outcomes, Indonesia, Malaysia

1. Introduction

The significance of vitamin D in the context of musculoskeletal health is widely acknowledged [1]. More recently, there has been increasing recognition of its importance in non-skeletal functions, including cardiovascular disorders, DM, and allergic diseases [2].

Though there is no generally agreed-upon classification of vitamin D status, it's evident that deficient vitamin D is a common public health issue that impacts individuals of various ethnicities, age groups, and geographical locations [3]. Pregnant women are vulnerable groups and susceptible to have vitamin D deficiency status [4]. Throughout pregnancy, vitamin D metabolism has significant changes to facilitate the growth of fetal bone mineralization [5]. Inadequate vitamin D levels in expectant mothers can lead to adverse outcomes for both the mother and the newborn, including an elevated risk of conditions such as preeclampsia [7], gestational diabetes [8], and the need for emergency cesarean section deliveries [9]. Furthermore, the mother's vitamin D status has a direct association on the newborn's vitamin D level [6]. Low maternal levels related with reducing fetal outcomes, including a heightened risk of intrauterine growth restriction [10], pre-term birth [11], and low birth weight in the infant [12]. Recent research has revealed that maternal vitamin D levels during pregnancy play a critical role in fetal programming, leading to many non-skeletal consequences for the children, such as nutritional deficits and allergy diseases [13, 14].

The most Southeast Asian countries have a tropical climate and enjoy plenty of sunlight throughout the year, making one to assume poor vitamin D status is unlikely to occur in this region. Nonetheless, previous investigations conducted in various Southeast Asian countries have consistently indicated a high prevalence of vitamin D deficiency among pregnant women in the later stages of pregnancy [15-17]. These studies have revealed that the occurrence of maternal vitamin D insufficiency and deficiency (defined as 25-hydroxyvitamin D [25 (OH) D] levels below 50 nmol/L) [18] ranged from 20% to 90% among third-trimester pregnant women [15, 16]. Common factors linked to low vitamin D levels in expectant women in Southeast Asia encompass ethnicity, adolescent pregnancies, vitamin D intake, physical inactivity, and lower pre-pregnancy body mass index [15-17].

The key sources of vitamin D are times of year, the amount of exposure, the extent of the uncovered surface area on the body, color of the skin, wardrobe choices, and the sun protection use [19, 20]. Aside from exposure to sunlight, vitamin D can also be acquired through dietary sources like oily fish (such as mackerel, sardines, and salmon), supplements, cod liver oil, cheese, and egg yolk. [21]. In Asian cultures, fair skin is associated with female beauty and UV protection behaviors, such as the use of sunscreen, happen frequently among such populations [15, 16, 22]. In addition, there is lacking of vitamin D-rich natural foods fortified with vitamin D and not commonly widespread practice in Southeast Asia [23].

The investigation on findings on maternal 25 (OH) D levels and delivery outcomes in Southeast Asian localities required consistency. Whereas there's a developing body of proof proposing an association between vitamin D insufficiency and unfavorable pregnancy results, the shortage of long-term thinks about centering on maternal vitamin D status has constrained our understanding of this relationship. The main objective of the present study was to investigate maternal 25(OH)D levels and their relationship with neonatal anthropometric measures such as birth weight, length, and head circumference among pregnant women living in tropical countries, more specifically Indonesia and Malaysia. Furthermore, the study aimed to examine vitamin D levels in late pregnancy, pregnancy characteristics, and lifestyle habits especially those who are expecting in these two tropical nations.

2. Materials and Methods

2.1. Subjects and Design Study

This was a prospective cohort study conducted in West Sumatra, Indonesia, from September 2016 to March 2018. Additionally, Malaysian Mother and Infant Cohort Study (MICOS Study) was carried out between November 2016 and January 2018. Comprehensive information about these cohort studies has been previously documented in published sources [1–5]. The study involved the recruitment of pregnant mothers from selected public health clinics in five towns within the West Sumatra province of Indonesia, which included Padang, Padang Pariaman, Payakumbuh, Lima Puluh Kota, and Pariaman. It also encompassed the state of Selangor and the Federal Territory of Kuala Lumpur in Malaysia. Subjects were recruited from registers maintained by community midwives at public health centers in each of these locations.

