Scientific Reports

https://doi.org/10.1038/s41598-026-66001-6

Article in Press

Prevalence and characteristics of anemia in Turkish adults insights from the PURE Türkiye Cohort

Received: 5 January 2026

Accepted: 4 August 2026

Published online: 07 August 2026

Cite this article as: Oguz A., Kilickap M., Imeryuz N. *et al.* Prevalence and characteristics of anemia in Turkish adults insights from the PURE Türkiye Cohort. *Sci Rep* (2026). https://doi.org/10.1038/s41598-026-66001-6

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Prevalence and Characteristics of Anemia in Turkish Adults

Insights from the PURE Türkiye Cohort

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Prevalence and Characteristics of Anemia in Turkish Adults

Insights from the PURE Türkiye Cohort

Abstract

Objectives

To determine the prevalence, severity, and morphological subtypes of anemia among adults aged 35–70 years in Türkiye and to examine their distribution according to sex, age, educational level, and urban–rural residence.

Design

Cross-sectional analysis of baseline data from a nationally representative prospective cohort study.

Setting

Community-based study conducted in urban and rural areas across eight provinces in Türkiye.

Participants

A total of 4,050 adults aged 35–70 years enrolled in the Prospective Urban Rural Epidemiology (PURE) Türkiye cohort between 2008 and 2009 with available hemoglobin measurements.

Primary and secondary outcome measures

Anemia was defined and classified according to World Health Organization criteria. Primary outcomes were the prevalence and severity of anemia. Secondary outcomes included morphological subtypes based on mean corpuscular volume, mean corpuscular

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hemoglobin concentration, and red cell distribution width, as well as associations with sociodemographic characteristics and estimated dietary iron and vitamin B12 intake.

Results

Overall, 13.6% of participants had anemia, with a significantly higher prevalence in women than in men (19.3% vs 4.8%; $p<0.001$). Microcytic anemia was the most common subtype (51.9%), followed by normocytic anemia (48.1%). Among individuals with anemia, approximately 37% had hypochromic microcytic anemia with elevated red cell distribution width, suggestive of iron deficiency. Anemia prevalence showed an inverse association with educational level ($p=0.009$) and was slightly higher in urban than in rural areas (14.4% vs 12.2%; $p=0.049$). Estimated dietary iron and vitamin B12 intake did not differ significantly across anemia subtypes or hemoglobin categories, except for lower vitamin B12 intake among anemic men.

Conclusions

Anemia affects a substantial proportion of adults aged 35–70 years in Türkiye, particularly women and individuals with lower educational attainment. The predominance of hypochromic microcytic anemia indicates that iron deficiency and non-nutritional factors may play an important role. These findings support the need for targeted public health strategies and routine anemia screening in high-risk adult populations.

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Strengths and limitations of this study

- This study is based on a large cohort of adults aged 35–70 years recruited using a nationally representative sampling strategy within the Prospective Urban Rural Epidemiology (PURE) Türkiye study, supporting broad generalisability of the findings to adults in this age range.
- Standardised data collection procedures and laboratory measurements were used across all study sites, enhancing the reliability and internal validity of the findings.
- The inclusion of both urban and rural populations enabled the assessment of sociodemographic and geographic differences in anemia prevalence and subtypes.
- Owing to the cross-sectional design, causal relationships between sociodemographic factors, nutritional intake and anemia cannot be inferred.
- Detailed biochemical markers of anemia aetiology (such as ferritin, inflammatory markers, or vitamin B12 levels) were not available, limiting aetiological classification beyond morphological subtypes.

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Introduction

Anemia is a major health problem affecting billions of people worldwide. Although it is often associated with nutritional deficiencies, it is also linked to chronic diseases, inflammation, and socio-economic inequalities (1). The prevalence of anemia varies by gender, age groups, and income level (2). The World Health Organization (WHO) reports that anemia remains highly prevalent worldwide, particularly among rural populations, low-income households, and individuals with little or no formal education (3).

Comprehensive nationwide data on the prevalence of anemia in Türkiye are limited. Existing studies have largely focused on specific subpopulations. The prevalence of anemia was 27.1% in a study of pregnant women (4) and 27.8% in another cohort of women aged 18-89 years (5). Another regional cohort aged 18-92 years (n=2187) demonstrated that the prevalence of anemia was 30.0% in women and 18.2% in men (6). These studies highlight anemia as a significant public health issue in Türkiye, but the absence of data representing the general adult population creates a critical evidence gap for the development of targeted public health strategies to address anemia and its underlying causes in Türkiye.

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The Prospective Urban Rural Epidemiology (PURE) study is a large-scale, prospective cohort study conducted in 27 countries, including Türkiye, that collects data on social, environmental, and individual risk factors, as well as chronic diseases, among individuals aged 35–70 years residing in both rural and urban areas. Accordingly, the aim of the present study was to determine the prevalence, severity, and morphological subtypes of anemia among adults aged 35–70 years in Türkiye using data from the nationally representative PURE Türkiye cohort and to examine their distribution according to sex, age, educational level, and urban–rural residence.

Materials and Methods

The PURE study is a multinational study led by the Population Health Research Institute (PHRI) at McMaster University. Details of the study methodology have been published previously (7). All methods were performed in accordance with the relevant guidelines and regulations.

Ethics approval: This study was approved by the Marmara University Faculty of Medicine Research Ethics Committee (Approval No: MAR-SBY2005-0183) and was carried out with the official permission of the Turkish Ministry of Health.

Data Collection and Participants

The sampling design for the PURE Türkiye study was developed in 2008. Based on the European Union Nomenclature of Territorial Units for Statistics (NUTS) classification and regional social and financial characteristics provided by the Turkish Statistical Institute, eight cities were selected to represent different regions of Türkiye (7). Seven of these cities were chosen through randomization, while Istanbul, due to its large population, was selected directly. Within these provinces, households in both rural and urban areas were then randomly chosen. Households with residents between 35 and 70 years of age who were expected to stay in the area for at least four years were included. After informed consent was obtained from all participants, questionnaires, anthropometric and clinical measurements were taken, and blood samples were collected.

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Recruitment for the study took place between 2008 and 2009, with a total of 4,056 participants from 2,576 households forming the cohort. This analysis includes baseline data for 4,050 individuals with complete data.

Calculation of dietary intake of iron and vitamin B12

A validated Turkish version of the food frequency questionnaire (FFQ), previously developed and validated by the PURE Türkiye investigators (8), was administered to each participant with permission to estimate habitual dietary food intake. Daily dietary iron (mg/day) and vitamin B12 (µg/day) intake were estimated using the corresponding country-specific nutrient database.

Definition of Anemia

Anemia was defined and classified per WHO criteria as mild (11.0–12.9 g/dL in men; 11.0–11.9 g/dL in women), moderate (8.0–10.9 g/dL), or severe (<8.0 g/dL) (9). Microcytic anemia was defined as a mean corpuscular volume (MCV) of <80 fL, while macrocytic anemia was defined as an MCV of >100 fL. Hypochromic anemia was identified based on a mean corpuscular hemoglobin concentration (MCHC) of <32 g/dL. In addition to hemoglobin, MCV, and MCHC, the following parameters were also measured: hematocrit (normal values: 41% - 50% for men, 36% - 44% for women), erythrocytes/red blood cell (normal values: 4.0 to 5.9 million/mm^3 for men, 3.8 to 5.2 million/mm^3 for women), platelets (normal value: 150 - 450 x 10^9/L), leukocytes (normal value: 4 - 11.0 x 10^9/L), mean platelet volume [(MPV), normal value: 7.5–11.5 fL, mean corpuscular hemoglobin [(MCH), normal value: 27.5 - 33.2 pg, and red cell distribution width [(RDW), normal value: 11.5 – 15%).

Statistical analysis

Anemia prevalence estimates were calculated using household-level survey weights and accounting for clustering of participants within households. The intraclass correlation coefficient (ICC) was calculated to assess household-level clustering of anemia.

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Participant characteristics were summarized overall and according to anemia status, both in the total population and stratified by sex. Categorical variables were presented as frequencies and percentages and compared using the chi-squared test or Fisher's exact test, as appropriate. Trends in anemia prevalence across educational levels were assessed using the Cochran–Armitage trend test. Continuous variables were presented as mean and standard deviation or median and interquartile range, according to their distribution. Comparisons between two groups were performed using the independent-samples t-test or Mann–Whitney U test, as appropriate.

Among participants with anemia, the distributions of anemia severity, red cell size, chromicity, and combined morphological subtypes were described overall and by sex. Differences between women and men were evaluated using the chi-squared test or Fisher's exact test, as appropriate. A two-sided p-value of less than 0.05 was considered statistically significant. Analyses were conducted using Stata version 17 (StataCorp, College Station, TX, USA).

Results

The PURE Türkiye cohort included 4,056 participants. Hemoglobin measurements were unavailable for six participants; therefore, 4,050 individuals were included in the present analysis. The intraclass correlation coefficient for anemia within households was 0.076 (95% CI, 0.020–0.132; p = 0.005), indicating modest but statistically significant household-level clustering.

Of the study population, 2,461 (60.8%) were women. The mean age was 50.0 ± 9.1 years, and women were younger than men (49.3 ± 9.1 vs. 51.1 ± 9.1 years, respectively; p <0.001). Educational attainment and urban–rural distribution differed significantly between sexes. Most participants (57.8%) had completed primary school education, whereas 19.5% had no formal education.

The mean hemoglobin concentration was 12.9 ± 1.4 g/dL in women and 15.1 ± 1.3 g/dL in men (p <0.001). Likewise, hematocrit, MCV, MCH, MCHC, erythrocyte count, and

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leukocyte count were significantly lower in women than in men (all p <0.001), whereas RDW values were slightly but significantly higher in women.

