

Effectiveness of iron supplementation and education in preventing iron deficiency anemia among frequent blood donors with low hemoglobin levels

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KEYWORDS

Donor care;
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ABSTRACT

Frequent blood donation can lead to iron deficiency anemia (IDA), especially in donors with low baseline hemoglobin (Hb) levels. This study aimed to evaluate the effectiveness of iron supplementation (ferrous fumarate) and donor education in preventing and managing IDA in frequent blood donors with low Hb levels, with particular attention to age and gender-specific responses. Frequent blood donors (more than two donations in the same 12-month period) with Hb levels below 13.00 g/dL (male) or 12.50 g/dL (female) received ferrous fumarate supplementation (200 mg twice daily) along with education on iron deficiency and compliance. Hb levels were measured pre-and post-intervention at 2-3 weeks. The study included 47 donors (76.60% female, 23.40% male), aged 20-64 years. After excluding donors with ferritin >100 ng/mL to focus on iron-deficient donors, 31 donors were analyzed. The median pre-intervention Hb was 12.10 g/dL, which increased to 13.20 g/dL post-intervention. In iron-deficient donors, younger donors (20-39 years, n=18) showed significantly higher median Hb increment compared to older donors (40-65 years, n=13) (2.00 vs 1.20 g/dL, p -value = 0.02). While not reaching statistical significance, younger donors demonstrated a trend toward higher overall response rates (94.44% vs 84.62%, p -value = 0.36) and significant response rates (83.33% vs 53.85%, p -value = 0.07). Female donors (n=26) showed higher response rates (92.31% vs 80.00% in males, p -value = 0.58) and greater Hb improvement (1.50 vs 1.20 g/dL, p -value = 0.81). Baseline ferritin levels were comparable between age groups (28.50 vs 39.00 ng/mL, p -value = 0.81), suggesting age-related differences in treatment response were independent of initial iron status. Iron supplementation with ferrous fumarate, combined with donor education, effectively improved Hb levels in frequent blood donors with iron deficiency, with younger donors showing particularly favorable responses. These findings suggest the benefit of age-specific approaches in managing iron deficiency among blood donors.

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Introduction

Blood donation is a fundamental aspect of healthcare systems worldwide as it provides the indispensable blood products necessary for treating and caring for patients in need. However, the repeated nature of blood donation can lead to substantial iron depletion, necessitating effective strategies to replenish these vital stores among donors, particularly those who donate frequently and are at heightened risk for iron deficiency and anemia⁽¹⁻³⁾. Iron deficiency anemia in blood donors not only compromises the health and well-being of the donors but also affects the quality and safety of the donated blood.

Frequent blood donors are especially vulnerable to iron deficiency due to the regular loss of blood, which depletes their iron stores. Research indicates that repeated blood donations without adequate recovery time can lower Hb and ferritin levels considerably, leading to iron deficiency anemia^(1,4). Female donors face an even greater risk of iron deficiency due to additional factors such as menstrual blood loss^(1,2,5), underscoring the need for targeted interventions to preserve adequate iron levels and prevent anemia in this group. Iron deficiency anemia can manifest as symptoms such as fatigue, weakness, and decreased physical performance, which may deter donors from continuing their donations⁽¹⁾. Furthermore, low Hb levels can result in donors being deferred from making donations, thereby diminishing the available blood supply and adversely impacting patients who rely on these vital blood products. As such, addressing iron deficiency in blood donors is crucial for safeguarding donor health and ensuring the sustainability of blood donation programs.

Iron supplementation is widely acknowledged as an effective measure for replenishing iron stores and improving Hb levels in individuals with iron deficiency anemia. Providing iron supplements to frequent donors can mitigate the risk of developing iron deficiency anemia and promote a healthier donor population, enhancing the

overall safety and quality of donated blood products^(1,3,6-8). Ferrous fumarate, a commonly used iron supplement containing approximately 66 mg of elemental iron per 200 mg tablet, has been shown to raise iron levels when administered consistently and effectively⁽⁹⁾.

Implementing routine ferritin testing in blood donation centers could further aid in identifying individuals at risk of iron deficiency, allowing for timely interventions that reinforce donor health and the quality of blood donations over time^(2,4). Educating donors about the dangers of iron deficiency and the significance of iron supplementation is vital for fostering compliance with supplementation regimens. Informed donors are more likely to adhere to these protocols, leading to improved health outcomes and sustained participation in blood donation programs^(1,7,10,11). Therefore, integrating iron supplementation with comprehensive donor education represents a promising approach to addressing IDA in frequent blood donors.