The study enrolled participants based on specific health criteria and adhered to inclusion and exclusion guidelines. The inclusion criteria included the following: 1) residing in urban areas, 2) expressing a willingness to fully participate in the study, including the follow-up process, by providing informed consent, 3) being pregnant for less than 13 weeks at the time of recruitment, and 4) carrying a singleton, viable, and healthy fetus. Women with twin pregnancies, a history of miscarriage, chronic conditions like cardiovascular disease, hypothyroidism, diabetes, preeclampsia, or newborn with congenital defects, as well as those using medications that could affect vitamin D metabolism, were excluded from the study. The total sample for the current study included 775 pairs of pregnant mothers and neonates, consisting of 452 from Malaysia and 323 from Indonesia, respectively. The study received approval from the appropriate institutional research ethics boards in each country, and all participants provided signed informed consent.

This study was carried out in compliance with the principles of the Helsinki Declaration and received approval from the Ethics Committees in both countries. The study in Indonesia was approved by the Research Ethics Committee of the Medical Faculty, Andalas University, West Sumatra (108/KEP/FK/2016), and the study in Malaysia was approved by the Ethics Committee for Research Involving Human Subjects, Universiti Putra Malaysia (FPSK(FR16)P006) and the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (NMRR-16-1047-30685). All respondents provided written informed consent prior to data collection.

2.2. Data Collection

In 28 weeks of gestation, one blood sample was obtained from each subject. Women's characteristics, anthropometric data, lifestyles, food intakes, and pregnancy profiles were obtained in person by qualified nutritionists who worked as research assistants. All data were saved in data storage as individual case report files and will be registered for future studies. After the delivery process, various anthropometric measurements, including birth weight, birth length, and head circumferences, were recorded. Information about prenatal body weight and height was extracted from maternal and child health handbook (MCH handbook/Buku KIA) at the selected public health care facilities. The MCH Handbook is useful for monitoring maternal and child health.

The lifestyle questionnaire asked about working status, duration of sunlight exposure, sunscreen usage, and dressing style habits. All these questions were related to risk factors that could affect maternal vitamin D status according to the association of sunlight with skin exposure. Sun exposure duration, dressing style, and sunscreen application procedure were explained and published elsewhere [6].

Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) was specifically developed for use in West Sumatra to assess the intake and supplementation of vitamin D [2,7]. Similarly, another SQ-FFQ was employed in Malaysia for this purpose [8]. In summary, the SQ-FFQ included categories for vitamin D-rich natural foods, vitamin D-fortified foods, and dietary supplements containing vitamin D. Since vitamin D substance information isn't readily accessible within the dietary composition tables of Indonesia and Malaysia, data around the vitamin D substance contained in the daily food was sourced from the United States Department of Agriculture National Nutrient Database for Standard Reference (USDA) [9]. Points of interest with respect to the vitamin D concentration in braced nourishment items and dietary supplements were collected from item names, as per Nourishment Composition Framework in Singapore. Indonesian pregnant ladies had their day-by-day vitamin D admissions assessed and compared to the Recommended Dietary Allowance (RDA) [10], whereas Malaysian supplement admissions were compared to the Recommended Nutrient Intake (RNI) [11]. Taking after these rules (RDA and RNI), vitamin D admissions were at that point categorized as either satisfactory (≥ 15 µg) or insufficient (< 15 µg).

