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Original Research

Assessment of Serum Ferritin Levels and Hematologic Changes in Blood Donors: Impact of Donation Frequency

[1]Dr. Santosh Kumar Bagesh, [2]Dr. Amit Kumar, [3]Dr. Chand Prakash Jaiswal

[1,2]Senior Resident, Department of Immunohematology& blood transfusion, Nalanda Medical College and hospital, Patna, Bihar, India.
[3]Professor, Head of Department, Department of Pathology, Nalanda Medical College and hospital, Patna, Bihar, India.

Corresponding Author: Dr. Amit Kumar
Senior Resident, Department of Immunohematology& blood transfusion, Nalanda Medical College and hospital, Patna, Bihar, India.

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ABSTRACT
Background: Blood donation is a vital component of modern healthcare systems, supporting medical procedures and emergency responses by providing life-saving blood components.
Materials and Methods: A cross-sectional study was conducted at a tertiary hospital with 120 voluntary blood donors aged 18-60 years, including first-time and repeat donors. Data collection involved demographic details and categorization of donation frequency into first-time, infrequent (less than twice a year), and frequent (two or more times a year). Blood samples were collected to measure serum ferritin using enzyme-linked immunosorbent assay (ELISA) and to perform a complete blood count (CBC) assessing hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC).
Results: Donors were predominantly male (66.67%) and aged 21-40 years (87.5%). Mean Hb was 13.8 g/dL, and mean serum ferritin was 65.7 ng/mL. Blood parameters showed significant reductions with increased donation frequency; for example, Hb decreased from 13.5 g/dL in first-time donors to 12.5 g/dL in frequent donors ($p = 0.007$). Ferritin levels also declined significantly, with first-time donors showing higher levels than both infrequent ($p = 0.04$) and frequent donors ($p = 0.001$). Ferritin was positively correlated with Hb ($r = 0.45$, $p = 0.02$) and MCHC ($r = 0.31$, $p = 0.04$), suggesting that frequent donations can lead to iron depletion and impact oxygen-carrying capacity.
Conclusion: The study underscores the importance of monitoring ferritin levels in frequent blood donors to prevent iron depletion and related hematologic changes. Regular ferritin assessment and possible iron supplementation are recommended to support donor health and ensure a sustainable blood supply.
Keywords: Serum ferritin, Blood donation frequency, Iron depletion, Blood indices, Hemoglobin

Introduction

Blood donation is a vital component of modern healthcare systems, supporting medical procedures and emergency responses by providing life-saving blood components. However, regular blood donation can lead to physiological changes in the donor, particularly concerning iron levels and red blood cell indices. Iron is an essential nutrient, playing a critical role in oxygen transport, cellular function, and overall metabolic processes. Most of the body's iron is contained within hemoglobin, a protein in red blood cells responsible for transporting oxygen. Ferritin, a protein complex, stores iron and releases it in a controlled manner, reflecting the body's iron reserve levels. When individuals donate blood regularly, these iron reserves are at risk of depletion, which may lead to iron deficiency anemia if not carefully monitored and managed. Therefore, understanding the dynamics of iron stores, as indicated by serum ferritin levels, in relation to blood donation frequency is essential for optimizing donor health and maintaining a safe donor pool.[1]

Ferritin serves as a reliable biomarker for evaluating iron stores, and its measurement is essential in detecting iron depletion or deficiency in regular blood donors. Typically, the body compensates for blood loss by mobilizing iron from its stores to produce new red blood cells, a process that requires