This study was conducted at the Blood Transfusion Center, Faculty of Medicine, Khon Kaen University. The center is committed to providing high-quality blood products and services and is critical in ensuring patients' continuous supply of safe blood. It focuses on donor health and safety, regularly monitoring Hb and ferritin levels and providing targeted iron supplementation strategies tailored to donor needs. Despite existing evidence on iron supplementation, more data are needed on the combined effect of iron supplementation and education in this population.

The study aims to evaluate the effectiveness of ferrous fumarate supplementation, donor education, and follow-up Hb monitoring in addressing iron deficiency anemia among frequent blood donors.

Materials and methods

This prospective cohort study was conducted at the Blood Transfusion Center, Faculty of Medicine, Khon Kaen University, Thailand.

The study population consisted of blood donors who had donated more than twice in a year and had Hb levels below the established thresholds. The inclusion criteria were based on the Thai Red Cross Society guidelines, which define anemia as Hb levels below 13.00 g/dL for male donors and below 12.50 g/dL for female donors, as determined by point-of-care Hb testing⁽¹²⁾. This group of donors is at high risk of iron deficiency anemia^(1-3,6,13,14). Donors with known hematological disorders unrelated to iron deficiency were excluded from the study.

Intervention

Participants meeting the inclusion criteria were invited to participate in the study. Consenting donors received 200 mg of ferrous fumarate supplements twice daily. They were also provided educational materials on iron deficiency, the importance of maintaining adequate iron levels, and the need for adherence to the supplementation regimen. The academic component included informational pamphlets, one-on-one counseling sessions, and follow-up phone calls to encourage compliance with the supplementation plan. Follow-up appointments were scheduled 2-3 weeks after the start of the intervention. Donors were considered to have responded positively if their Hb levels increased by more than 0.50 g/dL within 2-3 weeks⁽⁹⁾. The study collected the following measurements to enable a comprehensive assessment of each donor's iron status before and after the intervention:

- Gender, age, baseline Hb, ferritin, and

complete blood count (including red blood cell count, hematocrit, and related parameters)

- Hb levels measured at the start of the study and one month later
- Ferritin levels measured at the start to assess baseline iron stores

Sample Size Calculation

The sample size was determined to assess whether the response rate in our study population differed from the previously reported rate of 58.10%⁽⁵⁾. A margin of error of 15.00% was considered clinically significant. Using a 95.00% confidence level, the sample size was calculated using a single proportion formula with a minimum of 42 participants. This ensured that the study was adequately powered to detect meaningful differences in response rates.

The study adhered to rigorous ethical standards, with approval from the Center for Ethics in Human Research, Khon Kaen University (reference number HE661201), and written consent from all participants. Confidentiality was ensured by securing data and removing identifiable information. Statistical analyses were conducted using appropriate methods for non-normal distributions; median values were analyzed, and the Wilcoxon signed-rank test was employed to assess changes in Hb levels. Descriptive statistics summarized ferritin levels, and Spearman's rank correlation was used to evaluate the relationship between initial ferritin levels and Hb improvement.

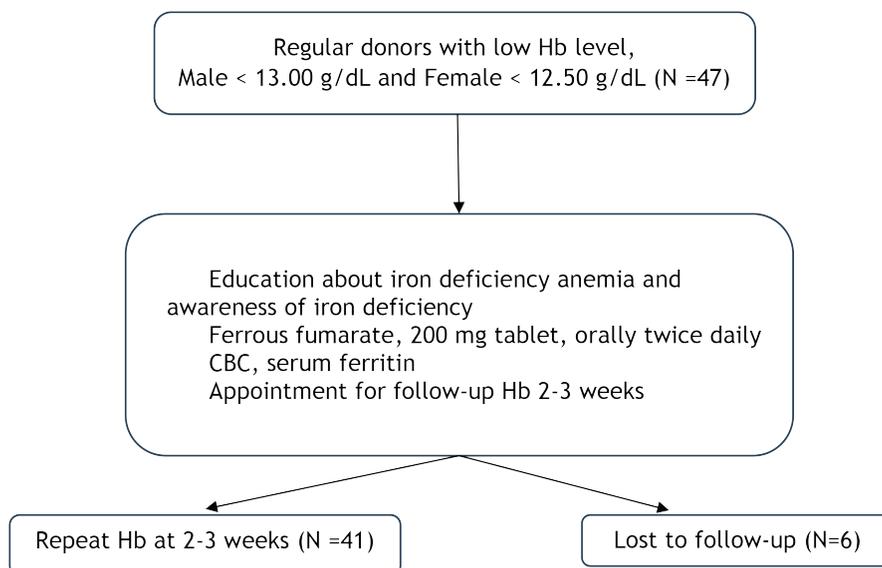


Figure 1 Consort diagram representing a flowchart of regular donors with low Hb levels and follow-up outcomes.