2.3. Assessment of 25-hydroxyvitamin D Concentration

During check-ups at the health care centers, pregnant women in their third trimester provided a venous blood sample of 2 mL. The serum from the blood was extracted and stored at -70°C for further examination. Blood tests collected from 323 pregnant ladies in Indonesia were sent to the Biomedical Research facility at the Staff of Medication, College of Andalas, for examination. These tests were analyzed utilizing the Demonstrative Organic chemistry Canada (DBC) test for 25(OH)D, and the precision and unwavering quality of this test had been already affirmed in distributed articles [12–15]. Taking after the examination, the serum concentrations of 25(OH)D within the pregnant ladies were categorized into three Deficient (<12 ng/ml), Insufficient (12-19.99 ng/ml), and sufficient (≥20 ng/ml), in understanding with Institute of Medicine (IOM) recommendations (IOM) [16].

2.4. Anthropometric Measurements

To conduct our study, we enlisted the assistance of nutritionists who followed standardized procedures for interviewing and measuring the subjects, including mother-infant pairs. Maternal height was measured with a microtoise stadiometer, guaranteeing exactness to the closest one millimeter. Maternal weight was measured utilizing an electronic scale exact to the closest 100 grams. The Body Mass Index (BMI) was calculated and categorized in understanding with the rules given by the World Health Organization (WHO) [17].

All the references and types of equipment used to get the measurements in detail during anthropometric measurements were published in our recent article [6]. The birth weight, length, and head circumference of the newborns were gotten from Maternal and Child Health (MCH) Clinics and were measured inside 24 hours of birth. Birth weight was recorded to the closest 100 grams utilizing an electronic weighing scale outlined for newborn children. Birth length was measured using an electronic newborn meter. Midwives carefully held the infant's head securely, ensuring both ears were cupped and in contact with the fixed vertical headpiece, aligning the inner and outer corners of the eyes in a vertical plane. The measurement process for the newborns involved specific techniques. With the left hand, the nurse applied gentle pressure to the infant's knees, securing them firmly against the measuring board. With the right hand, the nurse pushed the movable footpiece against the baby's heel, keeping it perpendicular to the board. The attached measuring tape was then read and recorded to the nearest one millimeter. Head circumference was measured with precision to the nearest 0.1 cm using a tape meter. This measurement was taken over the frontal region of the skull and across the occipital prominence located at the back of the head.

2.5. Pregnancy Outcomes

In this research, the gestational age at the time of delivery was determined based on the estimated gestational age, which was assessed by obstetricians or midwives using ultrasonography (USG) checked at the Maternity Center or Healthcare facility. When ultrasound data was unavailable, the gestational age was calculated using the date of the last menstrual period. Neonatal birth weight was then categorized into two groups: normal weight (≥2500 grams) and low birth weight (<2500 grams). Neonatal birth length was categorized into normal (≥ 48 cm) and short (<48 cm). Head circumference was categorized into normal (≥ 35 cm) or small (<35 cm). The mode of delivery was classified as either normal or a cesarean delivery.

2.6. Data Analysis

Statistical Software for Social Science (SPSS) version 23 was used for statistical analysis. The descriptive analysis looked at the cohort characteristics. On properly distributed data, categorical variables were given as numbers and percentages, while continuous variables were reported as mean and standard deviation (SD). If data with non-normal distribution were skewed, data are presented using median and interquartile ranges (IQR) and logarithmically transformed (log10) to approximate a normal distribution. Chi-square, Fisher's exact, and independent samples are all examples of statistical tests. For both continuous and categorical variables, the t-test was employed to compare the characteristics of the participants between the two regions.

Multivariable linear regression with robust standard error (SE) were used to determine association between 25(OH)D and neonatal anthropometric measurements (birth weight, birth length, and head circumference). Data were presented as mean ± standard error (SE). To examine the relationship between maternal vitamin D level and pregnancy outcomes (low birth weight, infant stunting, head circumference, and method of delivery), a multivariable logistic regression analysis was developed. To determine what the more likely maternal vitamin D status in the T3 was to have pregnancy outcomes (with specified characteristics), odds ratios (OR) with 95% confidence intervals (CI) were utilized. In each model, potential confounding factors such as maternal age at conception, job status, pre-pregnancy BMI, and gestational age at blood withdrawal were corrected. The level of statistical significance was chosen at p 0.05.

