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RESEARCH ARTICLE
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Knowledge, Attitude, and Practices Regarding Vitamin D Deficiency among Pregnant Women in Dodoma, Tanzania

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Abstract:

Introduction: Vitamin D deficiency during pregnancy is associated with significant risks to maternal and foetal health. However, studies on knowledge, attitude, and practices regarding vitamin D deficiency are limited in low-income countries.This study aimed to determine knowledge, attitude, and practices regarding vitamin D deficiency among pregnant women in Dodoma, Tanzania.

Methods: A cross-sectional study was conducted, and a pretested structured questionnaire was used for data collection from July 2024 to August 2024.

Results: Among the 384 participants, 48.7% demonstrated poor knowledge, while 60.9% exhibited moderate practices, and 60.9% had a positive attitude towards vitamin D deficiency. Knowledge was positively correlated with practices (r = 0.168, p = 0.001) and attitude (r = 0.124, p = 0.015), while attitude showed a negative correlation with practices (r = -0.155, p = 0.002). Monthly household income, education, practices, and attitude were significant predictors of knowledge regarding vitamin D deficiency, while monthly household income, knowledge, and attitude significantly predicted practices.

Discussion: The study identifies a substantial knowledge gap and a disconnect between positive attitudes and practices, highlighting the need to address contextual socio-cultural and structural barriers.

Conclusion: This study revealed that nearly half of the pregnant women had poor knowledge regarding vitamin D deficiency, which underscores the need to integrate vitamin D education into antenatal nutrition programmes.

Keywords: Vitamin D deficiency, Pregnant women, Knowledge, Attitude, Practice, Dodoma, Monthly household income, Socio-cultural and structural barriers, Antenatal nutrition programmes.

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1. INTRODUCTION

Vitamin D deficiency is a common nutritional disorder marked by low levels of 25-hydroxyvitamin D in the blood, typically below 50 nmol/L (20 ng/mL), which may pose serious health risks if left unaddressed [1, 2]. It has been recognised as a global health concern, affecting more than

1 billion people worldwide [3, 4]. Pregnant women are considered a high-risk group, with the prevalence of vitamin D deficiency ranging from 20% to 90% [5]. In Africa, several studies have examined vitamin D status in pregnant women, finding high rates of vitamin D insufficiency and deficiency. A study conducted by Haile *et al.* [6] in Ethiopia found that 39% of the pregnant women were Vitamin D-deficient, and 8.8% were severely deficient. Another study by Toko *et al.* [7] in Kenya found that 51% of pregnant women were vitamin D insufficient, and 21% were deficient. In Tanzania, there is a limited number of studies on vitamin D status among pregnant women; a study conducted by Finkelstein *et al.* [8] in Dar es Salaam, Tanzania, found that 39% of HIV-pregnant women had low vitamin D levels; another study conducted by Kalinjuma *et al.* [9] in Dar es Salaam, Tanzania found that 6.8% pregnant women suffer from vitamin D deficiency-insufficiency. Therefore, these studies highlight the problem of vitamin D deficiency in Tanzania.

Vitamin D plays a crucial role during pregnancy, particularly in supporting placental function [9], regulating calcium and phosphorus homeostasis, which is essential for proper bone mineralisation [3], and facilitating muscle contraction [9]. It also contributes to the development of the nervous system [10], cellular function [5], hormonal regulation [10], the reduction of inflammation [5], and the functioning of the immune system [11]. These functions are vital for the health of both the mother and the foetus.

Previous studies have reported associations between maternal vitamin D deficiency and adverse maternal and foetal outcomes, including preeclampsia, gestational diabetes mellitus, bacterial vaginosis, hypertension, polyhydramnios, miscarriage, small-for-gestational-age infants, preterm labour, low birth weight, caesarean section, intrahepatic cholestasis of pregnancy, postpartum haemorrhage, inadequate foetal immune system development, neural and skeletal developmental disorders, cardiovascular and respiratory dysfunction in newborns, nutritional rickets, intrauterine growth restriction, and placental implantation disorders [6, 12-21].

Adequate awareness, positive attitude, and healthy practices regarding vitamin D deficiency are crucial for addressing this deficiency among pregnant women [12, 22, 23]. Several studies have assessed pregnant women's knowledge, attitudes, and practices regarding vitamin D deficiency. A study of Iranian pregnant women found that 85.6% understood the importance and role of vitamin D during pregnancy. Furthermore, 75% of the participants understood the significance of preventing vitamin D deficiency during pregnancy [12]. Another study conducted in Egypt found that 35.1% of pregnant women had poor knowledge of vitamin D deficiency, while 31.2% had average knowledge. 38.6% of pregnant women had a neutral attitude towards vitamin D deficiency, and 29.8% had a positive attitude [24]. Additionally, a KAP study conducted among the general population in Ghana, West Africa, reported limited knowledge about vitamin D among participants [25].

Despite the effects of vitamin D deficiency on maternal and child health, there are limited studies to assess knowledge, attitude, and practices towards vitamin D deficiency in Tanzania, specifically in Dodoma. Assessing the knowledge, attitudes, and practices related to vitamin D deficiency among pregnant women in Dodoma is crucial for identifying gaps in understanding, perceptions, and preventive behaviours. The findings from this study can provide valuable evidence to guide policymakers and health professionals in developing effective awareness initiatives and interventions, such as targeted nutrition education and strengthened antenatal counselling, to enhance maternal knowledge and promote appropriate practices for maintaining adequate vitamin D status during pregnancy. Therefore, the current study aimed to determine the knowledge, attitude, and practices regarding Vitamin D deficiency among pregnant women attending antenatal care clinics in Dodoma.

This study employed the Knowledge, Attitude, and Practice (KAP) model to investigate pregnant women's knowledge, attitude, and practices regarding vitamin D deficiency. The KAP model is a widely used public health framework that explains how knowledge influences attitudes, which in turn shape health-related practices [26, 27]. It provides a structured approach for identifying knowledge gaps, attitude barriers, and behavioural patterns that affect health outcomes [28]. In this context, the model was applied to assess pregnant women's understanding of vitamin D deficiency, their attitudes toward its prevention, and their related practices such as sunlight exposure and dietary intake. The KAP framework facilitates a deeper understanding of behavioural determinants and supports the design of targeted interventions to enhance maternal vitamin D status.

2. MATERIALS AND METHODS

2.1. Study Design and Sampling

This study employed a cross-sectional design to assess the knowledge, attitudes, and practices regarding vitamin D deficiency among pregnant women attending antenatal care clinics in Dodoma, Tanzania. The study was conducted in three government health centres, namely Makole, Mkonze, and Kikombo. These health centres were purposively selected based on the availability of Reproductive and Child Health (RCH) clinic services, high antenatal clinic attendance, accessibility, and their representation of distinct catchment areas within Dodoma city. Collectively, these facilities serve a large and socioeconomically diverse population of pregnant women, thereby providing an appropriate setting for this study.

The sample size was estimated by using the formula described by Bartlett *et al.* [29].

$$n = (Z^2 \text{ x } p \text{ x } q) / e^2$$

$$n = ((1.96)^2 \text{ x } (0.50) \text{ x } (1\text{-}0.50)) / (0.05)^2$$

A 95% confidence level (Z = 1.96), an estimated proportion (p) of 50%, the complement of p (q = 1-p), and a 5% margin of error (e = 0.05) were used in the calculation. The assumed prevalence of 50% was selected due to the lack of prior data on knowledge, attitudes, and practices regarding vitamin D deficiency among pregnant women in Tanzania. This value provides the maximum possible sample size, thereby ensuring sufficient precision. After adjusting for an anticipated 10% non-response rate, the final target sample size was 422. However, a total of 384 pregnant women ultimately participated in the study, yielding a response rate of 91%. The reasons for non-participation were refusal and not meeting the inclusion criteria upon screening.

