Scientific Research Publishing

World Journal of Cardiovascular Diseases, 2025, 15(10), 509-518
https://www.scirp.org/journal/wjcd
ISSN Online: 2164-5337
ISSN Print: 2164-5329

Normal Physiological Values of Heart Rate, Respiratory Rate, Oxygen Saturation, Blood Pressure, and Hematocrit in Inhabitants of the Cajamarca Region Residing at Altitudes above 1000 Meters above Sea Level

Miguel Córdova-Castañeda, Ana Rimarachín-Chávez, Luis Linares-García, Nicolás López-Chegne, Belkis Herrera-Flores, Nátali Longa-Cerna, Victor Zavaleta-Gavidia, Pedro Ortiz-Oblitas

Faculty of Medicine, National University of Cajamarca, Cajamarca, Peru
Email: mcordovac@unc.edu.pe

How to cite this paper: Córdova-Castañeda, M., Rimarachín-Chávez, A., Linares-García, L., López-Chegne, N., Herrera-Flores, B., Longa-Cerna, N., Zavaleta-Gavidia, V. and Ortiz-Oblitas, P. (2025) Normal Physiological Values of Heart Rate, Respiratory Rate, Oxygen Saturation, Blood Pressure, and Hematocrit in Inhabitants of the Cajamarca Region Residing at Altitudes above 1000 Meters above Sea Level. *World Journal of Cardiovascular Diseases*, **15**, 509-518.
https://doi.org/10.4236/wjcd.2025.1510045

Received: August 27, 2025
Accepted: October 27, 2025
Published: October 30, 2025

Abstract

Objective: The main objective is to determine the normal physiological values of heart rate, respiratory rate, oxygen saturation, blood pressure, and hematocrit in populations living at altitudes between 1,000 and 3,500 meters above sea level in the Cajamarca Region during the year 2023. Methods: The study design was a descriptive observational cross-sectional study with a non-probabilistic sampling method. Inclusion criteria considered inhabitants aged 1 to 70 years, of both sexes, both native and non-native, who had resided for more than one year at the measured altitude and agreed to participate by signing the informed consent form. In the case of minors, consent was obtained from their parents. Exclusion criteria included a history of cardiovascular, pulmonary, or hematological disease; presence of respiratory symptoms at the time of the test such as cough, sputum, or dyspnea; diagnosis of obesity; body mass index greater than or equal to 30; and regular smoking. The total population included 476 individuals. Statistical analysis was performed using R Project software, and non-parametric statistical tests such as the Kruskal-Wallis test were applied. Results: Significant differences were found by sex in heart rate, respiratory rate, and hematocrit. Additionally, all physiological variables measured showed statistically significant differences according to sex, altitude, and life course. Conclusion: This study is relevant as it establishes a baseline for vital signs and hematocrit values in high-altitude populations. It is the first study of its kind conducted in the Cajamarca Region and represents a starting point for future research in high-altitude medicine.

Keywords

Vital Signs, Heart Rate, Respiratory Rate, Oxygen Saturation, Arterial Pressure, Hematocrit

1. Introduction

There is growing interest worldwide in understanding human adaptations to chronic hypoxia in high-altitude regions and at different ages [1]-[3].

In this regard, various parameters such as blood pressure, oxygen saturation, heart rate, respiratory rate, and hematocrit must be evaluated in humans, from newborns to adults [4]-[9].

In our region, South America, given that a number of countries have populations residing at high altitudes, reports such as that presented by Andrade V. *et al.* [10] provide oxygen saturation values for healthy children aged 1 to 12 years residing in Quito, Ecuador, a city of moderate altitude. Similarly, Trompetero A. C. *et al.* [3] analyzed the behavior of hemoglobin concentration, hematocrit, and oxygen saturation in the Colombian university population between the ages of 18 and 30, who were native or had been residents for at least three years, at different altitudes [3] [10].

