ORIGINAL ARTICLE

# Hemoglobin as a predictor of hematocrit and red blood cell count according to age and sex in a population of Villa El Salvador, Lima, Peru

Alberto Guevara Tirado* [1,2,a,b]


## ABSTRACT

**Objective:** To assess the degree of hemoglobin correlation as a possible predictor of hematocrit and red blood cell count according to age and sex in a population of the district of Villa El Salvador, Lima, Peru.
**Materials and methods:** An observational, analytical, correlational and prospective study carried out with 550 males and 700 females of all ages who attended monthly preventive-promotional health campaigns, as well as routine medical consultations, from January 2021 to June 2022. Non-probability convenience sampling was used. The variables were sex, age group, hematocrit and red blood cell count. The Spearman's rank correlation coefficient was used because the Kolmogorov-Smirnov normality test showed a non-normal distribution. A *p* value below 0.05 with a 95 % confidence interval was considered significant.
**Results:** There was a higher prevalence of anemia in the group of females older than 11 years (35.10 %), while hemoglobin levels in most children younger than 11 years were mainly normal. High and positive correlations between hemoglobin and hematocrit close to one were found in all age groups and both sexes. In addition, moderate and positive correlations were found in female toddlers and girls (Rho = 0.525), female adolescents (Rho = 624), as well as male toddlers and boys (Rho = 0.597).
**Conclusions:** Hemoglobin levels are highly and positively correlated with hematocrit. Simultaneous hemoglobin and hematocrit testing may be clinically and economically unnecessary in screening and preventive-promotional campaigns on anemia conducted in large population groups. Likewise, hemoglobin correlates moderately and positively with red blood cell in children of both sexes and female adolescents. Further research is needed to deepen the reasons why correlation varies in these groups.


**Keywords:** Hemoglobins; Hematocrit; Erythrocytes (Source: MeSH NLM).

# Hemoglobina como predictor del recuento de hematocrito y hematíes según edad y sexo en una población de Villa El Salvador en Lima-Perú


## RESUMEN

**Objetivo:** Evaluar el grado de correlación de la hemoglobina como posible predictor del hemotocrito y recuento de hematíes según la edad y el sexo en una población del distrito de Villa El Salvador, Lima-Perú.
**Materiales y métodos:** Estudio observacional, analítico, correlacional y prospectivo realizado a 550 hombres y 700 mujeres de todas las edades que acudieron a las campañas de prevención promocionales de salud mensuales, así como a las consultas médicas de rutina, desde enero de 2021 a junio de 2022. El muestreo fue no probabilístico por conveniencia. Las variables fueron sexo, grupo etario, hematocrito y recuento de hematíes; se aplicó la prueba de correlación de Spearman debido a que la prueba de normalidad de Kolmogorov-Smirnov mostró que la distribución no era normal. Se consideró un valor de *p* significativo menor del 0,05 con un intervalo de confianza al 95 %.
**Resultados:** Hubo mayor prevalencia de anemia en el grupo de mujeres mayores de 11 años (35,10 %), mientras que los niveles de hemoglobina en menores de 11 años fueron, principalmente, normales en la mayoría de los pacientes. Se encontraron correlaciones altas y positivas entre hemoglobina y hematocrito cercanas a 1 en todos los grupos de edad y para ambos sexos. También se halló correlaciones moderadas y positivas entre infantes y niñas (Rho = 0,525), adolescentes mujeres (Rho = 624), así como infantes y niños (Rho = 0,597).
**Conclusiones:** Los niveles de hemoglobina se correlacionan de forma alta y positiva con el hematocrito. Es posible que el análisis simultáneo de hemoglobina y hematocrito sea clínica y económicamente innecesario en el cribado y en las campañas de prevención promocionales sobre anemia en grandes grupos poblacionales. Asimismo, la hemoglobina se correlaciona de forma moderada y positiva con los hematíes en niños de ambos sexos y adolescentes mujeres. Es necesario ampliar la investigación con estudios que profundicen las razones que causan que la correlación varíe en estos grupos.


**Palabras clave:** Hemoglobinas; Hematocrito; Eritrocitos (Fuente: DeCS BIREME).

1 Universidad Científica del Sur, School of Human Medicine. Lima, Peru.
2 Universidad de San Martín de Porres, School of Human Medicine, Graduate Division. Lima, Peru.
a Doctor of Medicine.
b Master's degree in Medicine.
*Corresponding author.