[i] Allocation of sample size to the health centres

A proportional allocation method was employed to distribute the sample proportionally based on the monthly number of pregnant women attending each health centre. The approximated ANC clinic attendance records for each of the three health centres in the month prior to the study were as follows: Makole Health Centre, 1200 pregnant women per month, Mkonze Health Centre, 900 pregnant women per month, and Kikombo Health Centre, 600 pregnant women per month. Therefore, the approximate total ANC clinic attendance from all three centres in the month prior to the study was 2,700. The proportions for each health centre were calculated as follows:

- Makole Health Centre: (1200 / 2700) × 422 = 188 pregnant women
- Mkonze Health Centre: (900 / 2700) × 422 = 141 pregnant women
- Kikombo Health Centre: (600 / 2700) × 422 = 94 pregnant women

[i] Selection of study participants from health centres

Systematic random sampling was employed to choose the study participants from each health centre. The sampling interval (K) was calculated as follows:

$$K = \frac{Total\ pregnant\ women\ in\ the\ health\ centre}{Required\ sample\ size}$$

- Makole Health Centre (188 participants needed, 1200 ANC clinic attendees):

K = 1200/188 = 6

- Mkonze health centre (141 participants needed, 900 ANC clinic attendees):

K = 900/141 = 6

- Kikombo health centre (94 participants needed, 600 ANC clinic attendees):

K = 600/94 = 6

Therefore, the sampling interval (K) was 6. The first participant was selected using simple random selection from the list of attendance cards, and subsequent participants were chosen at every sixth interval until the required sample size was reached. The systematic random sampling method was selected because it reduces selection bias and is feasible in hospital settings, as applied in the previous study [6].

2.2. Study Area and Population

The study was conducted in Dodoma city, Dodoma Region, Tanzania, from 17th July to 15th August, 2024. Dodoma city is one of the seven districts of the Dodoma region of Tanzania. It is bordered to the west by the Bahi District and to the east by the Chamwino District, covering an area of 2,607 km^2. According to the 2022 National Census of Tanzania, the district's population is projected to be 765,179. Dodoma city is experiencing rapid urbanisation, characterised by a significant portion of the population engaging in trade and office-based occupations as their primary sources of income. Additionally, the city showcases a diverse religious composition, encompassing various Christian denominations, Islamic practices, and Indigenous beliefs that coexist harmoniously. In Dodoma city, there are three public hospitals, eight public health centres, and thirty-six public dispensaries [30]. Dodoma city features a semi-arid climate with warm to hot temperatures throughout the year. There is a clear seasonal rainfall pattern, with a long dry season lasting from late April to late November and a brief wet season lasting from late November to the end of April [31]. The study area was selected because in semi-arid regions, high daytime temperatures might drive people to avoid direct sunlight, spend more time indoors, and seek shade, especially during peak sunlight hours. This limits the duration and quality of Ultraviolet B radiation (UVB) exposure, which is necessary for the skin to produce vitamin D. Furthermore, the limited availability of vitamin D-rich foods, specifically fish, in the region might influence vitamin D synthesis from the diet [32]. Additionally, cultural norms, such as wearing long, loose clothing during pregnancy to cover the body out of modesty or fear of social judgment, may limit exposure to sunlight of particular body parts. Moreover, many women in the region avoid sunlight due to beauty preferences, believing that sun exposure may damage or darken their skin, thereby reducing opportunities for adequate sunlight. Gender roles and social expectations also play a role, as women often remain at home performing domestic tasks, spending more time indoors than men, thereby restricting overall sun exposure. The target population of the study was pregnant women living in Dodoma city.

2.3. Inclusion Criteria

Pregnant women aged 18 to 45 years in their second and third trimesters without psychiatric disorders who were willing to participate were included in the study.

2.4. Exclusion Criteria

Pregnant women who were in the first trimester were excluded from participation to minimise potential bias due to early pregnancy symptoms (for example, nausea, vomiting, fatigue, and stress) that could affect response accuracy. Additionally, women in the first trimester may not have received antenatal counselling on nutrition and vitamin D, and their dietary behaviours may not yet reflect established pregnancy practices, thereby limiting the reliability of knowledge, attitude, and practices (KAP) assessment. Pregnant women with psychiatric disorders were ineligible for participation due to disorders that can impact cognitive function, attention span, and memory, which are critical for accurately responding to questions assessing knowledge, attitude, and practices.

2.5. Data Collection and Measurements

A structured questionnaire was utilised to assess the study participants' KAP regarding vitamin D deficiency. The questionnaire was adapted with minor modifications from previous studies on KAP related to vitamin D deficiency in pregnant women [3, 12, 22, 33, 34] and aligned with established guidelines for evaluating nutrition-related knowledge, attitudes, and practices [35]. It comprised two sections, namely, the first collected socio-demographic and maternal obstetric data, and the second focused on questions related to knowledge, attitudes, and practices regarding vitamin D deficiency.

2.5.1. Socio-demographic and Maternal Obstetric Information

Information such as age, education status, employment status, monthly household income, trimester, and gravidity of pregnant women was collected in this section.

2.5.2. Knowledge of Pregnant Women Regarding Vitamin D Deficiency

Five questions were used to assess the knowledge of pregnant women regarding vitamin D deficiency. The first question addressed the causes of vitamin D deficiency, while the second focused on prevention strategies during pregnancy. The third question inquired about foods that are rich in vitamin D, the fourth explored effective methods to obtain vitamin D, and the fifth examined the health risks associated with vitamin D deficiency during pregnancy. To evaluate knowledge levels, respondents received a score of 1 for each correct answer and 0 for each incorrect answer. The total score, ranging from 0 to 5, represented the sum of responses to all five questions. A maximum score of 5 indicated a correct response to every question, while a minimum score of 0 reflected incorrect answers to all questions. Scores were then converted to percentages and categorised into three levels: poor knowledge (≤50%), moderate knowledge (51–74%), and good knowledge (≥75%), consistent with the previous study [36].

2.5.3. Practices of Pregnant Women Regarding Vitamin D Deficiency

Practices related to vitamin D deficiency were assessed using five structured questions focused on two primary components: (a) dietary intake of vitamin D-rich foods and supplements, and (b) sun exposure behaviour.

2.5.3.1. Intake of Vitamin D-rich Foods and Supplements

A simplified food-intake checklist, adapted from the 24-hour dietary recall method, was developed to evaluate the consumption of vitamin D-rich foods and supplements. Participants were asked to indicate whether they had consumed any vitamin D-rich foods or taken vitamin D supplements on the day prior to the interview, by responding with a simple “yes” or “no.” The checklist was designed based on the guidelines for assessing nutrition-related knowledge, attitudes, and practices and was refined through minor modifications from validated tools used in previous studies [1, 6, 37]. Food items included in the checklist comprised fish and fish products, fortified milk products, eggs, meat and meat products, fortified cereals, and other vitamin D-rich sources such as fortified margarine, mushrooms, and supplements. Participants who reported consuming at least one vitamin D-rich food or supplement were considered to have good dietary intake practices and were assigned a score of 1, whereas those who did not were categorised as having poor dietary intake practices and received a score of 0. Given that dietary intake typically contributes only about 10% of the body’s vitamin D requirements, and that few foods are naturally rich in vitamin D, inadequate intake, particularly when combined with limited sun exposure, can significantly impair vitamin D synthesis [13].

2.5.3.2. Sun Exposure Behaviour

The remaining four questions evaluated sun exposure practices. The first assessed the time of day participants exposed themselves to sunlight, with response options: “early morning (before 10:00 AM),” “late afternoon/evening (after 4:00 PM),” or “mid-day (10:00 AM to 4:00 PM).” Exposure during mid-day, when UVB rays are most intense and vitamin D synthesis is optimal, was scored as 1 (good practice), while early morning or late afternoon exposure was scored as 0 (poor practice). The second question examined the duration of sun exposure without sunscreen, with response options: “less than 5 minutes,” “5–30 minutes,” and “more than 30 minutes.” Participants who reported spending at least 5 minutes or more were considered to have good practice and scored 1, while those who spent less than 5 minutes were scored 0. The third question assessed the body surface area exposed to sunlight, offering options: “face and hands,” “face, hands, and arms,” and “face, hands, arms, and legs.” Participants who reported exposing their face, arms, hands, and legs were scored as 1, indicating good practice, whereas those who exposed fewer areas were scored as 0. The final question addressed sunscreen use. Participants who reported using sunscreen during sun exposure were assigned a score of 0, indicating poor practice. In contrast, those who did not use sunscreen were assigned a score of 1, indicating good practice. While sunscreen plays a vital role in preventing skin damage and skin cancer, excessive use can inhibit the skin's ability to synthesise vitamin D. For example, sunscreen with a sun protection factor (SPF) of 8 reduces vitamin D production by approximately 92.5%, and SPF 15 reduces it by about 99% [38]. Therefore, it is recommended that individuals expose their face, arms, hands, and legs to sunlight without sunscreen for 5 to 30 minutes at least twice per week between 10:00 AM and 4:00 PM to synthesise sufficient vitamin D before applying sun protection [38]. Total practice scores were computed by summing the five individual items. The possible total ranged from 0 (indicating consistently poor practices) to 5 (indicating consistently good practices). Scores were then converted to percentages and categorised into three levels: ≤50% (poor practice), 51–74% (moderate practice), and ≥75% (good practice), in alignment with the scoring system used in a previous study [36].