Results

The study population consisted of 47 regular blood donors from the Blood Transfusion Center, Faculty of Medicine, Khon Kaen University,

Thailand. As summarized in table 1, the participants included 36 females and 11 males, ranging in age from 20 to 64 years.

Table 1 Baseline characteristics

Characteristic	Value
Total donors	47
Female	36 (76.60%)
Male	11 (23.40%)
Age range (years)	20 - 64
Median pre-intervention Hb (g/dL)	12.10
IQR pre-intervention Hb (g/dL)	11.50-12.30
Median ferritin level (ng/mL)	42.00
IQR ferritin level (ng/mL)	24.00 - 96.00

Abbreviation: Hb, hemoglobin; IQR, interquartile range; g/dL, grams per deciliter; ng/mL, nanograms per milliliter.

Hemoglobin levels

The study assessed the participants' Hb levels before and after the intervention, which involved providing ferrous fumarate supplements and educating the donors. The median baseline Hb

level was 12.10 g/dL, which increased significantly to 13.20 g/dL following the intervention. The median improvement in Hb was 1.2 g/dL, indicating substantial enhancement. Moreover, the overall response rate, defined as an increase in Hb greater

than 0.50 g/dL within 2-3 weeks, was 87.80%. Iron deficiency and response by ferritin level

The effectiveness of iron supplementation varied based on the donors' ferritin levels, as summarized in table 2. Donors with ferritin levels below 30 ng/mL exhibited the highest median Hb increment of 1.30 g/dL, indicating a strong response to iron supplementation. Those with

ferritin levels between 30-50 ng/mL and 50-100 ng/mL showed moderate improvement, with median Hb increments of 0.80 g/dL and 0.90 g/dL, respectively. In contrast, donors with ferritin levels exceeding 100 ng/mL had the lowest median Hb increment of 0.20 g/dL, suggesting a more variable and less robust response to the iron supplementation.

Table 2 Iron deficiency and response by ferritin level

Ferritin level (ng/ml)	Number of donors (41)	Median Hb increment	p-value
< 30	10	1.30	< 0.001
30-50	7	0.80	
50-100	13	0.90	
>100	11	0.20	

Abbreviation: Hb, hemoglobin; ng/mL, nanograms per milliliter.

Response by gender

In the subgroup analysis of iron-deficient donors (ferritin \leq 100 ng/mL, n=31), we examined gender-specific responses to iron supplementation. Female donors (n=26) demonstrated a higher median Hb increment (1.50 g/dL) compared to male donors (n=5, 1.20 g/dL, p -value = 0.81), although this difference did not reach statistical significance. Similarly, while females showed higher overall response rates (92.31% vs 80.00%, p -value = 0.58) and a greater proportion achieving significant response (Hb increment \geq 1 g/dL: 73.08% vs 60.00%, p -value = 0.64), these differences were not statistically significant. Baseline ferritin levels differed between genders (females: 33.50 ng/mL vs males: 15.00 ng/mL, p -value = 0.78), but this difference also lacked statistical significance.

Response by age group in iron-deficient donors

Analysis of iron-deficient donors (ferritin \leq 100 ng/mL) revealed critical age-related differences in treatment response, as shown in table 3. Younger donors (20-39 years) demonstrated a significantly higher median Hb increment of 2.00 g/dL compared to 1.20 g/dL in older donors

(40-65 years) (p -value = 0.02). While examining other response parameters in table 3, we observed that although not reaching statistical significance, there was a consistent trend toward better outcomes in the younger group. The overall response rate was notably higher in younger donors (94.44% vs 84.62%, p -value = 0.36). Similarly, the proportion of donors achieving significant response (Hb increment \geq 1 g/dL) was substantially higher in the younger group (83.33% vs 53.85%, p -value = 0.07). Despite not all reaching statistical significance, these consistent trends across different measures of response suggest a biological pattern of better iron utilization in younger donors. As shown in table 3, baseline median ferritin levels were comparable between the age groups (28.50 vs. 39.00 ng/mL, p -value = 0.81), indicating that the observed differences in response were likely due to age-related factors rather than initial iron status. This observation aligns with known age-related changes in iron metabolism and absorption efficiency, even though the sample size may have limited the statistical power to detect significant differences in some parameters

Table 3 Response to iron supplementation by age group in iron deficient donors (ferritin ≤ 100 ng/mL)

Characteristic	20-39 years	≥ 40 years	p-value
Number of donors	18	13	
Median Hb increment (g/dL)†	2.00	1.20	0.02
Response rate (%)*	94.44	84.62	0.36
Significant response (increase Hb ≥ 1 g/dL) (%)	83.33	53.85	0.07
Median ferritin level (ng/mL)	28.50	39.00	0.81

Note: *Response rate defined as Hb increment > 0.50 g/dL within 2-3 weeks.

