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Assessment of Iron Profile and some Hematological Parameters among Regular Blood Donors at the National Blood Transfusion Service (NBTS), Owerri

Iheanacho MC[1], Amadi UV[1*], Ogunnaya FU[2] and Atiegha C[3]

[1]*Deparment of Hematology, Federal University Teaching Hospital, Nigeria*

[2]*Department of Internal Medicine, Newark Beth Israel Medical Center, USA*

[3]*Department of Medical Laboratory Sciences, College of Health Technology, Nigeria*

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***Corresponding author:** Amadi UV, Department of Hematology, Federal University Teaching Hospital, Owerri, Imo State, Nigeria

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Abstract

Regular blood donation is essential for maintaining adequate blood supplies but may predispose donors to iron depletion and anemia if not properly monitored. Repeated blood loss leads to progressive iron deficiency, which can adversely affect hematological parameters and compromise donor health, particularly in settings with limited nutritional support. This study evaluated and compared the iron profile and complete blood count, including red cell indices, of regular blood donors and non-donors at the National Blood Transfusion Service (NBTS), Owerri. It also examined the effects of gender and donation frequency on these parameters. A cross-sectional comparative study was conducted involving 300 participants, comprising 200 regular blood donors and 100 non-donors. Serum ferritin, serum iron, Total Iron-Binding Capacity (TIBC), transferrin saturation, and complete blood count parameters (RBC count, hemoglobin, MCV, MCH, and MCHC) were analyzed. Donors were further stratified by gender and annual donation frequency. Statistical significance was set at $p<0.05$. Regular donors exhibited significantly lower serum ferritin (45.7 ng/mL ± 12.3 ng/mL) and transferrin saturation (15.0% ± 4.5%) compared to non-donors (89.6 ng/mL ± 14.1 ng/mL and 22.5% ± 5.2%, respectively; $p<0.001$). Hemoglobin concentration and red cell indices (MCV, MCH, and MCHC) were also significantly reduced among donors. Female donors showed more pronounced reductions than males. Additionally, donors who donated four or more times per year had significantly lower iron stores and red cell indices compared to those donating two to three times annually. Frequent blood donation is associated with iron deficiency and early-stage anemia, particularly among female donors and high-frequency donors. Incorporating routine iron status assessment and individualized donation intervals is essential for protecting donor health and ensuring the long-term sustainability of blood transfusion services.

Keywords: Transferrin; Serum iron; Serum ferritin; Donors

Introduction

Blood donation is still one of the most important parts of modern healthcare systems around the world. It is the basis for emergency medicine, surgery, cancer treatment, obstetric care, and the treatment of long-term and blood-related illnesses. The presence of secure and sufficient blood supplies significantly affects morbidity and death rates, especially in low- and middle-income nations where healthcare resources are scarce and illness prevalence is elevated. Blood transfusion is essential in the treatment of trauma victims, patients undergoing significant surgical procedures, persons with malignancies, women experiencing postpartum hemorrhage, and youngsters afflicted with severe anemia resulting from malaria or nutritional deficiencies. So, making sure there is a steady supply of blood is a top issue for public health around the world [1].

The World Health Organization (WHO) strongly supports regular, voluntary, unpaid blood donation as the safest and most dependable way to get blood. Donors who give blood voluntarily are less likely to do things that put them at risk and more likely to give honest medical histories. This lowers the danger of illnesses that can be passed on through blood transfusions. Also, repeat voluntary donors help keep the national blood supply stable and make it easier to deal with public health emergencies and disasters. Even though there are numerous benefits, the effects of giving blood multiple times on the health of the donor have not been studied as much, especially in developing nations [2].

Although blood donation is generally considered safe, particularly when conducted in accordance with established clinical protocols, increasing data indicates that regular blood donation may negatively impact iron reserves and hematological indices in donors. Iron deficiency is one of the most frequent nutritional problems in the world and is still the main cause of anemia. The effects of frequent blood donation on iron metabolism are garnering heightened clinical and scholarly attention [3].

Iron is an important part of how the body works. It is an important part of hemoglobin, myoglobin, cytochromes, and several enzymes that help in oxidative metabolism, DNA synthesis, and cellular respiration. About 70% of the iron in the body is found in hemoglobin in red blood cells. The rest is kept in the liver, spleen, and bone marrow as ferritin and hemosiderin. These iron stores are like a backup for when the body needs more iron, like when you're growing, pregnant, or recovering from blood loss [4].

