

Association of Iron Deficiency Anemia in *Helicobacter pylori*-Infected Pregnant Women and *vacA* Allele Distribution in Sana'a, Yemen

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Abstract

Background: *Helicobacter pylori* (*H. pylori*) is a causative agent of several gastrointestinal disorders and is associated with iron deficiency anemia (IDA). This study examined the association between *H. pylori* and IDA among Yemeni pregnant women and assessed *vacA* s1/m1 alleles in IDA isolates.

Methods: Pregnant women were assessed for *H. pylori* using a stool antigen rapid test, and a subset was evaluated for hemoglobin and serum ferritin levels. *H. pylori* isolated from participants with IDA were analyzed for *vacA* s1 and m1 using PCR.

Results: Out of 184 pregnant women, *H. pylori* was detected in 76.1% (n=140), of which 46.4% (n=65) had anemia. Serum ferritin was measured in 48 *H. pylori* anemic patients, of whom 47.9 % (n = 23) had IDA. Among the 23 *H. pylori* isolates from IDA, *vacA* s1 was detected in 78.3% (n=18), while *vacA* m1 was not detected in any sample.

Conclusion: No significant association was found between *H. pylori* and IDA in this study. Further studies with larger sample sizes and multiple IDA diagnostic tools are warranted to clarify this relationship during pregnancy.

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Introduction

Helicobacter pylori (*H. pylori*) is a Gram-negative spiral bacterium identified as a significant human pathogen that can cause various upper gastrointestinal disorders (Kusters et al., 2006). It is one of the most common infections, affecting 50% of the population worldwide, and has been linked to extra-gastric manifestations such as anemia and iron-deficiency anemia (IDA) (Yu et al., 2019; Pu et al., 2025).

Anemia is defined as insufficient hemoglobin (Hb) concentration to meet physiological demands, affecting 37% of pregnant women (Al-Jawaldeh et al. 2021; WHO, 2025). Among different types of anemia, IDA is the most common during pregnancy, and it accounts for 40% of maternal deaths in developing countries (Nashaat and Mansour, 2014). The need for iron during pregnancy increases with gestational age, and insufficient intake has negative effects on the maternal immune system and fetal development, including intrauterine growth retardation, premature birth, and low birth weight (Ali et al., 2017; Abdella et al., 2020).

Since Hb levels increase with altitude and decrease with trimester, the Hb cutoffs in pregnant women were extracted from the updated criteria of the WHO (WHO, 2024). Additionally, serum ferritin levels during pregnancy should be higher than 30 ug/L to meet fetal demands; otherwise, iron deficiency is diagnosed (Malinowski & Murji 2021).

Several studies worldwide have reported an association between *H. pylori* and IDA. However, there is insufficient research on this topic in Yemen. One published case-control study in Sana'a City on 50 *H. pylori* and 50 healthy adults showed no significant difference in IDA rates (Al-absi et al., 2025).

One suggested mechanism explaining the association between *H. pylori* and IDA development is bacterial-host competition for iron-binding proteins. Several *H. pylori* genes have been proposed to be associated with increased virulence and IDA development, such as *vacA* (Kato et al., 2017). This study aimed to assess the association between *H. pylori* and IDA among Yemeni pregnant women and to describe the distribution of *vacA* *s1* and *m1* alleles in available *H. pylori*-positive isolates from women with IDA.

Materials and Methods

Study design and setting

A cross-sectional study was conducted among pregnant women attending Al-Zahrawi Public Medical Center, Al-Safa'a Specialized Hospital, and private outpatient gynecology clinics in Sana'a, Yemen, between June 2022 and April 2023. The sample size was calculated using Epi Info StatCalc (version 7.2.5.0) assuming a 95% confidence level, a 5% margin of error, and an expected prevalence of 54.7% based on Abdella et al. (2020). A finite population of 307 pregnant women attending the participating facilities during the study period was used, yielding a minimum required sample size of 170 participants. A total of 184 pregnant women were enrolled.

Detection of *H. pylori* infection

Stool samples were collected from all participants and tested for *H. pylori* using a commercial stool antigen rapid test cassette (Hangzhou AllTest Biotech Co., Ltd., China). Stool antigen testing is a non-invasive method used to detect active infection (Nieuwenburg et al., 2022).

Iron deficiency anemia assessment

Venous blood samples were collected to measure Hb levels for all participants using a 5-part hematology analyzer (Rayto Hemaray/ICEN, Guangdong, China). Serum ferritin was measured for a subset of 61 participants using the Cobas E411 analyzer (Roche Cobas E411, Hitachi, Ltd., Japan). To distinguish elevated serum ferritin due to inflammation to prevent IDA misdiagnosis, qualitative C-reactive protein (CRP) was evaluated using a latex agglutination CRP reagent (Monlab SL, Barcelona, Spain).