3. Results

3.1. Characteristics of Subjects

In total, 859 mothers-neonate pairs participated in the VDPM-study and MICOS-study. There were 84 of 859 mothers-neonate pairs excluded due to incomplete data collection during birth deliveries, allowing 775 mothers-neonate pairs data to be included in analyses. Tables 1 and 2 provide the cohort characteristics of both the mothers and the neonates. On average, the age of the mother-neonatal pairs was 29 years. There were comparable proportion of Indonesian pregnant mothers from rural areas (48.9%) and urban areas (51.1%), while all Malaysian pregnant mothers were recruited from urban areas (100.0%). In this study, there were notable differences in the characteristics of pregnant women between Malaysia and Indonesia. Malaysian pregnant women often had a greater degree of education than their Indonesian counterparts that mostly get tertiary education which is refers to post-secondary education received at universities (government or privately funded), polytechnics and colleges of education. After completing a secondary education, students may enroll in a tertiary institution or acquire a vocational education. The prevalence of underweight and normal nutritional status was significantly higher in Indonesian pregnant mothers compared to Malaysian pregnant mothers. Meanwhile, overweight and obesity prevalence was higher in Malaysian pregnant mothers than Indonesian pregnant mothers in the present study. Mean of vitamin D intake was significantly higher among pregnant mothers in Malaysia (10.1 ± 7.8 µg/day) than Indonesia (8.5 ± 6.1 µg/day). In this study, consumption of vitamin D supplements was uncommon with only 31.1% regularly consume vitamin D supplements. Compared to the Malaysian pregnant mothers (4.3 minutes per day), the Indonesian pregnant mothers (50 minutes per day) had more time in outdoors activities and exposed to sunlight. The proportion of pregnant mothers who had body surface area exposure with more than 27% (14.2% vs. 3.3%) and applied sunscreen (72.7% vs. 40.7%) were significantly higher among the Indonesian than the Malaysian pregnant mothers.

As indicated in Table 2, the average gestational age at delivery was similar for both Indonesian and Malaysian pregnant mothers, with an average of 38 weeks of gestation. The mean values for birth weight, birth length, and head circumference were 3,105 ± 446 grams, 48.8 ± 2.5 cm, and 33.5 ± 1.9 cm, respectively. Birth weight of infants was comparable between Indonesia and Malaysia cohorts. On the other hand, proportion of stunted or short birth length status was higher in Malaysian infants compared to Indonesian counterparts. Similarly, mean of head circumference of Malaysian infants was significantly smaller than Indonesian infants, which was corresponding with the significant higher proportion of small for head circumference of Malaysian infant cohort.

Table 1. Maternal Characteristics (N = 775)

Maternal Characteristics	Indonesia (n = 323)	Malaysia (n = 452)	p-value
Location			
Rural	48.9	0	0.001
Urban	51.1	100.0	
Age (years)	29.63 ± 5.9	29.99 ± 4.2	0.330
Gestational age at blood withdrawal (weeks)	31.4 ± 2.9	32.3 ± 3.6	0.001
Ethnicity			
Malay	0	92.5	0.001
Minangkabau	94.7	0	
Others*	5.3	7.5	
Educational level			
Primary	22.0	0	0.001
Secondary	52.6	18.1	
Tertiary	25.4	81.9	
Monthly household income			
Low	32.2	15.7	0.001
Moderate	28.8	54.2	
High	39.0	30.1	
Work status			
Non-working	69.3	31.9	0.001
Working	30.7	68.1	
Parity			
Primiparous	29.7	41.4	0.001
Multiparous	70.3	58.6	
Pre-pregnancy BMI (kg/m^2)	22.7 ± 4.2	24.1 ± 4.9	0.001
Underweight	13.6	8.4	0.005
Normal	60.4	54.9	
Overweight	18.3	25.0	
Obesity	7.7	11.7	
Intake of vitamin D (μg/day)	8.5 ± 6.1	10.1 ± 7.8	0.002
< 15	86.4	75.9	0.001
≥ 15	13.6	24.1	
Intake of supplements containing vitamin D			
No	72.4	66.4	0.083
Yes	27.6	33.6	
Duration of sun exposure (minutes/day)	50±30.0	4.3±17.1	0.001
Body surface area exposed to sunlight (%/day)			
≤ 27	85.8	96.7	0.001
> 27	14.2	3.3	
Sunscreen application			
No	27.6	59.3	0.001
Yes	72.4	40.7	