In our country, these efforts to obtain this knowledge are also evident, as shown in the study reported by Rondón Abuhadba E. *et al.*, who found a significant correlation between oxygen saturation, heart rate, and respiratory rate in full-term newborns at 3,400 meters above sea level.

In another study conducted in the Andean regions of Peru, Mejía C. R. *et al.* [11] evaluated oxygen saturation at different altitudes and found statistically significant variations in heart rate in different age groups between 1 and 50 years of age.

Segura Vega L. [12] reported that 134/89 is the normal blood pressure pattern for Andean adults, a calculation obtained using a sample of 12,448 normotensive individuals over the age of 18 from the TONASOL I and II studies, excluding compensated hypertensive individuals and pregnant women.

Having knowledge of the vital signs of the population living at high altitudes will enable us to propose strategies for the diagnosis and prevention of chronic degenerative diseases in the general population, as well as to address the problem of childhood anemia.

For these reasons, given that the Cajamarca Region has populations distributed in areas at altitudes between 1,000 and more than 3,000 meters above sea level, for which there is no research on their physiology, the objective of this study is to determine the normal physiological values of heart rate, respiratory rate, oxygen saturation, blood pressure, and hematocrit in populations living at altitudes between 1,000 and 3,500 meters above sea level in the Cajamarca region in 2023.

Other objectives to be studied include establishing gender differences and differences according to age groups among the various parameters to be investigated.

Materials and Methods

Study design: the present study is an observational, descriptive, cross-sectional design.

According to the altitude and accessibility to obtain the corresponding samples, the following localities of the Cajamarca Region, Peru, were considered.

Province	District	Location	Altitude
Cajamarca	Magdalena	Magdalena	1,294
Cajamarca	Llacanora	Llacanora	2,606
San Marcos	Pedro Gálvez	San Marcos	2,251
San Pablo	San Pablo	San Pablo	2,365
Cajamarca	Namora	Namora	2,733
Cajamarca	Cajamarca	Cajamarca	2,750
Cajamarca	Matara	Matara	2,819
Cajamarca	La Encañada	La Encañada	3,098
Hualgayoc	Hualgayoc	Hualgayoc	3,502

Blood pressure was recorded according to Williams B. *et al*. [13] and Unger *et al*. [14], using automatic and semi-automatic oscillometric devices, in accordance with the specifications of the Pan American Health Organization [15].

The measurement of pulse oximetry was performed as described by Mejía Salas and Mejía Suarez [16].

The procedure for obtaining the haematocrit and its corresponding reading was performed according to parameters described in the literature [17]-[20].

Study population

A non-probabilistic and convenience sample was considered and its ages ranged from 1 to 70 years of age. Recruitment was carried out systematically in each of the nine pre-established locations for the study, achieving the participation of a total of 476 people.

Inclusion criteria were considered to be: subjects of both sexes, of the determined altitude, natives and non-natives with a stay of more than one year at the altitude measured, and who accepted to participate in the project and signed the Informed Consent Form, in this last aspect, if they were adults, and in the case of minors, their parents did so.

Exclusion criteria included: a history of cardiovascular, pulmonary or haematological disease, respiratory symptoms at the time of the test such as cough, expectoration or dyspnoea. Patients with a diagnosis of obesity and with a body mass index greater than 30 or who were regular smokers were also excluded.

Data analysis

The statistical software R Project was used to analyze the data. An initial assessment of the distribution of the data revealed that they did not follow a normal distribution. Given this situation, it was decided to use non-parametric statistical tests.

Specifically, the Kruskal-Wallis test was applied to determine significant differences between proportions of continuous and categorical variables. The results were presented in tables using the R package gtsummary, which facilitates the creation of high-quality statistical tables.

Ethical considerations: Ethical considerations included requesting informed consent from participants, as well as discretion and confidentiality in the use of the information obtained.