Definitions of anemia and iron deficiency anemia

Anemia was defined according to the updated WHO criteria (WHO, 2024), adapted for the altitude of Sana'a City (~2200 m). Hb levels <12.4 g/dL in the first or third trimester, and <11.9 g/dL in the second trimester were classified as anemia. IDA was defined as anemia with serum ferritin <30 µg/L.

Culture of stool-derived *H. pylori* (subset) and preparation of selective media

Approximately 1 – 2 g of stool samples from *H. pylori*-positive participants were cultured in Campylobacter Agar Base for Helicobacter pylori (HIMedia, Ref: M994-500G, India) with 7% (v/v) horse serum (HIMedia, Ref: 400086, India) and one vial of Campylobacter Selective Supplement for *H. pylori* (HIMedia, Ref: FD090, India), rehydrated according to the manufacturer's instructions, and added aseptically.

Cholestyramine (0.2 g) and glycerol were added to the culture to support viability and moisture. The stool samples were streaked using a three-way streak technique under sterile conditions, sealed to preserve moisture, and incubated at 37°C in a candle jar with humidified conditions for 2–5 days until colonies were observed. Suspected colonies underwent biochemical tests for positive catalase, oxidase, and urease tests.

DNA extraction

Cultures with observed *H. pylori* growth confirmed by biochemical tests were suspended in Brucella broth prepared from Brucella Broth Base (HIMedia, Ref: M348, India) with 5% (v/v) horse serum (HIMedia, Ref: 400086, India).

DNA extraction was performed at the National Center for Public Health Laboratories. Approximately 200 µL of each culture in Brucella broth was transferred into a 1.5 mL microcentrifuge tube and extracted using the Presto Mini gDNA Bacteria Kit (Geneaid, Ver. 02.10.17, Taiwan) according to the manufacturer's instructions.

Conventional PCR amplification of *vacA* alleles (s1 and m1)

PCR was conducted at the Sana'a University Veterinary Medicine Department and the Science and Technology Hospital PCR Department. Conventional PCR was performed in a thermocycler (Genius Jencons-PLS, Techne/Cambridge, Model FGEN02TD, England) using the SuperScript III Platinum One-Step system (Thermo Fisher Scientific, Ref: 11732-020, USA). Primers targeting *vacA* s1 and *vacA* m1 were adopted from prior studies ([Atherton et al., 1995](#); [Kato et al., 2017](#)):

- *vacA* s1: forward 5'-ATGGAAATACAACAAACACAC-3'; reverse 5'-CTGCTTGAATGCGCCAAA-3'
- *vacA* m1: forward 5'-GGTCAAAATGCGGTCATGG-3'; reverse 5'-CCATTGGTACCTGTAGAAAC-3'

Each reaction consisted of 12.5 µL of 2× reaction buffer, 1 µL Taq polymerase, 4 µL DNA template, 1 µL forward primer, 1 µL reverse primer, and 5.5 µL distilled water. Cycling conditions were as follows: initial denaturation at 95°C for 5 min; 35 cycles of 95°C for 1 min, 52°C for 1 min, and 72°C for 1 min; followed by a final extension at 72°C for 10 min.

PCR products were run on a 1.5% agarose gel with ethidium bromide (20 µL). Samples (7 µL) and a 100 bp DNA ladder (4 µL) were loaded and electrophoresed for 45 min at low voltage. The bands were visualized using an LED gel documentation system. A band at the expected size (259 bp for *vacA* s1; 290 bp for *vacA* m1) was considered positive. Distilled water was used as a negative control.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Categorical variables were presented as frequencies and percentages, and continuous variables were presented as mean ± standard deviation (SD), 95% confidence interval (CI), and range, as appropriate. Pearson's chi-square test or Fisher's exact test was used to examine associations between categorical variables, and the independent-samples t-test was used to compare continuous variables between two groups. Analyses were conducted using available data for each variable.

Results

Participant characteristics

This study included 184 pregnant women. As shown in Table 1, most participants were third trimester non-smokers with elementary-level education and did not use antibiotics in the previous month.