2.5.4. Attitude of Pregnant Women Regarding Vitamin D Deficiency

Nine attitude statements were used to assess pregnant women's attitudes regarding vitamin D deficiency. The first statement was, "How likely do you think you are to be vitamin D deficient?" The second question asked, "How serious do you think vitamin D deficiency is?" The third statement inquired, "How beneficial do you believe it is to prepare meals with vitamin D-rich foods?" The fourth statement asked, "How important do you think it is to prevent vitamin D deficiency?" The fifth statement was, "How important do you think vitamin D is for maternal and foetal health?" The sixth question was, "How important is it for you to expose yourself to the sun?" The seventh statement asked, "How difficult do you find preparing meals with vitamin D-rich foods?" The eighth inquired, "How challenging is it to expose yourself to the sun?" Lastly, the ninth statement asked, "How confident do you feel in preparing meals with vitamin D-rich foods?" All statements were scored using a three-point Likert scale, where a score of 1 indicated a negative attitude, 2 demonstrated a neutral attitude, and 3 showed a positive attitude. This scoring means that if a respondent answered all statements negatively, the minimum total score would be 9; conversely, if they answered all positively, the maximum score would be 27. Finally, the attitude scores were then converted to percentages and categorised into three levels: ≤50% (negative attitude), 51–74% (neutral attitude), and ≥75% (positive attitude) [36].

2.5.5. Questionnaire Validity and Reliability Testing

The questionnaire was developed based on a comprehensive review of previous studies assessing knowledge, attitude, and practice regarding vitamin D deficiency among pregnant women [3, 12, 22, 33, 34]. The questionnaire was initially developed in English and then translated into Swahili, the primary language spoken by participants. An independent bilingual translator conducted back-translation into English to ensure semantic equivalence. Discrepancies were reviewed and corrected by the research team. To ensure content validity, the tool was reviewed by a panel of experts in nutrition and maternal health, who provided feedback on the relevance and clarity of each item. The suggested revisions were incorporated to improve the tool. Subsequently, a pilot study was conducted among 60 pregnant women at Kikuyu Health Centre to assess face validity and internal consistency. Participants were asked to evaluate the clarity and comprehensibility of the questions, and necessary adjustments were made. Internal consistency was evaluated using Cronbach's alpha, with statements measuring knowledge, attitude, and practice yielding alpha values of 0.85, 0.77, and 0.83, respectively, indicating acceptable reliability. After confirming the questionnaire's validity, reliability, and overall suitability during the pilot study, it was used for primary data collection. Data from the pilot study were not included in the final analysis.

2.6. Survey Administration

A team of two research assistants, one nutritionist, and one clinical officer was recruited and trained for one day on the study protocol and data collection techniques before data collection began. The survey was conducted in outpatient antenatal clinics within the selected health centres. Each participant was informed about the purpose and significance of the study by research assistants, and informed consent was obtained.

The research assistant interviewed each participant in a private area to ensure confidentiality, and each interview took approximately 30-40 minutes to complete. Responses were recorded on a digitised questionnaire using an Android device with a KOBO collect toolbox (https://www.kobotoolbox.org).

2.7. Statistical Analysis

Data were extracted from the Kobo Collect Toolbox and exported into Microsoft Excel format. Following extraction, the dataset was cleaned, checked for completeness and consistency, and then imported into IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA) and R version 4.4.1 for analysis. No missing data were encountered for the variables included in the final analysis. Descriptive statistics were used to summarise the participants' socio-demographic characteristics, as well as their knowledge, attitudes, and practices regarding vitamin D deficiency. Categorical variables were summarised using frequencies and percentages. Associations between socio-demographic factors and the levels of knowledge, attitudes, and practices were assessed using the Chi-square test of independence or Fisher's exact test, depending on cell size. The Chi-square test was applied when no more than 20% of expected cell counts were less than 5 and all expected counts were greater than 1; otherwise, Fisher's exact test was used. Pearson correlation was used to assess the relationships between knowledge, attitude, and practice scores. Ordinal logistic regression (cumulative logit model) was performed to identify predictors of knowledge and practice levels, each categorised as poor, moderate, or good. Prior to conducting regression analysis, assumptions of multicollinearity and model fit were assessed. Multicollinearity among predictor variables was evaluated using the Variance Inflation Factor (VIF), with all variables exhibiting VIF values below 5, indicating no evidence of significant multicollinearity. Model adequacy was assessed using the deviance goodness-of-fit test, with a non-significant result ($p > 0.05$) indicating an adequate fit. Additionally, the proportional odds assumption was evaluated using the Test of Parallel Lines, which was satisfied ($p > 0.05$), supporting the appropriateness of the ordinal regression model. Variables with a p-value < 0.25 in the bivariate analysis were considered for inclusion in the multivariable model, as recommended by Bursac *et al.* [39], to reduce the risk of omitting potentially essential predictors. The multivariable ordinal logistic regression model was used to adjust for potential confounders and identify independent predictors of knowledge and practices. Results were presented as adjusted odds ratios with corresponding 95% confidence intervals, and a *p*-value < 0.05 was considered statistically significant.

3. RESULTS

3.1. Socio-demographic Characteristics of Pregnant Women

A total of 384 pregnant women participated in the study. Among them, 184 (47.9%) were aged between 18 and 25 years. Approximately 174 participants (45.3%) had completed secondary education, while the majority, 347 (90.4%), were not formally employed. Nearly half of the respondents, 171 (44.5%), reported a monthly household income between 250,000 and 750,000 Tanzanian Shillings (TZS). More than half of the women, 231 (60.2%), were in their third trimester of pregnancy, and 158 (41.1%) were experiencing their first pregnancy (primigravida) (Table **1**).

3.2. Knowledge, Attitude, And Practice Classification

Nearly half of the participants, 187 (48.7%), demonstrated poor knowledge regarding vitamin D deficiency. In contrast, more than half, 234 (60.9%), exhibited moderate levels of practices and reported a positive attitude towards vitamin D deficiency (Table **2**).

Table 1. Socio-demographic characteristics of pregnant women (n = 384).

Variables	n (%)
Age	-
18-25 Years	184 (47.9)
26-35 Years	181 (47.1)
36-45 Years	19 (4.9)
Education status	-
Non-formal education	8 (2.1)
Primary school	138 (35.9)
Secondary school	174 (45.3)
Tertiary school	64 (16.7)
Employment status	-
Employed	37 (9.6)
Not employed	347 (90.4)
Monthly household income	-
≤ 250,000TZS	168 (43.8)
> 250,000 to < 750,000TZS	171 (44.5)
750,000 to < 1,000,000TZS	22 (5.7)
≥ 1,000,000TZS	23 (6.0)
Trimester	-
Second trimester	153 (39.8)
Third trimester	231 (60.2)
Gravidity	-
First pregnancy	158 (41.1)
Second pregnancy	97 (25.3)
Third pregnancy	76 (19.8)
Fourth pregnancy	33 (8.6)
Five or more	20 (5.2)

Table 2. Knowledge, attitude, and practices classification of pregnant women (384).

Variables	n (%)
Knowledge categories	-
Poor	187 (48.7)
Moderate	74 (19.3)
Good	123 (32.0)
Practice categories	-
Poor	49 (12.8)
Moderate	234 (60.9)
Good	101 (26.3)
Attitude categories	-
Negative	0 (0.0)
Neutral	150 (39.1)
Positive	234 (60.9)

3.3. Association Between Socio-demographic Characteristics and Knowledge Levels

There was a statistically significant association between pregnant women's knowledge levels regarding vitamin D deficiency and their education status ($p < 0.001$, Cramer's V = 0.102), employment status ($p = 0.007$, Cramer's V = 0.160), and monthly household income ($p = 0.002$, Cramer's V = 0.165). Although these relationships were statistically significant, the corresponding Cramer's V values indicate small to moderate effect sizes, suggesting that while education, employment, and income are related to knowledge levels, their practical influence may be modest. No significant associations were found between knowledge levels and age ($p = 0.096$, Cramer's V = 0.102), trimester of pregnancy ($p = 0.862$, Cramer's V = 0.028), or gravidity ($p = 0.137$, Cramer's V = 0.123), indicating that these factors had little or no meaningful association with knowledge regarding vitamin D deficiency among the participants (Table **3**).

