



Published in final edited form as:

J Nutr. 2025 March ; 155(3): 968–974. doi:10.1016/j.tjnut.2024.12.029.

Concordance Between Hemoglobin and Hematocrit Among Children and Pregnant Persons in National Health and Nutrition Examination Survey Data, 1999–2020

Maren E. Wolf^{1,2}, Maria Elena D. Jefferds², Lisa D. Gardner², Zuguo Mei², Christine M. Pfeiffer³, O. Yaw Addo²

¹Epidemic Intelligence Service, Centers for Disease Control and Prevention, Atlanta, GA,

²International Micronutrient Malnutrition Prevention and Control (IMMPaCt) Program, Nutrition Branch, Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, GA,

³Nutritional Biomarkers Branch, Division of Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, GA.

Abstract

Background: Hemoglobin and hematocrit are the two most common biomarkers used to identify anemia in clinical settings, but their results do not always agree.

Objective: To examine agreement between hemoglobin and hematocrit in identifying anemia among children aged 1–<5 years and pregnant persons.

Methods: Pregnant persons and children aged 1–<5 years with hemoglobin and hematocrit results from the same whole blood sample in National Health and Nutrition Examination Survey (NHANES, 1999–2020) were included. We used the Centers for Disease Control and Prevention (CDC) anemia cutoff values for children, pregnancy status, trimester, and smoking adjustments. We examined concordance of anemia, sensitivity, and specificity among those with anemia based on at least one test overall and by race/ethnicity, sex, and income level. Cohen's kappa was used to measure concordance.

Results: Analytic samples included 7,052 children and 1,437 pregnant persons, of which 1,119 had trimester data. Among children, anemia prevalence was 3.7% (95% CI: 3.1–4.3) based on hemoglobin and 5.5% (95% CI: 4.7–6.3) based on hematocrit. Among pregnant persons, anemia prevalence based on hemoglobin was 7.7% (95% CI: 5.9–9.5) and 12.4% (95% CI: 10.1–14.6) based on hematocrit. Kappa scores overall and by sociodemographic characteristics ranged from 0.64–0.75 (moderate concordance) among children and 0.53–0.78 (weak to moderate

Corresponding author: Yaw Addo, Nutrition Branch, Division of Nutrition, Physical Activity, and Obesity, Centers for Disease Control and Prevention (CDC), 4770 Buford Hwy NE, Atlanta, GA 30341. lyu6@cdc.gov.

Data described in the manuscript are publicly and freely available without restriction at <https://wwwn.cdc.gov/nchs/nhanes/Default.aspx>

Disclaimers: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Use of trade names and commercial sources are for identification only and does not imply endorsement by the U.S. Department of Health and Human Services.

concordance) among pregnant persons. Among those with anemia on at least one test, 53.5% of children and 61.5% of pregnant persons had anemia based on both tests.

Conclusions: We found substantial discordance between the two biomarkers; about 50% of children and 40% of pregnant women were identified by only one of the two biomarkers. Because hemoglobin and hematocrit may be used interchangeably in the clinical setting, individuals with anemia may be missed, not receive treatment, and therefore be at higher risk of adverse pregnancy, birth, and developmental outcomes.

Keywords

hemoglobin; hematocrit; anemia; concordance; discordance; children; pregnant; NHANES

Introduction

Anemia is the result of insufficient production of healthy red blood cells in the body, which lowers the oxygen-carrying capacity of blood and has a significant impact on morbidity and mortality, especially for groups at high risk, including young children and pregnant persons (1). Anemia is a symptom of an underlying condition, not a diagnosis, but is an essential starting point for a more in-depth health evaluation (2, 3). For this reason, being able to accurately identify anemia is crucial for anyone treating patients. Despite its well-known health impacts, the same individuals are not necessarily identified as having anemia using various existing clinical practice guidelines.

Hemoglobin and hematocrit are the two most common biomarkers used in the clinical setting to identify anemia, and the two modalities are different in important ways. Hemoglobin is a molecule inside red blood cells; the laboratory test for hemoglobin is a direct measure of the number of hemoglobin molecules present in the blood. Hematocrit is the proportion of red blood cells to whole blood and can be determined by two primary methods: (a) a complete blood count in which an autoanalyzer determines the size and number of red blood cells, and (b) centrifugation in a tube where the spun red blood cells are measured in relation to the other components of whole blood (1, 4). Hematocrit can also be calculated by multiplying hemoglobin results by three or multiplying hemoglobin by the mean corpuscular hemoglobin concentration (4–6).

