The Impact of Age and Gender on Hematological Parameters in a Blood Donor Population: A Cross-Sectional Analysis

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Abstract

Background: Hematological parameters, such as hemoglobin, red cell distribution width (RDW), and white blood cell (WBC) counts, are influenced by age and gender. Understanding these differences is essential for optimizing blood donor eligibility and managing donor health.

Objective: This study aimed to assess the impact of age and gender on hemoglobin, RDW, and WBC counts in a healthy blood donor population.

Methods: A cross-sectional analysis was conducted with 500 blood donors, stratified by age (18–65 years) and gender. Hematological parameters were measured using an automated analyzer. Two-way ANOVA was used to assess the effects of age and gender on these parameters.

Results: Male donors had significantly higher hemoglobin levels across all age groups compared to females, but both genders experienced a decline in hemoglobin with age. RDW increased with age in both genders, with females showing slightly higher RDW values after age 45. WBC counts were consistently higher in females across all age groups.

Conclusion: Age and gender significantly influence hematological parameters in blood donors. These findings suggest the need for age- and gender-specific strategies to optimize blood donor eligibility and maintain donor health.

Keywords: Hemoglobin, Red cell distribution width, White blood cell count, Age, Gender, Blood donors

Introduction

Hematological parameters such as hemoglobin concentration, red cell distribution width (RDW), and white blood cell (WBC) count are critical indicators of overall health and are widely used in both clinical practice and blood donor management. These parameters not only help in diagnosing various conditions but also serve as important criteria for blood donor eligibility (Mast et al., 2010). It is well established that factors such as age and gender can significantly influence hematological values, and understanding these variations is crucial for accurately interpreting laboratory results in both clinical and donor populations.

Age-related changes in hematological parameters are often attributed to physiological alterations in bone marrow function, decreased erythropoiesis, and increased red blood cell turnover (Jeklova et al., 2009). For example, hemoglobin levels tend to decline with age, especially in older adults, while RDW, which reflects variability in red blood cell size, often increases with aging due to a range of factors, including nutritional

deficiencies and chronic inflammation (Lippi and Plebani, 2014). Similarly, WBC counts may change with age, potentially affecting immune function and susceptibility to infections.

Gender also plays a significant role in influencing hematological parameters. Women, particularly those of reproductive age, often exhibit lower hemoglobin levels compared to men, largely due to menstruation and other hormonal differences (Murphy, 2014). In contrast, men tend to have higher hemoglobin concentrations due to the stimulatory effects of testosterone on erythropoiesis (Murphy, 2014). These gender-related differences can have important implications for blood donation, as women are more likely to be deferred due to low hemoglobin levels, potentially reducing the pool of eligible donors (Mast et al., 2010).

Despite these known influences, there is limited research specifically addressing how age and gender together impact hematological parameters in blood donor populations. Most existing studies focus on clinical settings, and fewer have examined healthy blood donors, who may exhibit different trends due to their health status and the rigorous screening processes they undergo prior to donation. This study aims to fill this gap by analyzing how age and gender influence key hematological parameters—hemoglobin, RDW, and WBC counts—within a large blood donor population.

Literature Review

Age-Related Changes in Hematological Parameters

Aging is associated with significant physiological changes that influence various hematological parameters. One of the most commonly observed age-related trends is a gradual decline in hemoglobin levels, particularly in individuals over 60 years old. This reduction in hemoglobin concentration can be attributed to decreased bone marrow activity, reduced erythropoietin production, and increased prevalence of chronic diseases that affect red blood cell production (Lippi and Plebani, 2014). Jeklova et al. (2009) further highlight that age-related anemia is a growing concern, especially among elderly populations, and is often linked to nutritional deficiencies such as low iron, vitamin B12, and folate levels.

Similarly, red cell distribution width (RDW), which reflects the variability in red blood cell size, has been shown to increase with age. Elevated RDW is often an indicator of underlying health conditions such as inflammation, iron deficiency, or bone marrow stress, all of which are more common as individuals age (Lippi and Plebani, 2014). RDW has emerged as a marker not only for anemia but also for broader health conditions, including cardiovascular disease and mortality risk in the elderly (Lippi et al., 2016).

White blood cell (WBC) counts, another critical hematological parameter, also exhibit age-related changes. While some studies suggest a gradual decline in WBC counts with aging, others indicate that this reduction is minimal in healthy older adults (Wang et al., 2011). Nevertheless, alterations in immune function with age, known as immunosenescence, may contribute to qualitative changes in WBC function and distribution, impacting an individual's ability to mount an effective immune response.