Table 3. Association between socio-demographic and knowledge levels (n = 384).

-	Knowledge Levels n (%)		
-	Poor (≤50%)	Moderate (51-74%)	Good (≥75%)
Age	-	-	-
18-25 Years	100 (53.5)	33 (44.6)	51 (41.5)
26-35 Years	75 (40.1)	39 (52.7)	67 (54.5)
36-45 Years	12 (6.4)	2 (2.7)	5 (4.1)
p-value	0.096#	-	-
Cramer's V value	0.102	-	-
Education status	-	-	-
Non-formal education	6 (3.2)	0 (0)	2 (1.6)
Primary school	93 (49.7)	26 (35.1)	19 (15.4)
Secondary school	76 (40.6)	35 (47.3)	63 (51.2)
Tertiary school	12 (6.4)	13 (17.6)	39 (31.7)
p-value	< 0.001#	-	-
Cramer's V value	0.274	-	-
Employment status	-	-	-
Employed	9 (4.8)	10 (13.5)	18 (14.6)
Not employed	178 (95.2)	64 (86.5)	105 (85.4)
p-value	0.007	-	-
Cramer's V value	0.160	-	-
Monthly household income	-	-	-
≤ 250,000TZS	92 (49.2)	26 (35.1)	50 (40.7)
> 250,000 to < 750,000TZS	79 (42.2)	44 (59.5)	48 (39.0)
750,000 to < 1,000,000TZS	6 (3.2)	2 (2.7)	14 (11.4)
≥ 1,000,000TZS	10 (5.3)	2 (2.7)	11 (8.9)
p-value	0.002#	-	-
Cramer's V value	0.165	-	-
Trimester	-	-	-
Second trimester	77 (41.2)	28 (37.8)	48 (39.0)
Third trimester	110 (58.8)	46 (62.2)	75 (61.0)
p-value	0.862	-	-
Cramer's V value	0.028	-	-
Gravidity	-	-	-
First pregnancy	75 (40.1)	27 (36.5)	56 (45.5)
Second pregnancy	47 (25.1)	20 (27.0)	30 (24.4)
Third pregnancy	36 (19.3)	15 (20.3)	25 (20.3)
Fourth pregnancy	18 (9.6)	11 (14.9)	4 (3.3)
Five or more	11 (5.9)	1 (1.4)	8 (6.5)
p-value	0.137#	-	-
Cramer's V value	0.123	-	-
-			
-			

Note: #, Fisher's exact test.
p-value significant at $p < 0.05$.

3.4. Association Between Socio-demographic Characteristics and Practice Levels

No statistically significant association was observed between pregnant women's practice levels regarding vitamin D deficiency and any of the assessed socio-demographic variables. Specifically, practice levels were not significantly associated with age (p = 0.293, Cramer's V = 0.076), education level (p = 0.156, Cramer's V = 0.126), employment status (p = 0.058, Cramer's V = 0.115), monthly household income (p = 0.556, Cramer's V = 0.077), trimester of pregnancy (p = 0.073, Cramer's V = 0.117), or gravidity (p = 0.090, Cramer's V = 0.134). The Cramer's V values indicate weak associations across all variables, suggesting that socio-demographic characteristics had little or no meaningful influence on the participants' practices related to vitamin D deficiency (Table **4**).

Table 4. Association between socio-demographic and practice levels (n = 384).

-	Practice Levels n (%)		
-	Poor (≤50%)	Moderate (51-74%)	Good (≥75%)
Age	-	-	-
18-25 Years	27 (55.1)	114 (48.7)	43 (42.6)
26-35 Years	18 (36.7)	111 (47.4)	52 (51.5)
36-45 Years	4 (8.2)	9 (3.8)	6 (5.9)
p-value	0.293	-	-
Cramer's V value	0.076	-	-
Education status	-	-	-
Non-formal education	4 (8.2)	3 (1.3)	1 (1.0)
Primary school	15 (30.6)	82 (35.0)	41 (40.6)
Secondary school	24 (49.0)	107 (45.7)	43 (42.6)
Tertiary school	6 (12.2)	42 (17.9)	16 (15.8)
p-value	0.156#	-	-
Cramer's V value	0.126	-	-
Employment status	-	-	-
Employed	6 (12.2)	27 (11.5)	4 (4.0)
Not employed	43 (87.8)	207 (88.5)	97 (96.0)
p-value	0.058#	-	-
Cramer's V value	0.115	-	-
Monthly household income	-	-	-
≤ 250,000TZS	22 (44.9)	101 (43.2)	45 (44.6)
> 250,000 to < 750,000TZS	21 (42.9)	104 (44.4)	46 (45.5)
750,000 to < 1,000,000TZS	4 (8.2)	16 (6.8)	2 (2.0)
≥ 1,000,000TZS	2 (4.1)	13 (5.6)	8 (7.9)
p-value	0.556#	-	-
Cramer's V value	0.077	-	-
Trimester	-	-	-
Second trimester	21 (42.9)	83 (35.5)	49 (48.5)
Third trimester	28 (57.1)	151 (64.5)	52 (51.5)
p-value	0.073	-	-
Cramer's V value	0.117	-	-
Gravidity	-	-	-
First pregnancy	16 (32.7)	108 (46.2)	34 (33.7)
Second pregnancy	10 (20.4)	60 (25.6)	27 (26.7)
Third pregnancy	13 (26.5)	40 (52.6)	23 (22.8)
Fourth pregnancy	4 (8.2)	18 (7.7)	11 (10.9)
Five or more	6 (12.2)	8 (3.4)	6 (5.9)
p-value	0.090#	-	-
Cramer's V value	0.134	-	-
-			
-			

Note: *p*-value significant at $p < 0.05$.

#, Fisher's exact test.

3.5. Association Between Socio-demographic Characteristics and Attitude Levels

There was a statistically significant association between participants' attitude levels regarding vitamin D deficiency and their employment status (p = 0.008, Cramer's V = 0.135), monthly household income (p = 0.005, Cramer's V = 0.183), and gravidity (p = 0.001, Cramer's V = 0.215). The effect sizes indicated by Cramer's V suggest that the associations with employment status and income were small to moderate. In contrast, the association with gravidity was moderate in strength, implying that these factors had a meaningful influence on participants' attitudes toward vitamin D deficiency. Conversely, no significant associations were found between attitude levels and age (p = 0.953, Cramer's V = 0.016), education level (p = 0.083, Cramer's V = 0.133), or trimester of pregnancy (p = 0.792, Cramer's V = 0.013), suggesting that these variables had minimal or no relationship with participants' attitudes (Table 5).

Table 5. Association between socio-demographic and attitude levels (n = 384).

-	Attitude Levels n (%)		
-	Negative (≤50%)	Neutral (51-74%)	Positive (≥75%)
Age	-	-	-
18-25 Years	0 (0)	71 (47.3)	113 (48.3)
26-35 Years	0 (0)	72 (48.0)	109 (46.6)
36-45 Years	0 (0)	7 (4.7)	12 (5.1)
p-value	0.953#	-	-
Cramer's V value	0.016	-	-
Education status	-	-	-
Non-formal education	0 (0)	1 (0.7)	7 (3.0)
Primary school	0 (0)	59 (39.3)	79 (33.8)
Secondary school	0 (0)	72 (48.0)	102 (43.6)
Tertiary school	0 (0)	18 (12.0)	46 (19.7)
p-value	0.083#	-	-
Cramer's V value	0.133	-	-
Employment status	-	-	-
Employed	0 (0)	7 (4.7)	30 (12.8)
Not employed	0 (0)	143 (95.3)	204 (87.2)
p-value	0.008#	-	-
Cramer's V value	0.135	-	-
Monthly household income	-	-	-
≤ 250,000TZS	0 (0)	82 (54.7)	86 (36.8)
> 250,000 to < 750,000TZS	0 (0)	52 (34.7)	119 (50.9)
750,000 to < 1,000,000TZS	0 (0)	9 (6.0)	13 (5.6)
≥ 1,000,000TZS	0 (0)	7 (4.7)	16 (6.8)
p-value	0.005#	-	-
Cramer's V value	0.183	-	-
Trimester	-	-	-
Second trimester	0 (0)	61 (40.7)	92 (39.3)
Third trimester	0 (0)	89 (59.3)	142 (60.7)
p-value	0.792#	-	-
Cramer's V value	0.013	-	-
Gravidity	-	-	-
First pregnancy	0 (0)	48 (32.0)	110 (47.0)
Second pregnancy	0 (0)	52 (34.7)	45 (19.2)
Third pregnancy	0 (0)	30 (20.0)	46 (19.7)
Fourth pregnancy	0 (0)	9 (6.0)	24 (10.3)
Five or more	0 (0)	11 (7.3)	9 (3.8)
p-value	0.001#	-	-
Cramer's V value	0.215	-	-
-			
-			

Note: *p*-value significant at $p < 0.05$.
#, Fisher's exact test.