Table 2. Neonatal Characteristics (n = 775)

Neonatal Characteristics	Indonesia (n = 323)	Malaysia (n = 452)	p-value
Gestational age at delivery (weeks)	38.7 ± 1.9	38.7 ± 1.4	0.500
Neonatal sex			
Boy	50.2	50.7	0.942
Girl	49.8	49.3	
Birth weight (g)	3184 ± 453	3048 ± 432	0.118
LBW	5.3	8.4	
Normal	94.7	91.6	
Birth length (cm)	48.7 ±2.4	48.9 ±2.5	0.142
Short	16.7	24.3	0.012
Normal	83.3	75.7	
Head Circumference	34.2 ± 2.3	32.9 ± 1.4	0.001
Small	54.8	89.1	0.001
Normal	45.2	10.9	
Mode of delivery			0.922
Vaginal	73.1	72.6	
Cesarean	26.9	27.4	

The data for continuous variables were reported as mean and standard deviation. For categorical variables, the percentage (%) of respondents was provided, and for non-normally distributed data, the median and interquartile range (IQR) were presented. P-values for differences were calculated using the Chi-square test for categorical variables and the Independent T-Test for two independent samples. In addition, the study included a diverse range of ethnicities, including Chinese, Indian, Javanese, and Bataknese. BMI refers to Body Mass Index, and T3 represents the third trimester of pregnancy.

The information for nonstop factors was detailed as mean and standard deviation, whereas for categorical factors, the rate (%) of respondents was given. P-values for contrasts were calculated utilizing the Chi-square test for categorical factors and the Autonomous T-Test for two free tests. Also, LBW stands for low birth weight.

Maternal Vitamin D Status

In Table 3, the maternal vitamin D status in the third trimester (T3) among Indonesian and Malaysian pregnant mothers was presented. The mean maternal 25 (OH) D concentrations were significantly higher among Indonesian pregnant mothers (24.4 ± 11.5 ng/ml) compared to Malaysian pregnant mothers (13.5 ± 5.2 ng/ml). Notably, Malaysian pregnant women had a significantly higher prevalence of vitamin D insufficiency and deficiency during late pregnancy, with 91.8% affected, in contrast to Indonesian pregnant women where 40.9% were affected.

The information for ceaseless factors was detailed as mean and standard deviation, and for categorical factors, the rate (%) of respondents was given. To calculate the P-values for contrasts, utilize the Chi-square test for categorical factors and the Autonomous T-Test for two free tests. In this setting, T3 speaks to the third trimester of pregnancy, and 25(OH)D stands for 25-hydroxyvitamin D.

The Maternal Vitamin D Levels and Pregnancy Outcomes Association

This present study identified the association between maternal vitamin D status during late pregnancy and pregnancy outcomes (Table 4). This study had significant difference in both unadjusted and adjusted model in birth weight, birth length status, and head circumference outcomes ($p<0.05$). Pregnant mothers who had lower 25(OH)D concentration were more likely to have lower birth weight and head circumference. Similarly, pregnant mothers who had insufficiency-deficiency vitamin D status were more likely to deliver low birth weight, short birth length, and small head circumference ($p<0.05$). However, there was no relationship between maternal vitamin D status and mode of delivery, gestational age at delivery, low birth weight status, and birth length either using unadjusted and adjusted models ($p>0.05$). Overall, this present study showed that mean of pregnancy outcomes met the guideline recommendation at only birth weight and birth length outcomes (≥2,500 g and ≥48 cm), yet not for the head circumference outcomes (<35 cm) [18].