Anemia was identified in 551 participants (13.6%). The prevalence of anemia was substantially higher in women than in men (475 [19.3%] vs. 76 [4.8%], respectively; p <0.001). Among women, participants with anemia were younger than those without anemia (47.0 ± 8.6 vs. 49.9 ± 9.1 years, p <0.001), whereas among men, participants with anemia were older than those without anemia (56.5 ± 9.4 vs. 50.8 ± 9.0 years, p <0.001). Compared with non-anemic participants, those with anemia had lower educational attainment and significantly lower hemoglobin, hematocrit, MCV, MCH, and MCHC values. These patterns were consistent in both women and men.

The prevalence of anemia was slightly higher in urban areas than in rural areas (14.4% vs. 12.2%, p = 0.049); however, no significant difference was observed in the severity of anemia between the two locations (p = 0.166).

Estimated nutritional iron intake was higher in men than in women (median [interquartile range], 16.55 [12.34–21.71] vs. 13.60 [10.14–17.91] mg/day; p <0.001). However, it did not differ between anemic and non-anemic women (p = 0.569) or between anemic and non-anemic men (p = 0.473).

Estimated nutritional vitamin B12 intake was higher in men than in women (6.67 [3.87–11.81] vs. 4.53 [2.76–8.52] μg/day; p <0.001). While vitamin B12 intake was similar between anemic and non-anemic women (p = 0.143), it was slightly lower in anemic men compared with non-anemic men (5.43 [3.33–9.56] vs. 6.75 [3.94–11.88] μg/day; p = 0.023). The demographic and laboratory characteristics of participants with and without anemia are presented in Table 1.

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Table 1: The demographic and laboratory characteristics of participants with and without anemia

	All Participants				Women				Men			
	Non-anemic	**Anemic**	**Total**	**P**	**Non-anemic**	**Anemic**	**Total**	**p**	**Non-anemic**	**Anemic**	**Total**	**p**
n, (%)	3499 (86.4)	551 (13.6)	4050		1986 (80.7)	475 (19.3)	2461		1513 (95.2)	76 (4.8)	1589	
Age, years	50.3 (9.1)	48.4 (9.3)	50.0 (9.1)	<0.001	49.9 (9.1)	47.0 (8.6)	49.3 (9.1)	<0.001	50.8 (9.0)	56.5 (9.4)	51.1 (9.1)	<0.001
Education, n (%)				0.009				0.042				0.022
None	677 (19.3)	113 (20.5)	790 (19.5)		588 (29.6)	106 (22.3)	694 (28.2)		89 (5.9)	7 (9.2)	96 (6.0)	
Primary	1998 (57.1)	341 (61.9)	2339 (57.8)		1070 (53.9)	289 (60.8)	1359 (55.2)		928 (61.3)	52 (68.4)	980 (61.7)	
Secondary	635 (18.1)	78 (14.2)	713 (17.6)		258 (13.0)	63 (13.3)	321 (13.0)		377 (24.9)	15 (19.7)	392 (24.7)	
Higher	189 (5.4)	19 (3.4)	208 (5.1)		70 (3.5)	17 (3.6)	87 (3.5)		119 (7.9)	2 (2.6)	121 (7.6)	
Rural vs. urban n (%)				0.049				0.155				0.985
Rural, n (%)	1249 (35.7)	173 (31.4)	1422 (35.1)		670 (33.7)	144 (30.3)	814 (33.1)		579 (38.3)	29 (38.2)	608 (38.3)	

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Urban, n (%)	2250 (64.3)	378 (68.6)	2628 (64.9)		1316 (66.3)	331 (69.7)	1647 (66.9)		934 (61.7)	47 (61.8)	981 (61.7)	
Hemoglobin (g/dL)	14.2 (1.3)	10.9 (1.2)	13.8 (1.7)	<0.001	13.4 (0.8)	10.8 (1.1)	12.9 (1.4)	<0.001	15.3 (1.0)	11.4 (1.5)	15.1 (1.3)	<0.001
Hematocrit (%)	42.6 (3.4)	34.7 (2.8)	41.5 (4.3)	<0.001	40.6 (2.5)	34.4 (2.5)	39.4 (3.5)	<0.001	45.1 (2.8)	36.4 (3.7)	44.7 (3.4)	<0.001
MCV (fL)	86.6 (4.7)	78.5 (8.8)	85.5 (6.1)	<0.001	86.4 (4.6)	78.7 (8.3)	84.9 (6.3)	<0.001	87.0 (4.8)	77.3 (11.7)	86.5 (5.7)	<0.001
MCH (pg)	28.9 (1.8)	24.7 (3.6)	28.4 (2.6)	<0.001	28.6 (1.7)	24.7 (3.4)	27.8 (2.7)	<0.001	29.4 (1.7)	24.3 (4.3)	29.2 (2.2)	<0.001
MCHC (g/dL))	33.4 (1.0)	31.3 (1.6)	33.1 (1.3)	<0.001	33.1 (0.9)	31.3 (1.6)	32.7 (1.3)	<0.001	33.8 (1.0)	31.4 (1.8)	33.7 (1.2)	<0.001
RDW-CV (%)	13.3 (12.8; 13.8)	15.3 (14.0; 17.1)	13.4 (12.9; 14.1)	<0.001	13.3 (12.8; 13.9)	15.2 (14.0; 16.9)	13.5 (12.9; 14.3)	<0.001	13.2 (12.8; 13.6)	16.3 (14.2; 18.8)	13.2 (12.8; 13.7)	<0.001
Erythrocyte ($\times 10^6/\mu L$)	4.9 (0.5)	4.5 (0.6)	4.9 (0.5)	<0.001	4.7 (0.4)	4.4 (0.5)	4.7 (0.4)	<0.001	5.2 (0.4)	4.8 (0.9)	5.2 (0.5)	<0.001
Leukocyte ($\times 10^9/L$)	6.8 (1.9)	6.4 (2.0)	6.8 (1.9)	<0.001	6.6 (1.7)	6.4 (1.7)	6.5 (1.7)	0.032	7.2 (2.0)	6.5 (3.3)	7.2 (2.1)	0.004
Platelet count ($\times 10^9/L$)	269.2 (67.7)	310.4 (86.1)	274.8 (71.9)	<0.001	281.0 (69.7)	315.8 (84.6)	287.7 (74.0)	<0.001	253.8 (61.9)	276.6 (88.2)	254.8 (63.5)	0.002
PDW (%)	45.6 (43.2; 52.6)	46.3 (43.3; 53.0)	45.7 (43.2; 52.6)	0.063	46.0 (43.3; 52.8)	47.2 (43.4; 53.3)	46.1 (43.3; 52.9)	0.107	45.3 (43.0; 52.1)	45.0 (43.1; 49.1)	45.3 (43.0; 52.0)	0.267
Vitamin B12 intake (µg/day)	5.3 (3.1; 9.9)	4.8 (2.9; 9.3)	5.2 (3.1; 9.8)	0.018	4.5 (2.7; 8.4)	4.7 (2.9; 9.2)	4.5 (2.8; 8.5)	0.143	6.7 (3.9; 11.9)	5.4 (3.3; 9.6)	6.7 (3.9; 11.8)	0.023

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Iron intake (mg/day)	14.7 (11.0; 19.6)	14.2 (10.2; 18.2)	14.6 (10.8; 19.5)	0.012	13.5 (10.2; 17.9)	13.8 (9.9; 17.9)	13.6 (10.1; 17.9)	0.569	16.6 (12.3; 21.8)	16.5 (12.8; 19.8)	16.5 (12.3; 21.7)	0.473

Normally distributed continuous variables were presented mean (Standard deviation) and compared using t-test; non-normally distributed continuous variables were presented as median (Q1; Q3) and were compared using Mann-Whtiney-U test, education was compared using Cochrane-Armitage test, other categorical variables were compared using chi-squared test. Abbreviations: MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PDW, Platelet distribution width; RDW-CV, red cell distribution width (coefficient of variation).

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The prevalence of anemia varied across age categories. In women, anemia prevalence was highest in younger age groups, declined until 55–59 years of age, and increased thereafter. In men, anemia prevalence was relatively low before the age of 50 years and increased thereafter, reaching the highest prevalence in participants aged ≥65 years. Across all age categories, anemia prevalence remained higher in women than in men (Figure 1). The distribution of microcytic and normocytic anemia also varied across age groups, with normocytic anemia becoming more common in older women, whereas microcytic anemia remained the predominant subtype in most male age groups (Supplementary Figure S1).

