Rocz Panstw Zakl Hig 2025;76(1):47-54
https://roczniki.pzh.gov.pl/ https://doi.org/10.32394/rpzh/203338

ORIGINAL ARTICLE

IRON STATUS IN WOMEN OF REPRODUCTIVE AGE IN MOROCCO

Bouchra Mekkaoui[1], Nabila Auajjar[1], Abdelhakim Yahyane[2], Laila El Ammari[2], Salwa Labzizi[2], Anouar Talouizte[2], Hasnae Gamih[2], Hassan Aguenaou[1], Kaoutar Benjeddou[1,3], Khalid El Kari[1]

[1]Ibn Tofail University-CNESTEN, Joint Research Unit in Nutrition and Food, RDC-Nutrition AFRA/IAEA, Rabat-Kénitra, Morocco
[2]Ministry of Health, Rabat, Morocco
[3]Higher Institute of Nursing and Health Technical Professions, Laayoune, Morocco

ABSTRACT

Background. Women of reproductive age (WRA) are one of the vulnerable population mostly impacted by anemia and iron deficiency (ID) worldwide.

Objective. This study aimed to assess the prevalence of anemia, ID, and iron deficiency anemia (IDA) among WRA in Morocco.

Material and Methods. This study included a representative sample of 2,012 non-pregnant women aged 15-49 years covering the entire territory of Morocco. Data collection encompassed socio-demographic information, anthropometric measurements, along with blood samples. Hemoglobin (Hb) concentration, serum ferritin (SF), and C-reactive protein (CRP) levels have been analyzed.

Results. The median of SF for the entire population was 27 µg/mL (Interquartile Range (IQR): 12-50 µg/mL), and the mean of Hb was 12.2 ± 1.5 g/dL. Significant differences were observed between urban and rural areas: urban SF median was 24 µg/mL (IQR: 11-45 µg/mL) versus rural 31 µg/mL (IQR: 15-55 µg/mL, $p < 0.001$), and urban Hb mean was 12.2 ± 1.5 g/dL compared to rural 12.4 ± 1.5 g/dL ($p = 0.02$). Furthermore, the prevalence of anemia, ID and IDA are consistently high; 34.3%, 29.8%, and 16.4%, respectively, with a significant difference in favor of urban areas.

Conclusion. Our findings from this national survey reveal that despite over a decade of implementing flour fortification strategy using electrolytic iron to address iron deficiency in Morocco, anemia, ID, and IDA remain widespread among WRA. Exploring alternative strategies or adopting a different form of iron for fortification could be beneficial in reducing or even eradicating iron deficiency among Moroccan women.

Keywords: *anemia, iron deficiency, women of reproductive age, hemoglobin, serum ferritin, Morocco*

INTRODUCTION

Anemia is a condition characterized by a deficiency of healthy red blood cells, which impairs the body's ability to deliver oxygen to vital tissues such as the brain, muscles, and heart [1]. On the other hand, ID refers to low levels of stored iron, leading to reduced SF and decreased saturation of the iron transport protein transferrin [2]. The World Health Organization (WHO) defines anemia as Hb levels below 12.0 g/dL in females, while ID is indicated by SF levels below 15 µg/mL [3, 4]. These conditions are global health concerns, primarily affecting WRA and children. Anemia affects millions of women worldwide, with higher prevalence rates in low- and middle-income countries [5]. The global prevalence of anemia in WRA was 30%, with significant geographical variations [5]. Indeed, nutritional deficiencies, infectious and inflammatory diseases, as well as genetic disorders of hemoglobin are the principal causes of anemia [6]. The most common type of anemia is IDA, which accounts for 50% of all anemia cases worldwide [7]. Anemia can have adverse effects on cognitive and physical abilities, leading to reduced economic productivity [8, 9], increased morbidity, and mortality [10].

Turning our focus to the situation in Morocco, previous surveys conducted in 1994 and 2000 indicated a high prevalence of anemia among WRA, with rates of 30.8% and 32.6% respectively [11]. In response, the Moroccan Ministry of Health (MH) implemented a National Program to Fight and Control Micronutrient Deficiencies, which included measures such as food fortification, dietary supplementation,

Corresponding author: Kaoutar Benjeddou, Higher Institute of Nursing and Health Technical Professions, Laayoune, Morocco; e-mail: kaoutar.benjeddou@uit.ac.ma

Publisher: National Institute of Public Health NIH - National Research Institute

and nutritional education [12]. Food fortification is considered a cost-effective and sustainable approach to increase iron intake and combat micronutrient deficiencies, especially ID, in the general population [13]. ID in Morocco has been estimated to cost 2 billion dirhams per year [14]. In 2005, a national wheat flour fortification program incorporating elemental electrolytic iron (EEI) was initiated to improve iron status across the country [15]. This program was followed by two sentinel surveys conducted in 2006 and 2008, which revealed anemia prevalence rates of 31.5% and 33.3% among WRA, respectively. During the same period, IDA accounted for 63.9% and 59.1% of all anemia cases [16]. However, these results indicated that the national coverage of the fortification program was only 38.3%, highlighting the need for higher coverage rates exceeding 80% to achieve significant improvements [17].