Table 3. Maternal vitamin D level in the third trimester of pregnancy (N = 775)

	Indonesia (n = 323)	Malaysia (n = 452)	p-value
Serum 25(OH)D levels	24.4 ± 11.5 ng/ml	13.5 ± 5.2 ng/ml	<0.001
Vitamin D status			
Deficient	12.1%	43.6%	<0.001
Insufficient	28.8%	48.2%	
Sufficient	59.1%	8.2%	

Table 4. The Association of Serum 25 (OH) D concentration and Vitamin D Status with Pregnancy Outcomes

		Unadjusted model		Adjusted model	
Variables	Mean [SD] or No (%)	Mean difference or OR (95% CI)	P value	Mean difference or OR (95% CI)	P value
Gestational age at delivery(weeks)*	38.7 [1.6]	0.018 (0.13)	0.898	0.012 (-0.24 to 0.26)	0.928
Birth weight (g)*	3,104 [446]	-0.09 (-0.16 to -0.02)	**0.009**	-0.111 (-0.18 to -0.40)	**0.001**
Birth length (cm)*	48.8 [2.5]	-0.09 (-0.23 to 0.41)	0.581	-0.126 (-0.50 to 0.25)	0.507
Head circumference (cm)*	33.5 [1.9]	-0.85 (-1.14 to -0.56)	**0.001**	-0.822 (-1.15 to -0.53)	**<0.001**
LBW (<2,500 g)**	55 (7.1%)	1.085 (0.69 to 1.69)	0.762	0.787 (0.40 to 1.55)	0.490
Short birth length (<48 cm)**	164 (21.2%)	1.561 (1.04 to 2.34)	**0.034**	1.871 (1.21 to 2.88)	**0.004**
Small head circumference (<35 cm)**	577 (74.5%)	2.896 (2.06 to 4.07)	**0.001**	2.637 (1.85 to 3.76)	**<0.001**
Cesarean deliveries	174 (22.5%)	1.170 (0.76 to 1.80)	0.501	1.244 (0.79 to 1.95)	0.343

* With group assessed using multivariable linear regression, differences were considered statistically significant at p 0.05. ** With group assessed using multivariable logistic regression, differences were considered statistically significant at p 0.05. Maternal vitamin D level was classified as sufficient (≥20 ng/ml) or deficient-insufficient (<20 ng/ml). The model was modified to account for maternal age at conception, employment status, pre-pregnancy BMI, and gestational age at blood withdrawal. LBW is for low birth weight, SD stands for standard deviation, and CI stands for confidence interval.

4. Discussion

4.1. Main Findings

The results of this study showed a significant difference in birth weight, birth length, and head circumference. Lower head circumference and birth weight were more common in pregnant women with lower vitamin D level. A systematic review and meta-analysis of randomized controlled trials found that maternal vitamin D supplementation had a positive effect on birthweight [19].

Changes in bone mineralization, metabolic forms, and fetal cell mass and work may be capable for the conceivable benefits of maternal vitamin D supplementation on low birth weight and small for gestational age (SGA) babies. The essential work of vitamin D within the human body is to maintain calcium and phosphate levels adequate. These components are essential for key forms counting the solidifying of bones amid fetal improvement within the uterus [20–22]. The dynamic shape of vitamin D impacts the qualities fundamental for healthy placental implantation, an imperative portion of fetal improvement, by means of official to vitamin D receptors completely different fetal organs. Besides, vitamin D may influence the way the placenta and mother's resistant framework connected [23, 24] Besides, maternal vitamin D insufficiency has been connected to an increased risk of premature birth [25,26].

