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Anemia in pregnant women: findings from Kuwait birth cohort study

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Abstract

Background Anemia is the most common hematologic disorder in pregnancy, affecting over one-third of pregnant women globally. This study aimed to assess the prevalence of anemia in pregnant women and its associated factors in the Kuwait Birth Cohort study.

Methods The Kuwait birth cohort ($n = 1,108$) was a prospective study in which pregnant women were recruited during their second or third trimester. Data were collected through personal interviews during antenatal care visits, including data on sociodemographic and lifestyle factors. Blood samples were analyzed under strict quality control to measure various laboratory indicators. Anemia was defined as hemoglobin (Hb) < 110 g/L. Predictors of anemia were categorized as underlying or direct factors, and logistic regression models were used to investigate their association with anemia.

Results The prevalence of anemia was 28.16% (95% CI:25.53–30.91%), with 8.75% of women experiencing moderate anemia and 19.40% mild anemia. No cases of severe anemia were observed. Multivariable analysis identified current iron supplement use, (Adjusted Odds Ratio [AOR] 0.52, 95%CI:0.28–0.99; $p = 0.049$), vitamin D status (sufficient vs. insufficient/deficient), (AOR 0.63, 95%CI:0.43–0.92; $p = 0.018$), iron levels ($p < 0.001$), and ferritin levels ($p < 0.001$) as factors significantly associated with anemia.

Conclusion Anemia in pregnant women in Kuwait represents a mild to moderate public health concern, primarily driven by iron deficiency. The estimated prevalence of anemia is influenced by the Hb threshold used to define anemia, a topic currently subject to vigorous debate. Our findings suggest that improved screening for iron deficiency during pregnancy may further reduce anemia in pregnant women in Kuwait.

Keywords Anemia, Pregnancy, Iron deficiency, Kuwait, Vitamin D

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Background

Approximately one-third of the global population is estimated to have anemia [1, 2], a condition defined by hemoglobin (Hb) concentrations below specific cut-off points based on age, sex, and physiological status. Anemia is the most common hematologic disorder in pregnancy [3], with an estimated prevalence of 16% in the United States [4] and 36% worldwide [5, 6]. During pregnancy, anemia is associated with an increased risk of delivery by cesarean section, low birth weight, preterm birth, perinatal mortality, stillbirth, and maternal mortality [7–11]. Additionally, it may negatively impact neurodevelopment in offspring [12, 13].

The World Health Organization (WHO) classifies anemia in pregnant women based on Hb concentration as severe anemia (< 70 g/L), moderate anemia (70–99 g/L), and mild anemia (100–109 g/L) [2]. Pregnant women with Hb ≥ 110 g/L are considered non-anemic. However, this classification has been criticized for relying on a limited number of studies conducted in pregnant women in Europe and North America, despite being uniformly applied across all geographical regions [14, 15]. These thresholds were originally derived from statistical cutoffs, defining anemia as an Hb level below the 5th percentile of normal values in pregnant women, without adequately considering the implications for maternal and offspring health [14]. Recently, the WHO conducted a review of its global guidelines for Hb thresholds used to define anemia at both the individual and population levels. The review revealed that the current Hb cutoffs, including those for pregnant women, lack a robust evidence base [15]. Updated WHO recommendations on Hb thresholds for defining anemia are expected to be announced in the future.

During pregnancy, blood volume increases by 30–50%, primarily due to an expansion in plasma volume [16]. While this is a normal physiological adaptation aimed at enhancing uteroplacental perfusion, it leads to hemodilution and consequently lower Hb levels [3, 16]. Additionally, pregnancy is associated with significantly increased nutritional demands, particularly for iron, which plays a major role in the development of anemia in pregnant women [17–19]. Other contributors to anemia during pregnancy include elevated requirements for folate and vitamin B_{12}, as well as bleeding, hemoglobinopathies, and hemolytic disorders.