In 2014, the World Health Organization approved a global implementation plan on maternal, infant and young child nutrition [18] specifying six global nutrition goals for 2025 [18]. The second of which is, to achieve a 50% reduction in the prevalence of anemia among WRA by 2025. In Morocco, the MH launched the National Nutrition Program in 2019 with the objective of improving the nutritional status of the Moroccan population and achieve by 2030 a one-third reduction in ID compared to the levels recorded in 2000 [14]. Therefore, the aim of this study is to provide an updated assessment of the prevalence of anemia, ID, and IDA among WRA in Morocco, following 12 years after mandatory fortification program implementation in 2008 and support from the MH.

MATERIAL AND METHODS

Study design and population

The study comes in the framework of Nutrition National Survey (2019-2020) conducted by Moroccan MH at the national level covering the 12 regions of Morocco based on the size-proportional probability sampling approach recommended by the WHO out of a total of 180 clusters [19], in each cluster, households were randomly selected based on the count sheet completed the day before the survey. A sample of 20 households was selected using the systematic approach at a point of departure with the same probability. A total of 3118 households were surveyed (60.4% in urban areas and 39.6% in rural areas). Briefly, in each selected household, a WRA between the ages of 15 and 49 years was recruited for the survey if she was present in the household, if several WRA met the criteria for inclusion and exclusion in a household, a draw based on Kish's table was conducted by the team supervisor. Each WRA younger than 15 years or older than 49 years and were taking iron supplements were excluded from the study. WRA presenting chronic or severe illness requiring hospitalization or treatment were excluded from the study. In a family meeting, the purpose of the study was explained and oral and written informed consent was obtained from women before the start of the investigation.

Ethical approval

The survey protocol was validated by a Steering Committee and a Committee Technical staff comprising representatives of all the institutions concerned (MH, Universities, CHU, HCP) and in a concerted and participatory way, were entrusted with the coordination and monitoring of all stages of the operation. The Ethics Committee for Biomedical Research in Rabat gave the favorable opinion to the realization of the National Nutrition Survey in Morocco after review of its protocol (Ethical Approval number 321; 3 April 2017).

Socio-economic assessments

A questionnaire was used to gather socioeconomic data relevant to the families of WRA. A face-to-face questionnaire included information on level of education, household size, socioeconomic variables of the participants.

Anthropometric measurement

Anthropometric measurements were taken by trained health professionals according to the WHO standard protocol and using calibrated instruments [20]. Measurements were conducted with minimal clothing and without shoes. Body weight was measured to the nearest 0.1 kg using an electronic scale (Seca GmbH and Co. KG). Height was measured to the nearest at 0.1 cm using a stadiometer (Seca GmbH and Co. KG). BMI was calculated as weight in kg divided by height in meter square (BMI; kg/m^2) to define nutritional status as follow: underweight ($< 18.5\,kg/m^2$), normal weight ($18.5\text{-}24.9\,kg/m^2$), overweight ($25.0\text{-}29.9\,kg/m^2$) and obese ($\geq 30.0\,kg/m^2$) [21].

Blood sampling

Blood was withdrawn by venipuncture from fasting participants and collected in dry tubes of 5 mL for the measurement of SF and CRP a marker of the presence of infection and/or inflammation [22]. These samples were subsequently centrifuged at 5000 rpm for 10 min. The serum was then collected and transported to the laboratory in cold boxes with icepacks, and preserved at –80 °C until analysis.

Hb analysis was performed in situ using the Hemocue portable spectrophotometer (HemoCue AB, Angelholm, Sweden) on a drop of venous blood withdrawn while doing the blood sampling. Anemia

was defined as Hb levels < 12.0 g/dL and ID as SF < 15 μg/mL [23], in non-pregnant women mild, moderate and severe anemia were defined as Hb levels 11.0 to 11.9 g/dL, 8.0-10.9 g/dL and lower than 8.0 g/dL respectively [3]. The ferritin and CRP determinations were performed on an auto-analyzer COBAS c311. These tests are based on the principle of immuno-turbidimetry. Furthermore, the values of ferritin were adjusted according to the inflammation status of the WRA based on the CRP values [24].

