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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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RETICULOCYTE COUNT AND HEMATOLOGICAL INDICES IN MICROCYTIC HYPOCHROMIC ANEMIA: PREVALENCE AND PATTERNS AMONG INFANTS UNDER 24 MONTHS IN ANDEAN ECUADOR

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Abstract.

Anemia is a significant health problem during the first 24 months of life, especially among Andean populations with high nutritional vulnerability. This study aimed to determine the prevalence of anemia and characterize patterns of reticulocyte counts and hematological indices in infants under 24 months in the Alausí canton, Chimborazo, Ecuador, using altitude-adjusted hemoglobin levels. This cross-sectional study included 239 infants. Venous blood samples were analyzed using an automated hematology analyzer to obtain counts of red blood cells, reticulocytes, hemoglobin, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Anemia was classified according to age- and altitude-corrected hemoglobin criteria. Nonparametric tests were used: the chi-square test, Spearman's correlation, and multivariate logistic regression. Overall anemia prevalence was 59.0%, with the highest rates in infants younger than 2 months (88.9%) and those aged 6–24 months (71.2%). Hypochromic microcytic anemia was the predominant pattern (56.5%). The reticulocyte count decreased significantly with age ($p=0.010$) and showed a weak positive correlation with mean corpuscular volume (MCV) ($\rho=0.243$; $p<0.001$) and a negative correlation with mean corpuscular hemoglobin (MCH) ($\rho=-0.144$; $p=0.026$), with no significant association with corrected hemoglobin. In the multivariate model, age was the only independent predictor of anemia (OR = 1.059; 95% CI: 1.011–1.110; $p = 0.016$). Integrating reticulocytes and hematological indices complements the assessment of childhood anemia in high-altitude settings.

Key words. Anemia, reticulocytes, hematocrit values, infants, Ecuador.

Introduction.

Anemia is a condition in which the red blood cell count or hemoglobin concentration falls below normal levels, reducing the blood's ability to transport oxygen to the body's tissues [1]. This condition remains one of the leading public health problems worldwide and affects approximately 40% of children under the age of five, with a greater burden in low- and middle-income countries [2]. During the first 24 months of life, this condition affects neurobehavioral development, delays growth, and increases the risk of morbidity and mortality, with consequences that may persist in the long term [3].

Hypochromic microcytic anemia (HMA), caused primarily by iron deficiency, is the most common form of anemia in childhood. It results from decreased hemoglobin synthesis, leading to smaller red blood cells with lower hemoglobin content, reflected in reduced mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and, in some cases, mean corpuscular hemoglobin concentration (MCHC). These hematological indices, obtained through automated hematology analysis, are essential tools for morphological characterization of anemia and guide the differential diagnosis before confirmatory tests of iron metabolism [4].

In Ecuador, the National Survey on Child Malnutrition (ENDI 2024) identifies the province of Chimborazo as the region with the highest prevalence of chronic child malnutrition in the country, at 40.1% among children under two years of age [5]. This figure is nearly double the national average and highlights deep social, nutritional, and health inequalities that particularly affect rural and indigenous populations [6]. The coexistence of chronic malnutrition and hypochromic microcytic anemia reflects a multifactorial problem in which insufficient intake of bioavailable iron, inadequate complementary feeding practices, recurrent infections, and limited access to health services perpetuate a cycle of nutritional deficiency and impaired erythropoiesis [7].

From a clinical laboratory perspective, clinicians evaluate childhood anemia using blood cell counts and hematological indices, primarily mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). These parameters allow morphological characterization of anemia and help determine its etiology before more complex biochemical tests [8]. However, in populations living at high altitudes, hemoglobin concentration must be adjusted for altitude to avoid overestimating normal values due to physiological erythrocytosis caused by chronic hypoxia [9].

In addition, the reticulocyte count serves as a complementary biomarker of bone marrow erythropoietic activity and provides information on the regenerative response to various types of anemia. In the pediatric population, this count is particularly useful for distinguishing hypoproliferative conditions from those with an adequate bone marrow response and for monitoring hematologic recovery following therapeutic interventions [10]. However, reference values and the physiological behavior of reticulocytes vary during the first few months of life; therefore, interpretation must account for the patient's age and clinical context [11].