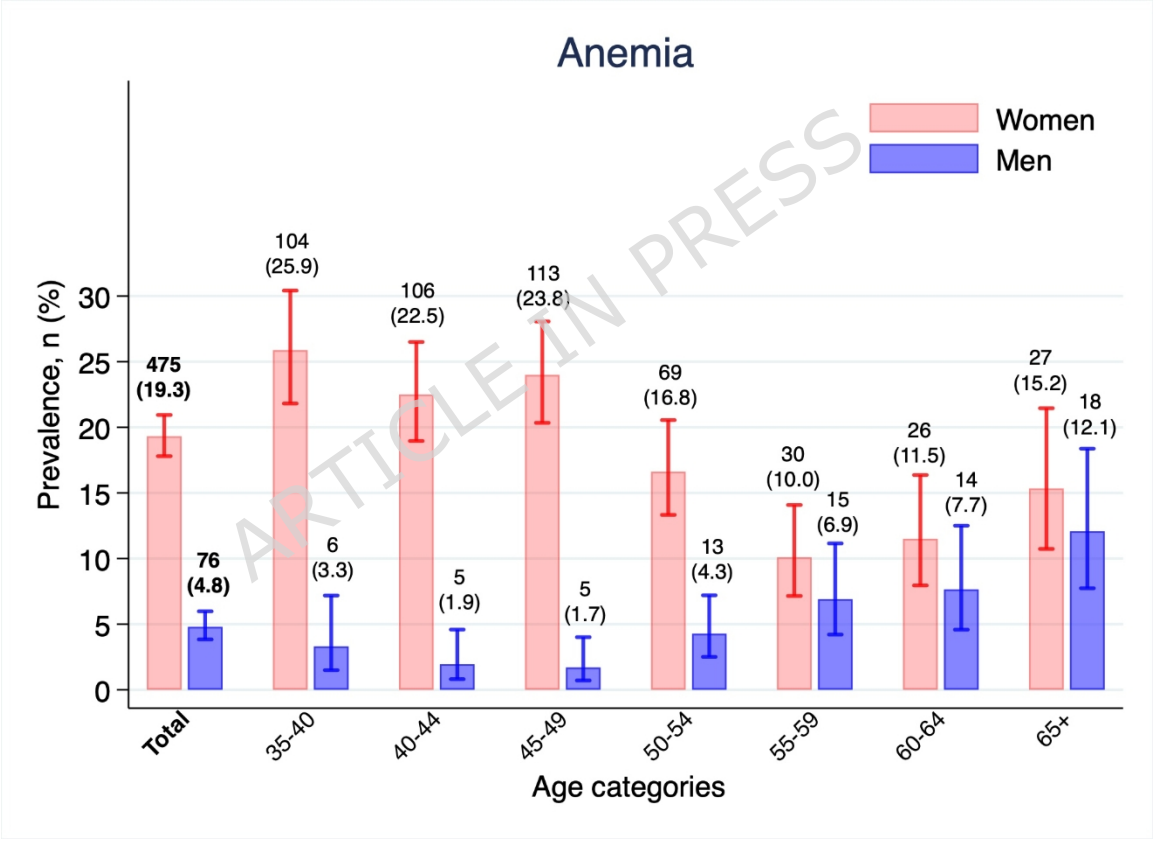


Figure 1. Prevalence of anemia in women and men across age categories. Error bars represent 95% confidence intervals. Numbers above bars indicate the number of participants in each age category and the corresponding prevalence (%).

Of the 551 participants identified with anemia, two cases of macrocytic anemia were excluded from the severity and morphological subtype analyses due to the very small sample size, leaving 549 participants for further evaluation (Table 2). Among them, 325

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(59%) had mild, 211 (38.3%) had moderate, and 15 (2.7%) had severe anemia. The distribution of anemia severity differed significantly between women and men ($p = 0.001$; Table 2). Mild anemia was more common in men than in women (75.0% vs. 56.4%, respectively), whereas moderate anemia was more frequent in women (41.3% vs. 19.7%). These sex-specific differences reflected a higher proportion of mild anemia in men and a higher proportion of moderate anemia in women (Supplementary Figure S2).

Among the 549 participants included in morphological subtype analyses, 285 (51.9%) had microcytic anemia and 264 (48.1%) had normocytic anemia. Microcytic anemia was slightly more common than normocytic anemia in both sexes, whereas macrocytic anemia was rare (Supplementary Figure S3). Hypochromic anemia predominated in both women and men, and the combined morphological classification identified hypochromic microcytic anemia as the predominant subtype in both sexes (Supplementary Figures S4 and S5). Hypochromic anemia accounted for approximately two-thirds of all anemia cases (65.9%). No significant sex differences were observed in the distribution of red cell size classification (microcytic vs. normocytic, $p = 0.607$), chromicity classification (hypochromic vs. normochromic, $p = 0.187$), or combined MCV–MCHC classification ($p = 0.223$). Overall, hypochromic microcytic anemia was the most common subtype, accounting for 233 cases (42.4%), followed by normochromic normocytic anemia (135 cases, 24.6%), hypochromic normocytic anemia (129 cases, 23.5%), and normochromic microcytic anemia (52 cases, 9.5%). Elevated RDW (>15%) was observed in 205 of 233 participants (88.0%) with hypochromic microcytic anemia.

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Table 2: Distribution of anemia severity and morphological subtypes among anemic participants by sex (excluding two cases of macrocytic anemia)

	Women (n=474)	**Men (n=75)**	**Total (n=549)**	**P-value**
Anemia severity, n (%)				0.001
Mild	268 (56.4)	57 (75.0)	325 (59.0)	
Moderate	196 (41.3)	15 (19.7)	211 (38.3)	
Severe	11 (2.3)	4 (5.3)	15 (2.7)	
Red cell size classification, n (%)				0.607
Microcytic	244 (51.5)	41 (54.7)	285 (51.9)	
Normocytic	230 (48.5)	34 (45.3)	264 (48.1)	
Chromicity classification, n (%)				0.187
Normochromic	157 (33.1)	31 (40.8)	188 (34.1)	
Hypochromic	318 (66.9)	45 (59.2)	363 (65.9)	
Combined MCV–MCHC classification, n (%)				0.223
Normochromic Microcytic	40 (8.4)	12 (16.0)	52 (9.5)	
Normochromic Normocytic	117 (24.7)	18 (24.0)	135 (24.6)	
Hypochromic Microcytic	204 (43.0)	29 (38.7)	233 (42.4)	
Hypochromic Normocytic	113 (23.8)	16 (21.3)	129 (23.5)	

Two participants with macrocytic anemia (MCV >100 fL) were excluded from the morphological subtype analyses because meaningful statistical comparisons could not be performed due to the very small sample size. Abbreviations: MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration

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Discussion

This study demonstrates that 13.6% of individuals aged 35–70 years in Türkiye have anemia, with a prevalence of 19.3% in women and 4.8% in men. In the 2023 Global Burden of Disease Study, the global prevalence of anemia in all ages was found to be 24.3% (1) . When analyzed by gender, the prevalence of anemia is higher in women than in men, reported as 31.2% in women and 17.5% in men for all ages, and 33% in women and 11.3% in men aged 15-49 years (1). In our study of individuals aged 35-70, the highest prevalence of anemia was observed in women aged 35-39 (25.9%) and in men aged 65-70 (12.1%), and the lowest prevalence was observed in women aged 55-59 (10%) and in men aged 45-49 (1.7%). The age- and sex-specific distribution of anemia observed in our study suggests that different mechanisms may contribute to anemia across the life course. The higher prevalence among women, particularly in the younger age groups, is likely related to menstrual blood loss and lower iron stores during the reproductive years. This interpretation is supported by recent global evidence showing that women of reproductive age continue to carry a disproportionate burden of anemia worldwide (10)**.** Although anemia prevalence decreased with age in women, it remained consistently higher than in men across all age categories. In contrast, the increasing prevalence observed among older men may reflect the growing burden of chronic diseases, chronic inflammation, renal impairment, occult gastrointestinal blood loss, and age-related changes in hematopoiesis. In addition, age-related reductions in androgen activity may contribute to this pattern, as testosterone has been shown to stimulate erythropoiesis through increased erythropoietin production and suppression of hepcidin (11)**.**

A study conducted on patients aged 65 and above in Europe indicated that the prevalence of anemia significantly increases with age (12). Similarly, the NHANES data show that the

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prevalence of anemia is approximately 2.5 times higher in individuals aged over 65 compared to those aged 26–45, and about 1.9 times higher in women than in men (13). These findings are broadly consistent with our results and support the role of aging and sex-specific biological factors in shaping anemia risk throughout adulthood.

In our study population, 59% of patients with anemia had mild anemia, 38.3% had moderate anemia and 2.7% had severe anemia. In a study conducted in a multiethnic Iranian population in Khuzestan, mild anemia was reported in 64.8%, moderate anemia in 32.4%, and severe anemia in 2.7% in the 35-49 age group (14). The higher prevalence of mild anemia observed in these studies aligns with the global data (1).

Hypochromic microcytic anemia was the most common anemia subtype in men and women, followed by normochromic normocytic, hypochromic normocytic, and normochromic microcytic anemia. Macrocytic anemia ranked last with a percentage of 1.3% in men and less than 1% in women. Microcytic anemias may be due to various causes including iron deficiency, thalassemia, lead poisoning, sideroblastic anemia, and anemia of chronic diseases. The main causes of hypochromic microcytic anemias are iron deficiency and thalassemia. Türkiye is one of the countries where beta thalassemia is common. The prevalence of beta thalassemia trait in Türkiye has been reported as 2.1%, with regional variations (15). Although it does not provide a definite distinction, hypochromic microcytic anemias with increased RDW can be considered iron deficiency anemia. In a study conducted in Brazil, increased RDW was reported in 94.5% of hypochromic microcytic anemias (16). In our population, among hypochromic microcytic anemias, 205 (88%) had increased RDW. Therefore, as a rough estimation, 37% of anemia cases (205 out of 551) in adults can be attributed to iron deficiency in Türkiye. Unlike the studies in the pediatric population, this finding draws attention to a serious public health problem that may be caused not only by nutritional deficiency but also by benign or malignant diseases that cause blood loss from the body. The absence of an association between dietary intake of iron and vitamin B12 and hemoglobin levels indicates that nutritional deficiency alone may not fully explain anemia in this population. This finding is consistent with previous research demonstrating that dietary iron intake shows only a weak association with anemia, suggesting that factors other than nutritional iron deficiency,