Table 1: Demographics of the participants

Demographics	No.	%
Trimester*	≤ 12 weeks	53
	12 – 24 weeks	52
	> 24 weeks	72
	Total Available	177
Antibiotic Use*	No	131
	Yes	35
	Total Available	166
	No	93
Smoking*	Occasional	12
	Daily	5
	Total Available	110
	Illiterate	14
Education*	Elementary	48
	High School	32
	University and above	13
	Total Available	107

No.: number of participants; %: percentage; *Data collected only when applicable

Prevalence of *H. pylori* and its association with demographic characteristics

The overall prevalence of *H. pylori* in this study was 76.1% (n=140/184). As shown in Table 2, no significant association was found between *H. pylori* infection and trimester, antibiotic use, smoking status, or education.

Iron deficiency anemia in the ferritin-tested subset

Of the *H. pylori* positive participants, 46.4% were classified with anemia (n=65/140) according to the WHO updated criteria. Table 3 summarizes Hb distribution between *H. pylori* positive and negative groups. Hb in *H. pylori* positive group was lower than *H. pylori* negative group without a significant difference.

Serum ferritin was measured in a subset of 61 participants due to limited serum ferritin tests. Of the 61 participants, 13 were lost due to logistic challenges or delivery. Therefore, serum ferritin was measured in 48 *H. pylori* positive participants and serum ferritin for 13 *H. pylori* negative participants was incorporated for comparison.

Table 2. Association between *H. pylori* infection and selected demographic characteristics

Variable	Category	<i>H. pylori</i> positive	<i>H. pylori</i> negative	Total available	p-value
		n (%)	n (%)		
Trimester	≤ 12 weeks	37 (69.8)	16 (30.2)	53	0.489
	12 – 24 weeks	39 (75.0)	13 (25.0)	52	
	> 24 weeks	57 (79.2)	15 (20.8)	72	
Antibiotic use	No	93 (71.0)	38 (29.0)	131	0.708
	Yes	26 (74.3)	9 (25.7)	35	
Smoking	No	65 (69.9)	28 (30.1)	93	0.842
	Occasional	9 (75.0)	3 (25.0)	12	
	Daily	4 (80.0)	1 (20.0)	5	
	Illiterate	8 (57.1)	6 (42.9)	14	
Education	Elementary	37 (77.1)	11 (22.9)	48	0.432
	High school	23 (71.9)	9 (28.1)	32	
	University and above	8 (61.5)	5 (38.5)	13	

Values are presented as n (%) within each category. Denominators vary according to data availability.

Table 3. Hemoglobin and serum ferritin levels according to *H. pylori* status

Variable	Statistic	<i>H. pylori</i> positive	<i>H. pylori</i> negative
Hb (g/dL) n = 184	No. participants	140	44
	Mean ± SD	12.15 ± 1.30	12.26 ± 1.26
	95% CI	11.9 – 12.4	11.9 – 12.6
	Range	8.0 – 15.3	9.6 – 15.0
S. Ferritin (ug/L) n= 61	No. participants	48	13
	Mean ± SD	28.96 ± 20.54	25.0 ± 13.97
	95% CI	23.0 – 34.9	16.92 – 33.08
	Range	5.0 – 105.70	10.00 – 48.10

Hb: hemoglobin; S. Ferritin: serum ferritin; SD: standard deviation; CI: confidence interval

IDA was found in 23/48 (47.9%) *H. pylori* positive participants and 7/13 (53.8%) of *H. pylori* negative participants. The mean serum ferritin level in *H. pylori* IDA group was higher (28.96 ± 20.54) than *H. pylori* negative group (25.0 ± 13.97) as described in Table 3. CRP levels of +2/+3 indicative of moderate/severe inflammation were detected in six IDA and three of the non-IDA

participants. These participants have high inflammation levels that can raise serum ferritin masking the severity of its depletion.

Table 4: Distribution of *H. pylori* infection between IDA and non-IDA cases

IDA classification	<i>H. pylori</i>		Total
	Positive	Negative	
IDA	23	7	30
Non-IDA	25	6	31
Total	48	13	61

Distribution of *vacA* alleles in *H. pylori*-positive IDA isolates

Among the 23 *H. pylori*-positive IDA isolates analyzed by PCR, *vacA s1* was detected in 78.3% (n=18/23), whereas *vacA m1* was not detected in any isolate. Representative gel electrophoresis findings are shown in Figure 1. A summary of the participant flow is shown in Figure 2.