Statistical analysis

Data were analyzed using IBM SPSS version 21.0. The Kolmogorov-Smirnov test was used to evaluate the normally distributed variables, which are presented as means ± SD, and non-normally distributed variables are presented as median (inter-quartile range (IQR)). Nominal variables are presented as a proportion and 95% confidence interval and *Chi*-square test was used to test independence between nominal variables. t-test was used to examine the difference in normally distributed variables. A p-value of < 0.05 was considered as statistically significant.

RESULTS

Characteristics of the study population

At the end of the field work, the study included a total of 2125 WRA, excluding pregnant or breastfeeding women and those who refused blood sampling. After laboratory analysis and elimination of outliers, a final sample of 2012 women was used for statistical processing. Table 1 presents the characteristics of the participants. On average, the WRA had an age of 32.8 ± 9.3 years, a weight of 69.1 ± 14.4 kg, a height of 159.7 ± 7 cm, and a BMI of 27.1 ± 5.7 kg/m^2. The majority of the women were married (73.2%), and 35.9% of them were illiterate. Regarding anthropometric characteristics, 37% of the women fell within the healthy weight range, while 32.4% were overweight and 27.5% were obese (Table 1).

When comparing between WRA in urban and rural areas, no significant differences were found in terms of age and height. However, the mean weight of WRA in urban areas was significantly higher than that of those living in rural areas ($p < 0.001$). Illiteracy was more prevalent in rural areas ($p < 0.001$), while obesity was more common in urban areas ($p < 0.001$) (Table 1).

Table 1. Characteristics of the participants

	Total	Urban	Rural	p-values
	N = 2012	N = 1193	N = 819	
Age (years), Mean ± SD	32.8 ± 9.3	32.6 ± 9.2	33.2 ± 9.4	0.163
Level of education				
Illiterate, % (95%CI)	35.9 (33.9-38)	24.5 (22.2-27.1)	52.6 (48.9-56.0)	< 0.001
Primary school, % (95%CI)	23.8 (21.9-25.6)	21.6 (19.2-23.8)	27.0 (23.9-30.3)	0.100
Secondary school, % (95%CI)	32.2 (30.2-34.1)	41.6 (38.5-44.3)	18.4 (15.8-21.1)	< 0.001
Superior, % (95%CI)	7.8 (6.6-8.9)	12.3 (10.4-14.3)	1.2 (0.6-2.0)	< 0.001
Other, % (95%CI)	0.4 (0.1-0.7)	0.1 (0-0.3)	0.9 (0.2-1.6)	0.034
Marital status				
Single, % (95%CI)	21.8 (20-23.5)	24.8 (22.3-27.3)	17.4 (14.7-20.2)	< 0.001
Married, % (95%CI)	73.2 (71.3-75)	69.7 (67-72.3)	78.3 (75.2-81.1)	< 0.001
Divorced, % (95%CI)	3.1 (2.3-3.8)	3.6 (2.6-4.7)	2.3 (1.3-3.6)	0.002
Widow, % (95%CI)	1.5(1-2.2)	1.7 (1-2.4)	1.3 (0.6-2.2)	0.106
Separated, % (95%CI)	0.4 (0.1-0.7)	0.3 (0-0.6)	0.6 (0.1-1.2)	0.480
Anthropometric characteristic				
Weight (kg), Mean ± SD	69.1 ± 14.4	70.5 ± 14.8	67 ± 13.4	< 0.001
Height (cm), Mean ± SD	159.7 ± 7	159.5 ± 7	160.1 ± 7.1	0.109
BMI (kg/m^2), Mean ± SD	27.1 ± 5.7	27.8 ± 6	26.2 ± 5.1	< 0.001
Underweight, % (95%CI)	3.2 (2.4-4)	2.6 (1.8-3.6)	4.0 (2.7-5.4)	0.803
Normal weight, % (95%CI)	37 (35.1-39.2)	33.5 (30.9-36.3)	42.0 (38.7-45.3)	0.040
Overweight, % (95%CI)	32.4 (30.3-34.3)	32.4 (29.7-35.1)	32.4 (29.2-35.5)	< 0.001
Obese, % (95%CI)	27.5 (25.4-29.5)	31.5 (28.8-34.2)	21.6 (18.6-24.4)	< 0.001