A key global nutrition target is to achieve a 50% reduction in the prevalence of anemia among women of reproductive age by 2025 [20, 21]. However, several challenges hinder the ability to monitor progress toward this target, including the lack of high-quality data for comparing different settings and tracking anemia trends over time. Variation in methodological approaches, such as reliance on capillary blood instead of venous blood and the use of HemoCue for Hb measurement [15, 22], further complicates data reliability. Additionally, ongoing debates regarding the Hb threshold used to define anemia, alongside disagreements among professional bodies about screening for iron deficiency and iron supplementation [23, 24], underscore the critical need for contemporary, high-quality data to effectively evaluate progress toward global anemia-related nutrition targets.

Although a few small cross-sectional studies [25, 26] and routinely collected data [27] exist, there is a notable lack of contemporary data on the prevalence of anemia among pregnant women in affluent Middle Eastern countries such as Kuwait. Over a decade ago, a small study ($n = 465$) reported a 24% prevalence of anemia in pregnant women in Kuwait [28], but it remains unclear whether this estimate has changed. Previously, we demonstrated that anemia is no longer a major public health issue among schoolchildren in Kuwait [22]. This study aimed to determine the current prevalence of anemia among pregnant women in Kuwait and to examine the relative importance of its associated factors. The findings will contribute to evaluating Kuwait's and the region's progress toward global nutrition targets and will inform public health policies.

Methods

Study area and population

Kuwait is a small country with a population of approximately 4 million, two-thirds of the population are non-Kuwaitis, with females comprising 39.9% of the total population. Women of childbearing age (15–49 years) account for 25.3% of the total population. The life expectancy at birth is 78.7 years for males and 79.4 years for females. Key health indicators, including infant mortality ratio, under-five mortality ratio, and maternal mortality ratio are estimated to be 8.7, 10.3, and 5.2 per 1,000 live births, respectively. Public healthcare services in Kuwait include more than 86 primary healthcare clinics, six secondary care hospitals, and various tertiary care centers. In addition, private clinics and hospitals are widely available. Public healthcare services are easily accessible, and nearly all deliveries occur under medical supervision in either public or private hospitals. The Maternity Hospital is the largest public maternity hospital in Kuwait, where almost one-third of all deliveries in the country occur, with between 10,000 and 12,000 deliveries occurring annually. The hospital is easily accessible to both Kuwaiti and non-Kuwaiti pregnant women.

Study design and participants

The Kuwait birth cohort was a prospective cohort study in which pregnant women were recruited during their second or third trimester while attending antenatal care. Women were eligible to participate if they were pregnant

in the second or third trimester, could speak Arabic or English, and provided written consent. Participants and their babies were followed until their discharge from the hospital and subsequently through home visits until the babies reached 12 months of age. More details about the study have been published previously [29]. The study recruited 1,108 pregnant women, a sample size sufficient to estimate the prevalence of anemia with a ±3% margin of error, assuming a prevalence of 24% [28] at a 5% level of significance. The study was approved by the Ethics Committee at the Ministry of Health, Kuwait (Ref: project 173/2014; date: February 14, 2017) and the Institutional Review Board at Old Dominion University (Ref: 1517949). Written informed consent was obtained from each study participant prior to recruitment.

Data collection

Sociodemographic and lifestyle data were collected through face-to-face interviews by a trained data collector using a standardized data collection form (available upon request). The form was developed and pilot-tested on 30 pregnant women who were not included in the study. Data on physical activity were collected using pregnancy physical activity questionnaire [30], which has been validated in a similar setting [31]. Data on diet were gathered either using questions from either Kuwait Nutritional Surveillance System or the WHO STEPwise approach to Noncommunicable Disease Risk Factor Surveillance [32]. Pre-pregnancy weight and height were self-reported, while current weight and height were measured using a standardized procedure. Clinical data, including comorbidities, were extracted from medical records by a clinician.