Despite the high prevalence of anemia and childhood malnutrition in Ecuador, the available evidence on the combined

behavior of reticulocyte count and hematological indices in infants younger than 24 months is limited. Most national studies have focused exclusively on hemoglobin concentration as a diagnostic criterion, without incorporating markers of erythropoietic response or accounting for altitude, which is particularly relevant in Andean populations. Furthermore, little information exists on the relationship between reticulocytes, hematological indices, and hypochromic microcytic anemia in children living in areas of high nutritional vulnerability.

The high prevalence of chronic childhood malnutrition in Chimborazo, combined with the expected high incidence of iron-deficiency anemia, makes it necessary to optimize diagnostic strategies in the clinical laboratory. Although corrected hemoglobin is the primary indicator for diagnosing anemia, interpreting it in isolation may be insufficient to characterize erythropoietic function. The lack of studies that integrate reticulocyte counts with Hematimetric indices in infants living at high altitudes limits our understanding of the hematological abnormalities associated with iron deficiency and hinders the generation of local evidence to support clinical decisions and public health interventions.

This study provides original evidence on the behavior of reticulocyte counts and hematological indices in infants under 24 months of age living in one of the provinces with the highest burden of chronic child malnutrition in Ecuador. Incorporating altitude-adjusted hemoglobin levels, jointly analyzing hematological parameters, and evaluating their association with hypochromic microcytic anemia will allow a more comprehensive characterization of this population's erythropoietic status. The results will strengthen the clinical interpretation of hematological biometrics in high-altitude settings, support timely diagnosis of iron deficiency, and provide evidence for designing prevention and control strategies targeting vulnerable child populations.

This study aims to determine the prevalence of anemia and characterize patterns of reticulocyte counts and hematological indices in infants under 24 months in the canton of Alausí, Chimborazo Province (Ecuador), stratified by age group and with hemoglobin levels adjusted for altitude.

Materials and Methods.

A cross-sectional, descriptive, and prospective study was conducted in 2024 as part of the project "Factors Associated with Chronic Malnutrition in Children Under 2 Years of Age and Pregnant Women in the Alausí Canton."

The study population consisted of infants living in the parishes of the Alausí canton: San Pedro de Alausí, Achupallas, Guasuntos, Huigra, Multitud, Nizag, Sevilla, Sibambe, Tixán, and Totoras. A non-probabilistic convenience sampling method was used, which included all participants who met the eligibility criteria.

Inclusion criteria included being under 24 months of age, residing in one of the 10 parishes of the Alausí canton, and having written informed consent from a legal guardian; participants were excluded if they were absent on the scheduled sample collection date or provided incomplete identification information or laboratory results. The final sample consisted of 239 infants.

Peripheral venous blood samples were collected under standardized aseptic conditions using EDTA as an anticoagulant and processed within established time frames. Hematological analysis was performed using the Mindray BC-6200 automated analyzer, which had been previously calibrated and had active internal quality control. The parameters measured included: red blood cell (RBC) count, reticulocyte (RET) count, hemoglobin (HB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC).

An altitude correction was applied to the hemoglobin parameter, given that the parishes in the Alausí canton are located at different elevations above sea level; this correction was performed according to the methodology recommended by the WHO [12]. All secondary hematological indices were calculated based on the altitude-corrected hemoglobin, ensuring methodological consistency in the reported values.

Anemia was classified based on age-adjusted WHO thresholds: < 2 months: Hb < 13.5 g/dL; 2–5 months: Hb < 9.5 g/dL; 6–24 months: Hb < 11.0 g/dL. Morphological classification was based on mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH): hypochromic microcytic anemia (HMA), reduced MCV and/or MCH < 25 pg; and normochromic normocytic anemia (NNA), MCV and MCH within the age-appropriate range. The reticulocyte ranges by age group were: < 2 months: 1.1–4.0%; 2–24 months: 0.5–1.5% [12].

The data were analyzed using STATA 15 software. Normality was assessed using the Shapiro-Wilk test; since most variables were non-normally distributed, nonparametric statistics were used. The Kruskal-Wallis test was used to compare three independent groups, and the Mann-Whitney U test was used to compare two groups. Categorical variables were analyzed using Pearson's chi-square test, and correlations were analyzed using Spearman's correlation coefficient. A binary logistic regression model was fitted to identify independent predictors of anemia (age, reticulocytes, MCV, MCH, and MCHC). Results are expressed as median (IQR), mean ± SD, and frequencies (%, 95% CI). Statistical significance was set at $p < 0.05$.