Abbreviations: Hb, hemoglobin; g/dL, grams per deciliter; ng/mL, nanograms per milliliter.

Discussion

The findings of this study provide important insights into the management of iron deficiency in regular blood donors. A combination of Hb monitoring and targeted iron supplementation showed significant improvements in Hb levels, particularly among female donors, who showed greater susceptibility to iron deficiency. The high response rate (87.70%) further emphasizes the effectiveness of this approach. Regularly monitoring blood donors' Hb levels is crucial for the timely identification and management of iron deficiency. Conducting pre-donation Hb screening can enable early detection of donors at risk of iron deficiency anemia, facilitating prompt intervention. Equipping blood donation centers with point-of-care Hb testing devices and training staff to interpret the results can enhance the efficiency of this screening process.

Targeted iron supplementation based on Hb levels and clinical symptoms is effective^(6,15-17). Administering ferrous fumarate (200 mg twice daily) to donors with Hb levels below 13.00 g/dL for males and 12.50 g/dL for females or those exhibiting symptoms of iron deficiency ensures that iron levels are restored adequately. Educating donors on the importance of adherence to the supplementation regimen and managing side effects is essential for maximizing the benefits of this treatment⁽⁷⁾. Previous research has demonstrated that such targeted supplementation significantly improves Hb levels in blood donors^(2,4-8,14,18). The higher response rate among

female donors underscores the importance of addressing gender-specific factors in iron management.

Although previous studies have consistently demonstrated higher rates of iron deficiency in female donors^(2,19,20), our subgroup analysis of donors with ferritin ≤ 100 ng/mL showed no significant gender differences in treatment response. While we observed trends favoring female donors in both Hb improvement and response rates, these differences were not statistically significant, possibly due to our limited male sample size. This finding suggests that once iron deficiency is established, the response to iron supplementation may be more influenced by individual factors than gender. These factors include baseline ferritin levels, which varied notably between our gender groups (females: 33.50 ng/mL vs males: 15.00 ng/mL), adherence to supplementation, and the presence of underlying conditions affecting iron metabolism⁽²⁰⁾. Therefore, our results support an individualized approach to iron supplementation in blood donors, focusing on these modifiable factors rather than gender-specific protocols for optimal IDA management.

Age-related response patterns and mechanisms

Analysis of iron-deficient donors (ferritin ≤ 100 ng/mL) revealed significant age-related differences in treatment response. Younger donors (20-39 years) achieved a significantly higher median Hb increment compared to older donors (40-65 years) (2.00 vs 1.20 g/dL,

p -value = 0.02). This marked difference in response, observed despite comparable baseline ferritin levels between age groups (28.50 vs 39.00 ng/mL, p -value = 0.81), suggests that age independently affects iron supplementation efficacy. The superior response in younger donors was further supported by their higher significant response rates (83.33% vs 53.85%, p -value = 0.07), although this difference approached but did not reach statistical significance.

These age-related differences in treatment response can be attributed to several physiological mechanisms. First, younger donors' superior response likely reflects more efficient gastrointestinal iron absorption, as aging is associated with reduced gastric acid secretion and alterations in intestinal mucosa that may impair iron absorption⁽²¹⁾. Additionally, the capacity to utilize absorbed iron for erythropoiesis appears more efficient in younger donors, independent of iron stores⁽²¹⁻²⁴⁾ like myelodysplastic syndrome (MDS). These age-related changes in both iron absorption and utilization suggest the need for age-adjusted supplementation strategies. Our findings indicate that donors over 40 years may require modified approaches, such as higher doses or alternative iron formulations, to achieve optimal response. Future studies should focus on developing and validating age-specific protocols to optimize iron replacement in blood donors.

Donor education and counseling play a pivotal role in the success of iron supplementation programs. Providing comprehensive information on iron deficiency, its symptoms, and the importance of maintaining healthy iron levels helps donors understand the significance of adherence to supplementation regimens. Personalized counseling sessions to discuss the test results, benefits of iron supplementation, and strategies for managing side effects can address individual concerns and encourage proactive management of iron levels. Similar approaches in other studies have been shown to enhance donor compliance and improve outcomes^(6-8,10).