2. Results

To establish gender differences between the physiological values of heart rate, respiratory rate, oxygen saturation, blood pressure and haematocrit of inhabitants of the Cajamarca Region living at altitudes higher than 1,000 masl, in the year 2023.

Table 1 shows that the clinical characteristics studied show significant differences by sex in heart rate, respiratory rate and haematocrit; no significant differences by sex were found in oxygen saturation and systolic blood pressure.

Table 1. Summary of variables by sex.

Clinical characteristics	**F** N = 336[1]	**M** N = 140[1]	**p-value**[2]
Frec_Card	76 (15)	80 (17)	0.012
Frec_Resp	19.60 (2.56)	20.71 (7.33)	0.002
Sat_Oxig	93.3 (2.9)	93.6 (2.7)	0.5
Pres_Art_Sist	111 (20)	109 (22)	0.10
Hto	46.4 (7.0)	48.1 (9.6)	0.020

[1]Mean (SD); [2]Wilcoxon rank sum test.

Table 2 shows that in all clinical characteristics studied, there are significant differences by sex and altitude.

Table 2. Summary of variables by sex and altitude.

		F									
Clinical characteristics	**N**	**1294** N = 35[1]	**2251** N = 21[1]	**2365** N = 30[1]	**2606** N = 92[1]	**2703** N = 44[1]	**2750** N = 18[1]	**2819** N = 30[1]	**3098** N = 18[1]	**3502** N = 48[1]	**p-value**[2]
Frec_Card	336	69 (12)	77 (11)	74 (14)	81 (20)	75 (12)	73 (10)	80 (9)	71 (12)	74 (14)	0.003
Frec_Resp	333	17.65 (4.99)	19.62 (2.54)	19.77 (2.37)	20.02 (1.82)	19.36 (0.99)	19.56 (1.10)	20.17 (3.53)	19.12 (1.36)	20.11 (1.72)	<0.001
Sat_Oxig	336	95.2 (2.8)	94.8 (2.7)	94.9 (2.7)	93.5 (2.1)	92.7 (2.6)	94.6 (2.2)	91.4 (3.0)	94.1 (1.7)	90.8 (3.2)	<0.001
Pres_Art_Sist	331	123 (18)	116 (31)	114 (26)	105 (19)	113 (15)	108 (19)	114 (19)	107 (13)	109 (17)	<0.001
Hto	326	43.7 (3.4)	47.0 (2.9)	44.3 (5.0)	45.2 (3.4)	43.3 (2.9)	44.6 (3.8)	57.8 (15.9)	45.1 (3.8)	48.0 (4.0)	<0.001

		M									
Clinical characteristics	**N**	**1294** N = 15[1]	**2251** N = 16[1]	**2365** N = 5[1]	**2606** N = 29[1]	**2703** N = 15[1]	**2750** N = 6[1]	**2819** N = 19[1]	**3098** N = 6[1]	**3502** N = 29[1]	**p-value**[2]
Frec_Card	140	70 (12)	71 (19)	84 (19)	90 (17)	78 (16)	67 (13)	78 (12)	72 (10)	84 (17)	<0.001
Frec_Resp	140	17.27 (2.81)	24.44 (20.44)	21.20 (1.10)	20.97 (1.74)	19.80 (1.37)	18.50 (1.97)	21.16 (3.99)	21.17 (1.72)	20.66 (2.74)	<0.001
Sat_Oxig	139	96.67 (1.39)	94.13 (1.55)	94.00 (3.74)	94.79 (1.76)	93.40 (2.87)	93.33 (1.21)	91.42 (1.57)	94.00 (2.53)	91.93 (2.80)	<0.001
Pres_Art_Sist	133	128 (27)	123 (25)	102 (17)	93 (16)	104 (16)	123 (31)	116 (17)	98 (9)	106 (17)	<0.001
Hto	138	45 (5)	48 (4)	42 (5)	43 (7)	45 (3)	47 (9)	62 (15)	47 (3)	48 (6)	<0.001

[1]Mean (SD); [2]Kruskal-Wallis rank sum test.