Clinical guidelines in the United States such as UpToDate (7) and institutional guidelines such as the Centers for Disease Control and Prevention's (CDC) 1998 recommendations (8) consider both hemoglobin and hematocrit as acceptable measures of anemia, but this recommendation is sometimes questioned, and authors have noted pros and cons of each. Ali-Baya et al. and Keen both note how external factors can influence hematocrit measurements, while Graitcer et al. and Nguyen et al. describe the benefit of direct measurement and better correlation to anemia diagnosis with the use of hemoglobin (9–12). Brunken et al. suggest hematocrit as the preferred measure due to its cost and simplicity (13). The American College of Obstetricians and Gynecologists suggests using hematocrit as the basis to identify anemia in pregnancy (14) while the American Gastroenterological Association (15) and the American Academy of Pediatrics (16) define anemia based on hemoglobin concentration.

Although hemoglobin and hematocrit both have support in the literature and clinical guidelines as the biomarker of choice for identifying anemia, there is evidence that the two measures are not concordant. This has important implications for the identification and treatment of patients with anemia in the United States and globally. In 1981, Graitcer et al. (10) concluded that hemoglobin and hematocrit are not comparable in their ability to detect anemia in a study among US children aged 12–23 months with 20%–50% of children with anemia being missed when using hematocrit testing alone and between 25%–57% being missed when using hemoglobin alone. More recent studies from the United States (17) and Tanzania (5) are consistent with this finding.

Based on reviews and studies using hemoglobin and ferritin measurements, young children and pregnant persons are at highest risk for poor outcomes secondary to anemia, such as impacts to behavior and neural plasticity, preterm birth, preeclampsia, low birth weight, and neonatal and perinatal death (18–21). The accurate identification and treatment of individuals with anemia is important considering the health sequelae if it goes untreated. The aim of this study was to assess the degree of concordance, sensitivity, specificity, and percent agreement between hemoglobin and hematocrit for identifying anemia in children aged 1–<5 years and pregnant persons in the United States.

Methods

Study Design and Participants

This study examined combined data from 10 continuous cycles (two-year period) of publicly available data from the National Health and Nutrition Examination Survey (NHANES) during 1999–2020. The NHANES is a nationally representative cross-sectional survey of the civilian non-institutionalized population, following a complex multi-stage sampling frame and has been previously described (22). We analyzed two groups at high risk for anemia: young children (aged 1 year to under 5 years) and pregnant persons (aged 15–49 years). Pregnant persons were disaggregated by trimester where data were available. Cycles 1999–2000 to 2011–2012 collected details on month of pregnancy; subsequent cycles did not collect these details. Pregnancy data from cycles 1999–2006 came from individuals aged 15–49 years. After 2006, the only publicly available data were from those aged 20–44 years. We also described results by race/ethnicity, sex (children only), and income level. Race/ethnicity categories included non-Hispanic white, non-Hispanic Black, Mexican American, and other including those reporting more than one race. Low income was defined as 130% of the poverty threshold (23). We would have excluded participants missing hemoglobin or hematocrit measurements for this study, but no participants had only one measurement. Hemoglobin and hematocrit were assessed by complete blood count using a single sample of venous blood and an automated Beckman Coulter hematology analyzer in the NHANES mobile examination centers (22). The Beckman Coulter measures hemoglobin directly via photometry of lysed red blood cells and hematocrit is calculated from hematologic indices of whole blood.

We defined anemia and adjusted hemoglobin and hematocrit for smoking based on CDC guidance. Age- and sex-specific cutoff values for anemia are based on the 5th percentile from the third National Health and Nutrition Examination Survey (NHANES III), which

excluded persons who had a high likelihood of iron deficiency(8). Although persons residing at higher altitudes (> 500 meters) (24) have higher hemoglobin and hematocrit levels than those residing at sea level, publicly available NHANES data do not contain information about location or altitude, so hemoglobin and hematocrit data were not adjusted for altitude.

Statistical Methods

All statistical procedures accounted for the complex survey design used in NHANES. Prevalence data were weighted and accounted for strata and primary sampling units for design effects (22). Participant characteristics were summarized using univariate descriptive statistics with proportions (% and 95% Wald CI) for categorical and means (95% CI) for continuous variables. The default Wald CI in SAS SURVEYFREQ procedure was used as sample sizes for subgroup stratified analyses (n>190 for lowest count) were sufficiently robust to support reliable estimates.

In cross-tabulation analysis, we used Cohen's weighted kappa statistic (25) to assess concordance between hemoglobin and hematocrit to identify anemia. The traditional interpretation for Cohen's kappa is defined as 0.01–0.20 none to slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1.00 almost perfect agreement (25). However, because it is more appropriately aligned with the needs of healthcare studies, we used McHugh's (26) interpretation defined as 0.0–0.20 none, 0.21–0.29 minimal, 0.40–0.59 weak, 0.60–0.79 moderate, 0.80–0.90 strong, and above 0.90 almost perfect. Sensitivity and specificity were also estimated with hemoglobin as the standard (27) and hematocrit as the screener test. We also calculated percent agreement (true positive and true negative percent) for all individuals and percent agreement limited to those with anemia on at least one test. All analyses were completed using SAS 9.4 software (SAS Institute, Cary, NC, USA).