Laboratory methods and outcome variable

Blood samples were collected and analyzed at Al Sabah Maternity Hospital, where these tests are routinely performed under strict quality control. Complete blood count (CBC) was measured using a Beckman hematology analyzer (Beckman Coulter Inc., Fullerton, CA, USA). Iron and ferritin levels were measured using the AU DxI 700 Beckman Coulter analyzer, using commercial kits for serum iron (Cat. # 6502022361861), and ferritin (Cat. # 3737551190). Vitamin B_{12}, folate, and 25-hydroxyvitamin D were analyzed with the Cobas e601 analyzer (Roche Diagnostics GmbH, Mannheim, Germany). Serum vitamin B_{12} was analyzed with the Roche commercial kit (Cat. #7212771190), while total folate in hemolyzed whole blood was analyzed with the Roche commercial kit (Cat. # 7559992190). Finally, 25-hydroxyvitamin D was analyzed using the Roche commercial kit (Cat. # 9038078190).

Statistical analysis

Data were entered into specifically designed database using Epidata [33] and analyzed by STATA Release 17 [34]. Anemia (yes/no), the outcome variable, was defined in accordance with the WHO criteria as Hb level below 110 g/L [2], further classified as mild (100–109 g/L), moderate (70–99 g/L), and severe (<70 g/L). This definition is also adopted by the Centers for Disease Control and Prevention (CDC) [35] and the American College of Obstetricians and Gynecologists (ACOG) [36]. Logistic regression was used to investigate factors associated with anemia in univariable and multivariable analyses. Based on the conceptual framework for anemia in mothers and children [37], variables were classified into two categories: (a) underlying factors included sociodemographic factors (Table S1), reproductive factors (Table S2), and dietary factors as well as body mass index (BMI) categories (Table S3); and (b) direct factors comprised clinical factors (Table S4), and laboratory factors (Table S5). Since iron and ferritin are considered in the causal pathway between 25-hydroxyvitamin D and anemia [38, 39], 25-hydroxyvitamin D was included in the underlying factors (Table S3). To account for different levels at which these factors act, underlying and direct factors were modeled separately. Given the ongoing debate regarding the Hb threshold used to define anemia, particularly in pregnant women [15], an additional analysis was conducted using Hb level as a continuous outcome variable. Multivariable linear regression was used, and assumptions such as normality of the Hb distribution, residuals, and homoscedasticity were checked graphically. The likelihood ratio test was used to test for the variables comparing the model with and without individual variables. Factors with $p<0.05$ were considered to be statistically significant.

Results

Table (1) presents the demographic and reproductive characteristics of 1,108 study participants. The mean (SD) age of the study group was 31.46 (5.28) years while the median (interquartile range) was 31.20 (27.75–35.27) years. Approximately 28% of the participants were pregnant with their first child. The mean Hb level in the study group was 115.21 g/L (95%CI: 114.56–115.87 g/L), with significant differences observed between age groups ($p=0.034$) (Table 2). The overall prevalence of anemia (defined as Hb < 110 g/L) was 28.16% (95%CI: 25.53–30.91%), with no significant difference by age group ($p=0.164$). There was a tendency for pregnant women under 25 years of age to have lower Hb and ferritin levels compared to other age groups (Table 2). Of the 1,108 pregnant women, 8.75% had moderate anemia (Hb 70–99 g/L) and 19.40% had mild anemia (Hb 100–109 g/L), while no cases of severe anemia (Hb < 70 g/L)

Table 1 Sociodemographic factors and basic characteristics of the study group ($N=1108$) in Kuwait birth cohort