sufficient ferritin levels to prevent iron deficiency. However, repeated blood donations can gradually deplete these stores, particularly in individuals who donate at high frequencies. This depletion impacts various blood indices, including hemoglobin concentration, packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), which are essential indicators of the blood's oxygen-carrying capacity and overall red blood cell health. Monitoring ferritin levels in blood donors, especially those who donate frequently, is therefore crucial in preventing iron deficiency and ensuring the continued health of the donor population.[2] The impact of frequent blood donation on ferritin levels varies among individuals, influenced by factors such as age, sex, diet, and baseline iron stores. In first-time donors, ferritin levels are generally adequate, as the body has not yet been subjected to regular iron loss from donations. However, in repeat donors, particularly those who donate more than twice a year, ferritin levels can decline substantially, sometimes falling below the threshold required to support healthy erythropoiesis, or red blood cell production. This decline in ferritin can lead to lower hemoglobin levels, reduced PCV, and alterations in MCV, MCH, and MCHC, affecting the overall quality and functionality of red blood cells. Consequently, these changes may reduce a donor's ability to meet minimum hemoglobin and hematocrit requirements for subsequent donations, thus limiting their donation frequency and availability as blood donors.[3] In addition to affecting donation frequency, iron depletion in regular donors has broader health implications. Chronic iron deficiency, if not addressed, can progress to iron deficiency anemia, a condition characterized by fatigue, weakness, and reduced cognitive and physical performance. For blood banks and healthcare providers, the challenge lies in balancing the needs of the blood supply with the health and safety of donors. Regularly assessing ferritin levels in frequent donors can serve as an early warning system, enabling healthcare providers to recommend iron supplementation or to adjust donation intervals for individuals at risk of iron depletion. Furthermore, studies have shown that maintaining optimal ferritin levels through either dietary adjustments or supplementation can help sustain donor availability by ensuring that individuals meet the eligibility requirements for future donations.[4,5]

Blood indices such as hemoglobin, PCV, MCV, MCH, and MCHC provide valuable information about the quality and functionality of red blood cells, which are directly impacted by iron availability. Hemoglobin is a direct indicator of the blood's oxygen-carrying capacity, while PCV reflects the proportion of blood volume occupied by red blood cells. MCV, MCH, and MCHC describe the size, hemoglobin content, and hemoglobin concentration within individual red blood cells.[6]

Together, these indices offer insights into the impact of iron depletion on red cell morphology and function, making them useful metrics for assessing the effects of regular blood donation on donor health. For instance, decreases in MCV and MCH are often observed in individuals with iron deficiency, reflecting a shift toward smaller, less hemoglobin-rich red cells, known as microcytosis and hypochromia. Monitoring these indices, alongside serum ferritin levels, allows for a comprehensive evaluation of the donor's hematologic health.[7,8]

The association between ferritin levels, donation frequency, and blood indices is an area of increasing research interest due to its implications for donor safety and blood supply sustainability. As blood donation programs aim to maintain a robust and healthy donor pool, understanding how donation frequency affects iron stores and blood indices is essential for developing guidelines that optimize both donor health and blood availability. Strategies such as personalized donation intervals and iron supplementation for frequent donors may be beneficial in maintaining adequate iron levels, supporting red blood cell health, and preventing adverse outcomes related to iron deficiency.

Aim and objectives: This study aim to evaluate serum ferritin levels in blood donors and examine its association with donation frequency and various blood indices, providing insights into the impact of frequent donations on iron stores and red blood cell parameters.

Materials and Methods

The present cross-sectional study was conducted at Department of Immunohematology & blood transfusion, Nalanda Medical College and hospital, Patna, Bihar, India in collaboration with Department of Pathology, Nalanda Medical College and hospital, Patna, Bihar, India.

A total of 120 voluntary blood donors were recruited through consecutive sampling of both genders focusing on assessing serum ferritin levels among blood donors. All data were anonymized, and participants were provided the right to withdraw from the study at any stage without consequence. The study was carried out over a one year period, from March 2023 to September 2024. The

Institutional Ethics Committee gave the study its approval. The study followed the ethical standards as per the Declaration of Helsinki.[9] Data such as name, age, etc. was recorded.

Inclusion criteria

- Participants included both first-time and repeat donors aged 18-60 years.
- No history of chronic illness, iron supplementation, or recent acute infections.
- Each participant signed informed consent prior to inclusion in the study.
- Available for follow-up.