Results

From the 10 NHANES cycles, 7,052 children and 1,437 pregnant persons met the inclusion criteria of having both hemoglobin and hematocrit test results. The mean age for children was 2.4 years, and 48% were female (Table 1). Mean age of pregnant persons was 27.9 years. Data on month of pregnancy were available for 1,119 (77.9%) individuals: 200 (17.4%) persons in their first trimester, 479 (41.8%) in their second trimester, and 440 (38.3%) in their third trimester (Table 1).

In both the children and pregnant populations, more individuals were identified as having anemia using hematocrit compared to hemoglobin (Tables 2 and 3). Among children aged 1–<2 years, anemia prevalence by hemoglobin was 6.3% (95% CI: 4.8–7.8) and 8.6% (95% CI: 7.0–10.2) by hematocrit. Among children aged 2–<5 years, anemia prevalence by hemoglobin was 3.0% (95% CI: 2.4–3.5) and 4.6% (95% CI: 3.8–5.4) by hematocrit (Table 2). Among pregnant persons, anemia prevalence by hemoglobin was 7.7% (95% CI: 5.9–9.5) and 12.4% (95% CI: 10.1–14.6) by hematocrit. Prevalence was highest among persons in their third trimester by both hemoglobin and hematocrit, 12.1% (95% CI: 7.5–16.7) and 15.2% (95% CI: 10.1–20.4), respectively (Table 3).

The overall kappa for children aged 1–<5 years was 0.68 (95% CI: 0.64–0.72), and the results by age, sex, race/ethnicity, and low-income threshold fell within the moderate concordance range, according to McHugh's (2012) interpretation (0.60–0.79) (Table 2). Females (0.64; 95% CI: 0.58 – 0.71), children 2–<5 (0.64; 95% CI: 0.59 – 0.70), Mexican American children (0.64; 95% CI: 0.55–0.73), and non-Hispanic white children (0.64; 95% CI: 0.54–0.73) had the lowest kappa scores, while the highest kappa was seen in children aged 1–<2 years (0.75; 95% CI: 0.69–0.81). In children, overall sensitivity of hematocrit to identify anemia using hemoglobin as the standard was 81.5%, and specificity was 97.4% (Table 2). By child characteristics, sensitivity of hematocrit ranged from 77.6% and 77.5% among female children and children aged 2–<5 years, respectively, to 88.9% among 1–<2-year-old children; specificity was high by all characteristics (>97%). Among young children identified as having anemia on at least one test, 237 of 510 (46.5%) individuals were identified as having anemia based on only one test, 62 by hemoglobin only, and 175 by hematocrit only (Table 4).

The overall kappa for pregnant persons was 0.73 (95% CI: 0.68–0.79) (Table 3). The lowest kappa was among pregnant persons in their second trimester (0.53; 95% CI: 0.36–0.70; weak concordance), and all others, including the highest kappa among pregnant Mexican American persons (0.78; 95% CI: 0.67–0.88), showed moderate concordance. In pregnant persons, overall sensitivity of hematocrit to identify anemia based on hemoglobin as the standard was 93.6%, and specificity was 94.4%. By trimester, sensitivity ranged from 82.4% among persons in their second trimester to 100% among those in their first trimester (Table 3). Among pregnant persons identified as having anemia on at least one test, 82 of 213 (38.5%) individuals were identified by only one test, 9 by hemoglobin only and 73 by hematocrit only (Table 5).

Discussion

While hemoglobin is a direct measure of the iron-containing protein and the oxygen carrying capacity in red blood cells, both hemoglobin and hematocrit are regularly used interchangeably to screen for anemia (3, 7). The two biomarkers measure different hematologic processes, and the literature documents differences in who is identified as having anemia based on the results of one biomarker or the other (5, 10, 17). This study aimed to examine the concordance, sensitivity, specificity, and percent agreement using thresholds from the 1998 CDC guidelines between hemoglobin and hematocrit for identifying anemia among children aged 1–<5 years and pregnant persons, two populations at high risk for anemia. We found a greater number of individuals identified as having anemia based on hematocrit for both populations, and the kappa results showed mostly moderate levels of agreement between hemoglobin and hematocrit in identifying anemia based on McHugh's (26) interpretation. Using hemoglobin as the standard, overall sensitivity and specificity of hematocrit was 81.5% and 97.4% among children, respectively, and 93.6% and 94.4% among pregnant persons, respectively. The percent disagreement by both tests (46.5% in young children, 38.5% in pregnant persons) among those with at least one positive test suggests the biomarkers are identifying a substantial number of different people as having anemia and suggests they are not interchangeable.