p-values were determined using *Chi*^{2} test or t-test

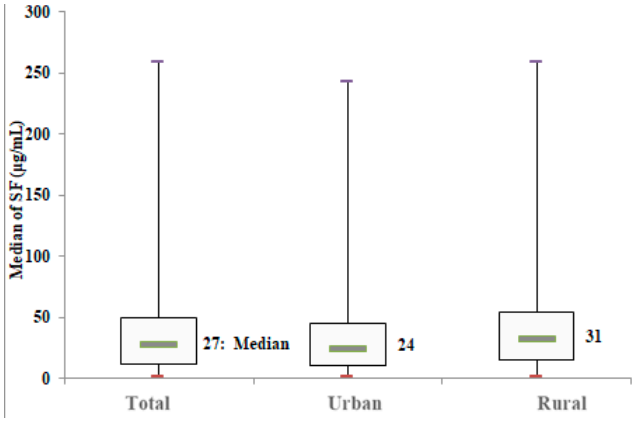
Iron status in WRA

SF status and mean hemoglobin were presented in the figure 1 (a, b). The median of SF for the entire population was 27 µg/mL (IQR: 12-50 µg/mL). Regarding the mean of hemoglobin in WRA, the overall average was 12.3 ± 1.5 g/dL. When analyzed according to living area, a significant difference was observed between urban and rural areas in terms of median serum ferritin ($p < 0.001$). In urban areas, the median serum ferritin was 24 µg/mL (IQR: 11-45 µg/mL), while in rural areas, it was 31 µg/mL (IQR: 15-55 µg/mL). There was a significant difference in the mean of hemoglobin between urban and rural areas ($p = 0.02$). In urban areas, the mean of hemoglobin was 12.2 ± 1.5 g/dL, whereas in rural areas, it was 12.4 ± 1.5 g/dL (Figure 1).

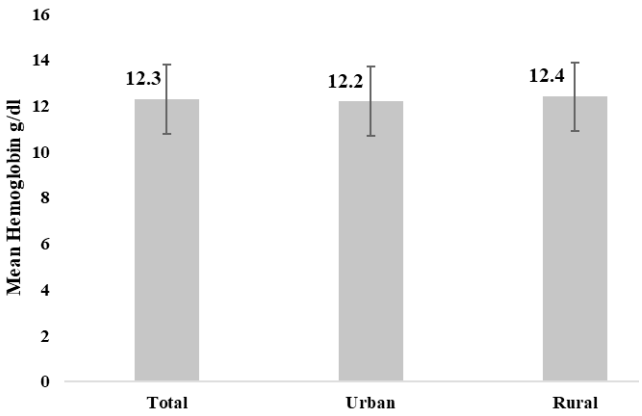
The analysis of the data revealed that out of the total enrolled WRA, 34.3% were found to be anemic, 29.8% had ID, and 16.4% were IDA which represented 47.9% of anemic women. When examining the urban vs the rural population, a highly significant difference was observed ($p < 0.001$). In urban areas 36.5% of WRA were anemic, with 33.5% having ID and 19.3% having IDA. On the other hand, in rural areas, 30.6% of WRA were found to be anemic, with 24.3% having ID and 12.1% having IDA (Figure 2).

According to anemia severity categories, the data revealed that severe anemia accounted for 1% of the total enrolled WRA. Additionally, 14.3% were classified as having moderate anemia, while 19% had mild anemia. When focusing on the urban population, the prevalence of severe anemia was 0.8%, with 16% classified as moderate anemia and 19.7% as mild anemia. In rural areas, the prevalence of severe anemia was slightly higher at 1.2%, with 11.3% classified as moderate anemia and 18.1% as mild anemia. No significant difference was observed in the prevalence of severe anemia between urban and rural areas. However, a highly significant difference was noticed in the prevalence of mild and moderate anemia, with a p-value of less than 0.001 (Figure 3).

a)

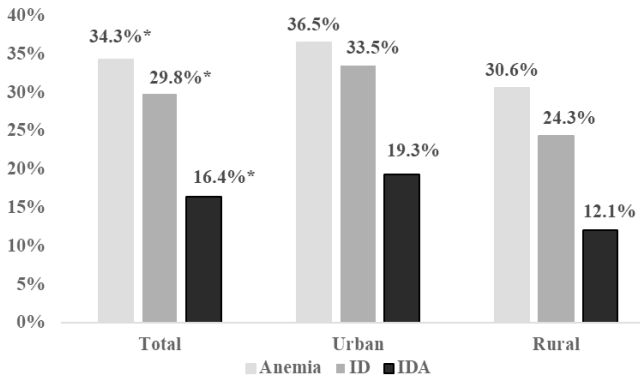


b)



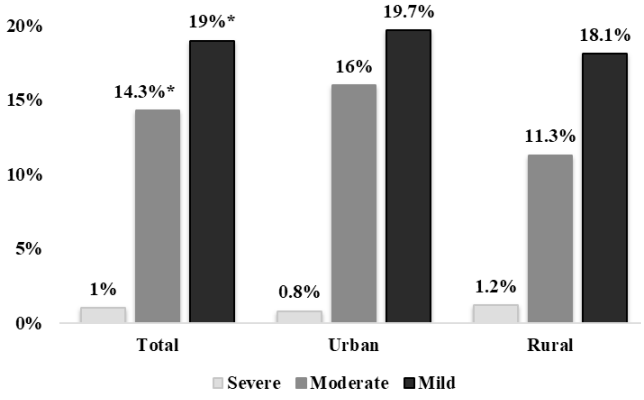
Results are presented as Median (interquartile at Q1: 25% and Q3: 75%) and Mean ± SD