Each unit of whole blood given has about 200 to 250 milligrams of iron. This loss is a big part of the body's total iron storage, especially for people who don't have a lot of iron stores. Under normal physiological settings, daily iron losses from the shedding of intestinal epithelial cells, skin, sweat, and mild bleeding total roughly 1 mg to 2 mg per day. Usually, dietary iron absorption makes up for these losses. But the iron lost during blood donation is much more than what the body can absorb from food each day, which is about 1 mg to 3 mg per day even when nutrition is at its best [5].

As a result, giving blood over and over again without getting enough iron from food or supplements will slowly deplete iron storage. At first, this shows up as lower serum ferritin levels, which show that iron stores are getting smaller. If iron losses keep happening, functional iron shortage may develop over time. This would damage erythropoiesis and eventually lead to iron deficiency anemia. This disorder is marked by a lower concentration of hemoglobin, a smaller number of red blood cells, and changes in the shape and size of red blood cells.

Red cell indices, such as Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC), give us important information on the size, hemoglobin content, and health of red blood cells. People often use these numbers to help figure out what kind of anemia someone has. They are also part of the Complete Blood Count (CBC). In iron deficiency anemia, red blood cells usually get smaller (microcytic) and have less hemoglobin (hypochromic), which makes the MCV, MCH, and MCHC readings go down [6].

Numerous studies have shown that regular blood donors have far lower serum ferritin levels than first-time or infrequent donors. Iron deficiency can occur even in individuals with normal hemoglobin levels, a condition known as "iron deficiency without anemia." During standard donor screening, which usually only looks at hemoglobin or hematocrit levels, this subclinical state is often missed. As a result, donors may keep giving blood even when their iron levels are low, which raises their risk of developing overt anemia over time.

Iron deficiency, even without anemia, has significant clinical ramifications. It is linked to tiredness, lower physical stamina, poorer cognitive function, a weaker immune system, and a lower quality of life. For regular blood donors, these consequences could hurt their health and make them less likely to donate again, which would make it harder to keep the blood supply going [7].

Gender is a significant factor influencing iron status and hematological reactions to blood donation. Several physiological and societal variables make female donors more likely to be iron deficient. Menstruation leads to extra iron loss every month, usually between 20 mg and 30 mg every cycle. Pregnancy and breastfeeding also require more iron. In addition, many women in impoverished nations don't get enough iron from their diets because of money problems and not being able to get iron-rich foods [8].

Another important thing that affects iron status is how often you donate. Regular donors, who give blood three or more times a year, are much more likely to run out of iron than people who only give blood once or twice. The total amount of iron lost from repeated donations may be more than the body can absorb and store. Research consistently demonstrates an adverse correlation between donation frequency and serum ferritin levels, including notable decreases in red cell indices among high-frequency donors [9].

The National Blood Transfusion Services (NBTS) have made a lot of progress in setting up voluntary donation systems, making it easier to find transfusion-transmissible illnesses, and raising public awareness. Still, monitoring the health of donors is not good enough because most screening techniques only look at infection concerns and not nutritional or hematological state [10].

There is a significant lack of local data regarding the iron profile and hematological health of Nigerian blood donors, especially among those who donate frequently. The majority of existing research are constrained in scope, utilize small sample sizes, or neglect to evaluate critical markers such as serum ferritin, serum iron, Total Iron-Binding Capacity (TIBC), and transferrin saturation. Moreover, limited research has investigated the synergistic effects of gender and donation frequency on red cell indices in the Nigerian environment. From a public health point of view, ensuring the health of donors is important for keeping the blood supply steady and reliable [11].

The current study was conducted to assess and compare the iron profile and complete blood count characteristics, including red cell indices, of regular blood donors and non-donors at the National Blood Transfusion Service (NBTS), Owerri. The investigation specifically seeks to evaluate serum iron, serum ferritin, total iron-binding capacity, transferrin saturation, hemoglobin concentration, packed cell volume, and red cell indices, including MCV, MCH, and MCHC. The study also looks at how these factors are affected by gender and how often people donate. This study aims to enhance donor management methods, educate policy development, and encourage safer blood donation practices in Nigeria by providing local evidence on the hematological and iron status of blood donors in Owerri. Ultimately, it is important to know how regular blood donation affects the body in order to balance the lifesaving benefits of transfusion with the health and well-being of those who give their blood.