Table 3 shows that in all the clinical characteristics studied, there is a significant difference by life course.

Table 3. Summary of variables by life course.

Clinical characteristics	**0 a 11** N = 120[1]	**12 a 17** N = 57[1]	**18 a 29** N = 73[1]	**30 a 59** N = 163[1]	**60 a Mas** N = 63[1]	p-value[2]
Frec_Card	90 (18)	76 (13)	75 (13)	71 (11)	72 (13)	<0.001
Frec_Resp	21.39 (2.51)	19.35 (1.48)	18.97 (1.60)	18.96 (1.74)	21.24 (11.09)	<0.001
Sat_Oxig	93.8 (2.9)	93.9 (2.5)	94.1 (2.7)	93.2 (2.7)	91.7 (3.0)	<0.001
Pres_Art_Sist	93 (13)	104 (13)	112 (17)	115 (15)	133 (25)	<0.001
Hto	44.4 (5.5)	46.2 (5.1)	46.6 (8.8)	48.3 (9.1)	49.1 (8.2)	<0.001

[1]Mean (SD); [2] Kruskal-Wallis rank sum test.

Table 4 shows that for all clinical characteristics studied, there is a significant difference by altitude.

Table 4. Summary of Variables by Altitude.

Clinical characteristics	**1294** N = 50[1]	**2251** N = 37[1]	**2365** N = 35[1]	**2606** N = 121[1]	**2703** N = 59[1]	**2750** N = 24[1]	**2819** N = 49[1]	**3098** N = 24[1]	**3502** N = 77[1]	p-value[2]
Frec_Card	69 (12)	74 (15)	75 (15)	83 (20)	76 (13)	72 (11)	79 (11)	71 (11)	78 (16)	<0.001
Frec_Resp	17.53 (4.41)	21.70 (13.54)	19.97 (2.28)	20.25 (1.84)	19.47 (1.10)	19.29 (1.40)	20.55 (3.71)	19.65 (1.70)	20.32 (2.17)	<0.001
Sat_Oxig	95.7 (2.5)	94.5 (2.3)	94.8 (2.9)	93.8 (2.1)	92.9 (2.6)	94.3 (2.0)	91.4 (2.5)	94.0 (1.9)	91.2 (3.1)	<0.001
Pres_Art_Sist	124 (21)	119 (28)	113 (25)	102 (19)	111 (15)	112 (23)	115 (18)	105 (12)	108 (17)	<0.001
Hto	44.2 (3.8)	47.6 (3.3)	44.1 (4.9)	44.6 (4.5)	43.8 (3.1)	45.1 (5.5)	59.5 (15.6)	45.5 (3.6)	48.2 (4.7)	<0.001

[1]Mean (SD); [2]Kruskal-Wallis rank sum test.

3. Discussion

In our study, we found higher average values for HR, HR and Hto in men than in women. In addition, typical responses to altitude, such as increased heart rate and respiratory rate, decreased oxygen saturation and increased haematocrit in the Cajamarca population were evident. Also, expected physiological patterns are observed, such as a higher heart and respiratory rate in childhood that decreases in adulthood, a progressive increase in systolic blood pressure and haematocrit with age, as responses to hypobaric hypoxia as altitude increases. Our results are consistent with the studies of Bardales Zuta *et al.* [21]. Healthy residents of Huamachuco were recruited for this cross-sectional convenience study. Arterial blood was drawn using standard procedures. People with obesity, diabetes, high levels of physical activity and a history of substance use were excluded. They concluded that in inhabitants of high Andean areas pO_2 and pCO_2 decreased and haematocrit increased.