Characteristic [a]			
		Mean	**(SD)**
Age[b](years)		31.46	(5.28)
Age at first marriage (years)		23.70	(4.22)
Age at first pregnancy (years)		25.09	(4.50)
		n	**(%)**
Nationality	Kuwaiti	262	(23.69)
	Non-Kuwaiti	844	(76.31)
Mother education	Elementary school of less	29	(2.64)
	High School	249	(22.70)
	University degree or more	819	(74.66)
Father education	Elementary school of less	28	(2.51)
	High School	269	(24.54)
	University degree or more	799	(72.90)
Mother employment	Homemaker	581	(53.01)
	Paid employment	492	(44.89)
	Others	23	(2.10)
Mother income	No specific income for mother	601	(55.04)
	Less than 500 KD	155	(14.19)
	Between 501 to 1000 KD	144	(13.19)
	More than 1000 KD	75	(6.87)
	Don't want to tell	117	(10.71)
Father income	Less than 500 KD	257	(23.73)
	Between 501 to 1000 KD	304	(28.07)
	More than 1000 KD	161	(14.87)
	Don't want to tell	361	(33.33)
Type of housing	Rented apartment	859	(78.45)
	Rented detached house	35	(3.20)
	Owned apartment	27	(2.47)
	Owned detached house	174	(15.89)
Number of children	Zero	312	(28.16)
	1–2	556	(50.18)
	3–4	190	(17.15)
	5 and more	50	(4.51)
Age of menarche (years)	8-	150	(13.54)
	12-	307	(27.71)
	13-	315	(28.43)
	14-	314	(28.34)
	Do not remember	22	(1.99)
Wanted to get pregnant	Yes	754	(68.80)
	No	342	(31.20)
Became pregnant while using contraception	Yes	80	(7.33)
	No	1012	(92.67)
Treatment to help get pregnant	Yes	106	(9.66)
	No	991	(90.34)
Ever had an abortion or miscarriage	Yes	426	(38.45)
	No	682	(61.55)
Smoking cigarettes/shisha during the last 9 months	Yes	60	(5.42)
	No	1,048	(94.58)
Father currently smoke	Yes	436	(39.93)
	No	656	(60.07)
Passive smoking at home	Yes	411	(37.09)
	No	697	(62.91)

[a] Number in some variables do not add up to 1108 because of few missing values

[b] median (first quartile-third quartile) of age was 31.20 (27.75–35.27) years

Table 2 Mean hemoglobin level, mean corpuscular volume and ferritin concentration by age among 1108 pregnant women

Age (years)	*N*	Hemoglobin, Mean (SD) g/L	% anemic[2]	Serum Ferritin, Median (IQR) ng/mL
Total[1]	1108	115.21 (11.13)	28.16	17.67 (11.16–28.39)
< 25 years	117	113.02 (12.19)	35.90	14.26 (8.32–25.18)
25- 29.99 years	329	116.40 (11.26)	25.84	17.95 (11.93–26.98)
30- 34.99 years	368	114.82 (11.05)	29.35	17.24 (11.26–28.36)
35 + years	293	115.22 (10.52)	26.28	19.72 (11.30-31.87)
p		0.034[3]	0.164[4]	0.006[5]

[1]Age is missing for one participant. [2]Defined as hemoglobin < 110 g/L. [3] Calculated using analysis of variance (F-test). [4] Calculated using chi-square test. [5] Calculated using Kruskal-Wallis test

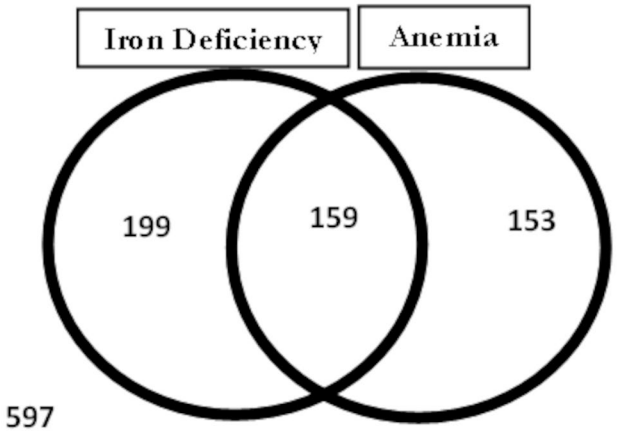

Fig. 1 The overlap between anemia (defined as hemoglobin < 110 g/L) and iron deficiency (defined as serum ferritin < 13 ug/L)

were observed. Of the 312 participants with anemia, 163 (52.24%) had a mean corpuscular volume (MCV) < 80 fL, indicating microcytic anemia, and only one participant had macrocytic anemia (MCV > 98fL). The overlap between anemia, iron deficiency anemia, and iron deficiency without anemia is illustrated in Fig. (1).