Physiologic changes in pregnancy could potentially explain the weak level of concordance seen during the second trimester of pregnancy. Plasma volume expands by about 50% during pregnancy while red blood cell mass only expands by 25% (7). This leads to physiologic anemia by dilution and a lowered hematocrit, occurring most notably when the blood volume is undergoing the biggest transformation during the second trimester. CDC anemia cutoff values for the second trimester are lower to reflect this change. More generally, components used to measure hematocrit - red blood cell count (RBC), mean corpuscular hemoglobin concentration (MCHC), and mean corpuscular volume (MCV) (28) could also be affected by physiologic factors such as sex and age, as well as other factors like micronutrient deficiencies notably RBC folate (28) and vitamin B12. Evidence shows that MCV increases over the lifespan with the most rapid increase in the first 25 years of life (29). These physiologic changes could also affect the level of agreement between the two biomarkers. Further, hemoglobin and hematocrit were derived from the same sample of blood and measured by the same hematology analyzer. It is unknown whether the discordant findings would vary if other analyzers were used and more evidence from different analyzers could inform discussions around the use of hemoglobin and hematocrit. We are not well positioned to highlight which biomarker is the better measure of the two.

A limited number of studies have looked at the concordance between hemoglobin and hematocrit. Results from Quinto et al. (5) showed differences in who is identified as having anemia based on using hemoglobin vs. hematocrit among children aged 2–18 months in two locations in Tanzania. In Ifakara, 74% and 10% of children were identified with mild and moderate anemia, respectively, as measured by hemoglobin, and 42% and 3% with mild and moderate anemia, respectively, using hematocrit. Similar results were seen in children from Manhica, Mozambique (5).

Sharma et al.(17) examined percent agreement among persons in their first trimester with at least one positive test for anemia using electronic health record data. They found 115 more women were identified as having anemia using the hematocrit marker compared to hemoglobin, in line with the findings from this study. Their results showed 45.2% percent agreement, lower than the results of this study (61.5% pregnant persons overall, 53.5% children aged 1–<5 years). We were not able to compare the percent agreement for the first trimester in this study due to the small sample size ($n=11$). According to McHugh “many texts recommend 80% as a minimum percent agreement” for healthcare settings (26). Neither study met that threshold.

The percent agreement between hemoglobin and hematocrit indicates that the two biomarkers are identifying different people as anemic. This is problematic because many clinical guidelines (including the guideline from the CDC) suggest that they are interchangeable (3, 7). The data presented here show that may not always be true. Understanding discordance, in addition to concordance, is also clinically relevant as it will be important to understand who might be missed when considering follow-up diagnostics and treatment options. In this study, hematocrit identified more people as having anemia than did hemoglobin. It will be helpful to understand how and if those identified as having anemia via hematocrit only or hemoglobin only differ in meaningful ways or in their health outcomes. This is relevant because consistently using both biomarkers to capture

all possible individuals with anemia could have important resource implications. Further, if hemoglobin and hematocrit are not interchangeable, it could influence the way clinicians make diagnostic testing and treatment decisions. If only one biomarker is used, there is risk of excess or insufficient follow-up and treatment.

In addition to the clinical implications of missing individuals with anemia, there are wider policy and surveillance implications if hemoglobin and hematocrit are not concordant. For example, the US Department of Agriculture Food and Nutrition Services Supplemental Nutrition Program for Women, Infants, and Children (WIC) includes anemia among the medical conditions that could be used to meet the eligibility requirements for the program (30). When programs use anemia screening as an eligibility criterion, it may be possible that applicants are denied services depending on how anemia screening is conducted. When anemia data are used for surveillance, such as with electronic health records, anemia prevalence may be different and result in different healthcare policy decisions by those who use the data. Other additional criteria that are relevant to the considerations of selecting biomarkers include feasibility, acceptability, resources, cost effectiveness, and health equity.

There are a few limitations of this study. Trimester data were not available for all years examined. The sample sizes for pregnant persons were small, limiting the ability to disaggregate by trimester, race/ethnicity, and income. There are no standard cutoff points for hematocrit severity, so it was not possible to investigate differences by anemia severity. Data for pregnant adolescents aged 15–19 years and persons aged 45–49 years were not available in public domain in cycles 2007–2020. However, it is unlikely conclusions would be impacted by this potential selection bias given that the same method (hematology auto-analyzers) was used for all participants over the cycles. We were unable to adjust hemoglobin values for elevation of participants residing at or above 500m (24).

Strengths of this study include that NHANES used venous blood and laboratory methods did not change during the 1999–2020 cycles making the assessment of hemoglobin and hematocrit consistent throughout the years of this study. In addition, this study used nationally representative data making the findings generalizable to the US population.

Conclusions

All groups had moderate levels of agreement in their hemoglobin and hematocrit kappa results (McHugh's interpretation), except for pregnant persons in their second trimester (kappa = 0.53) where agreement was weak. Among those who were identified as having anemia on at least one test, about 50% of children and 40% of pregnant persons were identified by only one of the two biomarkers, showing substantial discordance. Because hemoglobin and hematocrit are often used interchangeably in the clinical setting, individuals with anemia may be missed and not receive treatment, and therefore be at higher risk of adverse pregnancy, birth, and developmental outcomes.