Tremblay J. C. and Ainslie P. N. [22], who in their research used a Geographic Information Systems (GIS) approach to quantify the human population at 500 m altitude intervals in each country. Presenting the population for 500 m intervals to provide a flexible interpretation of "high altitude", as the threshold for high altitude eliciting a physiological response varies between individuals and populations. Concluding that research in countries with substantial high-altitude populations is needed to understand how the environmental (physiological and social) stresses of high altitude affect physiology, adaptation, health and disease. These conditioning factors are similar to the reality of the Peruvian highlands in our study.

On the other hand, Julian C. G. and Moore L. G. [23], in their review study, analyse the types of evidence that have evaluated the widespread acceptance of the idea that genetic adaptation in high altitude Andean residents with respect to the physiological characteristics that distinguish them from acclimatised newcomers and the genomic or genetic factors potentially involved. Concluding that, there are several unique O_2 transport characteristics of the Andean resident compared to acclimatised residents or newcomers including lower alveolar ventilation, lower hypoxic pulmonary vasoconstrictor response, slightly larger lung volumes, higher uterine artery blood flow and possibly lower mean cerebral blood flow, lower peak exercise O_2 consumption due to altitude and higher cardiac efficiency. Taken together, these suggest greater efficiency in O_2 transfer and utilisation; in turn, such differences between acclimatised or permanent residents of high altitude support the existence of an Andean genetic adaptation to high altitude.

Sex differences in physiological parameters show significant differences between sexes in heart rate (76 vs 80 bpm, $p = 0.012$), respiratory rate (19.60 vs 20.71 breaths/min, $p = 0.002$) and haematocrit (46.4% vs 48.1%, $p = 0.020$). 020), being consistent with previous studies reporting sexual dimorphism in adaptations to altitude [24]. A recent study in Andean populations confirmed that men tend to have higher haematocrit values as a compensatory mechanism to chronic hypoxia [25].

Regarding oxygen saturation, considered the fifth vital sign, it is an accurate and non-invasive measurement; alteration of vital signs occurs several hours before the occurrence of an adverse event; vital signs are the cheapest, simplest information; the measurement of $SatO_2$ trends added to respiratory rate provides a holistic view of respiratory function [26]. In our study, however, respiratory rate is not altered despite low saturations.

It is important to take into account the publication by Townsed [27], where food insecurity, female sex and BMI were significantly and independently associated with increased systolic blood pressure, the peculiarity of this study is that participants were mailed a kit containing a blood pressure monitor, scales and a tape measure for each participant to measure themselves; in our study the measurement was direct and carried out by the research team. However, we have not considered dietary habits and physical activity in our data, which could be a point to be taken into account in future research.

The study published by Yook Chin Chia [28] considers weight and height self-reported by the participants, the accuracy of these data may vary, 2781 participants were considered, the majority 61.7% of the participants were overweight or obese, these measurements were then corroborated with the measurement of the team finding reliability in the measurements, in our study the measurement was directly by the research team.

Particularly notable is that no significant sex differences were found in oxygen saturation (93.3% vs 93.6%, $p = 0.5$) or systolic blood pressure (111 vs 109 mmHg, $p = 0.10$). This contrasts with the previous study by Santos-Martínez L. E. *et al.* [29] who reported minor differences in SpO_2 between sexes in Andean populations, suggesting that the Cajamarca populations may present a specific adaptive pattern.

Variations by altitude and sex reveal that all clinical characteristics studied show significant differences by sex and altitude ($p < 0.001$ for all variables). Haematocrit values show a progressive increase with altitude in both sexes, from 43.7% in women at 1294 m to 48.0% at 3502 m, and from 45.1% to 48.6% in men at the same altitudes. This pattern is consistent with the Nishimura T. *et al.* [30] study describing increased erythropoiesis as a primary response to hypobaric hypoxia.

Heart rate showed an interesting behaviour, with lower values at higher altitudes (71 - 74 bpm in women and 67-84 bpm in men at different altitudes), which may reflect chronic cardiovascular adaptation. Ortiz-Prado E. *et al.* [24] study in Peruvian high altitude populations has reported lower heart rates in chronic residents compared to seasonal visitors.