Figure 1. Serum ferritin and hemoglobin status in WRA. a. Median of SF of WRA, b. Mean hemoglobin in WRA



Values are presented as percentage; p-values were determined using *Chi*^{2} test; * – a significant difference between urban and rural areas ($p < 0.05$)

Figure 2. Percentages of anemia, ID and IDA in WRA



Values are presented as percentage; p-values were determined using *Chi*^{2} test; * – a significant difference between urban and rural areas ($p < 0.05$)

Figure 3. Anemia severity categories

DISCUSSION

Anemia affecting WRA is a worldwide form of micronutrient deficiencies, especially in low- and middle-income countries. The aim of this study was to provide an updated assessment of the prevalence of anemia, ID and IDA in WRA in Morocco known that over the course of the last 12 years, the fortification program was mandated and supported by the government of Morocco.

The main finding of this study revealed that 34.3% of women were anemic, 29.8% had ID, and 16.4% had IDA. Numerous studies worldwide have emphasized that anemia caused by iron deficiency is a significant public health issue. For instance, in Turkey, 27.8% of WRA were reported to be anemic [25]. Similarly, a study conducted by Nour Abdo et al. in Jordan found that 19.3% of non-pregnant women were anemic [26]. Research in Uganda [27] and India [28] recorded anemia rates of 32% and 57.2%, respectively. Meanwhile, in Brazil, 25% of WRA were diagnosed with IDA [29]. In South Africa, the prevalence of anemia, ID, and IDA among WRA was reported at 44.0%, 19.0%, and 9.7%, respectively [30].

In Morocco, according to the survey conducted in 2000, it was found that 32.6% of WRA were diagnosed anemic. To solve this problem, in May 2002, an agreement on the fortification of flour with EEI and vitamin B group was signed jointly by the MH and the national flour milling federation. The choice of fortification is because this is the most profitable and sustainable strategies to increase iron consumption as well as it considered a good way to prevent and control this micronutrient deficiency in all populations [31, 32]. After four years of flour fortification strategy implementation, the prevalence of anemia slightly decreased to 31.5% in 2006, but then increased to 38.1% in 2008. The severe, moderate, and mild forms of anemia accounted for 1.3%, 18.3%, and 18.5% respectively in 2008 [11].

In terms of IDA, the rate of anemic women who were ID were 63.9% in 2006 and 59.1% in 2008. These data suggested that the iron-fortification program was having insufficient impact in WRA due to multifactor among others: 1 – The low bioavailability of EEI bioavailability because of its low solubility in gastric juice [33, 34]; 2 – Dietary behaviors consists of a lot of bad habits, it contains many iron absorption inhibitors such as phytic acid and polyphenols [35]; 3 – High rate (exceeds 70%) of *Helicobacter pylori* infection among Moroccan population [36, 37].

However, dietary quality affects absorption of non-heme iron from the gastrointestinal tract [38]. A variety of food factors impact the availability of iron for absorption and transport; the net effect of inhibitors and activators of iron intake can be used to describe food quality in terms of high or low bioavailability [38, 39]. Moreover, in Morocco, it is well documented that tea and coffee consumption inhibits non-heme iron absorption due to their high polyphenol content [40, 41]. The mean per capita annual consumption is estimated at 2,380 g for tea and 1,010 g for coffee, with tea alone accounting for more than 60% of hot drink consumption [42]. In the same context, even for NaFeEDTA which known for its high bioavailability [43], tea can decrease its bioavailability by more than 88% [35].

On the other hand, as the findings of this survey supported the fact that the fortification of flour with EEI did not have a significant effect on the reduction of the prevalence of anemia in WRA, it was recommended to replace the form of iron used for wheat flour fortification by one more bioavailable. The NaFeEDTA form has been chosen for this purpose. The choice was based on bioavailability study conducted in anemic and non-anemic Moroccan women. Indeed, Lazrak et al. [35] founded that fractional iron absorption from bread fortified with NaFeEDTA was equal to 36.7% and 16.7% in the case of anemic and non-anemic women, respectively. Making the fortification of flour with iron-NaFeEDTA mandatory by a Moroccan government decree No. 2-19-144 [44]. In addition to the change of the iron fortifier, the Moroccan MH has implemented various strategies based on the promotion of a diversified diet rich in or enriched with micronutrients, avoid drinking tea with meals and the promotion of public health measures (improvement of vaccination, improvement of hygiene conditions etc.) [14].