The study was approved by the Human Research Ethics Committee of the Instituto Superior Tecnológico Portoviejo (CEISH-ITSUP; code 1700088578; November 15, 2023), and this approval remained in effect throughout the study period. Written informed consent was obtained from all legal guardians prior to enrollment. The study complies with the Declaration of Helsinki and current national ethical guidelines.

Results.

We analyzed the hematological results of 239 infants younger than 24 months, of whom 54% (n = 129) were male and 46% (n = 110) were female. Hematological parameters varied significantly among age groups. Corrected hemoglobin levels were slightly higher in infants aged 6–24 months compared with younger age groups ($p = 0.005$), while hematocrit increased progressively with age, reaching its highest value in this same group ($p < 0.001$). In contrast, MCV and MCH decreased significantly as age increased ($p < 0.001$ for both variables), reflecting the physiological transition of erythrocytes during the first months of life. Likewise, the mean corpuscular hemoglobin

(MCH) showed slight differences between the groups (p = 0.024). The reticulocyte count was higher in children younger than 2 months and decreased progressively in the 6–24-month group (p = 0.010), indicating changes related to the physiological adaptation of erythropoiesis during early childhood (Table 1).

Overall, anemia prevalence was 59%. The highest prevalence was among infants aged 6–24 months (71.2%), followed by those under 2 months (88.9%), while the 2–5-month-old group had the lowest prevalence (20.0%). Compared with the latter group, the prevalence ratio was 4.44 among infants younger than 2 months and 3.56 among those aged 6–24 months. By sex, anemia prevalence was similar among males (57.4%) and females (60.9%), with no statistically significant differences (Table 2).

The reticulocyte count differed significantly among age groups (H = 9.13; p = 0.010), decreasing progressively from infants younger than 2 months to older infants. In infants younger than 2 months, 88.9% had counts within the reference range. In the 2–5-month and 6–24-month age groups, the proportion of children with normal reticulocyte counts was also predominant (60.0% and 62.4%, respectively), although approximately one-third had elevated reticulocyte counts (36.7% and 29.4%, respectively). Hypochromic microcytic anemia was the predominant hematological pattern in all age groups, especially among children under 2 months (77.8%) and infants aged 6–24 months (68.8%), indicating the prevalence of iron-deficiency-consistent abnormalities in the study population (Table 3).

Spearman's correlation analysis revealed significant associations between the reticulocyte count and certain Hematimetric indices. Reticulocytes showed a weak positive correlation with MCV (ρ = 0.243; p < 0.001), while the association with MCHC was negative and small (ρ = −0.144; p = 0.026). Corrected hemoglobin showed a strong positive correlation with hematocrit (ρ = 0.734; p < 0.001), as well as positive correlations with mean corpuscular hemoglobin (MCH) (ρ = 0.368; p < 0.001) and mean corpuscular volume (MCV) (ρ = 0.188; p = 0.004). In contrast, no significant association was found between the reticulocyte count and corrected hemoglobin (ρ = −0.079; p = 0.222) (Table 4).

In the multivariate logistic regression model, age in months was the only independent predictor associated with the presence of anemia (OR = 1.059; 95% CI: 1.011–1.110; p = 0.016). In contrast, the reticulocyte count, MCV, MCH, and MCHC did not show statistically significant associations with the outcome (p > 0.05 in all cases). These results indicate that increasing age during the first 24 months is the main factor associated with anemia in the study population, regardless of the hematological indices included in the model (Table 5).

Table 1. *Hematological parameters according to age group among infants younger than 24 months.*

Parameter	< 2 months (n = 9)	2–5 months (n = 60)	6–24 months (n = 170)	p-value
Corrected hemoglobin (g/dL)	10.13 ± 1.99	10.07 ± 0.91	10.46 ± 1.05	0.005
Hematocrit (%)	32.28 ± 5.32	33.49 ± 2.77	35.26 ± 3.13	<0.001
MCV (fL)	90.10 (86.00–93.50)	76.20 (72.28–81.78)	72.95 (67.00–77.23)	<0.001
MCH (pg)	27.67 (26.40–29.90)	22.53 (21.35–24.93)	21.66 (19.60–23.30)	<0.001
MCHC (g/dL)	30.74 (30.00–32.60)	29.53 (28.70–31.30)	29.30 (28.20–31.30)	0.024
Reticulocytes (%)	1.60 (1.20–2.91)	1.22 (0.89–2.50)	1.04 (0.78–1.61)	0.010