Findings of age group differences show significant differences in all variables by life course ($p < 0.001$). Haematocrit shows a progressive increase with age, from 44.4% in the 0 - 11 age group to 49.1% in the over 60 age group. This age pattern has been documented in the study by Santos-Martinez L. E. *et al.* [29] in Andean populations, where erythrocytes tend to increase with age as a result of prolonged chronic exposure.

Oxygen saturation showed a decrease with age (98.8% in children vs 91.7% in older adults), which is in agreement with the study by Bravo-Jaimes K. *et al.* [31], reporting lower ventilatory efficiency in older populations living at high altitude.

The impact of altitude on physiological parameters confirms significant differences in all parameters by altitude ($p < 0.001$). Haemoglobin and haematocrit values increase progressively with altitude, while oxygen saturation shows a decreasing trend. These findings are consistent with the physiological profile typical of Andean populations described by Santos-Martínez L. E. *et al.* [29], characterised by compensatory erythrocytosis and lower SpO_2 compared to Tibetan populations. These findings have clinical relevance for establishing specific reference values for high-altitude populations in the Peruvian context, considering the sex, age and altitude differences documented in the present study. The research contributes to the knowledge of Andean adaptive physiology and may guide differential diagnostic strategies in mid-altitude populations.

4. Conclusions

- In our study, we found higher mean values for HR, HR and Hto in men compared to women.

- In the present study, we found typical responses to altitude, such as increased heart and respiratory rate, decreased oxygen saturation and increased haematocrit in the Cajamarca population.
- In the present study, we observed a higher heart and respiratory rate in childhood and a progressive increase in systolic blood pressure and haematocrit with age.
- In the present study, we found significant sex differences in heart rate, respiratory rate and haematocrit.
- No significant sex differences were found in oxygen saturation and systolic blood pressure in the present study.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Rondón-Abuhadba, E.A., Ordoñez-Linares, M.E., Ccorahua-Rios, M.S. and Paucar-Tito, L. (2019) Saturación de oxígeno, frecuencia cardiaca y respiratoria en recién nacidos a término en poblaciones de altura. *Revista Cubana de Pediatría*, **91**, e687.

[2] Mendiola Espinoza, Y.W. (2020) Determinación de parámetros Hematimétricos y constantes vitales de normalidad en el Habitante permanente en altura a 5 000 m.s.n.m. Centro Poblado la Rinconada, marzo—mayo 2019. http://repositorio.uancv.edu.pe/handle/UANCV/4625

[3] Trompetero, A. and Cebwsmlm, R.J. (2015) Comportamiento de la concentración de hemoglobina, hematocrito y la saturación de oxígeno en una población universitaria en Colombia, a diferentes alturas. *Nutrición Hospitalaria*, **32**, 2309-2318.

[4] Dünnwald, T., Kienast, R., Niederseer, D. and Burtscher, M. (2021) The Use of Pulse Oximetry in the Assessment of Acclimatization to High Altitude. *Sensors*, **21**, Article 1263. https://doi.org/10.3390/s21041263

[5] Mcmgip, H.V. (2018) Niveles de presión arterial entre niños indígenas que viven a diferentes altitudes. *Fisiología Aplicada*, *Nutrición y Metabolismo*, **44**, 659-664. https://doi.org/10.1139/apnm-2018-0466

[6] Chacon Baltazar, O., Campero, A.C., Choquecallata Mamani, O.J., Choquecallata, R. and Mamani, O.J.C. (2010) Valor Normal de los Signos Vitales en Adultos de la Provincia Cercado debido a la Altura Correspondencia a [Normal Value of Vital Signs in Adult People in the Cercado Province Because of the Height Original]. *Revista Cientifica Ciencia Medica*, **13**, 19-21. http://bases.bireme.br/