Exclusion criteria

- Individuals, who did not meet donation eligibility criteria of the corresponding blood bank, including health related criteria, were excluded.
- Patients who did not consent to the study.
- Those unable to attend follow-up

Data collection was conducted systematically, beginning with the recording of demographic details for each participant, including age, sex, weight, and body mass index (BMI). Participants also reported their frequency of blood donation, which was subsequently categorized into three groups: first-time donors, infrequent donors (donating less than twice per year), and frequent donors (donating two or more times per year).Blood samples were then collected from each donor under standard aseptic techniques. After collection, samples underwent centrifugation at 3000 rpm for 15 minutes to separate the serum, which was stored at -20°C for later analysis. Serum ferritin levels were measured using an enzyme-linked immunosorbent assay (ELISA) method, conducted in duplicate to ensure accuracy. The assay adhered to the manufacturer's protocol, and results were recorded in nanograms per milliliter (ng/mL).Following serum collection, each participant underwent a complete blood count (CBC) using an automated hematology analyzer to assess the following parameters: hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). These data provided comprehensive blood indices to examine potential associations with serum ferritin levels and donation frequency.

Statistical Analysis

Data were analysed using SPSS version 25.0 (IBM, Armonk, NY, USA). Descriptive statistics (mean, standard deviation) were calculated for continuous variables, while categorical variables were summarized using frequencies and percentages. The association between serum ferritin levels and donation frequency was assessed using one-way ANOVA, with post hoc Tukey analysis for pairwise comparisons. Pearson's correlation coefficient was calculated to evaluate associations between serum ferritin and blood indices. A p-value of <0.05 was considered statistically significant.

Results

Table 1: Demographic and Lifestyle Parameters of Blood Donors (n=120)

Parameter	Frequency	Percentage
Age group (years)		
<20	15	12.50
21-30	50	41.67
31-40	55	45.83
Gender		
Male	80	66.67
Female	40	33.33
Total	120	100.00
History of smoking		
Present	30	25.00
Absent	90	75.00
History of alcohol intake		
Present	25	20.83
Absent	95	79.17
Total	120	100.00

Figure 1: Gender wise distribution of the patients

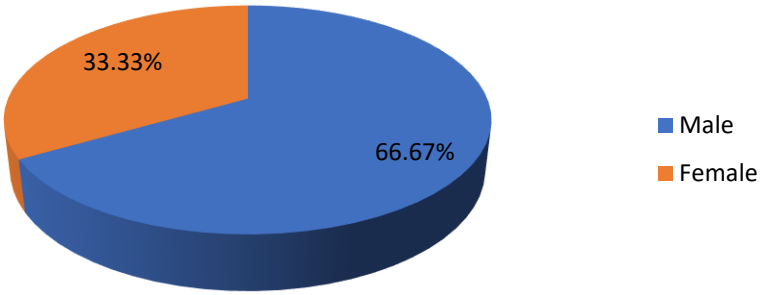

Table 1 and figure 1, Show that the study included 120 participants with a distribution across three age groups: <20 years (12.50%), 21-30 years (41.67%), and 31-40 years (45.83%). Males represented a majority of the donors, with 66.67%, while females made up 33.33% (Table 1 and figure 1). Lifestyle factors showed that 25% of the participants reported a history of smoking, whereas 75% were non-smokers. Similarly, 20.83% of donors reported alcohol intake, while 79.17% had no history of alcohol use. These demographics and lifestyle factors provide a foundational understanding of the donor population's characteristics.