4.2. Maternal Characteristics

The characteristics of mothers from two ethnicities, namely Indonesia and Malaysia, have some significant differences, namely from the location of residence, the occurrence of bleeding in early pregnancy, educational attainment, household income, employment status, parity. There was a P value of 0.005 for pre-pregnancy BMI, dietary vitamin D intake, duration of sun exposure, body area exposed to sunshine, and sunscreen application. These differences in characteristics may possibly influence the outcome of the association between maternal vitamin D status and pregnancy outcomes. Pregnant women in tropical countries showed a significant prevalence of vitamin D deficiency, according to this study—72.0% of Indonesian and 42.4% of Malaysian pregnant women. It has been shown that adhering to dietary guidelines regarding vitamin D consumption and increasing the amount of skin exposed to sunlight can prevent vitamin D deficiency in mothers [27].

4.3. Neonatal Characteristics

Neonatal characteristics that differ statistically significantly between Indonesian and Malaysian infants are the head circumference and birth length. The proportion of short stature at birth status was higher in Malaysian infants compared to Indonesian. Birth length is associated with maternal vitamin D insufficiency. A recent comprehensive review and meta-analysis of randomized controlled trials on the effect of vitamin D supplementation discovered that pregnant women who took vitamin D supplementation during pregnancy had higher circulating 25(OH)D levels and longer birth length [28]. According to our findings, vitamin D insufficiency during pregnancy is more common in Malaysia, and this is assumed to be the cause of low birth length status, which is also more prevalent in Malaysian infants. Regarding to the mean of head circumference, Malaysian infants have significantly smaller head circumference than Indonesian infants. The proportion of small for head circumference was also higher in Malaysian infants. Previous research discovered that maternal and neonatal vitamin D status influences head circumference [29,30]. The increased frequency of vitamin D insufficiency in Malaysia is assumed to be related to Malaysian newborns' smaller head size.

4.4. Vitamin D Status in the Late Pregnancy

The prevalence of maternal Vitamin D deficiency and insufficiency was found to be considerably higher in this study among Malaysian pregnant women than Indonesian (91,8% vs 40,9%, respectively). A meta-analysis and comprehensive review of studies on vitamin D levels in Malaysia found that the pooled proportion for <20 ng/ml was 64,5% (30 studies; 13,977 individuals) with the higher prevalence was in the pregnant women (80%) [31]. While in Indonesia, the results from a systematic review and meta-analysis of vitamin D deficiency among pregnant women found that the prevalence of vitamin D deficiency (<20 ng/ml) was 63% (6 studies; 830 pregnant women) [32]. Based on prior research, it is clear that the prevalence of vitamin D deficiency is higher among pregnant women in Malaysia than in Indonesia. In addition, in this study, 100% of respondents from Malaysia are urban residents, who may work more indoors, are more aware of the use of sunscreen, as a result, exposure to ultraviolet (UV) rays is reduced, resulting in a higher frequency of vitamin D insufficiency in Malaysian pregnant women. Previous research has also shown that the prevalence of vitamin D insufficiency is higher in urban regions than in rural areas [2]. Residents in rural areas do outdoor activities more often so their exposure to UV rays is higher [31].

4.5. Vitamin D Level and Newborn Anthropometry

This study discovered a substantial relationship between vitamin D levels and pregnancy outcomes. Pregnant women with higher vitamin D levels had significantly higher birth weights than those with lower vitamin D levels. This finding also shown compatible with other studies results [33–35]. A study in Indonesia and another in Iran found significantly lower birth weight among newborn to women with lower 25(OH)D [33,35]. Also, A meta-analysis investigation discovered that women who had vitamin D deficient had low birth weight two-fold increase risk and decrease by 0,08 kg in the mean birth weight comparison [34]. Although, other studies showed no relationship of vitamin D level in conjunction with either a low or normal birth weight [36–38].