[7] Bustamante, A., Alexandra, E. and Astudillo, V. (2015) Estudio preliminar para determinar valores referenciales de saturación de oxígeno medidos poroximetría de pulso en personas mayores de 18 años, sin patología cardiorrespiratoria, residentes en la ciudad de Quito. (altitud 2850 metros sobre el nivel del mar) https://repositorio.puce.edu.ec/items/e297a35c-33a8-45cb-aecd-c40f3be70fd2

[8] Botella de Maglia, J. and Compte Torrero, L. (2005) Saturación arterial de oxígeno a gran altitud. Estudio en montañeros no aclimatados y en habitantes de alta montaña. *Medicina Clínica*, **124**, 172-176. https://doi.org/10.1157/13071480

[9] Bilo, G., Caravita, S., Torlasco, C. and Parati, G. (2019) Blood Pressure at High Alti-

tude: Physiology and Clinical Implications. *Kardiologia Polska*, **77**, 596-603. https://doi.org/10.33963/kp.14832

[10] Andrade, V., Andrade, F., Riofrio, P., Nedel, F.B., Martin, M. and Romero-Sandoval, N. (2020) Pulse Oximetry Curves in Healthy Children Living at Moderate Altitude: A Cross-Sectional Study from the Ecuadorian Andes. *BMC Pediatrics*, **20**, Article No. 440. https://doi.org/10.1186/s12887-020-02334-z

[11] Rojas-Camayo, J., Mejia, C.R., Callacondo, D., Dawson, J.A., Posso, M., Galvan, C.A., *et al.* (2017) Reference Values for Oxygen Saturation from Sea Level to the Highest Human Habitation in the Andes in Acclimatised Persons. *Thorax*, **73**, 776-778. https://doi.org/10.1136/thoraxjnl-2017-210598

[12] Vega, L.S., Ruiz Mori, C.E. and Fuentes Neira, W.L. (2021) Systemic Blood Pressure in Peruvian Andean Populations: A Study. *Revista Peruana de Ginecologia y Obstetricia*, **67**, 1-6. http://www.scielo.org.pe/pdf/rgo/v67n4/2304-5132-rgo-67-04-00002.pdf

[13] Mccain, J., White, W.B. and William, B. (2016) White Explains the Changes in the Way We Look at Blood Pressure Which Numbers Matter Most and Why Can They Be Deceptive? *P&T*, **41**, 573-580.

[14] Unger, T., Borghi, C., Charchar, F., Khan, N.A., Poulter, N.R., Prabhakaran, D., *et al.* (2020) 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension*, **75**, 1334-1357. https://doi.org/10.1161/hypertensionaha.120.15026

[15] World Health Organization (2020) WHO Technical Specifications for Automated Non-Invasive Blood Pressure Measuring Devices with Cuff. World Health Organization.

[16] Mejía Salas, H. and Mayra Mejía Suárez, S. (2012) Educación médica continua. Oximetría de pulso. Pulse oximetry. *Revista de la Sociedad Boliviana de Pediatría*, **51**, 149-153.

[17] Burger, S.E. and Neff Pierre-Louis, J. (2003) A Procedure to Estimate the Accuracy and Reliability of HemoCue™ Measurements of Survey Workers. https://www.researchgate.net/publication/239557324

[18] Ernst, D.J. (2008) Procedures and Devices for the Collection of Diagnostic Capillary Blood Specimens: Approved Standard. Clinical and Laboratory Standards Institute, 25.

[19] Gonzales, G.F. and Tapia, Y.V. (2007) Hemoglobina, hematocrito y adaptación a la altura: Su relación con los cambios hormonales y el periodo de residencia multigeneracional. *RevistaMed*, **15**, 80-93.

[20] Ministerio de Salud—Instituto Nacional de Salud. Manual de procedimientos (2005) Bioseguridad en laboratorios de ensayo, biomédicos y clínicos. 3ra edition, Ministerio de Salud—Instituto Nacional de Salud. Manual de procedimientos.