Supplementary Table S1 presents the association between sociodemographic factors and anemia in univariable analysis. Nationality ($p < 0.001$), mother's education ($p = 0.043$) and father's education ($p = 0.006$), father's income ($p = 0.038$), and type of housing ($p = 0.003$) were all significantly associated with anemia. Reproductive factors, including age at first marriage ($p = 0.002$), age at first pregnancy ($p = 0.006$), and receiving treatment to assist with pregnancy ($p = 0.048$), were also significantly associated with anemia (Table S2). None of the dietary factors was significantly associated with anemia (Table S3). Current use of iron supplements was inversely associated with anemia, crude odds ratio 0.43 (95%CI: 0.26–0.73; $p = 0.002$). Additionally, underweight women were more likely to have anemia compared to women with normal weight (Table S3). Several clinical factors, such as hypertension ($p = 0.169$), gestational diabetes ($p = 0.242$), and bleeding during the first three months of pregnancy ($p = 0.532$), were not significantly associated with anemia (Table S4). However, all laboratory factors, including iron level ($p < 0.001$), ferritin ($p < 0.001$), vitamin B_{12} ($p = 0.021$), RBC folate ($p < 0.001$), and vitamin D status ($p = 0.011$), showed significant associations with anemia in univariable analysis (Table S5).

In the multivariable analysis, among all variables in the underlying factors group (listed in Tables S1 to S3), only current use of supplements, adjusted odds ratio (AOR) 0.52 (95%CI: 0.28–0.99; $p = 0.049$) and vitamin D status (sufficient vs. deficient/insufficient), AOR 0.63 (95%CI: 0.43–0.92; $p = 0.018$), were significantly associated with anemia (Table 3). Vitamin D remained significant even when fitted as a continuous variable, AOR 0.99 (95%CI:0.99-1.00; $p = 0.016$) (data not shown). In this analysis, several factors lost statistical significance, including age at first marriage, AOR 0.93 (95%CI: 0.87–1.01; $p = 0.090$), getting pregnant while using contraceptives, AOR 1.67 (95%CI: 0.97–2.90; $p = 0.065$), and consumption of energy drinks, AOR 3.04 (95%CI: 0.85–10.79; $p = 0.086$). Among the direct factors group (listed in Tables S4 and S5), only iron and ferritin levels were significantly associated with anemia ($p < 0.001$) (Table 3).

Another analysis was conducted using linear regression with Hb level as a continuousdependent variable. The supplementary tables (S6 to S10) present the results of the univariable linear regression analysis examining the association between Hb and sociodemographic factors (Table S6), reproductive factors (Table S7), supplements and dietary factors (Table S8), clinical factors and anthropometric measurements (Table S9), and laboratory factors (Table S10). Overall, the results of this analysis confirmed those of the logistic regression analysis. The associations between Hb level and both underlying factors and direct factors in multivariable linear regression are shown in Table (4). Among the underlying factors, treatment to assist with pregnancy and current use of supplements were significant predictors in the final model, adjusted $\beta = 2.41$ (95%CI: 0.007 to 4.82; $p = 0.044$) and adjusted $\beta = 4.26$ (95%CI: 1.08 to 7.44; $p = 0.007$), respectively. In this analysis women who were underweight were more likely to have lower Hb levels. Theoretical evidence suggests that iron and ferritin are in the causal pathway between 25-hydroxyvitamin D and

Table 3 Factors associated with anemia in 1,108 pregnant women in multivariable analysis

Characteristics	Total	Prevalence of anemia		Odds Ratio [95% CI]		*p*
		n	(%)			
Underlying factors[1]						
Current use of supplements and vitamins						
No	61	28	(45.90)		[Ref.]	0.049
Yes	1,024	276	(26.95)	0.52	[0.28–0.99]	
Vitamin D status[2]						
Vitamin D deficiency/insufficiency	845	254	(30.06)		[Ref.]	0.018
Vitamin D sufficiency	260	57	(21.92)	0.63	[0.43–0.92]	
Direct factors[3]						
Iron (umol/L)						
< 9 umol/L	340	162	(47.65)		[Ref.]	< 0.001
9–30 umol/L (normal)	730	137	(18.77)	0.35	[0.26–0.48]	
> 30 umol/L	32	11	(34.38)	0.51	[0.22–1.18]	
Ferritin ug/L						
< 13 ug/L	358	159	(44.41)		[Ref.]	< 0.001
13–150 ug/L (normal)	703	128	(18.21)	0.45	[0.32–0.62]	
> 150 ug/L	44	24	(54.55)	2.50	[1.25–4.95]	