## INTRODUCTION

The measurement of hemoglobin and hematocrit levels and red blood cell count are among the most common laboratory tests worldwide [1] because they are essential for the diagnosis and follow-up of hematologic disorders, mainly anemia [2], a disease highly related not only to iron deficiency and other nutrient (vitamin B12, folic acid) deficiencies [3] but also, to a lesser extent, to erythrocyte morphology and volume disorders, autoimmune diseases and neoplasia, among other conditions [4]. Hemoglobin, a complex hemoprotein found inside erythrocytes (although similar globins can also be found in non-erythroid cells [5]), phylogenetically conserved since the beginning of the evolution of living things (as functionally similar globins can be found in other vertebrates, invertebrates and prokaryotes [6]), is responsible for transporting oxygen and carbon dioxide, as well as serving as a pH buffer by capturing hydrons when it loses oxygen [7]. Hematocrit, also known as packed cell volume or erythrocyte volume fraction [8], is the volume percentage of red blood cells in blood, so this measurement depends on the number of red blood cells [9]. Red blood cell count is a test that is part of a complete blood count, measures the number of red blood cells in a blood sample [10] and is used in routine medical consultations to monitor or diagnose disorders involving decreased or excess red blood cell production [11].

Hemoglobin levels are measured in automated machines where erythrocytes are broken down and hemoglobin is released into a solution so that its concentrations are spectrophotometrically measured using the cyanmethemoglobin method [12]. Hematocrit is not directly measured: the automated system multiplies the number of red blood cells by their mean corpuscular volume [13]. This fact has led to questioning the relevance of performing both measurements in terms of cost-effectiveness [14] when the objective is the screening and diagnosis of anemia on a large scale since, as mentioned before, most hemoglobin is contained in red blood cells [15]. Furthermore, previous research studies have suggested that both tests are very highly correlated [16]; likewise, less frequent diseases with significant clinical symptomatology, such as macrocytic anemia and polycythemia, cause disagreement between hemoglobin and hematocrit [17].

This research aimed to determine the degree of correlation between hemoglobin and hematocrit and between hemoglobin and red blood cell count in apparently healthy patients attending routine medical consultations in the district of Villa El Salvador in Lima, Peru. The results will allow us to determine whether this relationship is strong enough to question the relevance and cost-benefit of requesting a hematocrit test paired with a hemoglobin test, and also to determine the degree of correlation between these parameters and red blood cell count in our population.

## MATERIALS AND METHODS

### *Study design and population*

A descriptive correlational study conducted in patients aged 18 years or older and of both sexes, asymptomatic, who attended private medical consultations and preventive-promotional health campaigns in a polyclinic in the district of Villa El Salvador in Lima, Peru. The population consisted of all patients who attended the polyclinic from January 2021 to June 2022, totaling 1,250 people (700 females and 550 males). Non-probability convenience sampling was used since patients were selected on a first-come, first-served basis. The inclusion criteria were being a patient aged 18 years or older, attending routine medical consultations and preventive-promotional health campaigns, being apparently healthy and of both sexes. The exclusion criteria were being a patient with a previous diagnosis of any hematological, autoimmune or endocrine metabolic disorder (anemia, diabetes, rheumatoid arthritis, lupus, and corticoid and mineralocorticoid disorders).

### *Variables and measurements*

The results from the laboratory tests performed during the preventive-promotional health campaigns, as well as during the routine medical consultations, were recorded. Sex was considered as the qualitative variable; age—grouped into toddlerhood and childhood (up to 10 years), adolescence (11 to 17 years), young adulthood (18 to 39 years), middle adulthood (40 to 59 years) and older adulthood (60 years and older)—hemoglobin (in grams/deciliter), hematocrit and red blood cell count were considered as the quantitative variables.

### *Data collection procedure*

Coordination was made with the polyclinic management for the collection of data using the medical records from private consultations and preventive-promotional medical health campaigns carried out every third Thursday of every month from January 2021 to June 2022. The information concerning the study was collected and entered in an anonymous Microsoft Excel 2016 spreadsheet so that, once the period of time set as a collection goal was completed, it could be analyzed and processed using IBM SPSS Statistics V25.

### *Statistical analysis*

Sex and age were the categorical variables for the descriptive statistical analysis. The numerical variables were hemoglobin, hematocrit and red blood cell count. The variables were dichotomized in 2 x 2 tables. The results were displayed in tables. The bivariate correlations procedure was used for the analytical statistical analysis. To this end, the correlation between the numerical variables was determined using Pearson's correlation coefficient, after the evaluation of normality with the Kolmogorov-Smirnov test, which showed a non-normal distribution. An

alpha value equal to 0.05 was considered as cut-off point for statistical significance.

### *Ethical considerations*

The research was approved by the polyclinic management. Patient data was coded in an anonymous database, i.e., it did not include personal information since only information concerning quantifiable data from the medical records was used. Therefore, informed consents were not required. Only the researcher had access to the information to ensure confidentiality. The study complied with the Declaration of Helsinki ethical principles.

## RESULTS

Most patients aged 11 years or younger who attended the polyclinic showed adequate hemoglobin ranges (Table 1).

