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Arterial blood gas in young adults at an average altitude of 1605-m above sea level: Armenia, Colombia 2016

Gasometría arterial en adultos jóvenes en una altura promedio de 1605 msnm. Armenia, Colombia 2016

Keywords: Oxygenation, Blood Gas Analysis, Acid-Base Equilibrium, Young Adult, Atmospheric Pressure

Palabras clave: Oxigenación, Análisis de los Gases de la Sangre, Equilibrio Ácido-Base, Adulto Jóven, Presión Atmosférica

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Abstract

Introduction: Arterial blood gas measurement is an essential quick test in clinical practice to evaluate oxygenation and for the identification and diagnosis of acid–base and metabolic disorders. Arterial blood gas reference values vary as a result of altitude changes associated with barometric pressure (bp).

Objectives: To determine the $PaCO_2$, PaO_2, HCO_3, and SaO_2% values for a young population without lung disease in a city located at an average altitude of 1605-m above sea level and a bp of 624 mm Hg.

Materials and methods: Descriptive cross-sectional study in 137 arterial blood gas samples from male and female healthy volunteers aged between 18 and 40 years old. An COPD® point of care blood analysis portable system was used for readings with single-use individual cards.

Results and conclusion: The 95% confidence interval (CI) limits were pH between 7.43 and 7.45, PaO_2 between 86.23 and 88.83, $PaCO_2$ between 32.64 and 33.87, and $SatO_2$% between 97.13 and 97.38. No gender or age differences were found. When comparing the findings against other trials conducted over 2640-m above sea level, some differences were identified: PaO_2 between 18 and 26 mm Hg lower at an altitude of 1605 m (Armenia), PCO_2 between 2.0 and 2.7 mm Hg higher in Armenia, and also the SaO_2% was between 3.6% and 6.2% higher. PaO_2 and HCO_3^- were mildly higher as compared with a study conducted in Medellin. The oxygenation index (PaO_2/FIO_2) was 416.83 (95% CI 410.63–423.03)—as expected—considering the difference in altitude due to the geographic location, pursuant to the referenced studies.

Resumen

Introducción: La gasometría arterial es una prueba rápida indispensable en la práctica clínica para la evaluación de la oxigenación y para identificar y diagnosticar desórdenes metabólicos, por alteración en el equilibrio ácido base. Los valores de referencia varían por los cambios de altitud relacionados con la presión barométrica (pb).

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Objetivos: Determinar los valores de $PaCO_2$, PaO_2, HCO_3^- y SaO_2% en población joven sin enfermedad pulmonar en una ciudad con altura promedio de 1605 msnm y pb de 624 mmHg.

Materiales y métodos: Estudio descriptivo transversal en 137 muestras de sangre arterial de voluntarios sanos de 18 a 40 años ambos sexos. Para la lectura se utilizó un equipo portátil "point of care en sangre EPOC®" con tarjetas individuales de un solo uso.

Resultados y conclusiones: Los límites de intervalos de confianza del 95% de las medias fueron: pH entre 7,43 y 7,45; PaO2 86,23 y 88,83; $PaCO_2$ 32,64 y 33,87 y SaO2% 97,13 y 97,38. No se encontraron diferencias por sexo ni edad. Al comparar los hallazgos con estudios realizados por encima de los 2640 msnm, se observaron diferencias: PaO_2 entre 18 y 26 mm de Hg menor que a 1605 msnm (Armenia), PCO_2 entre 2,0 y 2,7 mm Hg mayor en Armenia al igual que la SaO_2% entre 3,6 y 6,2%. La PaO2 y el HCO_3^- fueron levemente mayores que un estudio realizado en Medellín. El índice de oxigenación (PaO_2/FIO_2) fue de 416,83 (IC 95% 410,63- 423,03), resultados esperados, teniendo en cuenta la diferencia de altura por la ubicación geográfica, según los estudios referenciados.

Introduction

In clinical practice, arterial blood gas measurement is an essential test for analyzing arterial oxygenation (PaO_2), arterial oxygen saturation ($SatO_2$), acid–base balance, and indirectly, ventilation with the CO_2 arterial pressure value ($PaCO_2$). It also helps in evaluating and measuring the patient's response to therapeutic interventions such as oxygen therapy, mechanical ventilation, and to follow-up the evolution of the pulmonary and/or metabolic disease.[1]

Among other factors, the arterial blood gases measurement varies as a result of the atmospheric or barometric pressure (bp), which at sea level is 760 mm Hg.[2–6] The arterial oxygen pressure (PaO_2) depends on the oxygen that varies with bp, and hence with the altitude at which the individual breathes ambient air; the arterial partial pressure of oxygen is inversely proportional to the altitude at which a particular individual lives;[4] the PaO_2 may be further affected by age, because the normal lung tissue aging alters the oxygen exchange at the level of the alveolar capillary septum.[7,8]

The HCO_3^- (concentration of bicarbonate ions in plasma) is the most important base in the body to maintain a stable pH.[6,9] The pH is a critical parameter in the acid–base balance; the hydrogen ions concentration (H^+) depends on the interaction between $PaCO_2$ and HCO_3^-.[10]