[1]Adjusted for nationality, age group, mother education, father education, type of housing, age of menarche (categorical), age at first marriage (continuous), age at first pregnancy (continuous), treatment to help get pregnant, becoming pregnant while using contraception, passive smoking, Consumption of caned sugar-sweetened beverages, Consumption of energy drinks, and BMI categories. [2] Defined as 25-hydroxyvitamin D < 75 nmol/L

[3]Adjusted for hypertension, type 2 diabetes, presence of other disease condition, vitamin B12 (categorical), and RBC folate (categorical)

Hb levels [38, 39]. Therefore, 25-hydroxyvitamin D was included in the underlying factors (i.e., rather than in the direct factors such as iron and ferritin). Sufficient vitamin D status was associated with higher Hb level in the final model, adjusted $\beta = 2.43$ (95%CI: 0.74 to 4.12; $p = 0.004$). Among the direct factors, iron, ferritin, and folate were significantly associated with Hb levels in the final model. In this analysis, iron and ferritin levels alone explained 18% of the variability in Hb levels, compared to 19% explained by all direct factors (saturated model). Although normal ferritin level was associated with higher Hb level, it was surprising to observe that very high ferritin levels (> 150 ug/L) were associated with lower Hb levels (Table 4).

Discussion

This study estimated the current prevalence of anemia in pregnant women in Kuwait and investigated associated factors. Approximately 28% of pregnant women in their second or third trimester were found to have anemia, with most cases being mild or moderate anemia. According to the most recent WHO classification [40], anemia among pregnant women in Kuwait has moderate public health significance (designated for a prevalence range of 20–40%). The most important direct cause of anemia was iron deficiency, but several underlying factors were found to be associated with anemia, particularly in univariable analysis.

Our findings showed that anemia among pregnant women in Kuwait was lower than that reported in Saudi Arabia (34% [25] and 44% [26]), Egypt (51%) [41], and Bangladesh (44%) [42]. In Kuwait, a small study conducted over a decade ago reported a prevalence of 24% [28], slightly lower than our estimate, likely due to the inclusion of women in their first trimester. Anemia among pregnant women in Kuwait has moderate public health significance [40], with a prevalence lower than the global estimate (36%) [5, 6]. However, the prevalence in Kuwait appears much higher than that reported in developed countries like Norway (5.9%) [43] and the USA (16%) [4]. While direct comparisons are challenging due to methodological differences, such as the timing of assessments across trimesters and the use of venous versus capillary blood samples [15, 22], anemia in pregnant women in Kuwait seems less significant as a public health concern compared to low-income settings [44, 45].

The Hb threshold used to define anemia has a significant impact on both public health programs and clinical decision-making [15]. While we selected Hb cutoff point for defining anemia in pregnant women in accordance with the standards set by most organizations, including the WHO [2], CDC [35], and ACOG [36], the appropriateness of this cutoff point has been repeatedly questioned. The Hb threshold below which maternal and/or offspring adverse health outcomes occur remains uncertain [15]. Recently, using multinational data, Addo et al. proposed lowering the Hb cutoff point for defining anemia by 1.35 g/dL in children and 1.19 g/dL in nonpregnant women [14]. Several researchers have also suggested reducing the threshold for these demographic groups [46–51], although no similar work has been conducted for pregnant women. In our setting, reducing the Hb

Table 4 Factors associated with Hemoglobin level in 1,108 pregnant women in multivariable analysis