3.6. Correlation Between Knowledge, Practice, and Attitude

Knowledge was weakly and positively correlated with both practice (r = 0.168, p = 0.001) and attitude (r = 0.124, p = 0.015), whereas attitude demonstrated a weak negative correlation with practice (r = –0.155, p = 0.002) (Table **6**).

3.7. Predictors of Knowledge Regarding Vitamin D Deficiency

In the bivariate analysis, predictors such as age, education status, employment status, monthly household income, practice level, and attitude level met the inclusion criterion ($p < 0.25$). They were subsequently entered into the multivariate model. In the multivariate analysis, monthly household income, education status, practice levels, and attitude levels remained significantly associated with knowledge regarding vitamin D deficiency ($p < 0.05$).

Monthly household income of 750,000 to <1,000,000 TZS (AOR = 5.06; 95% CI: 1.41-18.14; p = 0.013) was associated with increased odds of good knowledge regarding vitamin D deficiency. In contrast, having a primary school education (AOR = 0.11; 95% CI: 0.05-0.22; $p < 0.001$), poor practice (AOR = 0.15; 95% CI: 0.07-0.33; $p < 0.001$), and a neutral attitude (AOR = 0.41; 95% CI: 0.26-0.64; $p < 0.001$) were associated with decreased odds of good knowledge regarding vitamin D deficiency (Table **7**).

Table 6. Correlation between knowledge, attitude and practices scores (n = 384).

Variable	Knowledge Score		Practices Score		Attitude Score	
	r-Value	*p*-value	r-Value	*p*-value	r-Value	*p*-value
Knowledge score	-	-	0.168**	0.001	0.124*	0.015
Practice score	0.168**	0.001	-	-	-0.155**	0.002
Attitude score	0.124*	0.015	-0.155**	0.002	-	-

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 7. Predictors of knowledge regarding vitamin D deficiency (n = 384).

Variables	COR (95% CI)	AOR (95% CI)	*p*-value
Age	-	-	-
18-25 Years	1.33 (0.52-3.40)	1.01 (0.36-2.79)	0.990
26-35 Years	2.15 (0.84-5.48)	1.35 (0.49-3.72)	0.564
36-45 Years	1	1	-
Education status	-	-	-
Non-formal education	0.10 (0.02-0.49)	0.14 (0.03-0.80)	0.027*
Primary school	0.12 (0.06-0.22)	0.11 (0.05-0.22)	<0.001*
Secondary school	0.34 (0.19-0.59)	0.34 (0.18-0.64)	0.001*
Tertiary school	1	1	-
Employment status	-	-	-
Employed	2.54 (1.33-4.85)	1.11 (0.51-2.40)	0.799
Not employed	1	1	-
Monthly household income	-	-	-
≤ 250,000TZS	0.52 (0.23-1.18)	1.54 (0.59-3.98)	0.375
> 250,000 to < 750,000TZS	0.63 (0.28-1.42)	1.13 (0.45-2.84)	0.801
750,000 to < 1,000,000TZS	2.1 (0.69-6.60)	5.06 (1.41-18.14)	0.013*
≥ 1,000,000TZS	1	1	-
Practice levels	-	-	-
Poor	0.24 (0.11-0.50)	0.15 (0.07-0.33)	<0.001*
Moderate	0.79 (0.51-1.21)	0.57 (0.36-0.92)	0.021*
Good	1	1	-
Attitude levels	-	-	-
Neutral	0.49 (0.33-0.72)	0.41 (0.26-0.64)	<0.001*
Positive	1	1	-

Note: **p*-value significant at $p < 0.05$.
Goodness of fit (Deviance = 276.652, *p*-value = 0.56).
Pseudo R-Square (Nagelkerke = 0.266).
Test of parallel lines (-2 Log likelihood = 371.487, *p*-value = 0.191).

Table 8. Predictors of practices regarding vitamin D deficiency (n = 384).

Variables	COR (95% CI)	AOR (95% CI)	*p*-value
Age	-	-	-
18-25 Years	0.91 (0.35-2.34)	0.80 (0.30-2.12)	0.654
26-35 Years	1.26 (0.49-3.24)	1.06 (0.40-2.81)	0.912
36-45 Years	1	1	-
Education status	-	-	-
Non-formal education	0.16 (0.04-0.67)	0.24 (0.05-1.10)	0.067
Primary school	1.13 (0.63-2.04)	1.49 (0.72-3.08)	0.283
Secondary school	0.87 (0.49-1.54)	1.00 (0.53-1.91)	0.995
Tertiary school	1	1	-
Employment status	-	-	-
Employed	0.50 (0.25-1.00)	0.40 (0.18-0.87)	0.021*
Not employed	1	1	-
Monthly household income	-	-	-
≤ 250,000TZS	0.67 (0.28-1.58)	0.41 (0.16-1.05)	0.062
> 250,000 to < 750,000TZS	0.69 (0.29-1.62)	0.49 (0.20-1.24)	0.134
750,000 to < 1,000,000TZS	0.32 (0.10-1.03)	0.18 (0.05-0.61)	0.006*
≥ 1,000,000TZS	1	1	-
Knowledge levels	-	-	-
Poor	0.51 (0.32-0.81)	0.27 (0.22-0.62)	<0.001*
Moderate	1.35 (0.76-2.39)	0.31 (0.67-2.23)	0.513
Good	1	1	-
Attitude levels	-	-	-
Neutral	1.48 (0.97-2.23)	0.57 (0.14-1.65)	0.011*
Positive	1	1	-

Note: *p-value significant at $p < 0.05$.
Goodness of fit (Deviance = 285.151, p-value = 0.48).
Pseudo R-Square (Nagelkerke = 0.132).
Test of parallel lines (-2 Log likelihood = 366.236, p-value = 0.053).

3.8. Predictors of Practices Regarding Vitamin D Deficiency

In the bivariate analysis, predictors including age, education status, employment status, monthly household income, knowledge level, and attitude level were considered for multivariate analysis with a value of $p < 0.25$. In the multivariate analysis, monthly household income, employment status, knowledge levels, and attitude levels were significantly associated with practices regarding vitamin D deficiency at $p < 0.05$.

Having a monthly household income of 750,000 to <1,000,000 TZS (AOR = 0.18; 95% CI: 0.05-0.61; p = 0.006), being employed (AOR = 0.40; 95% CI: 0.18-0.87; p = 0.021), poor knowledge (AOR = 0.27; 95% CI: 0.22-0.62; $p < 0.001$), and a neutral attitude (AOR = 0.57; 95% CI: 0.14-1.65; p = 0.011) were associated with decreased odds of good practices regarding vitamin D deficiency (Table **8**).

4. DISCUSSION

Our findings show that nearly half of the participants had poor knowledge of vitamin D deficiency. These findings align with those of Raafat Fathy Abo Shahba *et al.* [24], who reported that over one-third of pregnant women at Tanta University Hospital in Egypt had inadequate knowledge about vitamin D deficiency. Similarly, Manandhar *et al.* [40] found limited awareness of vitamin D among pregnant women in the Municipality of Bhaktapur. Additionally, Salmanpour *et al.* [41] reported that the majority of adults in Sharjah, United Arab Emirates, had insufficient knowledge regarding vitamin D and its deficiency. The consistency of these findings may be attributed to the similar characteristics of the participants across the study locations.