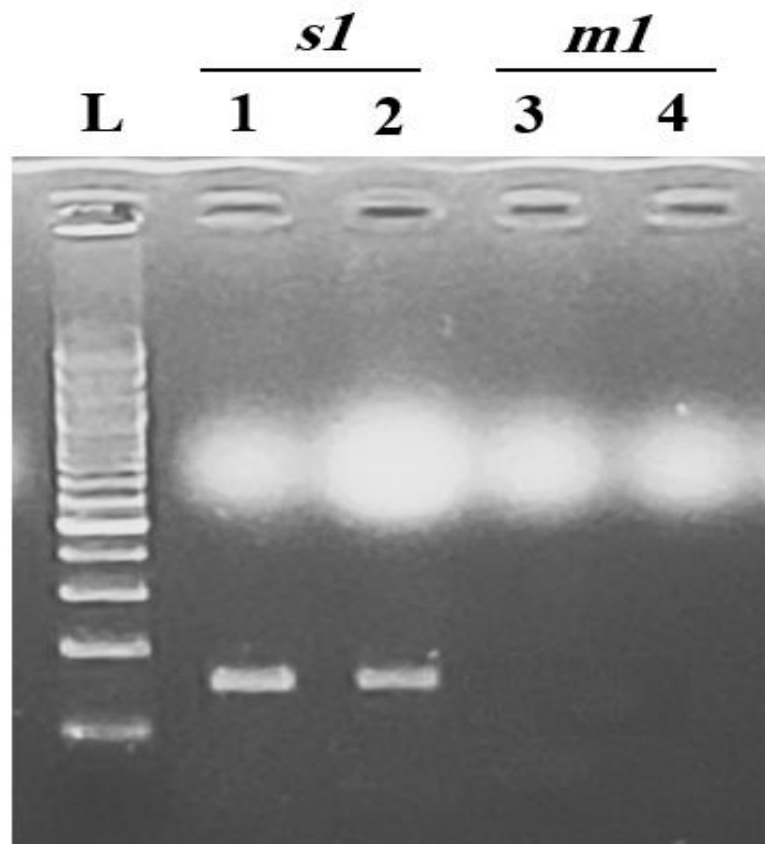


Figure 1. Representative gel electrophoresis of *vacA s1* and *vacA m1* PCR products in *H. pylori*-positive IDA isolates. L indicates the 100 bp DNA ladder; lanes 1 and 2 show *vacA s1*-positive amplicons at 259 bp, whereas lanes 3 and 4 show absence of *vacA m1* amplification at 290 bp.