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such as inflammation or chronic disease, may play a substantial role in the development of anemia (17). The lack of a significant association between dietary iron intake and anemia in our study suggests that nutritional deficiency alone may not fully explain the burden of anemia in this population. Differences in iron bioavailability, individual variation in iron absorption, inflammation-mediated iron sequestration, and the presence of chronic diseases may all contribute to the development of anemia despite apparently adequate dietary intake. In addition, although elevated RDW among hypochromic microcytic anemia cases supports a substantial contribution of iron deficiency, RDW is not a specific marker and may also be increased in mixed nutritional deficiencies or inflammatory conditions. Therefore, the estimated contribution of iron deficiency should be considered approximate and interpreted with caution in the absence of confirmatory biochemical markers such as ferritin or transferrin saturation. Although nutritional iron deficiency is a well-recognized major contributor to anemia in children and women of reproductive age our findings indicate that, among Turkish adults aged 35–70 years, anemia is predominantly attributable to factors other than nutritional deficiency. We found an inverse relationship between the prevalence of anemia and the level of education. This may be attributed to higher income and better surveillance with higher educational levels. Regarding location, the prevalence of anemia was slightly higher in urban areas compared to rural areas, with borderline significance, but the severity of anemia was similar in both locations. This finding is in contrast to global patterns, where anemia is generally more prevalent and more severe in rural areas (18). The slightly higher prevalence observed in urban areas may be related to a greater burden of obesity, metabolic disorders, chronic inflammatory conditions, and increased healthcare utilization leading to more frequent detection of anemia. However, given the small magnitude of the difference and its borderline statistical significance, this finding should be interpreted with caution. In our study, this pattern may also reflect a narrowing gap in social and economic conditions between rural and urban populations. The present study provides cross-sectional data that were obtained between 2008 and 2009 in Türkiye. Assuming there has been no substantial change in anemia prevalence over time, the increase in the adult (aged 20+) population —from 53.7 million in 2009 to 61.3 million in 2024— in Türkiye would lead to a higher absolute number of individuals affected, underscoring the persistent burden of anemia as a public health issue. There are several

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limitations of our study. First, it does not include all age groups, particularly the pediatric population and women of reproductive age (15-34 years). The PURE study aims to assess societal influences on cardiovascular risk factors and the incidence of non-communicable diseases. Since the development of such events typically requires time and increases with age—and given the high cost of long-term follow-up—the age range of 35 to 70 years was deliberately selected. Given that anemia tends to be more prevalent in younger age groups, the true prevalence may be slightly higher than reported here. Second, since this is an epidemiological rather than a clinical study, comprehensive testing required for a detailed etiological classification of anemia was not conducted. Third, we were unable to account for pregnancy status. Fourth, although validated previously, the FFQ showed only moderate correlation with the 24-hour dietary recall for iron Dietary intake estimates should therefore be interpreted with caution, particularly as no biological markers were used in validation(8). On the other hand, the present study has some strengths. First, since the sampling was designed to be representative of Türkiye, the results can be generalized to the national population aged 35 to 70 years. Moreover, this is the first anemia prevalence study conducted in the adult age group with a nationally representative sample. Second, the inclusion of both rural and urban areas enabled comparisons between these populations and offered community-specific insights. Third, blood tests were performed in the same laboratory utilizing standardized methods, enhancing the reliability of the measurements.

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In conclusion, anemia affects a significant portion of the adult population in Türkiye, particularly women and individuals with lower education levels, with a slightly but not substantially higher prevalence in urban areas. The predominance of hypochromic microcytic anemia indicates that iron deficiency is a major underlying factor. It seems that anemia is not associated with nutritional deficiency but may be attributed to non-nutritional factors, such as blood loss or absorption problems. These findings underscore the need for targeted public health strategies and routine anemia screening among high-risk populations.

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Figure legends:

Figure 1: Percentages of anemia in women and men across the age categories

Tables:

Table 1: The demographic and laboratory characteristics of participants with and without anemia

Table 2: Distribution of anemia severity and morphological subtypes among anemic participants by sex (excluding two cases of macrocytic anemia)

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Supplementary Figures:

Supplementary Figure S1: The distribution of microcytic and normocytic anemia across the age categories in women and men.

Supplementary Figure S2: Severity of anemia in women and men

Supplementary Figure S3: The distribution of anemia types according to mean corpuscular volume in women and men.

Supplementary Figure S4: Distribution of anemia subgroups based on mean corpuscular volume and mean corpuscular hemoglobin concentration in women and men.

Supplementary Figure S5: The distribution of anemia types according to mean corpuscular hemoglobin concentration in women and men

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Statements and Declerations:

Funding: This study was supported by the Metabolic Syndrome Society of Turkey. The Population Health Research Institute, McMaster University, provided scientific and logistical support.

Conflict of Interest: None

Data Availability: Deidentified participant data and a data dictionary may be made available upon reasonable request after approval of a proposal and signing of a data-sharing agreement.

Author Contributions: AO, MK, NI, FEG, SG, YA, KK, AT, KBCT, AAA, MVK, OTC, VM, SR, and SY contributed to study conception, design, data collection, and interpretation. MVK, MK, AO drafted the first version of the manuscript. MVK, MK, OTC, AO accessed and verified the underlying data and had final responsibility for the decision to submit for publication.

Disclaimer: The views expressed in this article are those of the authors and do not necessarily represent the views of the Population Health Research Institute (PHRI).

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Prevalence and Characteristics of Anemia in Turkish Adults

Insights from the PURE Türkiye Cohort

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Prevalence and Characteristics of Anemia in Turkish Adults

Insights from the PURE Türkiye Cohort

Abstract

Objectives

To determine the prevalence, severity, and morphological subtypes of anemia among adults aged 35–70 years in Türkiye and to examine their distribution according to sex, age, educational level, and urban–rural residence.

Design

Cross-sectional analysis of baseline data from a nationally representative prospective cohort study.

Setting

Community-based study conducted in urban and rural areas across eight provinces in Türkiye.

Participants

A total of 4,050 adults aged 35–70 years enrolled in the Prospective Urban Rural Epidemiology (PURE) Türkiye cohort between 2008 and 2009 with available hemoglobin measurements.

Primary and secondary outcome measures

Anemia was defined and classified according to World Health Organization criteria. Primary outcomes were the prevalence and severity of anemia. Secondary outcomes included morphological subtypes based on mean corpuscular volume, mean corpuscular

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hemoglobin concentration, and red cell distribution width, as well as associations with sociodemographic characteristics and estimated dietary iron and vitamin B12 intake.

Results

Overall, 13.6% of participants had anemia, with a significantly higher prevalence in women than in men (19.3% vs 4.8%; $p<0.001$). Microcytic anemia was the most common subtype (51.9%), followed by normocytic anemia (48.1%). Among individuals with anemia, approximately 37% had hypochromic microcytic anemia with elevated red cell distribution width, suggestive of iron deficiency. Anemia prevalence showed an inverse association with educational level ($p=0.009$) and was slightly higher in urban than in rural areas (14.4% vs 12.2%; $p=0.049$). Estimated dietary iron and vitamin B12 intake did not differ significantly across anemia subtypes or hemoglobin categories, except for lower vitamin B12 intake among anemic men.

Conclusions

Anemia affects a substantial proportion of adults aged 35–70 years in Türkiye, particularly women and individuals with lower educational attainment. The predominance of hypochromic microcytic anemia indicates that iron deficiency and non-nutritional factors may play an important role. These findings support the need for targeted public health strategies and routine anemia screening in high-risk adult populations.

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Strengths and limitations of this study

- This study is based on a large cohort of adults aged 35–70 years recruited using a nationally representative sampling strategy within the Prospective Urban Rural Epidemiology (PURE) Türkiye study, supporting broad generalisability of the findings to adults in this age range.
- Standardised data collection procedures and laboratory measurements were used across all study sites, enhancing the reliability and internal validity of the findings.
- The inclusion of both urban and rural populations enabled the assessment of sociodemographic and geographic differences in anemia prevalence and subtypes.
- Owing to the cross-sectional design, causal relationships between sociodemographic factors, nutritional intake and anemia cannot be inferred.
- Detailed biochemical markers of anemia aetiology (such as ferritin, inflammatory markers, or vitamin B12 levels) were not available, limiting aetiological classification beyond morphological subtypes.

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Introduction

Anemia is a major health problem affecting billions of people worldwide. Although it is often associated with nutritional deficiencies, it is also linked to chronic diseases, inflammation, and socio-economic inequalities (1). The prevalence of anemia varies by gender, age groups, and income level (2). The World Health Organization (WHO) reports that anemia remains highly prevalent worldwide, particularly among rural populations, low-income households, and individuals with little or no formal education (3).

Comprehensive nationwide data on the prevalence of anemia in Türkiye are limited. Existing studies have largely focused on specific subpopulations. The prevalence of anemia was 27.1% in a study of pregnant women (4) and 27.8% in another cohort of women aged 18-89 years (5). Another regional cohort aged 18-92 years (n=2187) demonstrated that the prevalence of anemia was 30.0% in women and 18.2% in men (6). These studies highlight anemia as a significant public health issue in Türkiye, but the absence of data representing the general adult population creates a critical evidence gap for the development of targeted public health strategies to address anemia and its underlying causes in Türkiye.

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The Prospective Urban Rural Epidemiology (PURE) study is a large-scale, prospective cohort study conducted in 27 countries, including Türkiye, that collects data on social, environmental, and individual risk factors, as well as chronic diseases, among individuals aged 35–70 years residing in both rural and urban areas. Accordingly, the aim of the present study was to determine the prevalence, severity, and morphological subtypes of anemia among adults aged 35–70 years in Türkiye using data from the nationally representative PURE Türkiye cohort and to examine their distribution according to sex, age, educational level, and urban–rural residence.

Materials and Methods

The PURE study is a multinational study led by the Population Health Research Institute (PHRI) at McMaster University. Details of the study methodology have been published previously (7). All methods were performed in accordance with the relevant guidelines and regulations.

Ethics approval: This study was approved by the Marmara University Faculty of Medicine Research Ethics Committee (Approval No: MAR-SBY2005-0183) and was carried out with the official permission of the Turkish Ministry of Health.

Data Collection and Participants

The sampling design for the PURE Türkiye study was developed in 2008. Based on the European Union Nomenclature of Territorial Units for Statistics (NUTS) classification and regional social and financial characteristics provided by the Turkish Statistical Institute, eight cities were selected to represent different regions of Türkiye (7). Seven of these cities were chosen through randomization, while Istanbul, due to its large population, was selected directly. Within these provinces, households in both rural and urban areas were then randomly chosen. Households with residents between 35 and 70 years of age who were expected to stay in the area for at least four years were included. After informed consent was obtained from all participants, questionnaires, anthropometric and clinical measurements were taken, and blood samples were collected.