Characteristics	Total	Coefficient [95% CI]		*p*
Underlying factors[1]				
Current use of supplements and vitamins				
No	61		[Ref.]	0.007
Yes	1,024	4.26	[1.08 to 7.44]	
Treatment to help get pregnant				
No	991		[Ref.]	0.044
Yes	106	2.41	[0.007 to 4.82]	
BMI categories				
Underweight	24	-7.02	[-11.75 to -2.29]	0.031
Healthy weight	305		[Ref.]	
Overweight	375	-0.33	[-2.05 to 1.38]	
Obesity	285	-0.35	[-2.21 to 1.51]	
Vitamin D status[2]				
Vitamin D deficiency/insufficiency	845		[Ref.]	0.004
Vitamin D sufficiency	260	2.43	[0.74 to 4.12]	
Direct factors[3]				
Iron (umol/L)				
< 9 umol/L	340		[Ref.]	< 0.001
9–30 umol/L (normal)	730	6.12	[4.66 to 7.58]	
> 30 umol/L	32	3.47	[-0.29 to 7.20]	
Ferritin ug/L				
< 13 ug/L	358		[Ref.]	< 0.001
13–150 ug/L (normal)	703	4.87	[3.40 to 6.33]	
> 150 ug/L	44	-5.31	[-8.63 to -2.00]	
RBC Folate ng/mL				
< 263 ng/mL	116		[Ref.]	0.015
≥ 283 ng/mL	990	2.46	[0.46 to 4.45]	

[1]Adjusted for nationality, age group, mother education, father education, type of housing, age first marriage (categorical), age at first pregnancy (categorical), times since last delivery (categorical), getting pregnant while using contraception, passive smoking, consumption of carbonated drinks, during the last 3 months, consumption of caned sugar-sweetened beverages, consumption of energy drinks, and consumption of fruits. [2] Defined as 25-hydroxyvitamin D < 75 nmol/L

[3]Adjusted for presence of other disease condition and vitamin B12 (categorical)

threshold by 5 g/L (0.5 g/dL) subsequently decreased the prevalence of anemia to only 15.1%. This new cutoff point aligned with the one used in the UK during the third trimester, which is 105 g/L (10.5 g/dL) [23]. This observation underscores that even minor adjustments to the Hb cutoff point can significantly impact the estimated burden of anemia. It highlights the importance of ongoing efforts to establish an evidence-based Hb cutoff point to enable accurate assessment of anemia burden and facilitate comparisons across different settings and time periods.

Anemia in our setting primarily appears to be linked to low iron levels, as evidenced by the majority of cases presenting with microcytic anemia (MCV < 80 fL). Given that mild iron deficiency anemia rarely results in MCV levels below 80 fL [3], it is possible that pregnant women with mild anemia with normal MCV may also have iron deficiency anemia. Maintaining adequate iron levels throughout pregnancy is crucial to meet the demands of fetal growth and normal brain development [52]. It is important to note that fetuses accumulate iron stores for postnatal use, particularly during the last trimester, through preferential transfer from the mother, regardless of her iron status [17, 24]. However, professional organizations disagree on screening and supplementation for iron deficiency during pregnancy [24]. The UK adopts a more aggressive approach to screening and supplementation [23, 24], whereas the US takes a less proactive approach [53]. Notably, the US Preventive Services Task Force (USPSTF) is currently updating its recommendations on iron screening and supplementation during pregnancy [54]. In Kuwait, pregnant women are screened for iron deficiency only if they fall within certain risk categories, such as having a previous diagnosis of iron deficiency, diabetes, smoking, inflammatory bowel syndrome, being multiparas, a history of abnormal uterine bleeding, being underweight or obese, having undergone bariatric surgery, or following a vegetarian diet. It is noteworthy that the prevalence of anemia was significantly lower in women taking iron supplements (26.95% vs. 45.90%); and moderate anemia (Hb 70–99 g/L) was much less common in pregnant women who took supplements

compared to those who did not (7.81% vs. 22.95%). Interestingly, our data indicated that while normal ferritin levels were protective against anemia, extremely high ferritin levels (>150 ng/L) were associated with increased risk of anemia (Table 3) and lower Hb levels (Table 4). This observation, however, was limited to a small number of pregnant women and may be explained by the fact that ferritin is an acute phase reactant, which increases significantly in response to inflammation. Inflammation (such as in cases of clinical or subclinical infection) can lead to anemia, and in such cases, high ferritin levels do not reflect excess iron storage [55].