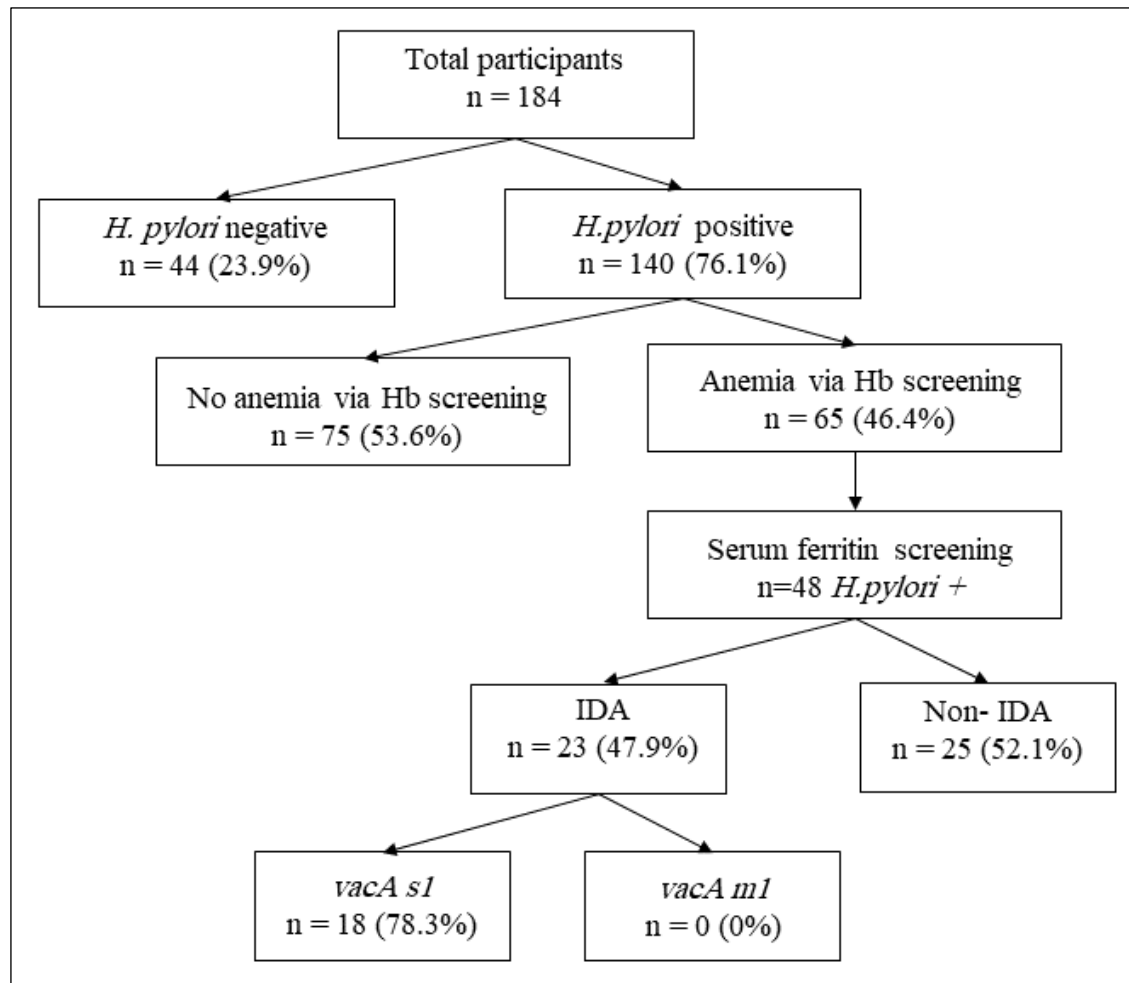


Figure 2. Flow diagram depicting participant selection through detection of *H. pylori*, anemia screening based on hemoglobin levels, iron deficiency anemia (IDA) classification based on serum ferritin in the tested subset, and *vacA* s1/m1 genotyping by PCR.

Discussion

In this study, pregnant women were recruited to assess the association between *H. pylori* and IDA, while the distribution of *vacA* alleles was described in *H. pylori*-positive IDA isolates. The study showed a high prevalence of *H. pylori* and anemia in the overall sample, while IDA was identified in nearly half of the ferritin-tested subset. *H. pylori* is endemic in Yemen, and anemia is a severe public health problem. However, no statistical association was observed between *H. pylori* and IDA, and the dominant *H. pylori vacA* genotype isolated was s1+/m1-.

The overall prevalence of *H. pylori* detected by stool antigen in this study was 76.1%. Data on *H. pylori* prevalence in pregnant Yemeni women is scarce; however, [Almashhadany et al., \(2023\)](#) reported higher infection rates in females than males among 460 adults in Dhamar City. Similarly, [Al-Awadhi et al., \(2020\)](#) documented a 39.0% overall prevalence in Ibb city, with diabetics showing significantly higher rates (49%) versus non-diabetics (29%). Given that pregnancy induces hormonal and immunological changes that increase susceptibility to

infections, elevated *H. pylori* prevalence is expected among pregnant women in Yemen (Yisak et al., 2022).

Globally, *H. pylori* investigations during pregnancy rely on serological detection. Regional serological prevalence show rates of 69.8%, 62%, and 54.7% of pregnant women in Sudan, Iraq, and South Ethiopia, respectively (Mubarak et al., 2014; Al-Dorri et al., 2022; Abdella et al., 2020). This supports the high prevalence of *H. pylori* in Yemen and neighboring regions.

The present investigation did not find a significant association between *H. pylori* and education or smoking. In a recent study comparing *H. pylori* detection techniques in Dhamar, the stool antigen test was not associated with education ($p=0.089$) or smoking ($p=0.720$) compared to antibody detection which did report a significant association with smoking only ($p=0.003$) (Al Ofairi et al., 2024). Another investigation in Sana'a showed that *H. pylori* was not associated with smoking ($p=0.73$) (Al-Absi et al., 2025).

In this study, the prevalence of IDA among a subset of *H. pylori* positive pregnant women was 47.9%. Although our findings do not represent Sana'a City due to the small sample size, they align with the high IDA prevalence rates in the region. In a Saudi Arabian systematic review, the reported pooled prevalence of IDA in pregnant women was 75.3% (Alhamed et al., 2024). IDA is the primary cause of anemia among pregnant women, which can be caused by nutritional deficiencies and chronic infections that are highly prevalent in developing countries (WHO, 2025).

In this study, pregnant women with IDA had a higher mean serum ferritin level in the presence of *H. pylori* than without. An increase in serum ferritin levels in the infected group may be a response to *H. pylori* inflammation (Kishore et al., 2021). Serum ferritin is the primary measurement of iron stores; however, it is sensitive to inflammation, tissue damage, immune response, and infection (Namaste et al., 2017). In the present study, nine of the ferritin-tested subset showed moderate-to-severe inflammation. This may have influenced serum ferritin levels in a proportion of participants suggesting masked cases of IDA.