Gender Differences in Hematological Parameters

Gender plays a significant role in determining baseline hematological values, with men and women exhibiting distinct differences in parameters such as hemoglobin concentration, RDW, and WBC counts. One of the most notable gender differences is in hemoglobin levels, with men typically having higher hemoglobin concentrations than women. This difference is largely driven by the hormonal influence of testosterone, which stimulates erythropoiesis, increasing red blood cell production (Murphy, 2014). In

contrast, women, particularly those of reproductive age, experience periodic blood loss through menstruation, leading to lower hemoglobin levels on average compared to men (Murphy, 2014).

Red cell distribution width also varies by gender, with women often exhibiting slightly higher RDW values than men, particularly during reproductive years. This may be linked to the higher prevalence of iron deficiency among women due to menstruation and pregnancy (Murphy, 2014). Iron deficiency, even in the absence of clinical anemia, can contribute to greater variability in red blood cell size, thus increasing RDW values (Murphy, 2014).

Gender differences are also evident in WBC counts, although these variations are less pronounced than those seen with hemoglobin and RDW. Women generally have slightly higher WBC counts than men, which may be related to hormonal fluctuations and immune system regulation. Research by Muehlenbein and Bribiescas (2005) suggests that estrogen plays a role in modulating immune function, potentially contributing to the observed differences in WBC counts between men and women.

Combined Effects of Age and Gender on Hematological Parameters

While age and gender independently influence hematological parameters, their combined effects are less frequently studied. Some research indicates that the gender gap in hemoglobin levels narrows with age, particularly after menopause, when women no longer experience menstrual blood loss and hormone levels shift (Murphy, 2014). This suggests that the interaction between age and gender is important for understanding hematological trends across the lifespan.

Studies focusing on blood donor populations are particularly limited in examining how these factors interact. Since blood donors are often pre-selected for health and fitness, they may exhibit different hematological trends compared to the general population. For instance, frequent blood donors, especially women, are at higher risk of iron deficiency, which can exacerbate age-related declines in hemoglobin and affect other parameters such as RDW (Mast et al., 2010). Therefore, understanding how age and gender influence hematological parameters in this population is crucial for improving donor screening and maintaining donor health.

Gaps in the Literature

Although age and gender are well-recognized as influencing hematological parameters, there is a lack of comprehensive studies that explore these factors within the specific context of blood donors. Most existing research focuses on clinical populations or elderly individuals with underlying health conditions. Few studies have addressed how these variables impact healthy blood donors, who represent a unique population with specific hematological characteristics. This study aims to fill this gap by analyzing the combined effects of age and gender on hemoglobin, RDW, and WBC counts within a blood donor population, providing insights that may improve donor management and screening processes.

Methodology

Study Design

This cross-sectional study was conducted at the Blood Donation Center of Tertiary Hospital. The primary objective was to investigate how age and gender influence key hematological parameters—hemoglobin, red cell distribution width (RDW), and white blood cell (WBC) counts—within a blood donor population.

Study Population

The study included 500 healthy blood donors who met the eligibility criteria for blood donation at the hospital. The inclusion criteria were:

- Age between 18 and 65 years
- Body mass index (BMI) within the normal range (18.5–24.9 kg/m²)
- No history of chronic illness, blood disorders, or recent infections
- No recent blood donations in the past three months

Donors were excluded if they had any hematological disorders, were pregnant, or used medications known to affect blood parameters. Participants were stratified into six age groups: 18–25, 26–35, 36–45, 46–55, and 56–65 years. Gender distribution was also recorded.

Data Collection

Blood samples were collected from each donor immediately prior to donation, following standard venipuncture procedures. Each blood sample was processed using an automated hematology analyzer (Sysmex XN-1000) to measure the following hematological parameters:

- Hemoglobin (g/dL)
- Red Cell Distribution Width (RDW, %)
- White Blood Cell Count (WBC, $\times 10^9$/L)

The hematology analyzer was calibrated before the start of the study, and quality control was maintained throughout the data collection process. Data were anonymized to protect participant privacy, and all samples were labeled with participant ID codes to ensure confidentiality.

Age and Gender Grouping

The donors were categorized into age groups as follows:

- 18–25 years
- 26–35 years
- 36–45 years
- 46–55 years
- 56–65 years

For gender analysis, participants were categorized as male or female. The data were analyzed to assess the impact of both age and gender on the measured hematological parameters.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and hematological data. The mean and standard deviation (SD) were calculated for hemoglobin, RDW, and WBC counts within each age and gender group.

The impact of age and gender on the hematological parameters was assessed using a two-way analysis of variance (ANOVA) to test for differences between the age groups, gender, and the interaction between age and gender. Tukey's post-hoc test was applied to identify specific differences between groups. Additionally, Pearson's correlation coefficient was used to examine the relationship between age and hematological parameters.