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Recruitment for the study took place between 2008 and 2009, with a total of 4,056 participants from 2,576 households forming the cohort. This analysis includes baseline data for 4,050 individuals with complete data.

Calculation of dietary intake of iron and vitamin B12

A validated Turkish version of the food frequency questionnaire (FFQ), previously developed and validated by the PURE Türkiye investigators (8), was administered to each participant with permission to estimate habitual dietary food intake. Daily dietary iron (mg/day) and vitamin B12 (µg/day) intake were estimated using the corresponding country-specific nutrient database.

Definition of Anemia

Anemia was defined and classified per WHO criteria as mild (11.0–12.9 g/dL in men; 11.0–11.9 g/dL in women), moderate (8.0–10.9 g/dL), or severe (<8.0 g/dL) (9). Microcytic anemia was defined as a mean corpuscular volume (MCV) of <80 fL, while macrocytic anemia was defined as an MCV of >100 fL. Hypochromic anemia was identified based on a mean corpuscular hemoglobin concentration (MCHC) of <32 g/dL. In addition to hemoglobin, MCV, and MCHC, the following parameters were also measured: hematocrit (normal values: 41% - 50% for men, 36% - 44% for women), erythrocytes/red blood cell (normal values: 4.0 to 5.9 million/mm^3 for men, 3.8 to 5.2 million/mm^3 for women), platelets (normal value: 150 - 450 x 10^9/L), leukocytes (normal value: 4 - 11.0 x 10^9/L), mean platelet volume [(MPV), normal value: 7.5–11.5 fL, mean corpuscular hemoglobin [(MCH), normal value: 27.5 - 33.2 pg, and red cell distribution width [(RDW), normal value: 11.5 – 15%).

Statistical analysis

Anemia prevalence estimates were calculated using household-level survey weights and accounting for clustering of participants within households. The intraclass correlation coefficient (ICC) was calculated to assess household-level clustering of anemia.

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Participant characteristics were summarized overall and according to anemia status, both in the total population and stratified by sex. Categorical variables were presented as frequencies and percentages and compared using the chi-squared test or Fisher's exact test, as appropriate. Trends in anemia prevalence across educational levels were assessed using the Cochran–Armitage trend test. Continuous variables were presented as mean and standard deviation or median and interquartile range, according to their distribution. Comparisons between two groups were performed using the independent-samples t-test or Mann–Whitney U test, as appropriate.

Among participants with anemia, the distributions of anemia severity, red cell size, chromicity, and combined morphological subtypes were described overall and by sex. Differences between women and men were evaluated using the chi-squared test or Fisher's exact test, as appropriate. A two-sided p-value of less than 0.05 was considered statistically significant. Analyses were conducted using Stata version 17 (StataCorp, College Station, TX, USA).

Results

The PURE Türkiye cohort included 4,056 participants. Hemoglobin measurements were unavailable for six participants; therefore, 4,050 individuals were included in the present analysis. The intraclass correlation coefficient for anemia within households was 0.076 (95% CI, 0.020–0.132; p = 0.005), indicating modest but statistically significant household-level clustering.

Of the study population, 2,461 (60.8%) were women. The mean age was 50.0 ± 9.1 years, and women were younger than men (49.3 ± 9.1 vs. 51.1 ± 9.1 years, respectively; p <0.001). Educational attainment and urban–rural distribution differed significantly between sexes. Most participants (57.8%) had completed primary school education, whereas 19.5% had no formal education.

The mean hemoglobin concentration was 12.9 ± 1.4 g/dL in women and 15.1 ± 1.3 g/dL in men (p <0.001). Likewise, hematocrit, MCV, MCH, MCHC, erythrocyte count, and

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leukocyte count were significantly lower in women than in men (all p <0.001), whereas RDW values were slightly but significantly higher in women.

Anemia was identified in 551 participants (13.6%). The prevalence of anemia was substantially higher in women than in men (475 [19.3%] vs. 76 [4.8%], respectively; p <0.001). Among women, participants with anemia were younger than those without anemia (47.0 ± 8.6 vs. 49.9 ± 9.1 years, p <0.001), whereas among men, participants with anemia were older than those without anemia (56.5 ± 9.4 vs. 50.8 ± 9.0 years, p <0.001). Compared with non-anemic participants, those with anemia had lower educational attainment and significantly lower hemoglobin, hematocrit, MCV, MCH, and MCHC values. These patterns were consistent in both women and men.

The prevalence of anemia was slightly higher in urban areas than in rural areas (14.4% vs. 12.2%, p = 0.049); however, no significant difference was observed in the severity of anemia between the two locations (p = 0.166).

Estimated nutritional iron intake was higher in men than in women (median [interquartile range], 16.55 [12.34–21.71] vs. 13.60 [10.14–17.91] mg/day; p <0.001). However, it did not differ between anemic and non-anemic women (p = 0.569) or between anemic and non-anemic men (p = 0.473).

Estimated nutritional vitamin B12 intake was higher in men than in women (6.67 [3.87–11.81] vs. 4.53 [2.76–8.52] μg/day; p <0.001). While vitamin B12 intake was similar between anemic and non-anemic women (p = 0.143), it was slightly lower in anemic men compared with non-anemic men (5.43 [3.33–9.56] vs. 6.75 [3.94–11.88] μg/day; p = 0.023). The demographic and laboratory characteristics of participants with and without anemia are presented in Table 1.

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Table 1: The demographic and laboratory characteristics of participants with and without anemia

	All Participants				Women				Men			
	Non-anemic	**Anemic**	**Total**	**P**	**Non-anemic**	**Anemic**	**Total**	**p**	**Non-anemic**	**Anemic**	**Total**	**p**
n, (%)	3499 (86.4)	551 (13.6)	4050		1986 (80.7)	475 (19.3)	2461		1513 (95.2)	76 (4.8)	1589	
Age, years	50.3 (9.1)	48.4 (9.3)	50.0 (9.1)	<0.001	49.9 (9.1)	47.0 (8.6)	49.3 (9.1)	<0.001	50.8 (9.0)	56.5 (9.4)	51.1 (9.1)	<0.001
Education, n (%)				0.009				0.042				0.022
None	677 (19.3)	113 (20.5)	790 (19.5)		588 (29.6)	106 (22.3)	694 (28.2)		89 (5.9)	7 (9.2)	96 (6.0)	
Primary	1998 (57.1)	341 (61.9)	2339 (57.8)		1070 (53.9)	289 (60.8)	1359 (55.2)		928 (61.3)	52 (68.4)	980 (61.7)	
Secondary	635 (18.1)	78 (14.2)	713 (17.6)		258 (13.0)	63 (13.3)	321 (13.0)		377 (24.9)	15 (19.7)	392 (24.7)	
Higher	189 (5.4)	19 (3.4)	208 (5.1)		70 (3.5)	17 (3.6)	87 (3.5)		119 (7.9)	2 (2.6)	121 (7.6)	
Rural vs. urban n (%)				0.049				0.155				0.985
Rural, n (%)	1249 (35.7)	173 (31.4)	1422 (35.1)		670 (33.7)	144 (30.3)	814 (33.1)		579 (38.3)	29 (38.2)	608 (38.3)	

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Urban, n (%)	2250 (64.3)	378 (68.6)	2628 (64.9)		1316 (66.3)	331 (69.7)	1647 (66.9)		934 (61.7)	47 (61.8)	981 (61.7)	
Hemoglobin (g/dL)	14.2 (1.3)	10.9 (1.2)	13.8 (1.7)	<0.001	13.4 (0.8)	10.8 (1.1)	12.9 (1.4)	<0.001	15.3 (1.0)	11.4 (1.5)	15.1 (1.3)	<0.001
Hematocrit (%)	42.6 (3.4)	34.7 (2.8)	41.5 (4.3)	<0.001	40.6 (2.5)	34.4 (2.5)	39.4 (3.5)	<0.001	45.1 (2.8)	36.4 (3.7)	44.7 (3.4)	<0.001
MCV (fL)	86.6 (4.7)	78.5 (8.8)	85.5 (6.1)	<0.001	86.4 (4.6)	78.7 (8.3)	84.9 (6.3)	<0.001	87.0 (4.8)	77.3 (11.7)	86.5 (5.7)	<0.001
MCH (pg)	28.9 (1.8)	24.7 (3.6)	28.4 (2.6)	<0.001	28.6 (1.7)	24.7 (3.4)	27.8 (2.7)	<0.001	29.4 (1.7)	24.3 (4.3)	29.2 (2.2)	<0.001
MCHC (g/dL))	33.4 (1.0)	31.3 (1.6)	33.1 (1.3)	<0.001	33.1 (0.9)	31.3 (1.6)	32.7 (1.3)	<0.001	33.8 (1.0)	31.4 (1.8)	33.7 (1.2)	<0.001
RDW-CV (%)	13.3 (12.8; 13.8)	15.3 (14.0; 17.1)	13.4 (12.9; 14.1)	<0.001	13.3 (12.8; 13.9)	15.2 (14.0; 16.9)	13.5 (12.9; 14.3)	<0.001	13.2 (12.8; 13.6)	16.3 (14.2; 18.8)	13.2 (12.8; 13.7)	<0.001
Erythrocyte ($\times 10^6/\mu L$)	4.9 (0.5)	4.5 (0.6)	4.9 (0.5)	<0.001	4.7 (0.4)	4.4 (0.5)	4.7 (0.4)	<0.001	5.2 (0.4)	4.8 (0.9)	5.2 (0.5)	<0.001
Leukocyte ($\times 10^9/L$)	6.8 (1.9)	6.4 (2.0)	6.8 (1.9)	<0.001	6.6 (1.7)	6.4 (1.7)	6.5 (1.7)	0.032	7.2 (2.0)	6.5 (3.3)	7.2 (2.1)	0.004
Platelet count ($\times 10^9/L$)	269.2 (67.7)	310.4 (86.1)	274.8 (71.9)	<0.001	281.0 (69.7)	315.8 (84.6)	287.7 (74.0)	<0.001	253.8 (61.9)	276.6 (88.2)	254.8 (63.5)	0.002
PDW (%)	45.6 (43.2; 52.6)	46.3 (43.3; 53.0)	45.7 (43.2; 52.6)	0.063	46.0 (43.3; 52.8)	47.2 (43.4; 53.3)	46.1 (43.3; 52.9)	0.107	45.3 (43.0; 52.1)	45.0 (43.1; 49.1)	45.3 (43.0; 52.0)	0.267
Vitamin B12 intake (µg/day)	5.3 (3.1; 9.9)	4.8 (2.9; 9.3)	5.2 (3.1; 9.8)	0.018	4.5 (2.7; 8.4)	4.7 (2.9; 9.2)	4.5 (2.8; 8.5)	0.143	6.7 (3.9; 11.9)	5.4 (3.3; 9.6)	6.7 (3.9; 11.8)	0.023