The second major result of this study is that the IDA was more prevalent in urban area than in rural areas. Generally, in developing countries, poverty, education level, socioeconomic differences, dietary pattern, are the main factors influencing IDA [45, 46], The long time working or crowded hours and poor eating habits can be one of the causes of this situation [45, 47]. Indeed, in Morocco according the last general census the employment rate of women was 22.3% [48] and the urban population is attracted by the convenience of ready-to-eat food products which are increasingly accessible and highly promoted. Eating out is also becoming more common, which encourages the consumption of foods that are higher in sugar and fat and with low nutritive added value [49]. Like our findings, an analysis of the Haiti Demographic and Health Survey revealed that women living in urban areas are more expected to anemia compared to living in rural areas [50].

CONCLUSIONS

In conclusion, this study highlights the persistent prevalence of anemia, ID, and IDA among WRA, particularly in urban areas. Addressing this issue requires targeted interventions, such as enhancing dietary iron intake through awareness-raising campaigns, optimizing fortification programs through the widespread use of NaFeEDTA flour fortification. However, given that we are now in 2025, it is clear that the goal of a 50% reduction in anemia prevalence among women of reproductive age has not been achieved. Comprehensive measures addressing socioeconomic and nutritional factors remain essential for sustainable improvement.

Funding

This study was funded by the World Health Organization, United Nations Children's Fund, and Global Alliance for Improved Nutrition.

Acknowledgments

We would like to kindly thank all participants in the present study for their patience, time, and consent.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. Kinyoki D, Osgood-Zimmerman AE, Bhattacharjee NV; Local Burden of Disease Anaemia Collaborators; Kassebaum NJ, Hay SI. Anemia prevalence in women of reproductive age in low- and middle-income countries between 2000 and 2018. Nat Med. 2021;27(10):1761-1782. doi: 10.1038/s41591-021-01498-0.
2. Rohr M, Brandenburg V, Brunner-La Rocca HP. How to diagnose iron deficiency in chronic disease: A review of current methods and potential markers for the outcome. Eur J Med Res. 2023;28(1):15. doi: 10.1186/s40001-022-00922-6.
3. World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. 2011. Avaiable from: https://www.who.int/vmnis/indicators/ haemoglobin.pdf.
4. World Health Organization. Guideline on haemoglobin cutoffs to define anaemia in individuals and populations. Geneva: World Health Organisation; 2024. Avaiable from: https://www.who.int/publications/i/item/9789240088542.
5. GBD 2017 Mortality Collaborators. Global, regional, and national age-sex-specific mortality and life expectancy, 1950-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392(10159):1684-1735. doi: 10.1016/S0140-6736(18)31891-9.
6. Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. Ann N Y Acad Sci. 2019;1450(1):15-31. doi: 10.1111/nyas.14092.
7. Mehrotra M, Yadav S, Deshpande A, Mehrotra H. A study of the prevalence of anemia and associated sociodemographic factors in pregnant women in Port Blair, Andaman and Nicobar Islands. J Family Med Prim Care. 2018;7(6):1288-1293. doi: 10.4103/jfmpc.jfmpc_139_18.
8. Haas JD, Brownlie T 4th. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. J Nutr. 2001;131(2S-2):676S-688S; discussion 688S-690S. doi: 10.1093/jn/131.2.676S.
9. Horton S, Ross J. The economics of iron deficiency. Food Policy. 2003;28:51-75. doi: 10.1016/S0306-9192(02)00070-2. Available from: http://dx.doi.org/10.1016/S0306-9192(02)00070-2.
10. Stephen G, Mgongo M, Hussein Hashim T, Katanga J, Stray-Pedersen B, Msuya SE. Anaemia in pregnancy: prevalence, risk factors, and adverse perinatal outcomes in Northern Tanzania. Anemia. 2018;2018:1846280. doi: 10.1155/2018/1846280.
11. Ministry of Health, Morocco. Sentinel system for monitoring and evaluating the fortification process and its impact on the nutritional status of the population. GAIN Project/Monitoring and Evaluation Component. Report. Directorate of Population, Rabat; 2008.
12. Ministry of Health, Morocco. Fight against micronutrient deficiency disorders. Ministry of Health, Directorate of Population. Kingdom of Morocco, 2008. Available from: https://www.sante.gov.ma/Publications/GuidesManuels/Pages/default.aspx.
13. Baltussen R, Knai C, Sharan M. Iron fortification and iron supplementation are cost-effective interventions to reduce iron deficiency in four subregions of the world. J Nutr. 2004;134(10):2678-84. doi: 10.1093/jn/134.10.2678.
14. Ministry of Health, Morocco. National Nutrition Program. 2019. Available from: https://www.sante.gov.ma/Documents/2019/06/Programme%20National%20de%20Nutrition.pdf.
15. Aguenaou H. La malnutrition invisible ou la «faim cachée» *au Maroc et les* stratégies de lutte. BiomatecEcho. 2007;5(2):158-164.
16. El Hamdouchi A, El Kari K, Rjimati EA, El Mzibri M, Mokhtar N, Aguenaou H. Does flour fortification with electrolytic elemental iron improve the prevalence of iron deficiency anaemia among women in childbearing age and preschool children in Morocco? Mediterr J Nutr Metab 2013;6(1):73-78. doi: 10.1007/s12349-012-0113-z.
17. Horton S. The economics of food fortification. J Nutr. 2006;136(4):1068-71. doi: 10.1093/jn/136.4.1068.
18. World Health Organization. Global Nutrition Targets 2025: Policy Brief Series. Geneva: World Health Organization; 2014. Available from: https://iris.who.int/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf?sequence=1
19. Lwanga SK, Lemeshow S, World Health Organization. Sample size determination in health studies: a practical manual. 1991. Available from: https://iris.who.int/handle/10665/40062.