Several research studies conducted in various places describe the variations in blood gas measurements at varying altitudes, but most of these studies take place in cities at high altitudes or at sea level; likewise, the studies identified at altitudes similar to Armenia have been conducted in small sample sizes.[8,11]

The evaluation and monitoring of the acid–base balance in the young critical patient need to associate various aspects of the clinical manifestations and the physical examination with the gas measurements.[10] In addition to the conditions that alter the acid–base balance in this age group, trauma (injuries from external causes) is much more frequent; in Colombia, trauma represents the third cause of death among males and the second cause of death among females.[12] Furthermore, the detection and management of acid–base balance alterations have a significant impact on morbidity and mortality.[13,14]

Due to the above considerations, and since the results of the parameters may vary with altitude, this study was intended to determine the blood gas measurements in a city located in the coffee-growing area, at 1605-m above sea level, with a bp of 624 mm Hg. The study population comprised healthy, non-smokers aged between 18 and 40 years old. In addition, the results were compared against a number of studies conducted at other altitudes; these findings are intended to contribute to the information about the region and other regions at similar altitudes.

Materials and methods

Type of study

Descriptive, cross-sectional study.

Study population

The study comprised 137 participants from the University of Quindío, where the project was publicized; undergraduate students, professors, and administrative staff were invited to participate. The importance of the study was clearly emphasized and most of the participants that volunteered to submit a sample were from the School of Health programs.

Exclusion criteria. Cigarette and/or tobacco use—more than 2 U/day—in the last 3 years. Chronic cardiopulmonary disease, systemic lupus erythematosus, rheumatoid arthritis, bronchial asthma, congenital heart disease, COPD, pneumoconiosis or occupational exposure to inhaled smoke or chemicals, and coagulopathies or anticoagulation therapy.

Techniques and procedures

The samples were collected by the anesthesiologist or the nurse (investigators) using an COPD® point of care blood analysis portable system with individual single-use cards, which render the following measurements: pH, $PaCO_2$, PaO_2, and HCO_3^-, and SaO_2% estimates.[15–19]

Pre-conditions. Before taking the sample, the patient was at rest for 10 minutes while being informed about the procedure, signed the informed consent and completed the sampling instrument. No fasting was required.

Test technique. With the patient seated the wrist is hyperextended at approximately 45° with the wrist resting on a dorsal cushion; the asepsis and antisepsis of the puncture site is conducted, and the radial artery is palpated with the fingers of 1 hand to localize the precise puncture site, whereas the other hand inserts and slowly advances the needle entering the skin at an angle of approximately 45°.

An amount of 1 mL of arterial blood is collected and then the needle is quickly removed. The samples are immediately processed.

Information processing and analysis

The information was processed using the SPSS version 19.0 (Armonk, New York) statistical package and the normality of the quantitative variables was determined with the Kolmogorov–Smirnov test. Central trend measurements, position, and confidence intervals (CIs) were estimated for the study variables; analysis of variance (ANOVA) was conducted to compare the parameters by age groups. The oxygenation index was estimated using the PaO_2/FiO_2 ratio. The results from the study were compared against other studies conducted at different altitudes above sea level.

Bioethical considerations

From the ethical–legal perspective, the project was conducted according to resolution 8430 of 1993 of the Ministry of Health, which establishes the technical, scientific, and administrative standards for every health-related research project. The project was previously approved by the Bioethics Committee of Universidad del Quindío. The resulting information was managed confidentially, ensuring the privacy of all patients and the results shall only be used with a view to obtaining scientific information. The informed consent form was duly completed by each participant and the consent form explained the test technique and warned against potential pain or puncture-associated complications.

Results

A total of 137 participants were enrolled. A sample was taken from each participant to analyze the parameters of the study; the mean age was 22.5 years (95% CI 21.7–23.3) and the age range as from 18 to 40 years old. Table 1 shows the results for PaO_2, $PaCO_2$, HCO_3^-, pH, and SaO_2%.

A total of 40.1% (n = 55) of the samples were taken from males and 59.9% (n = 82) from females. The HCO_3^- and $PaCO_2$ values were significantly higher in males than in females, with a 1.88 (95% CI 1.26–2.50) and 2.94 mm Hg (95% CI 1.78–4.09) difference, respectively (Table 2).

An analysis by age groups was conducted and ANOVA was administered; no significant differences were found (Table 3).

Table 1. Values of the parameters analyzed in a population living at an altitude of 1605-m above sea level

	Total population n = 137			
Parameters	Mean (95% CI)	SD	Median (P25–P75)	Range
PaO_2	87.53 (86.23–88.83)	7.70	87.0 (82.1–91.9)	70.9–107.9
$PaCO_2$	33.26 (32.64–33.87)	3.6345	33.26 (30.62–36.0)	25.5–45.7
pH	7.44 (7.43–7.45)	0.0279	7.44 (7.43–7.46)	7.38–7.57
SaO_2%	97.25 (97.13–97.38)	0.7467	97.3 (96.7–97.8)	95.2–98.8
HCO_3^-	23.04 (22.7–23.38)	2.0219	23.1 (21.6–24.5)	16.5–30.8

CI = confidence interval, SD = standard deviation.
Source: Authors.