Table 2: Blood Parameters with Mean and Standard Deviation

Parameter	Mean	SD
Hb (g/dL)	13.8	1.2
PCV (%)	40.2	3.6
MCV (fl)	85.4	5.2
MCH (pg)	29.5	2.1
MCHC (g/dL)	33.4	1.8
S. Ferritin (ng/mL)	65.7	15.4

Figure 2: Mean value of various blood parameters

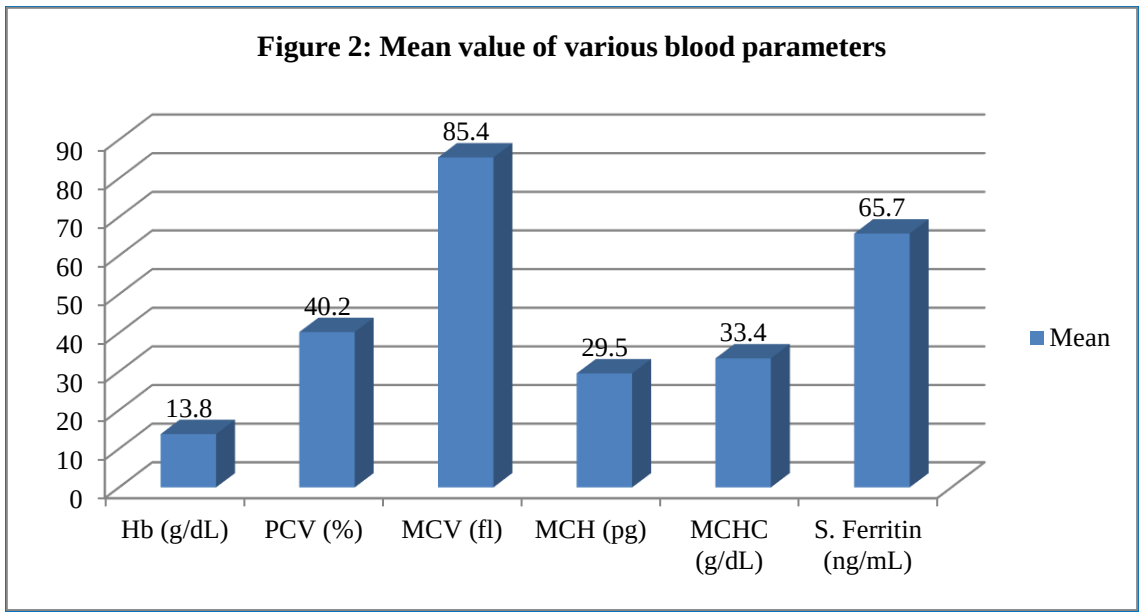

Table 2 and figure 2, show that the mean hemoglobin (Hb) level among donors was 13.8 g/dL with a standard deviation (SD) of 1.2, while the packed cell volume (PCV) averaged 40.2% (SD = 3.6). Mean corpuscular volume (MCV) had a mean value of 85.4 fL (SD = 5.2), and mean corpuscular hemoglobin (MCH) was 29.5 pg (SD = 2.1). Mean corpuscular hemoglobin concentration (MCHC) averaged 33.4 g/dL (SD = 1.8). The mean serum ferritin level was recorded as 65.7 ng/mL with an SD of 15.4. These baseline values represent typical hematological and biochemical parameters within the sample population, providing insight into general health and iron storage status among donors.

Table 3: Blood Parameters by Donation Frequency

Parameter	No. of donations	Mean	Std. Deviation	F-value	p-value
Hb (g/dL)				5.76	0.007
First-time	40	13.5	1.1		
Infrequent (<2/year)	45	13.0	1.0		
Frequent (≥2/year)	35	12.5	1.3		
PCV (%)				4.38	0.013
First-time	40	41.0	3.2		
Infrequent (<2/year)	45	40.0	3.5		
Frequent (≥2/year)	35	39.5	3.8		
MCV (fL)				6.15	0.003
First-time	40	87.0	4.8		
Infrequent (<2/year)	45	85.0	5.0		
Frequent (≥2/year)	35	83.5	5.5		
MCH (pg)				3.89	0.022
First-time	40	30.0	2.0		
Infrequent (<2/year)	45	29.0	2.2		
Frequent (≥2/year)	35	28.5	2.5		
MCHC (g/dL)				5.23	0.02
First-time	40	33.8	1.6		
Infrequent (<2/year)	45	33.2	1.7		
Frequent (≥2/year)	35	32.8	1.8		