20. Lohman Lohman TG, Roche AF, Martorell R. Anthropometric Standardization Reference Manual. Champaign, IL: Human Kinetics; 1988. doi: 10.1002/ajhb.1310040323.
21. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser. 2000;894:i-xii, 1-253.
22. Northrop-Clewes CA. Interpreting indicators of iron status during an acute phase response – lessons from malaria and human immunodeficiency virus. Ann Clin Biochem. 2008;45(Pt 1):18-32. doi: 10.1258/acb.2007.007167.
23. Cappellini MD, Motta I. Anemia in clinical practice – definition and classification: does hemoglobin change with aging? Semin Hematol. 2015;52(4):261-9. doi: 10.1053/j.seminhematol.2015.07.006.
24. Namaste SM, Rohner F, Huang J, Bhushan NL, Flores-Ayala R, Kupka R, et al. Adjusting ferritin concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr. 2017;106(Suppl 1):359S-371S. doi: 10.3945/ajcn.116.141762.
25. Saydam BK, Genc RE, Sarac F, Turfan EC. Prevalence of anemia and related factors among women in Turkey. Pak J Med Sci. 2017;33(2):433-438. doi: 10.12669/pjms.332.11771.
26. Abdo N, Douglas S, Batieha A, Khader Y, Jaddou H, Al-Khatib S, et al. The prevalence and determinants of anaemia in Jordan. East Mediterr Health J. 2019;25(5):341-349. doi: 10.26719/emhj.18.047.
27. Nankinga O, Aguta D. Determinants of anemia among women in Uganda: further analysis of the Uganda demographic and health surveys. BMC Public Health. 2019;19(1):1757. doi: 10.1186/s12889-019-8114-1.
28. Givens DI, Anitha S, Giromini C. Anaemia in India and its prevalence and multifactorial aetiology: a narrative review. Nutrients. 2024;16(11):1673. doi: 10.3390/nu16111673.
29. Macena M, Praxedes D, De Oliveira AD, Paula D, Barros M, Silva Júnior A, et al. Prevalence of iron deficiency anemia in Brazilian women of childbearing age: a systematic review with meta-analysis. PeerJ. 2022;10:e12959. doi: 10.7717/peerj.12959.
30. Turawa E, Awotiwon O, Dhansay MA, Cois A, Labadarios D, Bradshaw D, et al. Prevalence of anaemia, iron deficiency, and iron deficiency anaemia in women of reproductive age and children under 5 years of age in South Africa (1997-2021): A systematic review. Int J Environ Res Public Health. 2021;18(23):12799. doi: 10.3390/ijerph182312799.
31. Baltussen R, Knai C, Sharan M. Iron fortification and iron supplementation are cost-effective interventions to reduce iron deficiency in four subregions of the world. J Nutr. 2004;134(10):2678-84. doi: 10.1093/jn/134.10.2678.
32. Olson R, Gavin-Smith B, Ferraboschi C, Kraemer K. Food fortification: the advantages, disadvantages and lessons from Sight and Life programs. Nutrients. 2021;13(4):1118. doi: 10.3390/nu13041118.
33. Andang'o PE, Osendarp SJ, Ayah R, West CE, Mwaniki DL, De Wolf CA, et al. Efficacy of iron-fortified whole maize flour on iron status of schoolchildren in Kenya: a randomised controlled trial. Lancet. 2007;369(9575):1799-1806. doi: 10.1016/S0140-6736(07)60817-4.
34. Hurrell RF. Iron fortification practices and implications for iron addition to salt. J Nutr. 2021;151(Suppl 1):3S-14S. doi: 10.1093/jn/nxaa175.
35. Lazrak M, El Kari K, Stoffel NU, Elammari L, Al-Jawaldeh A, Loechl CU, et al. Tea consumption reduces iron bioavailability from NaFeEDTA in nonanemic women and women with iron deficiency anemia: stable iron isotope studies in Morocco. J Nutr. 2021;151(9):2714-2720. doi: 10.1093/jn/nxab159.
36. Bouihat N, Burucoa C, Benkirane A, Seddik H, Sentissi S, Al Bouzidi A, et al. *Helicobacter pylori* primary antibiotic resistance in 2015 in Morocco: a phenotypic and genotypic prospective and multicenter study. Microb Drug Resist. 2017;23(6):727-732. doi: 10.1089/mdr.2016.0264.
37. Bounder G, Boura H, Nadifiyine S, Jouimyi MR, Bensassi M, Kadi M, et al. Epidemiology of Helicobacter pylori infection and related gastric pathologies in Moroccan population. J Life Sci. 2017;211-218. doi: 10.17265/1934-7391/2017.05.001.
38. Piskin E, Cianciosi D, Gulec S, Tomas M, Capanoglu E. Iron absorption: factors, limitations, and improvement methods. ACS Omega. 2022;7(24):20441-20456. doi: 10.1021/acsomega.2c01833.
39. Coad J, Pedley K. Iron deficiency and iron deficiency anemia in women. Scand J Clin Lab Invest Suppl. 2014;244:82-9; discussion 89. doi: 10.3109/00365513.2014.936694.
40. Zijp IM, Korver O, Tijburg LB. Effect of tea and other dietary factors on iron absorption. Crit Rev Food Sci Nutr. 2000;40(5):371-98. doi: 10.1080/10408690091189194.
41. Disler PB, Lynch SR, Charlton RW, Torrance JD, Bothwell TH, Walker RB, et al. The effect of tea on iron absorption. Gut. 1975;16(3):193-200. doi: 10.1136/gut.16.3.193.
42. High Commission for Planning, Morocco. National survey on household consumption and expenditure [Internet]. Rabat (Morocco): High Commission for Planning; 2013/2014. Available from: https://www.hcp.ma/downloads/Enquete-Nationale-sur-la-Consommation-et-les-Depenses-des-Menages_t21181.html.
43. Walter T, Pizarro F, Abrams SA, Boy E. Bioavailability of elemental iron powder in white wheat bread. Eur J Clin Nutr. 2004;58(3):555-8. doi: 10.1038/sj.ejcn.1601844.
44. Ministry of Agriculture, Maritime Fisheries, Rural Development and Waters and Forests, Ministry of Health, Morocco. Decree No. 2-19-144 of Kaada 8, 1440 (July 11, 2019) relating to the quality and safety of certain food products marketed from cereals. OG. No 6810, 05.09.2019, p. 1852. Available from: https://www.onssa.gov.ma/wp-content/uploads/2025/01/DEC.2-19-144.ENG_.pdf.