Materials and Methods

Study design and population

This study employed a cross-sectional comparative design and was conducted among 300 adult participants, comprising 200 regular blood donors and 100 non-donors (controls). The study was carried out at the National Blood Transfusion Service (NBTS), Owerri.

Definition and recruitment of regular blood donors

Regular donors were defined as apparently healthy adults who had donated whole blood at least twice within the preceding 12 months at NBTS, Owerri. Eligible donors were consecutively recruited during routine donation visits over the study period. Donation history was verified using NBTS donor records to ensure accuracy of reported frequency and timing of previous donations.

Recruitment and characterization of non-donor controls

The non-donor group comprised adults with no prior history of blood donation. These participants were recruited from hospital staff, patient relatives, and community volunteers within Owerri metropolis through structured announcements and direct invitations. To ensure comparability with the donor group, all potential controls were screened using a structured questionnaire alongside a detailed medical history review. This process was undertaken to confirm that participants had no previous history of blood donation, no chronic medical conditions, and no acute infections within the preceding four weeks. In addition, individuals who were pregnant or lactating, had received recent blood transfusions, or were currently on iron supplementation were excluded from participation.

Baseline demographic characteristics, including age and sex, were obtained for all participants. The control group was subsequently frequency-matched to the donor group by age (within ± 5 years) and sex distribution in order to minimize the potential confounding effects of these variables on hematological indices and iron parameters.

Inclusion and exclusion criteria

Eligible participants included adults aged between 18 and 60 years who were apparently healthy at the time of recruitment. Both regular blood donors which defined as individuals who had donated blood at least twice within the preceding 12 months and confirmed non-donors were considered suitable for inclusion in the study.

Participants were excluded if they had any known chronic illnesses, such as diabetes mellitus, chronic kidney disease, or liver disease, as well as any diagnosed hematological disorders. Additional exclusion criteria included a recent history of acute infection within the previous four weeks, pregnancy or lactation, current or recent use of iron supplementation within the past three months, and a history of recent blood transfusion. These inclusion and exclusion criteria were applied uniformly to both donor and non-donor groups to ensure methodological consistency and enhance the validity of the study findings.

Control of confounding variables

Several strategies were employed to reduce potential confounding:

Frequency matching: Controls were frequency-matched to donors by age and sex.

Standardized eligibility screening: Identical health screening procedures were applied to both groups.

Restriction: Individuals with conditions known to affect iron metabolism or hematological parameters were excluded.

Statistical adjustment: Multivariate regression analysis was performed to adjust for potential residual confounders such as age and sex where necessary.

These measures were implemented to strengthen internal validity and ensure that observed differences in iron and hematological indices were primarily attributable to blood donation status.

Ethical considerations

Ethical approval for the study was obtained from the appropriate institutional ethics review committee. Written informed consent was secured from all participants prior to enrolment. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human subjects.

Sample collection and frequency of blood sampling

A single venous blood sample (approximately 5 mL) was collected from each participant during one study visit. No repeated sampling was performed. All samples were collected between 8:00 AM and 10:00 AM to minimize diurnal variation in iron parameters.

Blood was drawn aseptically using standard phlebotomy procedures and divided into two portions:

- EDTA tubes for hematological analysis
- Plain tubes for serum separation

Serum was separated by centrifugation at 3000 rpm for 10 minutes and stored at -20°C until analysis.

Hematological analysis

Complete blood count parameters were determined using an automated hematology analyzer according to standard laboratory procedures. Quality control materials were run daily to ensure analytical accuracy and precision. Hematological indices, including Hemoglobin Concentration (Hb), Packed Cell Volume (PCV/HCT), Red Blood Cell count (RBC), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), and White Blood Cell count (WBC), were determined using a fully automated hematology analyzer following standard operating procedures and routine quality control measures.

Iron profile analysis

Serum samples were analyzed for iron status parameters, including:

- Serum ferritin
- Serum iron
- Total Iron-Binding Capacity (TIBC)
- Transferrin Saturation (TSAT)

Assays were performed using Enzyme-Linked Immunosorbent Assay (ELISA) kits according to the manufacturer's instructions.