Acknowledgments

MEW, MEDJ, LDG, ZM, and OYA designed research; MEW and OYA conducted research; MEW analyzed data; MEW wrote paper. All authors read and approved the final manuscript.

Abbreviations

AAP	American Academy of Pediatrics
ACOG	American College of Obstetricians and Gynecologists
AGA	American Gastroenterological Association
CDC	Centers for Disease Control and Prevention
MCHC	Mean Corpuscular Hemoglobin concentration
MCV	Mean corpuscular Volume
NHANES	National Health and Nutrition Examination Survey
RBC	Red Blood Cell
WIC	Women, Infants, and Children

REFERENCES

1. Baldi A, Pasricha S-R. Anaemia: Worldwide Prevalence and Progress in Reduction. Edition ed. In: Karakochuk CD, Zimmermann MB, Moretti D, Kraemer K, eds. Nutritional Anemia. Cham: Springer International Publishing, 2022:3–17.
2. Jefferds MED, Mei Z, Addo Y, Hamner HC, Perrine CG, Flores-Ayala R, Pfeiffer CM, Sharma AJ. Iron Deficiency in the United States: Limitations in Guidelines, Data, and Monitoring of Disparities. *Am J Public Health*. 2022;112(S8):S826–S835. doi: 10.2105/AJPH.2022.306998. [PubMed: 36288529]
3. Turner J, Parsi M, Badireddy M. Anemia. Edition ed. StatPearls. Treasure Island (FL), 2023.
4. Mondal H, Lotfollahzadeh S. Hematocrit. Edition ed. StatPearls. Treasure Island (FL), 2023.
5. Quinto L, Aponte JJ, Menendez C, Sacarlal J, Aide P, Espasa M, et al. Relationship between haemoglobin and haematocrit in the definition of anaemia. *Trop Med Int Health*. 2006;11(8):1295–302. doi: 10.1111/j.1365-3156.2006.01679.x. [PubMed: 16903892]
6. Oduwole OA, Ameh S, Esu EB, Oringanje CM, Meremikwu JT, Meremikwu MM. Assessing agreement of hemoglobin and three- fold conversion of hematocrit as methods for detecting anemia in children living in malaria-endemic areas of Calabar, Nigeria. *Niger J Clin Pract*. 2019;22(8):1078–82. doi: 10.4103/njcp.njcp_66_19. [PubMed: 31417050]
7. Means RT Jr, Brodsky, Robert A. Diagnostic Approach to Anemia in Adults. Edition ed. In: Joann G Elmore M, MPH, ed. UpToDate: Wolters Kluwer, 2023.
8. CDC. Recommendations to prevent and control iron deficiency in the United States. Centers for Disease Control and Prevention. *MMWR Recomm Rep*. 1998;47(Rr-3):1–29.
9. Ali-Baya G, Zenile E, Aikins BO, Amoaning RE, Simpong DL, Adu P. Poor haemoglobin-haematocrit agreement in apparently healthy adult population; a cross-sectional study in Cape Coast Metropolis, Ghana. *Heliyon*. 2021;7(8):e07720. doi: 10.1016/j.heliyon.2021.e07720. [PubMed: 34401592]
10. Graitcer PL, Goldsby JB, Nichaman MZ. Hemoglobins and hematocrits: are they equally sensitive in detecting anemias? *The American Journal of Clinical Nutrition*. 1981;34(1):61–4. doi: 10.1093/ajcn/34.1.61. [PubMed: 7446459]
11. Keen ML. Hemoglobin and hematocrit: an analysis of clinical accuracy. Case study of the anemic patient. *ANNA Journal*. 1998;25(1):83–6. [PubMed: 9543916]
12. Nguyen WB, Wyse JM, Drollinger SM, Cheng K. Anemia Screening in Naval Aviation: Is Hemoglobin a Better Indicator Than Hematocrit as the Primary Index? *Mil Med*. 2020;185(3–4):461–7. doi: 10.1093/milmed/usz243.