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Iron intake (mg/day)	14.7 (11.0; 19.6)	14.2 (10.2; 18.2)	14.6 (10.8; 19.5)	0.012	13.5 (10.2; 17.9)	13.8 (9.9; 17.9)	13.6 (10.1; 17.9)	0.569	16.6 (12.3; 21.8)	16.5 (12.8; 19.8)	16.5 (12.3; 21.7)	0.473

Normally distributed continuous variables were presented mean (Standard deviation) and compared using t-test; non-normally distributed continuous variables were presented as median (Q1; Q3) and were compared using Mann-Whtiney-U test, education was compared using Cochrane-Armitage test, other categorical variables were compared using chi-squared test. Abbreviations: MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PDW, Platelet distribution width; RDW-CV, red cell distribution width (coefficient of variation).

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The prevalence of anemia varied across age categories. In women, anemia prevalence was highest in younger age groups, declined until 55–59 years of age, and increased thereafter. In men, anemia prevalence was relatively low before the age of 50 years and increased thereafter, reaching the highest prevalence in participants aged ≥65 years. Across all age categories, anemia prevalence remained higher in women than in men (Figure 1). The distribution of microcytic and normocytic anemia also varied across age groups, with normocytic anemia becoming more common in older women, whereas microcytic anemia remained the predominant subtype in most male age groups (Supplementary Figure S1).

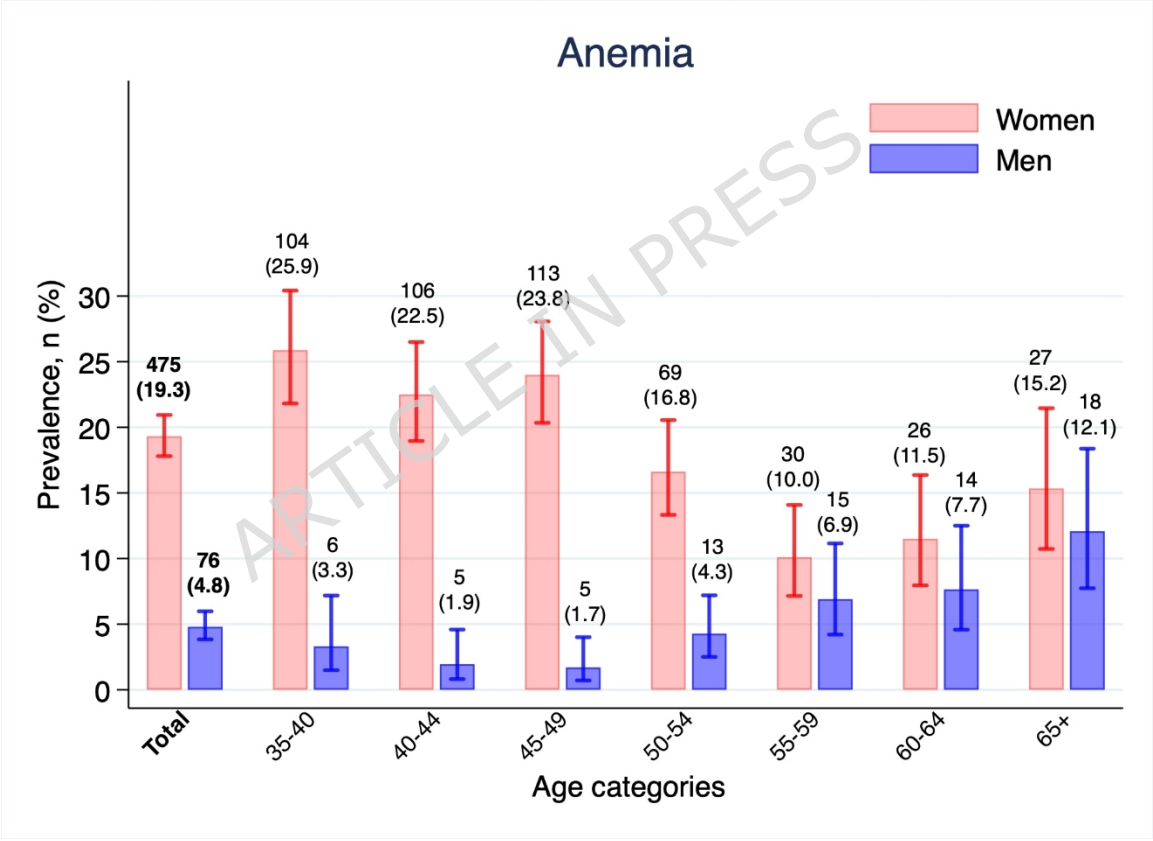


Figure 1. Prevalence of anemia in women and men across age categories. Error bars represent 95% confidence intervals. Numbers above bars indicate the number of participants in each age category and the corresponding prevalence (%).

Of the 551 participants identified with anemia, two cases of macrocytic anemia were excluded from the severity and morphological subtype analyses due to the very small sample size, leaving 549 participants for further evaluation (Table 2). Among them, 325

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(59%) had mild, 211 (38.3%) had moderate, and 15 (2.7%) had severe anemia. The distribution of anemia severity differed significantly between women and men ($p = 0.001$; Table 2). Mild anemia was more common in men than in women (75.0% vs. 56.4%, respectively), whereas moderate anemia was more frequent in women (41.3% vs. 19.7%). These sex-specific differences reflected a higher proportion of mild anemia in men and a higher proportion of moderate anemia in women (Supplementary Figure S2).

Among the 549 participants included in morphological subtype analyses, 285 (51.9%) had microcytic anemia and 264 (48.1%) had normocytic anemia. Microcytic anemia was slightly more common than normocytic anemia in both sexes, whereas macrocytic anemia was rare (Supplementary Figure S3). Hypochromic anemia predominated in both women and men, and the combined morphological classification identified hypochromic microcytic anemia as the predominant subtype in both sexes (Supplementary Figures S4 and S5). Hypochromic anemia accounted for approximately two-thirds of all anemia cases (65.9%). No significant sex differences were observed in the distribution of red cell size classification (microcytic vs. normocytic, $p = 0.607$), chromicity classification (hypochromic vs. normochromic, $p = 0.187$), or combined MCV–MCHC classification ($p = 0.223$). Overall, hypochromic microcytic anemia was the most common subtype, accounting for 233 cases (42.4%), followed by normochromic normocytic anemia (135 cases, 24.6%), hypochromic normocytic anemia (129 cases, 23.5%), and normochromic microcytic anemia (52 cases, 9.5%). Elevated RDW (>15%) was observed in 205 of 233 participants (88.0%) with hypochromic microcytic anemia.

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Table 2: Distribution of anemia severity and morphological subtypes among anemic participants by sex (excluding two cases of macrocytic anemia)

	Women (n=474)	**Men (n=75)**	**Total (n=549)**	**P-value**
Anemia severity, n (%)				0.001
Mild	268 (56.4)	57 (75.0)	325 (59.0)	
Moderate	196 (41.3)	15 (19.7)	211 (38.3)	
Severe	11 (2.3)	4 (5.3)	15 (2.7)	
Red cell size classification, n (%)				0.607
Microcytic	244 (51.5)	41 (54.7)	285 (51.9)	
Normocytic	230 (48.5)	34 (45.3)	264 (48.1)	
Chromicity classification, n (%)				0.187
Normochromic	157 (33.1)	31 (40.8)	188 (34.1)	
Hypochromic	318 (66.9)	45 (59.2)	363 (65.9)	
Combined MCV–MCHC classification, n (%)				0.223
Normochromic Microcytic	40 (8.4)	12 (16.0)	52 (9.5)	
Normochromic Normocytic	117 (24.7)	18 (24.0)	135 (24.6)	
Hypochromic Microcytic	204 (43.0)	29 (38.7)	233 (42.4)	
Hypochromic Normocytic	113 (23.8)	16 (21.3)	129 (23.5)	

Two participants with macrocytic anemia (MCV >100 fL) were excluded from the morphological subtype analyses because meaningful statistical comparisons could not be performed due to the very small sample size. Abbreviations: MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration

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Discussion

This study demonstrates that 13.6% of individuals aged 35–70 years in Türkiye have anemia, with a prevalence of 19.3% in women and 4.8% in men. In the 2023 Global Burden of Disease Study, the global prevalence of anemia in all ages was found to be 24.3% (1) . When analyzed by gender, the prevalence of anemia is higher in women than in men, reported as 31.2% in women and 17.5% in men for all ages, and 33% in women and 11.3% in men aged 15-49 years (1). In our study of individuals aged 35-70, the highest prevalence of anemia was observed in women aged 35-39 (25.9%) and in men aged 65-70 (12.1%), and the lowest prevalence was observed in women aged 55-59 (10%) and in men aged 45-49 (1.7%). The age- and sex-specific distribution of anemia observed in our study suggests that different mechanisms may contribute to anemia across the life course. The higher prevalence among women, particularly in the younger age groups, is likely related to menstrual blood loss and lower iron stores during the reproductive years. This interpretation is supported by recent global evidence showing that women of reproductive age continue to carry a disproportionate burden of anemia worldwide (10)**.** Although anemia prevalence decreased with age in women, it remained consistently higher than in men across all age categories. In contrast, the increasing prevalence observed among older men may reflect the growing burden of chronic diseases, chronic inflammation, renal impairment, occult gastrointestinal blood loss, and age-related changes in hematopoiesis. In addition, age-related reductions in androgen activity may contribute to this pattern, as testosterone has been shown to stimulate erythropoiesis through increased erythropoietin production and suppression of hepcidin (11)**.**

A study conducted on patients aged 65 and above in Europe indicated that the prevalence of anemia significantly increases with age (12). Similarly, the NHANES data show that the

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prevalence of anemia is approximately 2.5 times higher in individuals aged over 65 compared to those aged 26–45, and about 1.9 times higher in women than in men (13). These findings are broadly consistent with our results and support the role of aging and sex-specific biological factors in shaping anemia risk throughout adulthood.