45. Vibhute NA, Shah U, Belgaumi U, Kadashetti V, Bommanavar S, Kamate W. Prevalence and awareness of nutritional anemia among female medical students in Karad, Maharashtra, India: A cross-sectional study. J Family Med Prim Care. 2019;8(7):2369-2372. doi: 10.4103/jfmpc.jfmpc_353_19.
46. Obai G, Odongo P, Wanyama R. Prevalence of anaemia and associated risk factors among pregnant women attending antenatal care in Gulu and Hoima Regional Hospitals in Uganda: A cross sectional study. BMC Pregnancy Childbirth. 2016;16:76. doi: 10.1186/s12884-016-0865-4.
47. Retnakumar C, Chacko M, Ramakrishnan D, George LS, Krishnapillai V. Prevalence of anemia and its association with dietary pattern among elderly population of urban slums in Kochi. J Family Med Prim Care. 2020;9(3):1533-1537. doi: 10.4103/jfmpc.jfmpc_1113_19.
48. High Commission for Planning, Morocco. Moroccan Women and the Labor Market: Characteristics and Evolution, 2013. Available from: https://www.hcp.ma/file/231711/.
49. ALLALI Allali F. Evolution des pratiques alimentaires au Maroc: Nutrition transition in Morocco. Int J Med Surg. 2017;4(Special Issue):ID 145. doi: 10.15342/ijms.v4is.145.
50. Heidkamp RA, Ngnie-Teta I, Ayoya MAA, Stoltzfus RJ, Mamadoultaibou A, Durandisse EB, et al. Predictors of anemia among Haitian children aged 6 to 59 months and women of childbearing age and their implications for programming. Food Nutr Bull. 2013;34(4):462-79. doi: 10.1177/156482651303400411.

Received: 01.12.2024
Revised: 15.03.2025
Accepted: 25.03.2025
Published online first: 17.04.2025