13. Brunken G, França G, Luiz R, Szarfarc S. Agreement assessment between hemoglobin and hematocrit to detect anemia prevalence in children less than 5 years old. *Cadernos Saúde Coletiva*. 2016;24:118–23. doi: 10.1590/1414-462X201600010x01.
14. ACOG. Anemia in Pregnancy: ACOG Practice Bulletin Summary, Number 233. *Obstetrics & Gynecology*. 2021;138(2):317–9. doi: 10.1097/aog.0000000000004478.
15. Ko CW, Siddique SM, Patel A, Harris A, Sultan S, Altayar O, Falck-Ytter Y. AGA Clinical Practice Guidelines on the Gastrointestinal Evaluation of Iron Deficiency Anemia. *Gastroenterology*. 2020;159(3):1085–94. doi: 10.1053/j.gastro.2020.06.046. [PubMed: 32810434]
16. Baker RD, Greer FR, Nutrition TCo. Diagnosis and Prevention of Iron Deficiency and Iron-Deficiency Anemia in Infants and Young Children (0–3 Years of Age). *Pediatrics*. 2010;126(5):1040–50. doi: 10.1542/peds.2010-2576. [PubMed: 20923825]
17. Sharma AJ, Ford ND, Bulkley JE, Jenkins LM, Vesco KK, Williams AM. Use of the Electronic Health Record to Assess Prevalence of Anemia and Iron Deficiency in Pregnancy. *The Journal of Nutrition*. 2021;151(11):3588–95. doi: 10.1093/jn/nxab254. [PubMed: 34386820]
18. Georgieff MK. Long-term brain and behavioral consequences of early iron deficiency. *Nutrition Reviews*. 2011;69(suppl_1):S43–S8. doi: 10.1111/j.1753-4887.2011.00432.x. [PubMed: 22043882]
19. McCarthy EK, Murray DM, Hourihane JOB, Kenny LC, Irvine AD, Kiely ME. Behavioral consequences at 5 y of neonatal iron deficiency in a low-risk maternal–infant cohort. *The American Journal of Clinical Nutrition*. 2021;113(4):1032–41. doi: 10.1093/ajcn/nqaa367. [PubMed: 33515035]
20. Ren A, Wang J, Ye RW, Li S, Liu JM, Li Z. Low first-trimester hemoglobin and low birth weight, preterm birth and small for gestational age newborns. *International Journal of Gynecology & Obstetrics*. 2007;98(2):124–8. doi: 10.1016/j.ijgo.2007.05.011. [PubMed: 17585914]
21. Smith C, Teng F, Branch E, Chu S, Joseph KS. Maternal and Perinatal Morbidity and Mortality Associated With Anemia in Pregnancy. *Obstetrics & Gynecology*. 2019;134(6):1234–44. doi: 10.1097/aog.0000000000003557. [PubMed: 31764734]
22. NHCS. National Health and Nutrition Examination Survey Data [Internet]. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Available from: <https://wwwn.cdc.gov/nchs/nhanes/Default.aspx>.
23. NHANES. 2007 – 2008 Data Documentation, Codebook, and Frequencies. INQ_E [Internet]. 2007 – 2008; Available from: https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/INQ_E.htm.
24. WHO. WHO guideline on haemoglobin cutoffs to define anaemia in individuals and populations. Edition ed. In: Organization WH, ed. *Guideline on haemoglobin cutoffs to define anaemia in individuals and populations*. Geneva, 2024.
25. Cohen J A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*. 1960;20(1):37–46. doi: 10.1177/001316446002000104.
26. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012;22(3):276–82. [PubMed: 23092060]
27. Joint World Health Organization/Centers for Disease C, Prevention Technical Consultation on the Assessment of Iron Status at the Population L. Assessing the iron status of populations: including literature reviews: report of a Joint World Health Organization/Centers for Disease Control and Prevention Technical Consultation on the Assessment of Iron Status at the Population Level, Geneva, Switzerland, 6–8 April 2004. 2nd ed. Geneva: World Health Organization, 2007.
28. Zhang M, Sternberg MR, Yeung LF, Pfeiffer CM. Population RBC folate concentrations can be accurately estimated from measured whole blood folate, measured hemoglobin, and predicted serum folate-cross-sectional data from the NHANES 1988–2010. *Am J Clin Nutr*. 2020;111(3):601–12. doi: 10.1093/ajcn/nqz307. [PubMed: 31858145]
29. Lee JY, Choi H, Park JW, Son BR, Park JH, Jang LC, Lee JG. Age-related changes in mean corpuscular volumes in patients without anaemia: An analysis of large-volume data from a single institute. *J Cell Mol Med*. 2022;26(12):3548–56. doi: 10.1111/jcmm.17397. [PubMed: 35599236]
30. Kline N, Zvavitch P, Wroblewska K, Worden M, Mwombela B, Thorn B, Cassar-Uhl D. WIC Participant and Program Characteristics 2020 [Internet]. U.S. Department of Agriculture, Food and

Nutrition Service; 2022; Available from: <https://fns-prod.azureedge.us/sites/default/files/resource-files/WICPC2020-1.pdf>.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 1

Sociodemographic characteristics of children aged 1–<5 years and pregnant persons in the United States with hemoglobin and hematocrit lab results, National Health and Nutrition Examination Survey 1999–2020.