Dodoma city experiences high levels of sunlight throughout the year. However, the observed prevalence of poor knowledge among pregnant women highlights a critical gap. Despite the abundant sunlight, many women may not understand the appropriate ways to expose themselves to sunlight for optimal vitamin D synthesis or appreciate its significance during pregnancy. Furthermore, limited availability of vitamin D–rich foods, particularly fish, combined with poor knowledge of other dietary sources, may further compromise dietary intake of vitamin D in the region. Cultural perceptions, such as avoiding sunlight to prevent skin darkening or discomfort, may also be reinforced by limited awareness of the health consequences of vitamin D deficiency. Therefore, tailored educational interventions are needed to promote correct sun exposure practices, including the recommended duration and time of day, raise awareness of dietary sources of vitamin D, and address cultural factors that hinder adequate sunlight exposure. Strengthening such knowledge could improve maternal vitamin D status and reduce the risk of deficiency among pregnant women in the region.

The findings revealed that over half of the women demonstrated moderate practices regarding vitamin D deficiency. The predominance of moderate practices suggests that some positive behaviours exist, such as partial sun exposure or occasional consumption of vitamin D-rich foods, but these are not consistent or sufficient to prevent deficiency. The rapid urbanisation of Dodoma city may partly explain the suboptimal practices related to vitamin D among pregnant women. As the city continues to expand and modernise, a growing proportion of residents are employed in indoor occupations, such as office and service jobs, which limit exposure to direct sunlight. Furthermore, increased use of private or public transport reduces outdoor walking. At the same time, the adoption of urban housing designs with enclosed compounds or multi-storey apartments further restricts access to open, sunlit spaces. These behavioural shifts, driven by urbanisation, may collectively reduce opportunities for natural vitamin D synthesis despite Dodoma's abundant sunlight throughout the year. In addition, the limited availability and consumption of fish in the Dodoma region may reduce dietary sources of vitamin D, as fish and fish products are among the richest natural sources of this nutrient. Cultural norms common in the area, such as wearing long, loose garments during pregnancy to maintain modesty or avoid social scrutiny, may further restrict skin exposure to sunlight. Moreover, aesthetic preferences and beauty perceptions among women, particularly the belief that sunlight may cause skin darkening or damage, often discourage intentional sun exposure. Traditional gender roles may also contribute to this challenge, as many women spend a significant portion of their day indoors engaged in domestic activities. This results in limited time outdoors and, consequently, inadequate sunlight exposure necessary for optimal vitamin D synthesis. To improve vitamin D-related practices among pregnant women in this context, community-based health education programmes should be prioritised to promote safe and culturally acceptable sun exposure habits, such as brief morning or late afternoon outdoor activities within private household spaces. Antenatal care sessions could integrate practical guidance on dietary diversification, including affordable and locally available vitamin D sources such as eggs, liver, and fortified foods to compensate for limited fish access. Collaboration with local leaders and women's groups can also help address cultural misconceptions about sunlight and beauty while respecting modesty norms. Additionally, urban planning strategies that encourage outdoor spaces and walking paths could indirectly enhance sunlight exposure among women living in Dodoma city.

Based on the study findings, most participants demonstrated a positive attitude towards vitamin D deficiency, while none demonstrated a negative attitude. Similar findings were reported by Jamil *et al*., Soliman *et al*., and Alkalash *et al*. [36, 42, 43]. The similarities in these results may be attributed to effective public health campaigns, increased awareness of maternal health issues, and better access to antenatal education within these populations. It is also possible that these studies were conducted in similar socioeconomic and cultural contexts, which emphasised nutrition and sunlight exposure during pregnancy, contributing to the consistently positive attitudes observed across these regions. This indicates that most women acknowledge the importance of vitamin D, despite their limited knowledge and suboptimal practices. Such a positive attitude presents a valuable opportunity for targeted interventions. Health promotion programmes should capitalise on this receptiveness by addressing contextual barriers, such as cultural tendencies to avoid sunlight for fear of skin darkening, that prevent women from translating their positive attitudes into appropriate vitamin D-related behaviours.

In this study, a positive correlation was found between knowledge, attitude, and practices, suggesting that increased knowledge may contribute to improvements in attitudes and behaviours related to vitamin D deficiency. These results are consistent with previous findings from the Qassim region in Saudi Arabia, where positive correlations were also observed between knowledge, attitudes, and practices among mothers [44]. However, a negative correlation between attitude and practice was noted in the current study, indicating that a positive attitude does not always lead to better practices. The disconnect between attitude and practices may reflect underlying structural and cultural barriers within the region that hinder behavioural change, including the predominance of indoor domestic work, the wearing of long and covering clothing during pregnancy, limited availability of fish, sun avoidance due to concerns about skin darkening, and the effects of rapid urbanisation. Overall, these findings highlight the importance of designing interventions that go beyond merely raising knowledge by combining it with practical support and strategies that encourage sustainable behaviour change.

Similarly, our study found that pregnant women with higher household income were more likely to have good knowledge about vitamin D deficiency. A similar pattern was observed in a study conducted in Saudi Arabia, where women with lower income showed limited awareness of vitamin D [45]. One possible reason is that women from higher-income households often have better access to health services and educational resources, and they may also be more exposed to health information through the internet or media.

Women with only a primary education were less likely to have good knowledge, which is consistent with findings from previous research that showed higher education levels are linked with a better understanding of vitamin D [46]. Education likely influences a woman’s ability to access, interpret, and apply health-related information, including advice received during antenatal visits [47]. To address this gap, targeted health literacy interventions should be developed for women with lower educational attainment. Such strategies may include simplified and culturally appropriate educational materials in Swahili, the use of visual aids and demonstrations during antenatal sessions, and community-based peer education led by trained health volunteers. Integrating brief, interactive education modules on vitamin D into routine antenatal care could further enhance understanding and retention of key messages among this group.

Likewise, poor practices in this study were linked to reduced knowledge. This supports findings from the Qassim region of Saudi Arabia, where mothers who practised healthy behaviours related to vitamin D had better awareness [44]. Regular engagement in behaviours such as sun exposure or consuming vitamin D-rich foods may reinforce knowledge over time, either through experience or repeated exposure to health messages in clinics. Lastly, having a neutral attitude was associated with lower knowledge levels. This could be due to reduced motivation to learn or pay attention to health advice. Women who are unsure about the importance of vitamin D may not actively seek information or ask questions during healthcare visits. A positive attitude may help women to value and remember what they are taught, as shown in the Qassim study, where mothers with more positive attitudes had better knowledge [44]. These findings highlight the importance of integrating education, motivation, and behaviour change into antenatal nutrition counselling to help improve both knowledge and practice around vitamin D.

The multivariate regression analysis revealed that women with higher household income were less likely to engage in good practices related to vitamin D deficiency. This finding may be explained by lifestyle patterns associated with higher socioeconomic status. Women with higher incomes are more likely to work in indoor environments such as offices, which limits their exposure to sunlight, the primary source of vitamin D synthesis. Moreover, dietary habits among higher-income groups may favour the consumption of energy-dense, processed foods that are poor in essential nutrients, including vitamin D. In addition, higher-income pregnant women may lead more sedentary lifestyles, characterised by reduced physical activity and reliance on private transportation, which further decreases opportunities for sunlight exposure and increases the risk of vitamin D deficiency.

Interestingly, the multivariate regression analysis found that being employed was also linked to poorer practices. Similar findings were reported in a study from Saudi Arabia, where employed pregnant women were less likely to adopt healthy behaviours related to vitamin D [44]. This could be explained by the nature of formal employment, which often involves long working hours indoors and reduces exposure to sunlight, the primary source of vitamin D synthesis. Employed women may also have limited time to engage in outdoor physical activities or prepare balanced meals rich in vitamin D. Additionally, the limited availability of vitamin D-rich foods, particularly fish, within the region may hinder the preparation of meals that adequately supply this nutrient. Moreover, factors such as increasing urbanisation, cultural norms that promote the wearing of long garments during pregnancy, and beauty preferences that discourage sunlight exposure may further constrain appropriate practices, even among women with good knowledge.

Having a neutral attitude towards vitamin D deficiency was associated with poor practice in addressing it. A neutral attitude suggests a lack of strong belief in the importance of vitamin D, which can reduce motivation to take action. These findings highlight the need for more practical and tailored health education during antenatal visits, particularly for women with competing priorities or limited access to resources. Improving knowledge alone may not be enough; strategies should also consider social and economic realities that affect how women apply that knowledge in everyday life.