Many studies support the association between IDA and *H. pylori*; however, a few do not, mainly because they found no statistical significance (Sikorska, et al., 2021). In this study, mean Hb with *H. pylori* (12.15 ± 1.30 g/dL) was lower than that of the non-infected group (12.26 ± 1.26 g/dL), but the difference was not significant. In Taiwanese adults, mean Hb among *H. pylori*-infected individuals (13.57 g/dL) was not significantly different from that of the non-infected group (13.65 g/dL) (Shih et al., 2013). Similarly, Iranian children with unknown abdominal pain and dyspepsia mean Hb in the infected group (12.1 ± 1.3 g/dL) was not significantly different from the uninfected group (12.9 ± 1.2 g/dL) (Zahmatkeshan et al., 2019). In addition, Swedish female high school athletes with *H. pylori* infection had a mean Hb (13.36 g/dL) that was not significantly different from that of uninfected controls (13.70 g/dL) (Sandström et al., 2014). Similarly, these studies showed no significant difference in serum ferritin levels with or without *H. pylori*. This supports our current finding that showed differences in Hb and serum ferritin without a statistical significance.

VacA protein is a vacuolating cytotoxin that induces vacuolization in host epithelial cells and has been reported by [Kato et al., \(2017\)](#) to be expressed 3.5 times more in IDA isolates than non-IDA *H. pylori*-infected Japanese children by microarray analysis.

VacA protein is expressed with varying severity according to the combination of s1 or s2 with m1 or m2. The s1/m1 combination shows the highest vacuolization activity, whereas s2/m2 shows absent vacuolization activity ([Brasil-Costa et al., 2022](#)). *In this investigation, vacA* s1 was detected in the majority of our participants, whereas *vacA* m1 was absent.

Studies on *vacA* genotypes in the Middle East reported that the s1 allele was significantly predominant in Turkey, Iraq, and Iran than in Saudi Arabia, Israel and Jordan ([Sugimoto et al., 2009](#)). This implies that *H. pylori vacA* pattern in Yemen is closely similar to that in Turkey, Iraq, and Iran.

Conclusion

This study did not detect a statistically significant association between *H. pylori* and IDA in the ferritin-tested subset. The small sample size, CRP detected inflammation, and use of a single diagnostic tool for classifying IDA are some limitations of this study. Future investigations should adhere to the updated WHO criteria for classifying anemia and IDA, include a larger sample, incorporate genetic analyses exploring other *H. pylori* virulence genes associated with IDA, utilize multiple diagnostic tests for IDA, and measure CRP quantitatively to calculate true serum ferritin levels. If bacterial–host iron competition contributes to IDA development via *vacA*, we hypothesize that the observed *vacA* allele pattern (s1 detected with absent m1) may be associated with lower cytotoxic potential compared with the *vacA* s1/m1 combination; however, this interpretation remains speculative and requires confirmation.

Abbreviations

H. pylori – Helicobacter pylori

IDA – Iron Deficiency Anemia

Hb – Hemoglobin

CRP – C – reactive protein

PCR – Polymerase chain reaction

WHO – World Health Organization

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Declarations

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Author Contributions

Conceptualization: W.H.A.; Methodology: S.M.A, A.M.A.; Investigation: W.H.A., A.A.Z.; Data curation: W.H.A.; Formal analysis: W.H.A.; Visualization: A.A.Z.; Writing-original draft: W.H.A.; Writing-review & editing: S.M.A., H.A.A., A.M.A.; Supervision: S.M.A., H.A.A. All authors have read and agreed to the published version of the manuscript.

Competing Interests

The authors declare no competing interests.

Ethics Statement

Ethical approval was granted by the Department Council (Microbiology Section), Department of Biological Sciences, Faculty of Science, Sana'a University (Decision No. 480, 05/06/2023), which serves as the official ethical approval identifier. Due to literacy constraints, oral informed consent was obtained from all participants, and the oral consent procedure was approved by the same ethics body. The study was conducted in accordance with the Declaration of Helsinki and relevant institutional regulations.

Data Availability Statement

The raw data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI disclosure

The authors confirm that no generative AI tools were used in the writing, analysis, editing, or preparation of this manuscript.