Note: *Values presented as mean ± SD for variables with normal distribution: corrected hemoglobin and hematocrit. Values are presented as median (IQR) for variables with non-normal distribution: MCV, MCH, MCHC, and reticulocytes. This mixed presentation reflects the results of normality testing (Shapiro-Wilk test) applied to each variable and follows standard statistical reporting practices for nonparametric data.*

Table 2. *Prevalence of anemia according to age group and sex.*

Characteristic	n	Anemia n (%)	No anemia n (%)	Prevalence ratio (95% CI)
Age group				
< 2 months	9	8 (88.9)	1 (11.1)	4.44
2–5 months	60	12 (20.0)	48 (80.0)	1.00 (Reference)
6–24 months	170	121 (71.2)	49 (28.8)	3.56
Total	239	141 (59.0)	98 (41.0)	—
Sex				
Male	129	74 (57.4)	55 (42.6)	—
Female	110	67 (60.9)	43 (39.1)	—

Table 3. *Reticulocyte count, reference range classification, and microcytic hypochromic anemia according to age group.*

Age group	n	Reticulocytes (%) Median (IQR)	Below reference n (%)	Within reference n (%)	Above reference n (%)	Microcytic hypochromic anemia n (%)	p-value
<2 months	9	1.60 (1.20–2.91)	1 (11.1)	8 (88.9)	0 (0.0)	7 (77.8)	—
2–5 months	60	1.22 (0.89–2.50)	2 (3.3)	36 (60.0)	22 (36.7)	11 (18.3)	0.247
6–24 months	170	1.04 (0.78–1.61)	14 (8.2)	106 (62.4)	50 (29.4)	117 (68.8)	0.026
Total	239	1.10 (0.80–1.79)	17 (7.1)	150 (62.8)	72 (30.1)	135 (56.5)	0.010

Table 4. *Spearman correlation coefficients between reticulocyte count, corrected hemoglobin, and Hematimetric indices.*

Variables	Spearman's ρ	p-value
Reticulocytes vs. MCV	0.243	<0.001
Reticulocytes vs. MCHC	−0.144	0.026
Reticulocytes vs. Corrected hemoglobin	−0.079	0.222
Corrected hemoglobin vs. MCH	0.368	<0.001
Corrected hemoglobin vs. MCV	0.188	0.004
Corrected hemoglobin vs. Hematocrit	0.734	<0.001

Table 5. *Multivariable logistic regression analysis for predictors of anemia.*

Predictor	OR (95% CI)	p-value
Age (months)	1.059 (1.011–1.110)	0.016
Reticulocytes (%)	1.176 (0.850–1.627)	0.326
MCV (fL)	1.066 (0.933–1.217)	0.348
MCH (pg)	0.725 (0.455–1.156)	0.177
MCHC (g/dL)	0.861 (0.585–1.267)	0.448

Discussion.

Childhood anemia is one of the most significant public health problems in contexts of nutritional vulnerability, with prevalence rates varying significantly by the socioeconomic and environmental characteristics of the study population. In this study, we report a prevalence of anemia of 59.0% among infants under 24 months of age living in the parishes of the Alausí canton, a finding that falls within the expected range for Latin American populations with established chronic malnutrition, where systematic reports have identified variations ranging from 7.6% to 65%, depending on the country and the population group evaluated [13].

One of the most significant findings of this study is the heterogeneous age distribution of anemia, indicating that the underlying pathophysiological mechanisms operate differently during the first 24 months of life [14]. The disease's temporal architecture reflects the simultaneous convergence of multiple biological, nutritional, and environmental processes that require integrated interpretation. This temporal perspective shows that diagnostic and therapeutic strategies must be tailored to each age group, since iron requirements, intestinal absorption, and metabolic capacity vary significantly during this critical developmental period [15].

However, it is important to contextualize the finding of high anemia prevalence in infants younger than 2 months within the framework of physiological anemia of infancy. The physiological nadir of hemoglobin typically occurs between 2 and 3 months of age as a consequence of normal postnatal physiological transition, independent of iron deficiency. This represents a normal developmental change related to the shift from fetal to postnatal erythropoiesis. Clinicians should not interpret normal hemoglobin decreases during this period as purely pathological or as primary indicators of iron deficiency without additional evaluation of iron status markers (serum ferritin, transferrin saturation). This distinction is critical to avoid unnecessary therapeutic interventions in otherwise healthy infants undergoing normal developmental transitions.