5. STRENGTHS AND LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. The research included only pregnant women attending public health centres in one district, excluding those in their first trimester and those attending private or rural clinics. This exclusion may have introduced selection bias and limited the generalisability of the findings. Knowledge regarding vitamin D deficiency in the KAP questionnaire was assessed using only five items, which may not have fully captured the multidimensional aspects of vitamin D knowledge, such as seasonal variations and cultural practices. Furthermore, the use of a self-reported KAP questionnaire may have introduced recall bias, particularly in the 24-hour dietary recall for assessing vitamin D intake and social desirability bias in responses related to attitudes. The study did not include biochemical measurements of serum 25-hydroxyvitamin D levels. Therefore, the actual clinical prevalence of vitamin D deficiency could not be determined, and the reported KAP scores were not biochemically validated. Lastly, the cross-sectional study design precludes any inference of causal relationships between knowledge, attitudes, practices, and associated factors.

Despite these limitations, this research has several strengths. Systematic random sampling was utilised to select participants from health centres, which helped reduce selection bias. The interviews were conducted in Swahili by trained research assistants, enabling participants to better understand the research topic and questions, thereby improving data quality. Additionally, this is the first study in Tanzania to assess the knowledge, attitudes, and practices regarding vitamin D deficiency among pregnant women.

CONCLUSION

This study revealed that nearly half of the pregnant women had poor knowledge, while the majority demonstrated positive attitudes and moderate practices regarding vitamin D deficiency. These findings highlight the need for integrated, context-specific interventions to improve maternal vitamin D awareness and behaviours. Healthcare providers should prioritise vitamin D education during antenatal clinic visits through targeted health talks and counselling sessions. Additionally, community-based initiatives such as group education programmes, mobile health messaging, and sun exposure awareness campaigns should be implemented to reinforce positive practices. Practical demonstrations on safe sun exposure, locally available dietary sources of vitamin D, and strategies to overcome cultural and lifestyle barriers could further enhance behavioural change among pregnant women.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: A.I.A.: Study conception and design; A.I.A.: Data collection; A.I.A.: Analysis and interpretation of results; A.I.A.: Draft manuscript; C.M., T.A.: Supervision. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

AOR	=	Adjusted Odds Ratio
COR	=	Crude Odds Ratio
HIV	=	Human Immunodeficiency Virus
KAP	=	Knowledge, Attitude, and Practice
RCH	=	Reproductive and Child Health
SPF	=	Sun Protection Factor
UK	=	United Kingdom
UVB	=	Ultraviolet B Radiation

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Northern Tanzania Health Research Ethics Committee (KNCHREC), Tanzania on July 15, 2024, with approval number KNCHREC00016/01/2024.

HUMAN AND ANIMAL RIGHTS

All research procedures with human participants followed the ethical standards of the relevant institutional and research committees and were consistent with the Declaration of Helsinki (1975) and its 2013 revision.

CONSENT FOR PUBLICATION

Written informed consent was obtained from each study participant before the data collection process began.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The datasets utilised and analysed in this study can be obtained from the corresponding author [A.A] upon reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

[1] Cabaset S, Krieger JP, Richard A, *et al.* Vitamin D status and its determinants in healthy pregnant women living in Switzerland in the first trimester of pregnancy. BMC Pregnancy Childbirth 2019; 19(1): 10. http://dx.doi.org/10.1186/s12884-018-2150-1 PMID: 30621626

[2] Jeyakumar A, Shinde V, Ravindran R. Pooled estimate of vitamin D deficiency among pregnant women in India: A systematic review and meta-analysis. J Health Popul Nutr 2021; 40(1): 28. http://dx.doi.org/10.1186/s41043-021-00253-y PMID: 34187594

[3] Alibrahim H, Swed S, Bohsas H, *et al.* Assessment the awareness of vitamin D deficiency among the general population in Syria: An online cross-sectional study. BMC Public Health 2024; 24(1): 938. http://dx.doi.org/10.1186/s12889-024-18376-2 PMID: 38561740

[4] Urio V, Musiime V, Piloya T, Kasirye P, Swanson S. Vitamin D status among infants attending a reproductive and child health clinic in Arusha, Tanzania: A cross-sectional study. Open J Pediatr 2021; 11(3): 421-37. http://dx.doi.org/10.4236/ojped.2021.113040

[5] Yang C, Jing W, Ge S, Sun W. Vitamin D status and vitamin D deficiency risk factors among pregnancy of Shanghai in China. BMC Pregnancy Childbirth 2021; 21(1): 431. http://dx.doi.org/10.1186/s12884-021-03889-0 PMID: 34144704

[6] Haile DT, Damote TT, Sadamo FE, Demissie ZG, Dake SK. Vitamin D deficiency and associated factors among antenatal care attending pregnant women in Sodo town, South Ethiopia: A facility-based cross-sectional study. PLoS One 2022; 17(12): 0279975. http://dx.doi.org/10.1371/journal.pone.0279975 PMID: 36584237

[7] Toko E, Sumba O, Daud I, *et al.* Maternal vitamin D status and adverse birth outcomes in children from rural Western Kenya. Nutrients 2016; 8(12): 794. http://dx.doi.org/10.3390/nu8120794 PMID: 27941597

[8] Finkelstein JL, Mehta S, Duggan C, *et al.* Maternal vitamin D status and child morbidity, anemia, and growth in human immunodeficiency virus-exposed children in Tanzania. Pediatr Infect Dis J 2012; 31(2): 171-5. http://dx.doi.org/10.1097/INF.0b013e318245636b PMID: 22252204

[9] Kalinjuma AV, Darling AM, Sudfeld CR, *et al.* Vitamin D concentration during early pregnancy and adverse outcomes among HIV-negative women in Dar-es-Salaam, Tanzania: A case-control study. Nutrients 2019; 11(12): 2906. http://dx.doi.org/10.3390/nu11122906 PMID: 31810155

[10] Mvoundza Ndjindji O, Minto'o Rogombe S, Mveang-Nzoghe A, *et al.* Vitamin D deficiency may be associated with allergies in sub-Saharan Africa. J Allergy Hypersens Dis 2024; 2: 100011. http://dx.doi.org/10.1016/j.jahd.2024.100011

[11] Sudfeld CR, Manji KP, Muhihi A, *et al.* Vitamin D3 supplementation during pregnancy and lactation for women living with HIV in Tanzania: A randomized controlled trial. PLoS Med 2022; 19(4): 1003973. http://dx.doi.org/10.1371/journal.pmed.1003973 PMID: 35427363

[12] Aghaei F, Heidarnia A, Allahverdipour H, Eslami M, Ghaffarifar S. Knowledge, attitude, performance, and determinant factors of Vitamin D deficiency prevention behaviours among Iranian pregnant women. Arch Public Health 2021; 79(1): 224.