In our study population, 59% of patients with anemia had mild anemia, 38.3% had moderate anemia and 2.7% had severe anemia. In a study conducted in a multiethnic Iranian population in Khuzestan, mild anemia was reported in 64.8%, moderate anemia in 32.4%, and severe anemia in 2.7% in the 35-49 age group (14). The higher prevalence of mild anemia observed in these studies aligns with the global data (1).

Hypochromic microcytic anemia was the most common anemia subtype in men and women, followed by normochromic normocytic, hypochromic normocytic, and normochromic microcytic anemia. Macrocytic anemia ranked last with a percentage of 1.3% in men and less than 1% in women. Microcytic anemias may be due to various causes including iron deficiency, thalassemia, lead poisoning, sideroblastic anemia, and anemia of chronic diseases. The main causes of hypochromic microcytic anemias are iron deficiency and thalassemia. Türkiye is one of the countries where beta thalassemia is common. The prevalence of beta thalassemia trait in Türkiye has been reported as 2.1%, with regional variations (15). Although it does not provide a definite distinction, hypochromic microcytic anemias with increased RDW can be considered iron deficiency anemia. In a study conducted in Brazil, increased RDW was reported in 94.5% of hypochromic microcytic anemias (16). In our population, among hypochromic microcytic anemias, 205 (88%) had increased RDW. Therefore, as a rough estimation, 37% of anemia cases (205 out of 551) in adults can be attributed to iron deficiency in Türkiye. Unlike the studies in the pediatric population, this finding draws attention to a serious public health problem that may be caused not only by nutritional deficiency but also by benign or malignant diseases that cause blood loss from the body. The absence of an association between dietary intake of iron and vitamin B12 and hemoglobin levels indicates that nutritional deficiency alone may not fully explain anemia in this population. This finding is consistent with previous research demonstrating that dietary iron intake shows only a weak association with anemia, suggesting that factors other than nutritional iron deficiency,

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such as inflammation or chronic disease, may play a substantial role in the development of anemia (17). The lack of a significant association between dietary iron intake and anemia in our study suggests that nutritional deficiency alone may not fully explain the burden of anemia in this population. Differences in iron bioavailability, individual variation in iron absorption, inflammation-mediated iron sequestration, and the presence of chronic diseases may all contribute to the development of anemia despite apparently adequate dietary intake. In addition, although elevated RDW among hypochromic microcytic anemia cases supports a substantial contribution of iron deficiency, RDW is not a specific marker and may also be increased in mixed nutritional deficiencies or inflammatory conditions. Therefore, the estimated contribution of iron deficiency should be considered approximate and interpreted with caution in the absence of confirmatory biochemical markers such as ferritin or transferrin saturation. Although nutritional iron deficiency is a well-recognized major contributor to anemia in children and women of reproductive age our findings indicate that, among Turkish adults aged 35–70 years, anemia is predominantly attributable to factors other than nutritional deficiency. We found an inverse relationship between the prevalence of anemia and the level of education. This may be attributed to higher income and better surveillance with higher educational levels. Regarding location, the prevalence of anemia was slightly higher in urban areas compared to rural areas, with borderline significance, but the severity of anemia was similar in both locations. This finding is in contrast to global patterns, where anemia is generally more prevalent and more severe in rural areas (18). The slightly higher prevalence observed in urban areas may be related to a greater burden of obesity, metabolic disorders, chronic inflammatory conditions, and increased healthcare utilization leading to more frequent detection of anemia. However, given the small magnitude of the difference and its borderline statistical significance, this finding should be interpreted with caution. In our study, this pattern may also reflect a narrowing gap in social and economic conditions between rural and urban populations. The present study provides cross-sectional data that were obtained between 2008 and 2009 in Türkiye. Assuming there has been no substantial change in anemia prevalence over time, the increase in the adult (aged 20+) population —from 53.7 million in 2009 to 61.3 million in 2024— in Türkiye would lead to a higher absolute number of individuals affected, underscoring the persistent burden of anemia as a public health issue. There are several

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limitations of our study. First, it does not include all age groups, particularly the pediatric population and women of reproductive age (15-34 years). The PURE study aims to assess societal influences on cardiovascular risk factors and the incidence of non-communicable diseases. Since the development of such events typically requires time and increases with age—and given the high cost of long-term follow-up—the age range of 35 to 70 years was deliberately selected. Given that anemia tends to be more prevalent in younger age groups, the true prevalence may be slightly higher than reported here. Second, since this is an epidemiological rather than a clinical study, comprehensive testing required for a detailed etiological classification of anemia was not conducted. Third, we were unable to account for pregnancy status. Fourth, although validated previously, the FFQ showed only moderate correlation with the 24-hour dietary recall for iron Dietary intake estimates should therefore be interpreted with caution, particularly as no biological markers were used in validation(8). On the other hand, the present study has some strengths. First, since the sampling was designed to be representative of Türkiye, the results can be generalized to the national population aged 35 to 70 years. Moreover, this is the first anemia prevalence study conducted in the adult age group with a nationally representative sample. Second, the inclusion of both rural and urban areas enabled comparisons between these populations and offered community-specific insights. Third, blood tests were performed in the same laboratory utilizing standardized methods, enhancing the reliability of the measurements.

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In conclusion, anemia affects a significant portion of the adult population in Türkiye, particularly women and individuals with lower education levels, with a slightly but not substantially higher prevalence in urban areas. The predominance of hypochromic microcytic anemia indicates that iron deficiency is a major underlying factor. It seems that anemia is not associated with nutritional deficiency but may be attributed to non-nutritional factors, such as blood loss or absorption problems. These findings underscore the need for targeted public health strategies and routine anemia screening among high-risk populations.

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Figure legends:

Figure 1: Percentages of anemia in women and men across the age categories

Tables:

Table 1: The demographic and laboratory characteristics of participants with and without anemia

Table 2: Distribution of anemia severity and morphological subtypes among anemic participants by sex (excluding two cases of macrocytic anemia)

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Supplementary Figures:

Supplementary Figure S1: The distribution of microcytic and normocytic anemia across the age categories in women and men.

Supplementary Figure S2: Severity of anemia in women and men

Supplementary Figure S3: The distribution of anemia types according to mean corpuscular volume in women and men.

Supplementary Figure S4: Distribution of anemia subgroups based on mean corpuscular volume and mean corpuscular hemoglobin concentration in women and men.

Supplementary Figure S5: The distribution of anemia types according to mean corpuscular hemoglobin concentration in women and men

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Statements and Declerations:

Funding: This study was supported by the Metabolic Syndrome Society of Turkey. The Population Health Research Institute, McMaster University, provided scientific and logistical support.

Conflict of Interest: None

Data Availability: Deidentified participant data and a data dictionary may be made available upon reasonable request after approval of a proposal and signing of a data-sharing agreement.

Author Contributions: AO, MK, NI, FEG, SG, YA, KK, AT, KBCT, AAA, MVK, OTC, VM, SR, and SY contributed to study conception, design, data collection, and interpretation. MVK, MK, AO drafted the first version of the manuscript. MVK, MK, OTC, AO accessed and verified the underlying data and had final responsibility for the decision to submit for publication.