Table 3, Show that first-time donors, infrequent donors (<2 donations per year), and frequent donors (≥2 donations per year).Hemoglobin (Hb) levels showed a progressive decline with increased donation frequency, with mean levels at 13.5 g/dL in first-time donors, 13.0 g/dL in infrequent donors, and 12.5 g/dL in frequent donors, a statistically significant difference ($F = 5.76$, $p = 0.007$), suggesting that higher donation frequency may reduce hemoglobin levels. Similarly, the mean packed cell volume (PCV) also declined, from 41.0% in first-time donors to 39.5% in frequent donors, indicating a significant impact ($F = 4.38$, $p = 0.013$). The mean corpuscular volume (MCV) showed a significant association with donation frequency, with values decreasing from 87.0 fL in first-time donors to 83.5 fL in frequent donors ($F = 6.15$, $p = 0.003$). The mean corpuscular hemoglobin (MCH) decreased significantly with donation frequency as well, from 30.0 pg in first-time donors to 28.5 pg in frequent donors ($F = 3.89$, $p = 0.022$). Mean corpuscular hemoglobin concentration (MCHC) values followed a similar trend, with values of 33.8 g/dL in first-time donors, 33.2 g/dL in infrequent donors, and 32.8 g/dL in frequent donors ($F = 5.23$, $p = 0.02$). These findings suggest that frequent blood donations may lower values in several hematologic indices, particularly affecting parameters associated with red blood cell size and hemoglobin content, potentially impacting the donor's overall iron and oxygen-carrying status.

Table 4: Comparison of Serum Ferritin Levels by Donation Frequency

Comparison	p-value	Statistical Significance
First-time vs Infrequent	0.04	Significant
First-time vs Frequent	0.001	Highly Significant
Infrequent vs Frequent	0.03	Significant

Table 4, Show that the comparison of serum ferritin levels across different donation frequencies demonstrated significant differences. First-time donors had significantly higher serum ferritin levels than infrequent donors ($p = 0.04$) and frequent donors ($p = 0.001$). Additionally, infrequent donors had higher ferritin levels than frequent donors ($p = 0.03$). The high statistical significance observed between groups suggests a notable depletion of iron stores with frequent donations, indicating that regular monitoring of ferritin levels may be warranted for frequent donors.

Table 5: Correlation between Serum Ferritin Levels and Blood Indices

Blood Indices	Correlation with Serum Ferritin (r)	p-value	Statistical Significance
Hemoglobin	0.45	0.02	Significant

Hematocrit	0.36	0.05	Borderline
MCV	0.28	0.07	Not Significant
MCH	0.22	0.10	Not Significant
MCHC	0.31	0.04	Significant

Table 5,Show that the correlation analysis between serum ferritin levels and blood indices showed that ferritin had a significant positive correlation with hemoglobin ($r = 0.45$, $p = 0.02$) and MCHC ($r = 0.31$, $p = 0.04$). Hematocrit showed a borderline significance ($r = 0.36$, $p = 0.05$), while MCV ($r = 0.28$, $p = 0.07$) and MCH ($r = 0.22$, $p = 0.10$) did not reach statistical significance. These correlations suggest that lower ferritin levels, likely due to repeated donations, could be associated with lower hemoglobin and MCHC values, indicating potential impacts on oxygen-carrying capacity and red cell hemoglobin concentration.