http://dx.doi.org/10.1186/s13690-021-00712-2 PMID: 34893075
[13] Aji AS, Erwinda E, Yusrawati Y, Malik SG, Lipoeto NI. Vitamin D deficiency status and its related risk factors during early pregnancy: A cross-sectional study of pregnant Minangkabau women, Indonesia. BMC Pregnancy Childbirth 2019; 19(1): 183. http://dx.doi.org/10.1186/s12884-019-2341-4 PMID: 31117971
[14] Bärebring L, Amberntsson A, Augustin H. A validated screening tool correctly identifies the majority of pregnant women at high risk of vitamin D deficiency. Clin Nutr ESPEN 2022; 49: 301-6. http://dx.doi.org/10.1016/j.clnesp.2022.03.034 PMID: 35623830
[15] Bhatnagar A, Mittal K, Meena JK. Quantitative estimation of serum 25(OH) D and associated risk factors of vitamin D deficiency among pregnant women attending a tertiary care hospital in Udaipur, Rajasthan. AlmeenJMedSci 2022; 15(3): 234-41.
[16] Chen B, Chen Y, Xu Y. Vitamin D deficiency in pregnant women. Medicine 2021; 100(41): 27505. http://dx.doi.org/10.1097/MD.0000000000027505 PMID: 34731133
[17] Ghafarzadeh M, Shakarami A, Tarhani F, Yari F. Evaluation of the prevalence of vitamin d deficiency in pregnant women and its correlation with neonatal vitamin D levels. Clin Nutr Open Sci 2021; 36: 91-7. http://dx.doi.org/10.1016/j.nutos.2021.02.007
[18] Lee SB, Jung SH, Lee H, *et al.* Maternal vitamin D deficiency in early pregnancy and perinatal and long-term outcomes. Heliyon 2023; 9(9): 19367. http://dx.doi.org/10.1016/j.heliyon.2023.e19367 PMID: 37809851
[19] Llopis M, Ventura PS, Brachowicz N, *et al.* Sociodemographic, lifestyle, and environmental determinants of vitamin D levels in pregnant women in Spain. Environ Int 2023; 182: 108293. http://dx.doi.org/10.1016/j.envint.2023.108293 PMID: 37984291
[20] Ni M, Zhang Q, Zhao J, *et al.* Relationship between maternal vitamin D status in the first trimester of pregnancy and maternal and neonatal outcomes: A retrospective single center study. BMC Pediatr 2021; 21(1): 330. http://dx.doi.org/10.1186/s12887-021-02730-z PMID: 34325665
[21] Zhang H, Wang S, Tuo L, *et al.* Relationship between maternal vitamin D levels and adverse outcomes. Nutrients 2022; 14(20): 4230. http://dx.doi.org/10.3390/nu14204230 PMID: 36296914
[22] Tariq A, Khan SR, Basharat A. Assessment of knowledge, attitudes and practice towards Vitamin D among university students in Pakistan. BMC Public Health 2020; 20(1): 355. http://dx.doi.org/10.1186/s12889-020-8453-y PMID: 32183774
[23] Toher C, Lindsay K, McKenna M, *et al.* Relationship between vitamin D knowledge and 25-hydroxyvitamin D levels amongst pregnant women. J Hum Nutr Diet 2014; 27(3): 261-9. http://dx.doi.org/10.1111/jhn.12150 PMID: 24033613
[24] Raafat Fathy abo Shahba H, Tosson Labib A, Morsy Yousif A. Pregnant women's perception regarding vitamin D deficiency in Tanta University Hospital. Egypt J Health Care 2024; 15(4): 497-505. http://dx.doi.org/10.21608/ejhc.2024.388804
[25] Kwabena AA, Appiah B, Danso SA, *et al.* Knowledge, attitude and practices regarding vitamin D among adults in Ghana: A cross-sectional study. BMC Public Health 2025; 25(1): 212. http://dx.doi.org/10.1186/s12889-025-21370-x PMID: 39825262
[26] Shacho E, Ambelu A, Yilma D. Knowledge, attitude, and practice of healthcare workers towards healthcare- associated infections in Jimma University Medical Center, southwestern Ethiopia: Using structural equation model. BMC Health Serv Res 2024; 24(1): 1611. http://dx.doi.org/10.1186/s12913-024-12094-6 PMID: 39696490
[27] Tan L, Chen Y, Gu M, *et al.* Self-medication among university students in Guangdong province, China: A cross-sectional study using the KAP model. Front Public Health 2025; 13: 1601731. http://dx.doi.org/10.3389/fpubh.2025.1601731 PMID: 40726944
[28] Liao X, Nguyen TPL, Sasaki N. Use of the knowledge, attitude, and practice (KAP) model to examine sustainable agriculture in Thailand. Reg Sustain 2022; 3(1): 41-52. http://dx.doi.org/10.1016/j.regsus.2022.03.005
[29] Bartlett JE, Kotrlik JW, Higgins CC. Organizational research: Determining appropriate sample size in survey research. ITL&PJ 2001.
[30] Ngao OD, Mboineki JF. Comparative study of exclusive breastfeeding practice among employed mothers and housewives in Tanzania. J Health Popul Nutr 2023; 42(1): 72. http://dx.doi.org/10.1186/s41043-023-00407-0 PMID: 37496065
[31] Shemsanga C, Muzuka ANN, Martz L. Statistics in Climate Variability, Dry Spells, and Implications for Local Livelihoods in Semi-arid Regions of Tanzania: The Way Forward. In: Chen W-Y, Suzuki T, Lackner M, Eds. Handb Clim Change Mitig Adapt. Cham: Springer International Publishing 2017; pp. 801-48. http://dx.doi.org/10.1007/978-3-319-14409-2_66
[32] Mramba R, Kahindi E. The status and challenges of aquaculture development in Dodoma, a semi-arid region in Tanzania. Aquacult Int 2022; 31: 1551-68. http://dx.doi.org/10.1007/s10499-022-01041-z
[33] Alfadly S, Anaam M, Alsahali S, *et al.* Knowledge, attitude, and practice (KAP) towards vitamin D deficiency among adult population in Qassim, Saudi Arabia. Open Public Health J 2024; 17(1): 18749445302986. http://dx.doi.org/10.2174/0118749445302986240306072242
[34] O'Connor C, Glatt D, White L, Revuelta Iniesta R. Knowledge, attitudes and perceptions towards vitamin D in a UK adult population: A cross-sectional study. Int J Environ Res Public Health 2018; 15(11): 2387. http://dx.doi.org/10.3390/ijerph15112387 PMID: 30373274
[35] Fautsch Macías Y, Glasauer P. Guidelines for assessing nutrition-related knowledge, attitudes and practices: KAP manual. Rome: FAO 2014.
[36] Jamil NA, Shahudin NN, Abdul Aziz NS, *et al.* Knowledge, attitude and practice related to vitamin D and its relationship with vitamin D status among malay female office workers. Int J Environ Res Public Health 2019; 16(23): 4735. http://dx.doi.org/10.3390/ijerph16234735 PMID: 31783521
[37] Woon FC, Chin YS, Ismail IH, *et al.* Vitamin D deficiency during pregnancy and its associated factors among third trimester Malaysian pregnant women. PLoS One 2019; 14(6): 0216439. http://dx.doi.org/10.1371/journal.pone.0216439 PMID: 31233513
[38] Holick MF, Vitamin D. Vitamin D deficiency. N Engl J Med 2007; 357(3): 266-81. http://dx.doi.org/10.1056/NEJMra070553 PMID: 17634462
[39] Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. Source Code Biol Med 2008; 3(1): 17. http://dx.doi.org/10.1186/1751-0473-3-17 PMID: 19087314
[40] Manandhar P, Manandhar N, Joshi SK. Knowledge, attitude and practice about vitamin D among pregnant women at a municipality of Bhaktapur. JNMA J Nepal Med Assoc 2020; 58(232): 1036-40. http://dx.doi.org/10.31729/jnma.5496 PMID: 34506380
[41] Salmanpour VA, Ibrahim HS, Salameh AG, Yahya AM, Debal BK. Vitamin D deficiency: Knowledge and practices among the adult population in Sharjah, United Arab Emirates. Arch Osteoporos 2016; 11(1): 15. http://dx.doi.org/10.1007/s11657-016-0269-0 PMID: 27026018
[42] Soliman NS, Wahdan MM, Abouelezz NF. Knowledge, attitude and practice towards vitamin D importance and supplementation among mothers of under five children in a primary health care center in Cairo. Egypt J Community Med 2020; 38(4): 62-75. http://dx.doi.org/10.21608/ejcm.2020.119419
[43] Alkalash SH, Odah M, Alkenani HH, *et al.* Public knowledge, attitude, and practice toward vitamin D deficiency in Al-Qunfudhah Governorate, Saudi Arabia. Cureus 2023; 15(1): 33756. http://dx.doi.org/10.7759/cureus.33756 PMID: 36793814
[44] Bassam SEA, Abd-Elmageed FNM. Mothers' knowledge, practice, and attitudes toward vitamin D deficiency among children in the

Qassim region, Kingdom of Saudi Arabia. J Med Life 2022; 15(9): 1100-4.
http://dx.doi.org/10.25122/jml-2021-0384 PMID: 36415522

[45] Mumena WA, Hanbazaza MA. Predictors of maternal knowledge, attitude, and practices toward vitamin D supplements in Saudi infants and toddlers. Matern Child Health J 2023; 27(5): 805-14.
http://dx.doi.org/10.1007/s10995-023-03612-9 PMID: 36807236

[46] Alkubur A, Boubaid J, Alghazal N, *et al.* Knowledge, attitude and practice of vitamin D deficiency among adults in Saudi Arabia. J Pioneer Med Sci 2025; 14: 105-15.
http://dx.doi.org/10.47310/jpms2025140615

[47] Shahid R, Shoker M, Chu LM, Frehlick R, Ward H, Pahwa P. Impact of low health literacy on patients' health outcomes: A multicenter cohort study. BMC Health Serv Res 2022; 22(1): 1148.
http://dx.doi.org/10.1186/s12913-022-08527-9 PMID: 36096793