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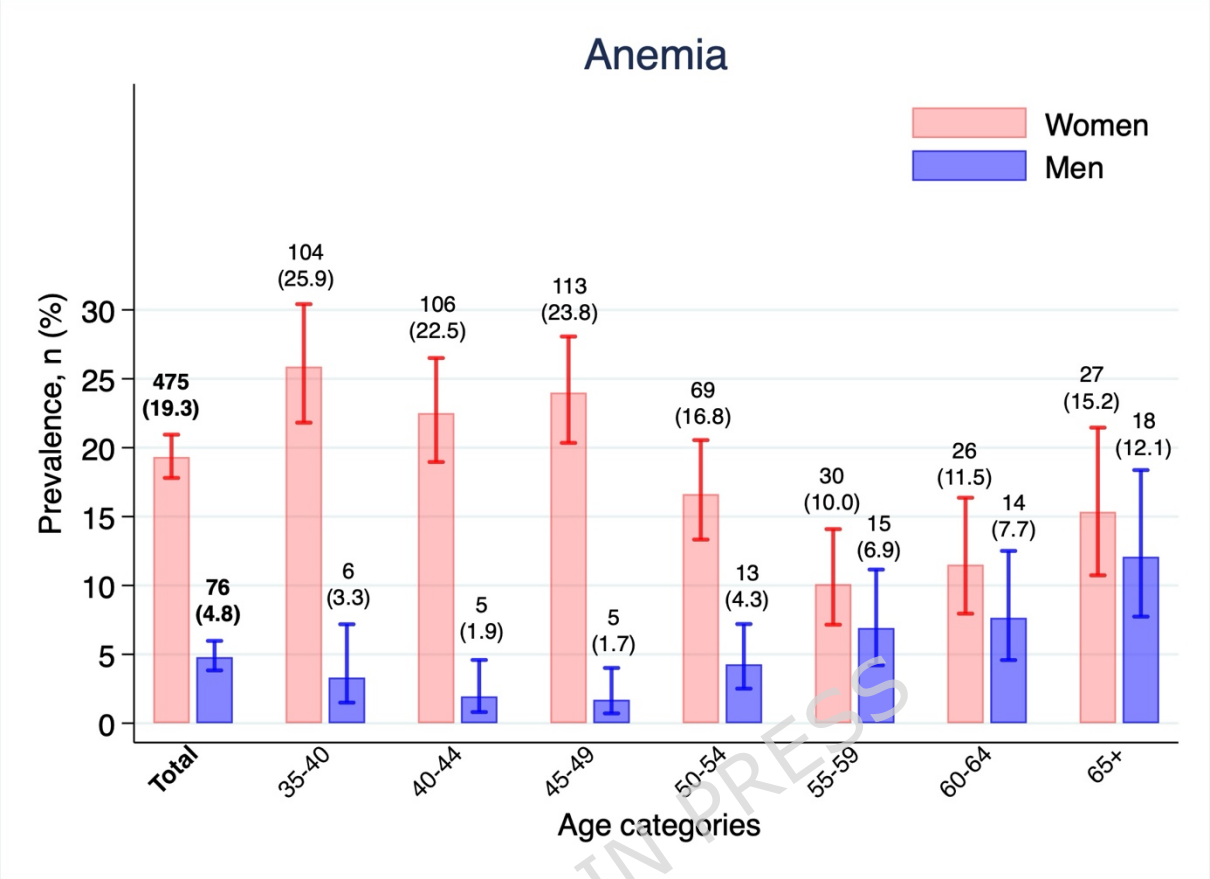


Figure 1: Prevalence of anemia in women and men across age categories. Error bars represent 95% confidence intervals. Numbers above the bars indicate the number of participants with anemia in each age category and the corresponding prevalence (%).

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Tables

Table 1: The demographic and laboratory characteristics of participants with and without anemia

	All Participants				Women				Men			
	Non-anemic	Anemic	Total	P	Non-anemic	Anemic	Total	p	Non-anemic	Anemic	Total	p
n, (%)	3499 (86.4)	551 (13.6)	4050		1986 (80.7)	475 (19.3)	2461		1513 (95.2)	76 (4.8)	1589	
Age, years	50.3 (9.1)	48.4 (9.3)	50.0 (9.1)	<0.001	49.9 (9.1)	47.0 (8.6)	49.3 (9.1)	<0.001	50.8 (9.0)	56.5 (9.4)	51.1 (9.1)	<0.001
Education, n (%)				0.009				0.042				0.022
None	677 (19.3)	113 (20.5)	790 (19.5)		588 (29.6)	106 (22.3)	694 (28.2)		89 (5.9)	7 (9.2)	96 (6.0)	
Primary	1998 (57.1)	341 (61.9)	2339 (57.8)		1070 (53.9)	289 (60.8)	1359 (55.2)		928 (61.3)	52 (68.4)	980 (61.7)	
Secondary	635 (18.1)	78 (14.2)	713 (17.6)		258 (13.0)	63 (13.3)	321 (13.0)		377 (24.9)	15 (19.7)	392 (24.7)	
Higher	189 (5.4)	19 (3.4)	208 (5.1)		70 (3.5)	17 (3.6)	87 (3.5)		119 (7.9)	2 (2.6)	121 (7.6)	
Rural vs. urban n (%)				0.049				0.155				0.985
Rural, n (%)	1249 (35.7)	173 (31.4)	1422 (35.1)		670 (33.7)	144 (30.3)	814 (33.1)		579 (38.3)	29 (38.2)	608 (38.3)	
Urban, n (%)	2250 (64.3)	378 (68.6)	2628 (64.9)		1316 (66.3)	331 (69.7)	1647 (66.9)		934 (61.7)	47 (61.8)	981 (61.7)	
Hemoglobin (g/dL)	14.2 (1.3)	10.9 (1.2)	13.8 (1.7)	<0.001	13.4 (0.8)	10.8 (1.1)	12.9 (1.4)	<0.001	15.3 (1.0)	11.4 (1.5)	15.1 (1.3)	<0.001
Hematocrit (%)	42.6 (3.4)	34.7 (2.8)	41.5 (4.3)	<0.001	40.6 (2.5)	34.4 (2.5)	39.4 (3.5)	<0.001	45.1 (2.8)	36.4 (3.7)	44.7 (3.4)	<0.001
MCV (fL)	86.6 (4.7)	78.5 (8.8)	85.5 (6.1)	<0.001	86.4 (4.6)	78.7 (8.3)	84.9 (6.3)	<0.001	87.0 (4.8)	77.3 (11.7)	86.5 (5.7)	<0.001

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MCH (pg)	28.9 (1.8)	24.7 (3.6)	28.4 (2.6)	<0.001	28.6 (1.7)	24.7 (3.4)	27.8 (2.7)	<0.001	29.4 (1.7)	24.3 (4.3)	29.2 (2.2)	<0.001
MCHC (g/dL))	33.4 (1.0)	31.3 (1.6)	33.1 (1.3)	<0.001	33.1 (0.9)	31.3 (1.6)	32.7 (1.3)	<0.001	33.8 (1.0)	31.4 (1.8)	33.7 (1.2)	<0.001
RDW-CV (%)	13.3 (12.8; 13.8)	15.3 (14.0; 17.1)	13.4 (12.9; 14.1)	<0.001	13.3 (12.8; 13.9)	15.2 (14.0; 16.9)	13.5 (12.9; 14.3)	<0.001	13.2 (12.8; 13.6)	16.3 (14.2; 18.8)	13.2 (12.8; 13.7)	<0.001
Erythrocyte ($\times 10^6/\mu L$)	4.9 (0.5)	4.5 (0.6)	4.9 (0.5)	<0.001	4.7 (0.4)	4.4 (0.5)	4.7 (0.4)	<0.001	5.2 (0.4)	4.8 (0.9)	5.2 (0.5)	<0.001
Leukocyte ($\times 10^9$/L)	6.8 (1.9)	6.4 (2.0)	6.8 (1.9)	<0.001	6.6 (1.7)	6.4 (1.7)	6.5 (1.7)	0.032	7.2 (2.0)	6.5 (3.3)	7.2 (2.1)	0.004
Platelet count ($\times 10^9$/L)	269.2 (67.7)	310.4 (86.1)	274.8 (71.9)	<0.001	281.0 (69.7)	315.8 (84.6)	287.7 (74.0)	<0.001	253.8 (61.9)	276.6 (88.2)	254.8 (63.5)	0.002
PDW (%)	45.6 (43.2; 52.6)	46.3 (43.3; 53.0)	45.7 (43.2; 52.6)	0.063	46.0 (43.3; 52.8)	47.2 (43.4; 53.3)	46.1 (43.3; 52.9)	0.107	45.3 (43.0; 52.1)	45.0 (43.1; 49.1)	45.3 (43.0; 52.0)	0.267
Vitamin B12 intake (µg/day)	5.3 (3.1; 9.9)	4.8 (2.9; 9.3)	5.2 (3.1; 9.8)	0.018	4.5 (2.7; 8.4)	4.7 (2.9; 9.2)	4.5 (2.8; 8.5)	0.143	6.7 (3.9; 11.9)	5.4 (3.3; 9.6)	6.7 (3.9; 11.8)	0.023
Iron intake (mg/day)	14.7 (11.0; 19.6)	14.2 (10.2; 18.2)	14.6 (10.8; 19.5)	0.012	13.5 (10.2; 17.9)	13.8 (9.9; 17.9)	13.6 (10.1; 17.9)	0.569	16.6 (12.3; 21.8)	16.5 (12.8; 19.8)	16.5 (12.3; 21.7)	0.473

Normally distributed continuous variables were presented mean (Standard deviation) and compared using t-test; Non-normally distributed continuous variables were presented as median (Q1; Q3) and were compared using Mann-Whtiney U test, education was compared using Cochrane-Armitage test, other categorical variables were compared using chi-squared test. Abbreviations: MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PDW Platelet distribution width; RDW-CV, red cell distribution width (coefficient of variation).

Table 2: Distribution of anemia severity and morphological subtypes among anemic participants by sex (excluding two cases of macrocytic anemia)

	Women (n=474)	**Men (n=75)**	**Total (n=549)**	**P-value**
Anemia severity, n (%)				0.001

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Mild	268 (56.4)	57 (75.0)	325 (59.0)	
Moderate	196 (41.3)	15 (19.7)	211 (38.3)	
Severe	11 (2.3)	4 (5.3)	15 (2.7)	
Red cell size classification, n (%)				0.607
Microcytic	244 (51.5)	41 (54.7)	285 (51.9)	
Normocytic	230 (48.5)	34 (45.3)	264 (48.1)	
Chromicity classification, n (%)				0.187
Normochromic	157 (33.1)	31 (40.8)	188 (34.1)	
Hypochromic	318 (66.9)	45 (59.2)	363 (65.9)	
Combined MCV–MCHC classification, n (%)				0.223
Normochromic Microcytic	40 (8.4)	12 (16.0)	52 (9.5)	
Normochromic Normocytic	117 (24.7)	18 (24.0)	135 (24.6)	
Hypochromic Microcytic	204 (43.0)	29 (38.7)	233 (42.4)	
Hypochromic Normocytic	113 (23.8)	16 (21.3)	129 (23.5)	

Data are presented as n (%). Two participants with macrocytic anemia (MCV >100 fL) were excluded from the morphological subtype analyses because meaningful statistical comparisons could not be performed due to the very small sample size. Abbreviations: MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration

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