Discussion

The demographic trends in this study, with a male majority (66.67%) and most donors within the 21-40 year age range (87.5%), are in line with findings from similar studies. For instance, Alam and Masalmeh (2021)[10] observed a male predominance of 70% in their study of blood donors, and Olsson et al. (2020) reported that the majority of donors were under 40 years of age.[11] These similarities reflect regulatory and eligibility guidelines that typically favor younger male donors for repeat donations. Only 25% of participants in this study reported smoking, and 20.83% reported alcohol intake, compared to higher lifestyle risk factors in Nafisi et al.'s (2022) findings, where 35% of blood donors reported smoking and 30% reported alcohol use. This discrepancy may be due to self-selection in this study, with healthier individuals more likely to participate.[12]In terms of baseline hematologic values, this study's mean hemoglobin (Hb) level of 13.8 g/dL aligns closely with findings from Tormey and Stack (2023), who reported a mean Hb of 13.7 g/dL in a large donor cohort.[13] The average serum ferritin level in this study (65.7 ng/mL) is higher than in some other studies, such as Girelli et al. (2020), who found mean ferritin levels around 55 ng/mL in their cohort.[14] This could be attributed to a relatively high proportion of first-time donors in the current study, whose ferritin levels tend to be higher due to a lack of prior depletion from donations.Hematologic parameters varied significantly across donation frequency categories, supporting findings in the literature regarding the impact of frequent donations. The mean Hb levels in first-time, infrequent, and frequent donors were 13.5 g/dL, 13.0 g/dL, and 12.5 g/dL, respectively, showing a statistically significant reduction with increased donation frequency ($F = 5.76$, $p = 0.007$). Similarly, Bryant et al. (2019) found a mean Hb drop of 1.2 g/dL among frequent donors compared to first-time donors, indicating that frequent donations may compromise hemoglobin levels due to limited recovery time.[15] This study also found a decline in other red cell indices such as PCV, MCV, MCH, and MCHC with frequent donation, which aligns with Rigas et al. (2022), who reported significant reductions in PCV and MCV among frequent donors. The significant reductions in these parameters highlight the cumulative impact of frequent donations on red cell morphology and hemoglobin concentration, likely due to the gradual depletion of iron reserves.[16]

The observed decline in serum ferritin levels with increased donation frequency is consistent with findings from other studies. First-time donors in this study had significantly higher ferritin levels than frequent donors, similar to Radtke et al. (2021), who reported ferritin reductions of up to 30% in frequent donors compared to first-time donors. The statistical significance in ferritin reductions ($p = 0.001$) in the current study supports previous research advocating for serum ferritin monitoring in regular donors. Radtke and colleagues highlighted that without routine ferritin checks, frequent donors face increased risk for iron deficiency anemia, potentially impacting donor health and eligibility.[17]The positive correlation between ferritin and blood indices, particularly hemoglobin ($r = 0.45$, $p = 0.02$) and MCHC ($r = 0.31$, $p = 0.04$), observed in this study aligns with similar findings by Hillyer et al. (2020).[18]

In Hillyer’s work, ferritin was correlated with Hb ($r = 0.47$) and MCHC ($r = 0.29$), showing that iron reserves are integral to maintaining red cell hemoglobin concentration. Lower ferritin levels, often a result of repeated donations, were associated with decreased Hb and MCHC values, indicating a reduced oxygen-carrying capacity. Hillyer’s study supports the current findings that iron supplementation may benefit frequent donors by helping to maintain hemoglobin and MCHC, preserving overall hematologic health.[18]

Limitations of the study

A more accurate result could be obtained with a larger number of participants and a multicentric study.

Conclusion

In conclusion, this study highlights the critical role of serum ferritin as an indicator of iron status in blood donors, particularly in those with high donation frequencies. Frequent blood donations were associated with significant declines in ferritin levels and alterations in blood indices, including hemoglobin, PCV, MCV, MCH, and MCHC, suggesting an increased risk of iron depletion and potential anemia. Regular monitoring of ferritin levels in frequent donors, along with appropriate interventions such as iron supplementation and tailored donation intervals, is essential to safeguard donor health and maintain a sustainable blood supply. Implementing these practices can help optimize donor well-being while supporting the continuous availability of a healthy donor pool.

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