Transferrin Saturation (TSAT) was calculated using the formula:

$$\text{TSAT (\%)} = \frac{\text{Serum Iron}}{\text{TIBC}} \times 100$$

All samples were analyzed in duplicate to enhance reliability, and internal quality control procedures were strictly observed.

Statistical analysis

Data were analyzed using appropriate statistical software. Results were expressed as mean ± Standard Deviation (SD). Comparisons between donors and non-donors, as well as subgroup analyses based on gender and donation frequency, were performed using independent t-tests and one-way Analysis of Variance (ANOVA) where appropriate. Statistical significance was set at $p<0.05$.

Results

Table 1 gives the comparison results of iron profile and red cell indices in donors *vs.* non-donors. All comparisons had significant p values of $p=0.001$.

Table 2 is the gender-based comparison of parameters under study among donors. In this table also, the comparison of all parameters among gender gave p values of <0.05.

Table 3 is the effect of donation frequency on male and female donors. The table reveals that the values of all parameters reduce with the frequency of donation.

Discussion

The results of this study reveal a distinct and continuous trend of diminished iron status and modified hematological parameters among regular blood donors relative to non-donors. Regular donors showed much lower levels of serum ferritin, serum iron, hemoglobin concentration, Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC). These alterations together suggest that there is subclinical or early-stage iron deficiency anemia, even if there are no obvious signs of it. This reinforces the notion that traditional donor screening techniques, which predominantly depend on hemoglobin assessment, might not identify iron deficiency until it advances to clinically evident anemia [12].

The large drop in serum ferritin levels among donors is very interesting. Serum ferritin is largely acknowledged as the most sensitive and specific biochemical indicator of body iron reserves. The approximately 50% decrease seen among donors compared to non-donors demonstrates that frequent blood donation has a big effect on iron levels. This result is very similar to what other studies have found: regular blood donors have far lower ferritin levels than first-time or infrequent donors [13]. These investigations generally substantiate the claim that iron depletion from donation surpasses the body's ability for dietary replacement in several individuals, particularly in resource-constrained environments where nutritional intake may already be inadequate.

Along with ferritin, transferrin saturation was also much lower in donors, which shows that iron was not available for erythropoiesis. Transferrin saturation shows how much iron is bound to transferrin and is a key sign of how well iron is working in the body. When transferrin saturation is low, it means that not enough iron is getting to the bone marrow to make hemoglobin, which hinders the creation of red blood cells. This functional iron deficit may precede quantifiable reductions in hemoglobin and acts as an early indicator of future anemia.

The noted decreases in red cell indices further substantiate the existence of iron-deficient erythropoiesis in donors. The donor group had considerably lower levels of both MCV and MCH, which means that microcytic and hypochromic red blood cells were present. These are signs of iron deficient anemia. These results align with prior studies indicating that red cell indices serve as dependable indicators of early iron shortage and may identify nuanced alterations prior to the decline of hemoglobin levels beneath diagnostic limits [14-16]. The decrease in MCHC corroborates the existence of hypochromia, indicating less hemoglobin concentration inside individual red blood cells.

These changes in blood were seen even in donors who had enough hemoglobin to give blood, which is an important point. This underscores a significant deficiency in contemporary donor screening processes, which predominantly utilize hemoglobin concentration as the principal eligibility criterion. Hemoglobin

Table 1: Iron profile and red cell indices in donors *vs.* non-donors.

Parameters		Donors	Non-Donors	t-value	p-value
Hemoglobin (g/dL)	Mean ± SD	12.9 ± 1.2	14.0 ± 1.1	-7.14	0.001
Hematocrit (%)	Mean ± SD	38.5 ± 3.1	42.1 ± 3.0	-8.49	0.001
RBC ($\times 10^{12}$/L)	Mean ± SD	4.3 ± 0.4	4.7 ± 0.3	-7.53	0.001
MCV (fL)	Mean ± SD	86.4 ± 4.2	89.1 ± 3.6	-5.18	0.001
MCH (pg)	Mean ± SD	28.2 ± 1.6	29.7 ± 1.3	-7.21	0.001
MCHC (g/dL)	Mean ± SD	32.6 ± 1.1	33.4 ± 0.9	-6.2	0.001
Serum Ferritin (ng/mL)	Mean ± SD	45.7 ± 12.3	89.6 ± 14.1	-24.25	0.001
Serum Iron (µg/dL)	Mean ± SD	64.7 ± 11.6	83.2 ± 12.9	-12.17	0.001
TIBC (µg/dL)	Mean ± SD	430.6 ± 29.1	395.3 ± 27.8	9.43	0.001
Transferrin Saturation (%)	Mean ± SD	15.0 ± 4.5	22.5 ± 5.2	-12.01	0.001