Our findings revealed a link between maternal 25(OH)D concentration and birth length status, with pregnant women with lower 25(OH)D concentrations having shorter birth lengths (<48cm). This finding is consistent with prior study that found a link between low vitamin D levels and shorter birth duration [33,35], Other research found no relationship among maternal insufficiency with birth length [36,37,39,40].

The relationship between maternal vitamin D levels and circumference of the head was established, with women who had low 25(OH)D levels having a threefold increase in having a small head circumference (<35 cm) compared to women with adequate vitamin D status. This finding is consistent with prior study that found a link between low vitamin D levels, obesity, and lower head circumference when the study involving genetic variations has important role in regulating vitamin D metabolism and synthesis pathway. Women with neonatal head size < 35 cm, if they had a higher genetic risk score or more risk alleles, they had a significantly lower 25(OH)D [4]. Further research into the relationship between vitamin D level and newborn anthropometry is needed and may need take it into account to confirm which pathway of vitamin D associate with birth length.

It suggests that vitamin D's contribution to newborn anthropometry is related to the vitamin's role in bone mineralization and low levels of it result in impaired growth in the bones [35,41]. As a result, the vitamin D levels in mothers may predict the infants' growth indicators at birth. Not only affect in pregnancy outcomes, but also vitamin D deficient during pregnancy can be linked with incidence of gestational diabetes mellitus as well as preeclampsia and preterm birth [42]. As vitamin D function in skeletal development, the calcium absorption in intestine was determined by vitamin D [43]. Pregnant women with insufficient vitamin D and calcium intake caused a lower birth weight, which could be a factor in the occurrence of lower newborn anthropometry outcomes [20,44]. In this and earlier research, both Malaysia and Indonesia reported a high frequency of poor vitamin D and calcium intake [8,32].

4.6. Strength and Limitation of The Study

The purpose of this study was to assess the frequency of vitamin D status in late pregnancy in Indonesia and Malaysia. The findings show that most pregnant women are vitamin D deficient, and the majority of them do not fulfill the daily vitamin D requirement. We investigated the relationship between 25(OH)D concentrations or vitamin D status and pregnancy outcomes, particularly infant anthropometry results. We discovered a substantial link between lower birth weight and head circumference, as well as small head size and short birth length. These findings may serve to influence policy in Indonesia and Malaysia that is associated with enhanced vitamin D status of pregnant women and provide policymakers with additional evidence when creating a supplementation program. Not only for calcium supplements, but also for vitamin D supplementation during pregnancy, as vitamin D is crucial for calcium absorption.

There are some drawbacks to this study as well. First and foremost, this research failed to follow up until the delivery process as some women move in other facilities. Second, because this was a prospective cohort study, we cannot prove that vitamin D had a causal effect on pregnancy outcomes. Third, different assay was used between two cohorts. As a result, accuracy in the procedures of analyzing serum 25(OH)D levels is vital for ensuring the data's quality, reliability, and validity. Further well-constructed and prospective investigations will be needed to determine the causal relationship between maternal level of vitamin D and maternal and neonatal outcomes.

5. Conclusions

Despite having access to sunlight throughout the year, women in Southeast Asian countries like Malaysia and Indonesia are more likely to be vitamin D deficient. The late-stage pregnancy vitamin D levels of the mother were linked to the anthropometric characteristics of the newborn, specifically the birth weight and head size. Before feasible intervention programs can be launched, more investigation is required to confirm the role of the connected elements. Studies, particularly randomized controlled trials, are required to corroborate the findings before feasible intervention measures can be followed.

Competing Interests

The writers say they have no competing interests.

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Author Contributions

ASA and FCW designed the study, conceived of the presented idea, carried out data collection and statistical analysis, interpreted the data, writing original draft preparation, review, and editing the manuscript; NIL, YSC, and YMC conceived, designed and supervised the project; YP, SN, NAMF, and AUF helped revise the manuscript. All authors read and approved the final manuscript.

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