	N ¹	Mean (95% CI) or % (95% CI)
Children		
Mean Age, years	7052	2.4 years (2.36–2.41)
1–<2 years	1893	26.8% (25.8–27.9)
2–<5 years	5159	73.2% (72.1–74.2)
Sex		
Male	3685	52.3% (51.1–53.4)
Female	3367	47.7% (46.6–48.9)
Race/ethnicity		
Mexican American	1908	27.1% (26.0–28.1)
Non-Hispanic White	2047	29.0% (28.0–30.1)
Non-Hispanic Black	1808	25.6% (24.6–26.7)
Other Hispanic/Multi-race	1289	18.3% (17.4–19.2)
Low Income (<130%) ²		
Above	3044	46.4% (45.2–47.6)
At or below	3520	53.6% (52.4–54.8)
Pregnant Persons		
Mean Age ³ , years	1437	27.9 (27.4 – 28.4)
Trimester ⁴	1119	-
Trimester 1	200	17.4% (15.2 – 19.6)
Trimester 2	479	41.8% (38.9 – 44.6)
Trimester 3	440	38.3% (35.5 – 41.2)
Race/ethnicity		
Mexican American	403	28.0% (25.7 – 30.4)
Non-Hispanic Black	230	16.0% (14.1 – 17.9)
Non-Hispanic White	609	42.4% (39.8 – 44.9)
Other Hispanic/Multi-race	195	13.6% (11.8 – 15.3)
Low Income (<130%) ²		
Above	840	63.0% (60.5–65.7)
At or below	492	36.9% (34.3–39.5)

¹Percentages (%) and sample sizes(n) are unweighted; children low-income missing n = 488; pregnant persons trimester missing = 318; pregnant persons low-income missing n=105

²Low income = 130% of the poverty threshold

³Pregnancy data from cycles 1999–2006 came from individuals aged 15–49 years. After 2006, the only publicly available data were from those aged 20–44 years.

⁴Overall sample includes all pregnant persons confirmed by a lab test or self-report at the time of exam. During the 1999–2000 to 2011–2012 National Health and Nutrition Examination Survey cycles, gestational age data (month of pregnancy) were collected in the reproductive health questionnaire but was unknown or refused for 28 persons.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 2

Anemia prevalence by hemoglobin and hematocrit, unweighted kappa, sensitivity, and specificity among children aged 1–<5 years by sociodemographic characteristics in the United States, National Health and Nutrition Examination Survey 1999–2020.

	N ¹	Anemia prevalence by hemoglobin ² (%, 95% CI)	Anemia prevalence by hematocrit ³ (%, 95% CI)	Kappa ⁴ (95% CI)	Sensitivity ⁵ (95% CI)	Specificity ⁵ (95% CI)
All under 5 years	7052	3.7 (3.1–4.3)	5.5 (4.7–6.3)	0.68 (0.64–0.72)	81.5 (77.3–85.7)	97.4 (97.0–97.8)
1 < 2 years	1893	6.3 (4.8–7.8)	8.6 (7.0–10.2)	0.75 (0.69–0.81)	88.9 (83.2–94.6)	97.2 (96.5–98.0)
2 < 5 years	5159	3.0 (2.4–3.5)	4.6 (3.8–5.4)	0.64 (0.59–0.70)	77.5 (72.0–83.1)	97.4 (97.0–97.9)
Sex						
Male	3685	3.9 (3.2–4.7)	5.8 (4.8–6.9)	0.71 (0.65–0.76)	84.9 (79.7–90.2)	97.5 (96.9–98.0)
Female	3367	3.6 (2.8–4.4)	5.2 (4.2–6.1)	0.64 (0.58–0.71)	77.6 (71.0–84.1)	97.3 (96.8–97.9)
Race/ethnicity						
Mexican American	1908	3.6 (2.7–4.4)	5.3 (4.2–6.3)	0.64 (0.55–0.73)	81.9 (73.1–90.8)	97.4 (96.7–98.1)
Non-Hispanic White	2047	7.4 (6.3–8.5)	8.8 (7.6–10)	0.64 (0.54–0.73)	87.9 (79.5–96.3)	97.6 (96.9–98.3)
Non-Hispanic Black	1808	2.7 (1.9–3.6)	4.8 (3.6–5.9)	0.72 (0.66–0.78)	79.3 (72.7–85.9)	97.1 (96.3–97.9)
Other Hispanic/Multi-race	1289	3.9 (2.6–5.1)	5.3 (3.8–6.7)	0.67 (0.58–0.77)	80.0 (69.9–90.1)	97.5 (96.6–98.4)
Low Income (<130%) ⁶						
Above	3044	3.2 (2.4–4.0)	5.0 (3.9–6.1)	0.68 (0.61–0.74)	84.3 (77.7–91.0)	97.7 (97.1–98.2)
At or below	3520	4.4 (3.5–5.2)	6.2 (5.1–7.2)	0.69 (0.63–0.74)	81.5 (75.9–87.0)	97.2 (96.6–97.8)

¹Unweighted; low-income missing n=488

²Hemoglobin anemia thresholds: 1–<2 years hemoglobin <11.0g/dL; 2–<5 years hemoglobin <11.1 g/dL

³Hematocrit anemia thresholds: 1–<2 years hematocrit <32.9%; 2–<5 years hematocrit <33.0%

⁴McHugh's (2012) interpretation (25): 0–0.20 none, 0.21–0.39 minimal, 0.40–0.59 weak, 0.60–0.79 moderate, 0.80–0.90 strong, above 0.90 almost perfect

⁵Hemoglobin was used as the standard for sensitivity and specificity analyses.