RBC: Red Cell Count; MCV: Mean Cell Volume; MCH: Mean Cell Hemoglobin; MCHC: Mean Cell Hemoglobin Concentration; TIBC: Total Iron Binding Capacity

Table 2: Gender-based comparison among donors.

Parameters		Male donor	Female donor	t value	p value
Hemoglobin (g/dL)	Mean ± SD	13.2 ± 1.1	12.3 ± 1.0	5.91	0.002
Hematocrit (%)	Mean ± SD	39.4 ± 2.9	36.7 ± 3.3	6.08	0.001
RBC ($\times 10^{12}$/L)	Mean ± SD	4.4 ± 0.3	4.1 ± 0.4	6	0.008
MCV (fL)	Mean ± SD	87.3 ± 3.9	85.1 ± 4.6	3.28	0.015
MCH (pg)	Mean ± SD	28.8 ± 1.4	27.4 ± 1.5	4.16	0.011
MCHC (g/dL)	Mean ± SD	32.9 ± 0.9	32.3 ± 1.2	3.83	0.018
Serum Ferritin (ng/mL)	Mean ± SD	48.3 ± 10.4	41.2 ± 11.1	4.59	0.005
Serum Iron (µg/dL)	Mean ± SD	68.4 ± 10.2	59.1 ± 11.7	5.87	0.004
TIBC (µg/dL)	Mean ± SD	426.1 ± 28.5	436.8 ± 30.3	-2.29	0.023
Transferrin Saturation (%)	Mean ± SD	15.9 ± 4.1	13.6 ± 3.9	3.01	0.007

RBC: Red Cell Count; MCV: Mean Cell Volume; MCH: Mean Cell Hemoglobin; MCHC: Mean Cell Hemoglobin Concentration; TIBC: Total Iron Binding Capacity

Table 3: Effect of donation frequency on male and female donors.

Gender	Freq	Hb (g/dL)	Ferritin (ng/ml)	TSAT (%)	MCV (fL)	MCH (pg)	MCHC (g/dl)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Male	2–3	13.5 ± 0.8	52.1 ± 9.3	17.1 ± 3.2	88.1 ± 3.2	29.1 ± 1.1	33.1 ± 0.8
	≥ 4	12.7 ± 1.2	42.3 ± 8.7	14.2 ± 3.7	85.4 ± 4.1	27.6 ± 1.3	32.4 ± 1.0
Female	2–3	12.7 ± 0.7	44.5 ± 9.8	14.8 ± 3.4	86.0 ± 4.2	27.9 ± 1.2	32.5 ± 1.0
	≥ 4	11.9 ± 1.1	38.2 ± 8.1	12.1 ± 3.5	83.9 ± 4.6	26.3 ± 1.5	31.8 ± 1.3

Hb: Hemoglobin; MCV: Mean Cell Volume; MCH: Mean Cell Hemoglobin; MCHC: Mean Cell Hemoglobin Concentration; TSAT: Transferrin Saturation

testing can help stop anemia from happening just after a donation, but it doesn't tell you anything about your iron stores or the long-term danger of iron depletion. As a result, donors with low iron levels may keep giving until they become anemic, which could lead to more donor deferrals, a lower quality of life, and possible long-term health problems.

A gender-based analysis indicated that female donors exhibited more significant decreases in hemoglobin, serum ferritin, MCH, and transferrin saturation in comparison to male donors. This data aligns with current literature, which consistently indicates a higher prevalence of iron insufficiency among female blood donors [17,18]. Physiological variables, including monthly blood loss, pregnancy, and lactation, substantially elevate iron requirements in women, although dietary iron intake frequently fails to adequately offset these deficiencies. Furthermore, social factors and dietary habits in numerous underdeveloped nations may further restrict women's access to iron-rich foods, intensifying the risk of deficiency.