References

- Abdella, B., Ibrahim, M., Tadesse, I., Hassen, K., & Tesfa, M. (2020). Association between *Helicobacter pylori* infection and occurrence of anemia among pregnant women attending antenatal care in Kulito Health Center, Halaba Zone, South Ethiopia, 2018. *Anemia*, 2020(1), 6574358. <https://doi.org/10.1155/2020/6574358>
- Al-Absi, B., Al-Henhena, N., Almorish, M. A. W., & Othman, A. M. (2025). The relationship between *Helicobacter pylori* infection and iron deficiency anemia in Yemeni adults. *Sana'a University Journal of Medicine and Health Sciences*, 19(1), 164–169. <https://doi.org/10.59628/jchm.v19i1.1435>
- Al-Awadhi, E., Bahaj, S., Al-Oferi, B., Esmail, A., & Al-Arnoot, S. (2020). *Helicobacter pylori* infection among patients with type II diabetes mellitus. *J Diab Metab Disorder Control*, 7(2), 53–56. <https://doi.org/10.15406/jdmdc.2020.07.00200>

- Al-Dorri, A., Salih, N. I., & Khuder, H. S. (2022). Serological detection of *Helicobacter pylori* infection in pregnant women related to ABO blood group. *Archives of Razi Institute*, 77(2), 591–597. <https://doi.org/10.22092/ari.2022.357092.1970>
- Alhamed, M. S., Alhashim, A. A. A., & Al Joher, A. (2024). Prevalence and risk factors of iron deficiency anemia in Saudi Arabia: A systematic review. *Saudi Journal of Medical and Pharmaceutical Sciences*, 8(12), 823–828. <https://doi.org/10.36348/sjmps.2022.v08i12.016>
- Ali, M., Muhammad, E., Hameed, B., & Hasoobe, H. (2017). The impact of *Helicobacter pylori* infection on iron deficiency anemia in pregnancy. *Iraqi Journal of Hematology*, 66(2), 61–64. https://doi.org/10.4103/ijh.ijh_19_17
- Al-Jawaldeh, A., Taktouk, M., Doggui, R., Abdollahi, Z., Achakzai, B., Aguenau, H., et al. (2021). Are countries of the Eastern Mediterranean region on track towards meeting the World Health Assembly target for anemia? A review of evidence. *International Journal of Environmental Research and Public Health*, 18(5), 2449. <https://doi.org/10.3390/ijerph18052449>
- Almashhadany, D. A., Mayas, S. M., Mohammed, H. I., Hassan, A. A., & Khan, I. U. (2023). Population- and gender-based investigation for prevalence of *Helicobacter pylori* in Dhamar, Yemen. *Canadian Journal of Gastroenterology and Hepatology*, 2023(1), 3800810. <https://doi.org/10.1155/2023/3800810>
- Al-Ofairi, B. A., Saeed, M. K., Al-Qubaty, M., Abdulkareem, A. M., & Al-Jahrani, M. A. (2024). Diagnostic value of IgG antibody and stool antigen tests for chronic *Helicobacter pylori* infections in Ibb Governorate, Yemen. *Scientific Reports*, 14(1), 7536. <https://doi.org/10.1038/s41598-024-58165-w>
- Atherton, J. C., Cao, P., Peek, R. M., Tummuru, M. K., Blaser, M. J., & Cover, T. L. (1995). Mosaicism in vacuolating cytotoxin alleles of *Helicobacter pylori*: association of specific *vacA* types with cytotoxin production and peptic ulceration. *Journal of Biological Chemistry*, 270(30), 17771–17777. <https://doi.org/10.1074/jbc.270.30.17771>
- Brasil-Costa, I., Souza, C. D. O., Monteiro, L. C. R., Santos, M. E. S., Oliveira, E. H. C. D., & Burbano, R. M. R. (2022). *H. pylori* infection and virulence factors *cagA* and *vacA* (s and m regions) in gastric adenocarcinoma from Pará State, Brazil. *Pathogens*, 11(4), 414. <https://doi.org/10.3390/pathogens11040414>
- Kato, S., Osaki, T., Kamiya, S., Zhang, X. S., & Blaser, M. J. (2017). *Helicobacter pylori sabA* gene is associated with iron deficiency anemia in childhood and adolescence. *PLoS ONE*, 12(8), e0184046. <https://doi.org/10.1371/journal.pone.0184046>
- Kishore, G., Ejaz, M., Kumar, J., Lal, A., Tahir, H., Anjum, Z., et al. (2021). Association between *Helicobacter pylori* infection and serum iron profile. *Cureus*, 13(9), e17925. <https://doi.org/10.7759/cureus.17925>
- Kusters, J. G., Van Vliet, A. H., & Kuipers, E. J. (2006). Pathogenesis of *Helicobacter pylori* infection. *Clinical Microbiology Reviews*, 19(3), 449–490. <https://doi.org/10.1128/cmr.00054-05>
- Malinowski, A. K., & Murji, A. (2021). Iron deficiency and iron deficiency anemia in pregnancy. *CMAJ*, 193(29), E1137–E1138. <https://doi.org/10.1503/cmaj.210007>
- Mubarak, N., Gasim, G. I., Khalafalla, K. E., Ali, N. I., & Adam, I. (2014). *Helicobacter pylori*, anemia, iron deficiency and thrombocytopenia among pregnant women at Khartoum, Sudan. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 108(6), 380–384. <https://doi.org/10.1093/trstmh/tru044>
- Namaste, S. M., Rohner, F., Huang, J., Bhushan, N. L., Flores-Ayala, R., Kupka, R., et al. (2017). Adjusting ferritin concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. *The American Journal of Clinical Nutrition*, 106(suppl_1), 359S–371S. <https://doi.org/10.3945/ajcn.116.141762>