⁶Low income = 130% of the poverty threshold

TABLE 3

Anemia prevalence by hemoglobin and hematocrit, unweighted kappa, sensitivity, and specificity among pregnant persons by trimester and sociodemographic characteristics in the United States, National Health and Nutrition Examination Survey 1999–2020.

	N ¹	Anemia prevalence by hemoglobin ² (%, 95% CI)	Anemia prevalence by hematocrit ³ (%, 95% CI)	Kappa ⁴ (95% CI)	Sensitivity ⁵ (95% CI)	Specificity ⁵ (95% CI)
All	1437	7.7 (5.9–9.5)	12.4 (10.1–14.6)	0.73 (0.68–0.79)	93.6 (89.5–97.6)	94.4 (93.1–95.6)
Trimester	1119					
Trimester 1	200	2.9 (0.7–5.0)	3.9 (1.5–6.3)	0.77 (0.55–0.99)	100 (100–100)	97.9 (95.9–99.9)
Trimester 2	479	3.4 (2.1–4.6)	7.0 (4.7–9.3)	0.53 (0.36–0.70)	82.4 (64.2–100.0)	95.7 (93.8–97.5)
Trimester 3	440	12.1 (7.5–16.7)	15.2 (10.1–20.4)	0.74 (0.66–0.83)	93.1 (86.6–99.6)	93.2 (90.7–95.7)
Race/ethnicity						
Mexican American	403	7.2 (4.8–9.5)	10.6 (7.4–13.8)	0.78 (0.67–0.88)	97.1 (91.6–100.0)	95.7 (93.6–97.7)
Non-Hispanic White	609	19.1 (13.7–24.5)	25.3 (18.6–32.0)	0.74 (0.64–0.84)	93.8 (86.9–100.0)	89.6 (85.1–94.0)
Non-Hispanic Black	230	3.0 (1.2–4.9)	7.2 (4.1–10.3)	0.62 (0.49–0.74)	87.1 (75.3–98.9)	95.5 (93.8–97.2)
Other Hispanic/Multi-race	195	14.2 (8.1–20.3)	20.0 (12.3–27.8)	0.76 (0.63–0.88)	96.2 (88.7–100.0)	92.9 (89.0–96.8)
Low Income (<130%) ⁶						
Above	840	5.7 (3.6–7.9)	9.8 (7.0–12.5)	0.70 (0.62–0.79)	91.8 (84.9–98.7)	95.3 (93.8–96.7)
At or below	492	13.4 (9.8–17.1)	17.4 (13.1–21.7)	0.77 (0.69–0.85)	94.1 (88.5–99.7)	93.6 (91.3–96.0)

¹ Unweighted; trimester missing = 318; low-income missing n=105

² Hemoglobin anemia thresholds: 1-<2 years hemoglobin <11.0g/dL; 2-<5 years hemoglobin <11.1 g/dL

³ Hematocrit anemia thresholds: 1-<2 years hematocrit <32.9%; 2-<5 years hematocrit <33.0%

⁴ McHugh's (2012) interpretation (25): 0 – 0.20 none, 0.21 – 0.39 minimal, 0.40 – 0.59 weak, 0.60 – 0.79 moderate, 0.80 – 0.90 strong, above 0.90 almost perfect

⁵ Hemoglobin was used as the standard for sensitivity and specificity analyses.

⁶ Low income = 130% of the poverty threshold.

TABLE 4
 Number of children aged 1–<5 years identified as anemic by hemoglobin and hematocrit for examination of percent agreement, National Health and Nutrition Examination Survey 1999–2020.

		Hemoglobin total sample		Total	Hemoglobin sub-sample (n=510) ²		
		Anemic	Non-anemic		Anemic	Non-anemic	Total
Hct ¹ total sample	Anemic	4.1% (273/7052)	2.5% (175/7052)	448	Hct sub-sample (n=510) ²	53.5% (273/510)	34.3% (175/510)
	Non-anemic	0.9% (62/7052)	92.8% (6542/7052)	6604		12.2% (62/510)	0
		335	6717	7052			
						335	175
							510

¹ Hct = hematocrit

² Among those with anemia based on at least one test.

TABLE 5
Number of pregnant persons identified as having anemia by hemoglobin and hematocrit for examination of percent agreement, National Health and Nutrition Examination Survey 1999–2020.

	Hemoglobin total sample		Total	Hemoglobin sub-sample (n=213) **	
	Anemic	Non-anemic		Anemic	Non-anemic
	Total				Total
Hct ¹ total sample	Anemic	9.1% (131/1437)	204	Anemic	61.5% (131/213)
	Non-anemic	0.6% (9/1437)	1233	Non-anemic	34.3% (73/213)
		140	1437		73
		1297			213

¹ Hct = hematocrit

² Among those with anemia based on at least one test