The increased susceptibility of female donors identified in this study underscores the necessity for gender-specific donation protocols. More and more, international standards say that women should wait longer between donations, that their maximum yearly donation limit should be lower, and that women who donate often should take iron supplements on a regular basis. Using these kinds of procedures in Nigeria's blood donation system could make it easier for people to get iron and make donors safer.

The frequency of donations became another important factor in determining iron status and hematological parameters. Donors who contributed four or more times annually demonstrated markedly reduced hemoglobin, ferritin, and red cell indices in comparison to those who donated two to three times per year. The dose–response association between how often someone donates blood and how much iron they lose has been thoroughly studied in the literature [19-21]. Each donation causes a loss of about 200 mg to 250 mg of iron, and giving blood again too soon makes it hard for the body to replace the iron it has lost. Over time, losing iron over and over again leads to gradual depletion and problems with making red blood cells.

The clinical ramifications of these discoveries are significant. Iron deficiency, even in its initial or subclinical phases, correlates with fatigue, diminished physical performance, compromised cognitive function, and lowered immunological efficacy. These consequences may make blood donors less likely to keep giving blood, more likely to put off giving blood because their hemoglobin levels are low, and in the end, they may hurt the long-term viability of blood supply systems. From a public health point of view, protecting the health of donors is important for both ethical and practical reasons.

In Nigeria, where there is a tremendous need for blood and it is hard to find new donors, keeping donors is very important. Most blood transfusion clinics don't regularly check donors' iron levels, which is a big problem for donor care. This study offers local evidence advocating for the incorporation of iron profiling into donor screening processes, especially for high-frequency and female donors. Regular assessment of serum ferritin, albeit more expensive than hemoglobin testing, may be warranted in high-risk populations to avert iron deficiency and enhance long-term donor results.

The findings also show that iron supplements and food counselling could be simple, low-cost ways to help. Numerous studies have shown that short-term oral iron supplementation after donating blood greatly speeds up the recovery of iron reserves and hemoglobin levels. Informing donors about iron-rich foods, including red meat, legumes, leafy greens, and fortified cereals, may improve dietary iron consumption and lower the risk of insufficiency.

In general, the results of this study support the rising belief that blood donation is not physiologically neutral for donors, even though it saves lives for those who receive it. Repeated donation has a detectable effect on iron metabolism and blood health, especially in women and people who donate often. It is important to use evidence-based donor management measures to deal with these consequences in order to protect the health of donors and keep blood transfusion services going.

Conclusion

This study shows that giving blood often leads to a big drop in iron storage and changes in blood tests, especially red blood cell tests. Regular donors, particularly women and those with a high frequency of donations, are at an elevated risk of developing iron insufficiency and early-stage iron deficiency anemia. These alterations can happen even when hemoglobin levels are still within acceptable donation ranges. This shows that screening procedures that solely look at hemoglobin levels are not enough to protect donor health.

Because blood donation is both a public health need and a possible source of stress for the body, these results have substantial effects on transfusion policy and how donors are managed.

Recommendations

Adding iron status monitoring

Regular or periodic testing of serum ferritin in regular donors should be considered, especially for high-risk populations such women of childbearing age and high-frequency donors. Ferritin-based screening has demonstrated efficacy in identifying asymptomatic iron deficiency prior to the reduction in hemoglobin levels.

Personalized Donation Intervals: Guidelines for how often people can donate blood may work better if they are based on each person's iron level instead of a set time period. Donors with low ferritin may be able to lower their risk of cumulative iron loss by extending the time between donations.

Iron supplementation programs

Taking a small amount of iron by mouth for a short time after donating blood is a practical and cost-effective way to speed up the recovery of iron stores. Structured supplementation programs, particularly for regular donors, can greatly lower the number of people who are iron deficient without hurting the supply of blood.

Donor instruction and nutritional counselling

Donor retention programs should include targeted instruction on dietary iron intake, such as sources of heme and non-heme iron and factors that affect iron absorption. Giving donors information helps them feel better and stay with the organization for a long time.

Policy-level integration

National transfusion services should think about adding iron management frameworks to donor health recommendations so that the need for blood supply is balanced with the safety and long-term health of donors.

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