In cases where donors do not respond to iron supplementation, a comprehensive assessment is necessary. Additional tests, such as ferritin and transferrin saturation (TSAT), can provide a more accurate evaluation of iron status, helping to identify underlying causes of non-response^(2,4,14,25-27). Considering other potential causes of anemia, such as chronic disease or thalassemia, and adjusting treatment accordingly ensures that donors receive appropriate and targeted care. Studies have highlighted the benefits of using ferritin and TSAT testing to differentiate between iron deficiency and other conditions^(4,28-30).

Monitoring and evaluation are critical for continuously improving iron deficiency management strategies. Scheduling follow-up Hb tests and clinical evaluations at regular intervals helps track the effectiveness of supplementation and overall donor health. Regular data analysis on donor Hb levels, supplementation adherence, and outcomes can provide valuable insights into the effectiveness of the implemented strategies and identifying areas for improvement. This approach aligns with findings from other research that underscore the importance of continuous monitoring and data analysis in donor management programs. Compared to other studies, the significant improvements in Hb levels and high response rate in this study are consistent with the findings from similar research^(2,3,8,18). Our approach of using Hb levels and clinical symptoms for therapeutic diagnosis of iron deficiency, rather than relying solely on ferritin testing, has proven practical and cost-effective, particularly in resource-limited settings^(3,6,9,18,28,31).

The findings of this study on the effectiveness of iron supplementation with ferrous fumarate in frequent blood donors with low Hb levels are consistent with previous studies, such as those by Cable et al⁽²⁾ and Mast et al⁽⁷⁾, which demonstrated significant improvements in Hb levels following supplementation. However, our study adds new insights by integrating an educational component, which enhances compliance and maximizes the

clinical benefits of supplementation. In this study, the combination of strategies resulted in a higher response rate than those reported in earlier studies, suggesting that a comprehensive approach may be more effective in managing iron deficiency among frequent donors.

Our stratification of donors based on ferritin levels provided a further understanding of how baseline iron stores influence the response to supplementation. Similar to the findings of Bialkowski et al⁽³⁾, donors with lower ferritin levels exhibited greater improvements in Hb, reinforcing the need for targeted interventions. Our study also highlights the importance of tailoring supplementation strategies to individual donor risk profiles, which could inform future guidelines for blood donation centers.

These new insights underline the potential benefits of integrating supplementation and education programs in routine donor management, particularly in settings with limited resources. Future research should explore the long-term sustainability of these interventions as well as their impact on donor retention and blood supply adequacy. Our findings highlight the importance of age and gender-specific considerations in blood donor iron supplementation programs. Young donors (20-29 years) showed optimal response to standard protocols (response rate 100%, Hb improvement 1.83 g/dL), while older donors required more intensive monitoring and alternative supplementation strategies due to lower response rates and higher baseline ferritin levels. Female donors demonstrated better overall response (90.00% vs 81.80% in males), suggesting the benefit of gender-specific approaches. These demographic variations indicate that personalized supplementation strategies, along with targeted education programs, could enhance the effectiveness of iron repletion in blood donors. Future research

should focus on optimizing these demographically-tailored interventions and their impact on long-term donor retention.

Conclusion

This study demonstrates that targeted iron supplementation with ferrous fumarate, combined with donor education, effectively improves Hb levels among frequent blood donors with iron deficiency (ferritin \leq 100 ng/mL). Our findings revealed that age, rather than gender, may be a more crucial factor in treatment response. Younger donors (20-39 years) showed significantly better Hb improvement compared to older donors (40-65 years), while gender differences in response were not statistically significant in our iron-deficient cohort.

Given these findings, blood donation centers should consider implementing regular Hb monitoring and individualized iron supplementation based primarily on age and individual factors rather than gender-specific protocols. Particular attention should be paid to donors over 40 years who demonstrated lower response rates, potentially requiring modified supplementation strategies. Education programs should focus on promoting adherence to supplementation regimens and addressing individual risk factors that might affect treatment response.

Future research should focus on validating age-specific supplementation protocols and investigating the mechanisms underlying age-related differences in iron supplement response. Additionally, larger studies with more balanced gender distribution are needed to definitively assess the role of gender in iron supplementation response. These efforts will help optimize donor care and ensure a sustainable blood supply.

Take home messages

Regular iron supplementation and education significantly improve Hb levels in frequent blood donors with low Hb, with particularly strong responses among women and younger donors. Ensuring proper iron intake and awareness, with consideration for gender and age-specific needs, can help maintain donor health and a sustainable blood supply. Regular monitoring and demographically-tailored interventions are essential for preventing donor iron deficiency and anemia.

Conflicts of Interest

The authors declare no conflict of interest.

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