**Table 1.** Hemoglobin ranges in patients aged 11 years or younger of both sexes

| | | | Patient's sex | | |
|---|---|---|---|---|---|
| | | | Male | Female | Total |
| **Hemoglobin range** | 6-10.4 g/dl | *n* | 17 | 8 | 25 |
| | | % | 8.60 | 6.20 | 7.60 |
| | 10.5-16 g/dl | *n* | 177 | 120 | 297 |
| | | % | 91.40 | 93.80 | 92.40 |
| **Total** | | *N* | 194 | 128 | 322 |
| | | % | 100.0 | 100.0 | 100.0 |

It was observed that most male patients had adequate hemoglobin ranges (90.2 %) and a relatively high percentage of female patients had inadequate hemoglobin levels (35.1 %) (Table 2).

**Table 2.** Hemoglobin ranges in patients older than 11 years of both sexes

| Patient's sex | | | | Age group | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | | | Adolescence | Young adulthood | Middle adulthood | Older adulthood | |
| **Male** | Hemoglobin | 6-12.9 g/dl | *n* | 13 | 6 | 7 | 15 | 41 |
| | | | % | 17.90 | 7.90 | 7.20 | 10.30 | 9.80 |
| | | 13-17 g/dl | *n* | 62 | 70 | 95 | 132 | 359 |
| | | | % | 82.10 | 92.10 | 92.80 | 89.70 | 90.20 |
| | Total | | *N* | 75 | 76 | 102 | 147 | 400 |
| | | | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| **Female** | Hemoglobin | 6-11.9 g/dl | *n* | 52 | 40 | 46 | 45 | 183 |
| | | | % | 51.90 | 39 | 29 | 28 | 35.20 |
| | | 12-16 g/dl | *n* | 48 | 63 | 111 | 115 | 337 |
| | | | % | 48.10 | 61 | 71 | 72 | 64.80 |
| | Total | | *N* | 100 | 103 | 157 | 160 | 520 |
| | | | % | 100 | 100 | 100 | 100 | 100 |

Spearman's rank correlation coefficient showed that, in general, making no difference between groups, there was a strong positive correlation between hemoglobin and hematocrit (Rho = 0.928) compared to hemoglobin and red blood cell count (Rho = 0.838). Likewise, a strong positive correlation between hemoglobin and hematocrit was observed in males and females, as well as between hemoglobin and red blood cell count, being this correlation higher in the male group (Table 3).

**Table 3.** Spearman's rank correlation coefficient between hemoglobin and hematocrit and between hemoglobin and red blood cell count in apparently healthy patients in general, according to sex, who attended preventive-promotional health campaigns in the district of Villa El Salvador, 2020-2022

| Global | | Hematocrit | Red blood cell |
|---|---|---|---|
| **Hemoglobin** | Correlation coefficient | 0.928** | 0.838** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 1.250 | 1.250 |
| **Sex** | | **Hematocrit** | **Red blood cell** |
| **Male** | Correlation coefficient | 0.933** | 0.854** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 550 | 550 |
| **Female** | Correlation coefficient | 0.902** | 0.789** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 700 | 700 |

** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

The correlation between hemoglobin and hematocrit was high and positive in all female age groups; on the other hand, the correlation between hemoglobin and red blood cell count was moderate and positive in the 1-10 and 11-17 year old groups and high in the young adulthood, middle adulthood and older adulthood groups (Table 4).

**Table 4.** Spearman's rank correlation coefficient between hemoglobin and hematocrit and between hemoglobin and red blood cell count in apparently healthy females, according to age group, who attended preventive-promotional health campaigns in the district of Villa El Salvador, 2020-2022

| | | Hematocrit | Red blood cell |
|---|---|---|---|
| **Toddlerhood and** | Correlation coefficient | 0.948** | 0.525** |
| **childhood** | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 180 | 180 |
| **Adolescence** | Correlation coefficient | 0.806** | 0.624** |
| | Sig. (two-tailed) | 0.000 | 0.006 |
| | *N* | 100 | 100 |
| **Young adulthood** | Correlation coefficient | 0.912** | 0.901** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 103 | 103 |
| **Middle adulthood** | Correlation coefficient | 0.864** | 0.861** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 157 | 157 |
| **Older adulthood** | Correlation coefficient | 0.901** | 0.878** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 160 | 160 |

** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

The correlation analysis according to the male age group showed a high and almost perfect positive correlation in the 1–10 year old group; correlations between hemoglobin and hematocrit and between hemoglobin and red blood cell count were high and positive in all groups except in the 1–10 year old group, in which a moderate and positive correlation between hemoglobin and red blood cell count was found (Table 5).