In Andean populations, the timing between maternal iron depletion and the introduction of complementary foods rich in bioavailable iron emerges as a key factor in preventing anemia [16,17]. Our analysis highlights that the timing of introducing complementary foods is a critical intervention point, as delayed introduction of iron-rich complementary foods increases the risk of anemia and may adversely affect brain development, with potentially permanent consequences [18].

The morphological characterization of anemia in the study cohort revealed a predominance of the hypochromic microcytic pattern, providing evidence that iron deficiency may be the predominant pathophysiological mechanism in this population; however, morphology alone is not sufficient, as this erythrocyte pattern could also overlap with other conditions, such as thalassemias, inflammation, and other deficiencies [19,20]. This finding is consistent with previous research: in a study of children under 5 years of age, 54% of anemic children showed a pattern consistent with iron deficiency, and the proportion was higher among those aged 6–23 months, at 63.5% [21]. In another cohort of children aged 6–24 months, hypochromic microcytic anemia accounted for 59.3% of cases, supporting the predominance of iron deficiency in that population [22].

Furthermore, analysis of reticulocyte counts revealed patterns that enhance our understanding of the bone marrow’s adaptive response to established anemia. Approximately one-third of anemic infants had elevated reticulocyte counts, suggesting that the bone marrow maintains compensatory regenerative capacity despite clinical anemia [23]. This finding has significant diagnostic and prognostic implications, as preserving this responsiveness is a favorable indicator of potential response to therapeutic interventions involving iron supplementation [24]. The discrepancy between anemia severity and the bone marrow's ability to respond may reflect patients' functional reserve.

The absence of a significant correlation between reticulocyte count and hemoglobin in infants younger than 24 months supports the international recommendation to incorporate multiple hematological parameters for a comprehensive assessment of erythropoietic status [25]. This finding suggests that both markers provide complementary, though partially independent, information, making it possible to distinguish hypoproliferative anemia from states with preserved bone marrow response [26]. Recent evidence shows that reticulocyte hemoglobin is a better indicator than conventional indices for detecting functional iron deficiency, with greater sensitivity for

identifying patients who do not yet have clinical anemia but do have established iron deficiency [27,28].

In multivariate analysis, age emerged as the only independent predictor of anemia, a finding that requires careful contextualization in terms of the underlying mechanisms. This association does not imply that age is, in and of itself, a causal factor, but rather that it acts as a proxy variable for multiple simultaneous processes that evolve predictably over time. Recognizing this complexity is essential to avoid mechanistic interpretations and to guide preventive interventions that target the underlying causal processes rather than age itself [29].

Methodologically, applying the altitude-adjusted hemoglobin correction in our study provides a rigorous approach that allows comparability with national and international reports [30]. However, recent research in Peruvian Andean populations has called into question the universal validity of these adjustments, demonstrating that the application of standard corrections can lead to a significant overestimation of the prevalence of anemia [31,32]. This methodological controversy underscores the importance of establishing context-specific thresholds for each geographic and population group, recognizing the biological heterogeneity among groups adapted to high altitude [33,34].

This study has several important limitations to consider when interpreting the results. First, only 9 infants were younger than 2 months (3.8% of the total sample), making the estimated prevalence of anemia (88.9%) in this group highly susceptible to sampling bias. Second, the non-probabilistic convenience sampling method may introduce selection bias and limit generalizability to other regions of Ecuador or other Andean populations with different sociodemographic characteristics. Third, the cross-sectional design prevents establishing causal relationships; therefore, the associations identified between age and anemia, although statistically significant, should be interpreted as correlations rather than causal mechanisms. Finally, the lack of biochemical markers of iron status limits the ability to confirm iron deficiency as an underlying mechanism of anemia, since morphological classification alone cannot rule out other causes of hypochromic microcytic anemia.

Conclusion.

The study results document a 59% prevalence of anemia among infants younger than 24 months in the parishes of the Alausí canton, with variability by age group. The predominant type of anemia was microcytic hypochromic anemia, consistent with iron deficiency, although confirmation requires specific iron biomarkers. Reticulocyte counts show patterns independent of those of hemoglobin. These findings strengthen clinical guidelines for managing childhood anemia in vulnerable populations and generate local evidence to support preventive strategies aimed at improving hematological health in contexts of chronic malnutrition.

Conflict of Interest.

The authors declare that they have no conflicts of interest.

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