According to the conceptual framework [37], we identified multiple underlying factors associated with anemia in pregnant women through univariable analysis, including nationality, mothers' and fathers' education, fathers' income, type of housing, and age at first marriage (or pregnancy). These results align with the finding of the linear regression analysis, which examined both underlying and direct factors associated with Hb level as a continuous outcome variable. These findings underscore the significance of socio-cultural factors in anemia, even in affluent settings like Kuwait, where citizens benefit from a high standard of living, free medical care, and highly subsidized food. However, in our multivariable analysis, only current supplement use, and vitamin D status were significant predictors among the underlying factors, while ferritin and iron levels emerged as the most important predictors among the direct factors.

In our study, vitamin D status was associated with anemia in univariable analysis and multivariable analysis (Table 3). Additionally, vitamin D levels were a significant predictor of Hb level in the linear regression analysis (Table 4). It has been suggested that vitamin D, in conjunction with other vitamins, plays a role in regulating hepcidin, a hormone responsible for controlling the storage and distribution of iron in human tissues [38, 39, 56]. While previous studies on the link between vitamin D levels and anemia in pregnant women have produced conflicting results, a recent literature review concluded that pregnant women with vitamin D deficiency have 61% higher odds of developing anemia [57]. However, despite the theoretical biological plausibility of this association, it remains unclear whether it is causal. Reviews have indicated an association based on observational studies but have not found conclusive evidence from interventional studies [57, 58].

This is the only major study that estimated the prevalence of anemia in pregnant women in Kuwait over the past decade. The study size was sufficient to precisely estimate the prevalence and identify important risk factors. Data were collected on most key risk factors, and a conceptual framework was used to analyze the data. However, the study has several limitations, including data collection through face-to-face interview, which may introduce interviewer bias and respondent bias, particularly due to social desirability. Additionally, data on parasitic infections, such as malaria and helminths, were not collected. Nevertheless, given Kuwait's arid desert environment, it is reasonable to assume that parasitic infections play a negligible role in anemia among pregnant women in this region. While our study was conducted in a single setting, this location accounts for nearly one-third of all deliveries in Kuwait, making it a significant site for understanding anemia in this population.

Conclusion

Approximately 28% of pregnant women in Kuwait have anemia, with the majority classified as mild or moderate cases. Iron deficiency remains the primary direct cause of anemia during pregnancy in this setting. The estimated prevalence of anemia is highly influenced by the Hb threshold used to define anemia, a topic currently under vigorous debate. While the prevalence of anemia among pregnant women in Kuwait appears lower than in other settings, our findings suggest that improved guidelines for screening and iron supplementation could further reduce anemia and provide additional benefits for maternal and child health. Although we identified a few key risk factors for anemia in pregnant women, our findings should be interpreted cautiously due to the use of face-to-face interviews for data collection, which may introduce interviewer and respondent biases.

Abbreviations

WHO	World Health Organizatio
CDC	Centers for Disease Control and Preventio
Hb	Hemoglobin
BMI	Body Mass Index
CBC	Complete Blood Count
MCV	Mean Corpuscular Volume
Fe	Iron
SD	Standard Deviation
AOR	Adjusted Odds Ratio
>ACOG	College of Obstetricians and Gynecologists

Supplementary Information

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Supplementary Material 1

Author contributions

AAT: designed the study, applied for fund, analyzed the data, and drafted the paper. AHZ: contributed to the data analysis, helped drafting the paper, and revised the manuscript. MSH: contributed to the study design, application for fund, and data collection/interpretation in addition to revising the manuscript. RSB: contributed to the study design and application for fund in addition to revising the manuscript. SAK: contributed to the study design and application for fund in addition to revising the manuscript. All authors have read and approved the manuscript for publication.

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Data availability
Data analyzed in this study will be available from the corresponding authors upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethics committee at the Ministry of Health, Kuwait (Ref: project 173/2014; date: February 14th, 2017) and the Institutional Review Board at Old Dominion University Ref: 1517949). Written informed consent was taken from each study participant before recruitment.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing or conflict of interest.

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