**Table 5.** Spearman's rank correlation coefficient between hemoglobin and hematocrit and between hemoglobin and red blood cell count in apparently healthy males, according to age group, who attended preventive-promotional health campaigns in the district of Villa El Salvador, 2020–2022

| | | Hematocrit | Red blood cell |
|---|---|---|---|
| **Toddlerhood and childhood (1 to 10** | Correlation coefficient | 0.937** | 0.597** |
| **years old)** | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 150 | 150 |
| **Adolescence (11 to 17 years old)** | Correlation coefficient | 0.798** | 0.905** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 75 | 75 |
| **Young adulthood (18 to 39 years old)** | Correlation coefficient | 0.827** | 0.920** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 76 | 76 |
| **Middle adulthood (40 to 59 years old)** | Correlation coefficient | 0.815** | 0.798** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 102 | 102 |
| **Older adulthood (60 years old or older)** | Correlation coefficient | 0.915** | 0.944** |
| | Sig. (two-tailed) | 0.000 | 0.000 |
| | *N* | 147 | 147 |

** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

## DISCUSSION

It was observed that a higher percentage of females had lower-than-normal hemoglobin levels than males. The reason for this is that iron deficiency anemia is usually more common in females than in males [18] because of menstrual losses (which may involve up to 20 mg of iron [19]), pregnancy [20], blood loss such as in abnormal uterine bleeding, among others [21]. Meanwhile, males are not exposed to these risk factors, with the exception of occult bleeding in the elderly, usually from the gastrointestinal tract [22], as well as disorders involving the intestinal absorption of vitamin B12 [23].

A high and positive correlation between hemoglobin and hematocrit and between hemoglobin and red blood cell count was found in general and according to sex: specifically, a correlation close to one between hemoglobin and hematocrit. This agrees with a study by Nijboer (2007) that, although focused on establishing the correlation between hemoglobin and hematocrit in patients with different grades of acute blood loss due to trauma, showed that even in these conditions both hemoglobin and hematocrit behaved as almost identical parameters [24]. Moreover, although there are studies that question the classic 3:1 hematocrit to hemoglobin ratio [25], the high correlation found in the aforementioned background (acute blood loss) and in the present study (healthy population) shows that they are almost identical parameters; therefore, the systematic use of both tests in preventive-promotional campaigns and screening studies in the general population could be discouraged. A high and positive correlation was also observed between hemoglobin and red blood cell count, which was slightly lower than the relationship between hemoglobin and hematocrit. Even though it could be reasonable to think that a higher correlation should exist because hemoglobin is a hemoprotein found in red blood cells of human beings from the development of the embryonic yolk sac [26], different types of hemoglobin with different affinity for oxygen or carbon dioxide, such as methemoglobin, carboxyhemoglobin, glycated hemoglobin, among others, could slightly decrease the statistical correlation [27].

It was observed that the correlation between hemoglobin

and red blood cell count was high and positive in all adult groups of both sexes but moderate in females younger than 18 years and boys younger than 11 years. This agrees with Ahmad (2020), who identified a moderate and positive correlation between hemoglobin and hematocrit in a study aimed at assessing the correlation between blood count variables among children from a school in Rabwah, Pakistan [28]. Because hemoglobin is a hemoprotein physiologically bound to red blood cells, it can be stated that increased hemoglobin is related—by yet unclear mechanisms—to a smaller increase in red blood cells among infants, toddlers and children. This could probably be attributed, for example, to the fact that fetal hemoglobin (with shorter life span and oxygen-carrying capacity) is still found in infants, persisting until about 6 months of age [29]. In addition, erythrocyte production in early life stages and part of childhood may be considered in almost every bone in the body [30], which could imply a large production of less mature erythrocytes than those of later life stages.

The limitations of this study were the lack of randomization, as patients were selected on a first-come, first-served basis. Moreover, since the study was limited to measuring degrees of correlation, it was not possible to define the presence and types of anemia based on hemoglobin, hematocrit or red blood cell count in the study patients.

In conclusion, hemoglobin levels are positively and highly correlated with hematocrit in males and females of all ages. Likewise, hemoglobin correlates moderately and positively with red blood cell count in females younger than 18 years and boys younger than 11 years. The results suggest that simultaneous hemoglobin and hematocrit testing may be unnecessary in screening and preventive-promotional campaigns on anemia conducted in large population groups. Likewise, with respect to the correlation between hemoglobin and red blood cell count, further research is needed to deepen the reasons why correlation goes from moderate to high in the age groups of both sexes.

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**Corresponding author:**
Alberto Guevara Tirado
Address: Calle Doña Delmira manzana E lote 4, Urbanización Los Rosales, Santiago de Surco. Lima, Perú.
Telephone: +51 978 459 469
E-mail: albertoguevara1986@gmail.com

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**ORCID iD**
**Alberto Guevara Tirado** https://orcid.org/0000-0001-7536-7884