A p-value of <0.05 was considered statistically significant. All analyses were performed using SPSS software (version 25).

Ethical Considerations

This study was approved by the ethics committee. Written informed consent was obtained from all participants before data collection. Participants were informed of their right to withdraw from the study at any time without any impact on their ability to donate blood in the future. All data were anonymized, and strict confidentiality was maintained throughout the study.

Limitations

One limitation of the study is that it was conducted at a single tertiary hospital, which may limit the generalizability of the findings to other populations. Additionally, the cross-sectional design does not allow for the assessment of longitudinal changes in hematological parameters over time. Future studies could explore the impact of repeated blood donations and track changes in hematological parameters across multiple time points.

Findings

Participant Characteristics

A total of 500 healthy blood donors participated in the study. Of these, 250 (50%) were male, and 250 (50%) were female. The age distribution was relatively even across the five age groups, with each group comprising approximately 100 participants. The demographic breakdown of participants is summarized in Table 1.

Table 1: Demographic Characteristics of the Study Population

Characteristic	Total (n = 500)	Male (n = 250)	Female (n = 250)
Age Group			
18–25 years	100	50	50
26–35 years	100	50	50
36–45 years	100	50	50
46–55 years	100	50	50
56–65 years	100	50	50

Hemoglobin Levels by Age and Gender

Hemoglobin levels were significantly influenced by both age and gender. Male donors consistently had higher hemoglobin levels across all age groups compared to female donors. Hemoglobin levels showed a gradual decline with age, particularly in males, while female hemoglobin levels remained relatively stable across age groups, with a slight decline after 55 years.

Table 2: Hemoglobin Levels by Age and Gender (Mean ±SD, g/dL)

Age Group	Male (n = 250)	Female (n = 250)	p-value
18–25 years	15.5 ±1.2	13.8 ±0.9	<0.001
26–35 years	15.3 ±1.1	13.7 ±0.9	<0.001
36–45 years	15.0 ±1.3	13.5 ±1.0	<0.001
46–55 years	14.7 ±1.2	13.4 ±1.1	<0.001
56–65 years	14.4 ±1.3	13.2 ±1.1	<0.001

Red Cell Distribution Width (RDW) by Age and Gender

RDW values increased with age in both male and female donors. While no significant gender difference was observed in younger age groups, RDW values for females were slightly higher than for males in the 46–65-year age range. This increase in RDW with age suggests greater variability in red blood cell size, likely due to factors such as declining bone marrow function or nutritional deficiencies.

Table 3: RDW by Age and Gender (Mean ±SD, %)

Age Group	Male (n = 250)	Female (n = 250)	p-value
18–25 years	13.1 ±0.7	13.0 ±0.6	0.231
26–35 years	13.3 ±0.8	13.2 ±0.7	0.201
36–45 years	13.5 ±0.9	13.6 ±0.8	0.142
46–55 years	14.0 ±1.1	14.2 ±1.0	0.043*
56–65 years	14.4 ±1.2	14.7 ±1.3	0.029*

*p < 0.05 indicates statistically significant differences between genders.

White Blood Cell Count (WBC) by Age and Gender

WBC counts did not vary significantly between age groups but were consistently higher in females compared to males. The gender differences in WBC counts were statistically significant across all age groups. The higher WBC count in females may be related to hormonal influences on immune function.

Table 4: White Blood Cell Count by Age and Gender (Mean ±SD, $\times 10^9$/L)

Age Group	Male (n = 250)	Female (n = 250)	p-value
18–25 years	6.2 ±0.9	7.1 ±1.0	<0.001
26–35 years	6.1 ±0.8	7.0 ±0.9	<0.001
36–45 years	6.0 ±0.8	6.8 ±1.0	<0.001
46–55 years	5.9 ±0.7	6.7 ±0.9	<0.001
56–65 years	5.8 ±0.9	6.6 ±1.1	<0.001

Summary of Findings

The results of this study highlight significant differences in hematological parameters based on both age and gender in a healthy blood donor population. Hemoglobin levels were consistently higher in males than in females, but both genders showed a decline in hemoglobin with age, particularly after 55 years. RDW increased with age, particularly in the 46–65-year range, and was slightly higher in females. WBC counts were higher in females across all age groups, with significant differences observed between males and females. These findings suggest that age and gender have a considerable impact on key hematological parameters in blood donors.

Discussion

The results of this study provide important insights into the influence of age and gender on key hematological parameters—hemoglobin, red cell distribution width (RDW), and white blood cell (WBC) counts—within a healthy blood donor population. These findings highlight significant differences that could have practical implications for blood donation management, clinical practice, and broader public health applications.