[21] Bardales-Zuta, V.H., Fernández-Rodríguez, L.J. and Romero-Goicochea, C. (2023) Arterial Blood Analysis of Healthy Residents in Huamachuco, Peru (3,164 M): A Cross-Sectional Study. *F1000Research*, **12**, Article 885. https://doi.org/10.12688/f1000research.134567.2

[22] Tremblay, J.C. and Ainslie, P.N. (2021) Global and Country-Level Estimates of Human Population at High Altitude. *Proceedings of the National Academy of Sciences of the United States of America*, **118**, e2102463118. https://doi.org/10.1073/pnas.2102463118

[23] Julian, C.G. and Moore, L.G. (2019) Human Genetic Adaptation to High Altitude: Evidence from the Andes. *Genes*, **10**, Article 150.

https://doi.org/10.3390/genes10020150

[24] Ortiz-Prado, E., Portilla, D., Mosquera-Moscoso, J., Simbaña-Rivera, K., Duta, D., Ochoa, I., *et al.* (2021) Hematological Parameters, Lipid Profile, and Cardiovascular Risk Analysis among Genotype-Controlled Indigenous Kiwcha Men and Women Living at Low and High Altitudes. *Frontiers in Physiology*, **12**, Article 749006. https://doi.org/10.3389/fphys.2021.749006

[25] Nishimura, T., Ugarte, J., Ohnishi, M., Nishihara, M., Alvarez, G., Yasukochi, Y., *et al.* (2020) Individual Variations and Sex Differences in Hemodynamics with Percutaneous Arterial Oxygen Saturation (SpO_2) in Young Andean Highlanders in Bolivia. *Journal of Physiological Anthropology*, **39**, Article No. 31. https://doi.org/10.1186/s40101-020-00240-y

[26] Singhal, A., Prafull, K., Daulatabad, V., John, N. and John, J. (2023) Arterial Oxygen Saturation: A Vital Sign? *Nigerian Journal of Clinical Practice*, **26**, 1591-1594. https://doi.org/10.4103/njcp.njcp_2026_21

[27] Ing, C.T., Clemens, B., Ahn, H.J., Kaholokula, J.K., Hovmand, P.S., Seto, T.B., *et al.* (2023) Food Insecurity and Blood Pressure in a Multiethnic Population. *International Journal of Environmental Research and Public Health*, **20**, Article 6242. https://doi.org/10.3390/ijerph20136242

[28] Chia, Y.C., Ching, S.M., Ooi, P.B., Beh, H.C., Chew, M.T., Chung, F.F.L., *et al.* (2023) Measurement Accuracy and Reliability of Self-Reported versus Measured Weight and Height among Adults in Malaysia: Findings from a Nationwide Blood Pressure Screening Programme. *PLOS ONE*, **18**, e0280483. https://doi.org/10.1371/journal.pone.0280483

[29] Santos-Martínez, L.E., Gómez-Tejada, R.A., Murillo-Jauregui, C.X., Hoyos-Paladines, R.A., Poyares-Jardim, C.V. and Orozco-Levi, M. (2022) Exposición crónica a la altura. Características clínicas y diagnóstico. *Archivos de Cardiología de México*, **91**, 500-507. https://doi.org/10.24875/acm.20000447

[30] Richalet, J. (2021) Adaptation à l'hypoxie chronique des populations de haute altitude. *Revue des Maladies Respiratoires*, **38**, 395-403. https://doi.org/10.1016/j.rmr.2020.11.007

[31] Bravo-Jaimes, K., Lozano Moreno, D., Orozco, J., Rosales, W., Macedo, N., Medina, M., *et al.* (2024) Tamizaje neonatal de cardiopatías congénitas críticas en el Perú: Un llamado de urgencia. *Archivos Peruanos de Cardiología y Cirugía Cardiovascular*, **5**, 157-166. https://doi.org/10.47487/apcyccv.v5i3.366