- Nashaat, E. H., & Mansour, G. M. (2014). *Helicobacter pylori* and anemia with pregnancy. *Archives of Gynecology and Obstetrics*, 289, 1197–1202. <https://doi.org/10.1007/s00404-013-3138-8>
- Nieuwenburg, S. A. V., Mommersteeg, M. C., Wolters, L. M. M., van Vuuren, A. J., Erler, N., Peppelenbosch, M. P., et al. (2022). Accuracy of *H. pylori* fecal antigen test using fecal immunochemical test (FIT). *Gastric Cancer*, 25(2), 375–381. <https://doi.org/10.1007/s10120-021-01264-8>
- Pu, S., Zhuang, Z., Liu, N., Luo, Q., & Zhang, D. (2025). Research progress on the relationship between *Helicobacter pylori* infection and iron deficiency anemia. *Frontiers in Microbiology*, 16, 1552630. <https://doi.org/10.3389/fmicb.2025.1552630>
- Sandström, G., Rödger, S., Kaijser, B., & Börjesson, M. (2014). *Helicobacter pylori* antibodies and iron deficiency in female adolescents. *PLoS ONE*, 9(11), e113059. <https://doi.org/10.1371/journal.pone.0113059>
- Shih, H. Y., Kuo, F. C., Wang, S. S., Liu, Y. C., Wu, M. C., Chang, Y. P., et al. (2013). *Helicobacter pylori* infection and anemia in Taiwanese adults. *Gastroenterology Research and Practice*, 2013(1), 390967. <https://doi.org/10.1155/2013/390967>
- Sikorska, S., Lewkowicz, A., & Kedziora-Kornatowska, K. (2021). Association between infection of *Helicobacter pylori* and iron deficiency anemia of unknown origin: A systematic review. *Medical Science Pulse*, 15(2), 1–7. <https://doi.org/10.5604/01.3001.0014.8979>
- Sugimoto, M., Zali, M. R., & Yamaoka, Y. (2009). The association of *vacA* genotypes and *Helicobacter pylori*-related gastroduodenal diseases in the Middle East. *European Journal of Clinical Microbiology & Infectious Diseases*, 28(10), 1227–1236. <https://doi.org/10.1007/s10096-009-0772-y>
- World Health Organization. (2024). Guideline on haemoglobin cutoffs to define Anaemia in individuals and populations. World Health Organization. <https://www.who.int/publications/i/item/9789240088542>
- World Health Organization. (2025, February 10). Anaemia. <https://www.who.int/news-room/fact-sheets/detail/anaemia>
- Yisak, H., Belete, D., & Mahtsentu, Y. (2022). *Helicobacter pylori* infection and related factors among pregnant women at Debre Tabor General Hospital, Northwest Ethiopia, 2021: Anemia highly related with *H. pylori*. *Women's Health*, 18, 17455057221092266. <https://doi.org/10.1177/17455057221092266>
- Yu, Y., Cai, J., Song, Z., Wang, J., & Wu, L. (2019). Association of *Helicobacter pylori* infection with metabolic syndrome in aged Chinese females. *Experimental and Therapeutic Medicine*, 17(6), 4403–4408. <https://doi.org/10.3892/etm.2019.7509>
- Zahmatkeshan, M., Karimi, M., Geramizadeh, B., Eslaminasab, S., Esmailnejad, A., & Safarpour, A. R. (2019). Association between *Helicobacter pylori* infection and iron deficiency anemia in school-aged Iranian children. *Indian Pediatrics*, 56(5), 387–389. <https://doi.org/10.1007/s13312-019-1536-0>