Hemoglobin Levels and Gender Differences

As expected, male donors exhibited consistently higher hemoglobin levels compared to females across all age groups. This gender difference in hemoglobin is well-documented in the literature and is primarily attributed to the effects of testosterone in males, which stimulates erythropoiesis and leads to higher red blood cell production (Murphy, 2014). In contrast, women, particularly those of reproductive age, tend to have lower hemoglobin levels due to menstrual blood loss and the absence of testosterone's erythropoietic effect (Murphy, 2014). These physiological differences explain why women are more likely to be deferred from blood donation due to low hemoglobin levels (Mast et al., 2010).

Interestingly, while male hemoglobin levels declined with age, the decline in females was less pronounced until after menopause, at which point both genders showed a more marked reduction. This observation is consistent with previous research indicating that post-menopausal women experience a rise in hemoglobin levels due to the cessation of menstrual blood loss, which narrows the gender gap in hemoglobin as individuals age (Murphy, 2014). These findings suggest that age-specific strategies may be necessary for optimizing donor eligibility, particularly in older adults.

Red Cell Distribution Width (RDW) and Aging

The study revealed an age-related increase in RDW values, particularly after the age of 45 in both men and women. RDW reflects the variability in red blood cell size and is often associated with underlying health conditions, such as iron deficiency, chronic inflammation, and aging-related bone marrow stress (Lippi and Plebani, 2014). The increase in RDW with age observed in this study aligns with previous research showing that older adults tend to have greater red cell size variation due to nutritional deficiencies or chronic diseases (Lippi et al., 2016).

While there were no significant gender differences in RDW in younger age groups, females had slightly higher RDW values than males in the 46–65-year age range. This could be attributed to the higher prevalence of iron deficiency in women, even post-menopausal, which can lead to greater variability in red blood cell size. Iron deficiency is a common issue among female blood donors, especially those with a history of frequent donation (Mast et al., 2010). These findings highlight the need for targeted interventions, such as iron supplementation programs, to address iron depletion and improve donor health, particularly in female and older donor populations.

White Blood Cell Count and Gender Differences

WBC counts were consistently higher in females compared to males across all age groups, with statistically significant differences observed between genders. These results are consistent with prior research suggesting that hormonal differences, particularly the role of estrogen, may contribute to the regulation of immune function and higher baseline WBC counts in women (Muehlenbein&Bribiescas, 2005). Estrogen has been shown to have a stimulatory effect on certain immune cells, which may explain the observed differences.

The lack of significant age-related decline in WBC counts suggests that, in a healthy blood donor population, immune function remains relatively stable with aging, at least in terms of quantitative measures. However, it is important to note that while WBC counts may remain consistent, the functional capacity of immune cells may decline with age due to immunosenescence, which was not directly measured in this study (Wang et al., 2011).

Clinical and Public Health Implications

The findings of this study have several important implications for clinical practice and blood donation management. The observed gender differences in hemoglobin levels reinforce the need for gender-specific hemoglobin thresholds in donor eligibility criteria, particularly in settings where female donors are more likely to be deferred. Additionally, the age-related decline in hemoglobin levels, particularly in males, suggests that older donors may benefit from more frequent screening or interventions to ensure they remain eligible to donate while maintaining their health.

The increase in RDW with age highlights the need for routine monitoring of red blood cell indices in older donors, as elevated RDW is associated with a range of health conditions. Targeted nutritional interventions, such as iron supplementation, could help mitigate the effects of aging on red blood cell variability and improve the long-term health of donors.

Finally, the consistently higher WBC counts in females suggest that gender differences in immune function may be an important consideration in clinical settings. Understanding these differences could improve disease diagnosis and treatment, particularly in immunological disorders.

Limitations and Future Research

While this study provides valuable insights into the impact of age and gender on hematological parameters in blood donors, it is not without limitations. The cross-sectional design limits the ability to establish causal relationships or assess longitudinal changes in hematological parameters over time. Future research should consider longitudinal studies to track changes in hematological parameters with aging and repeated donations.

Additionally, the study was conducted in a single tertiary hospital, which may limit the generalizability of the findings to other populations. Including a more diverse population with different ethnic backgrounds and geographic regions could provide a broader understanding of how age and gender affect hematological parameters across various demographic groups.

Conclusion

This study demonstrates that both age and gender significantly influence key hematological parameters in a healthy blood donor population. Male donors exhibited higher hemoglobin levels across all age groups, but these levels declined with age, particularly after 55 years. Females had higher WBC counts across all age groups, while RDW increased with age in both genders, reflecting age-related changes in red blood cell variability. These findings underscore the importance of considering age and gender when assessing donor eligibility and managing blood donor health.

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