As a second stage, studies conducted in Bogotá and Cusco with altitudes of 2640 and 3350-m above sea level, respectively, were selected; the results of other altitudes, but with very alike populations to ours, were compared with the results of our study, calculating the median differences. According to the observations, in Armenia, the $PaCO_2$, PaO_2, and SaO_2% values were higher as compared against the referred studies; the pH was identical. When comparing against the trial conducted in Medellin at an altitude of 1538-m above sea level, in Armenia the PaO_2, and HCO_3^- were slightly higher (Table 4).

Finally, the oxygenation index was calculated (PaO_2/FIO_2) obtaining average values of 416.83 (95% CI 410.63–423.03), ranging between 337.62 and 513.81; no gender or age differences were identified (P = 0.69). The scatter plot illustrating the relationship between (PaO_2/FIO_2) and SaO_2% indicated that the 76.6% variability (variance) was the same for both variables, with an R^2 of 0.875 (Fig. 1).

Table 2. Values of parameters analyzed according to gender at an altitude of 1605-m above sea level

	Mean (95% CI) according to gender		
Parameters	Males n = 55	Females n = 82	MD (P)
PaO_2	87.20 (85.06–89.34)	87.75 (86.08–89.42)	0.683
$PaCO_2$	35.01 (33.99–36.03)	32.08 (31.41–32.74)	0.000
pH	7.44 (7.43–7.45)	7.44 (7.43–7.45)	0.560
SaO_2%	97.18 (96.97–97.39)	97.30 (97.14–97.46)	0.373
HCO_3^-	24.17 (23.66–24.67)	22.29 (21.90–22.67)	0.000

CI = confidence interval, MD = mean differences (significance).
Source: Authors.

Table 3. Parameters analyzed according to age groups at an altitude of 1605-m above sea level

	<25		25–32		≥33		
Years	Mean (95% CI)	Me	Mean (95% CI)	Me	Mean (95% CI)	Me	AV (P)
PaO_2	88.20 (86.80–89.59)	87.75	85.58 (80.70–90.45)	84.3	82.41 (78.13–86.7)	81.4	0.064
$PaCO_2$	33.18 (32.54–33.82)	33.17	33.56 (30.85–36.26)	34.54	33.69 (31.42–35.97)	33.41	0.870
pH	7.44 (7.438–7.448)	7.437	7.45 (7.44–7.46)	7.437	7.45 (7.43–7.47)	7.467	0.522
SaO_2%	97.31 (97.18–97.44)	97.3	97.07 (96.57–97.57)	97.1	96.81 (96.18–97.44)	96.75	0.104
HCO_3^-	22.95 (22.60–23.29)	22.95	23.39 (21.88–24.89)	23.9	23.62 (21.79–25.45)	23.73	0.499
IO	420.0 (413.4–426.6)	417.9	407.5 (384.3–430.7)	401.4	392.44 (372.03–412.8)	387.6	0.064

AV = analysis of variance (significance), CI = confidence interval, Me = median, OI = oxygenation index (PaO_2/FIO_2), X = average.
Source: Authors.

Table 4. Difference of parameter measurements at an altitude of 1605-m above sea level vs other altitudes

			Statistics		MD with Armenia[†]	
Author/place[*]	n	Parameters	Mean (95% CI)	SD	Difference	95% CI
Pereira-Victorio et al[24] Cusco, 3350-m above sea level	118	PaO_2	61.1 (60.0–62.1)	5.4314	26.43	24.8–28.1
		$PaCO_2$	30.6 (30.0–31.2)	3.2588	2.66	1.81–3.51
		pH	7.4 (7.4–7.4)	0.0	0.04	0.03–0.04
		SaO_2%	91.1 (90.7–91.6)	2.1726	6.15	5.76–6.54
		HCO_3^-	19.70 (19.4–20.1)	0.0	3.34	2.97–3.70
Restrepo et al[25] Bogotá, 2640-m above sea level	36	PaO_2	68.60 (63.0–67.0)	3.72	18.93	16.33–21.52
		$PaCO_2$	31.27 (26.0–36.0)	2.6	1.99	0.72–3.26
		pH	7.44 (7.37–7.54)	0.038	0	−0.01 to 0.01
		SaO_2%	93.65 (92.0–97.0)	1.14	3.6	3.29–3.91
		HCO_3^-	21.50 (18.4–23.4)	1.51	1.54	0.83–2.25
Ortega et al[8] Medellin, 1538-m above sea level	76	PaO_2	80.82 (79.73–81.57)	4.173	6.71	4.84–8.58
		$PaCO_2$	31.68 (31.06–32.35)	2.85	1.58	0.63–2.53
		pH	7.42 (7.416–7.424)	0.017	0.02	0.01–0.03
		SaO_2%	MD			
		HCO_3^-	20.37 (20.02–20.78)	1.66	2.67	2.14–3.20

CI = confidence interval, MD = missing data, SD = standard deviation.
[*] Place: city and altitude in meters above sea level.
[†] Difference with Armenia vs measurements in other places (MD).
Source: Authors.

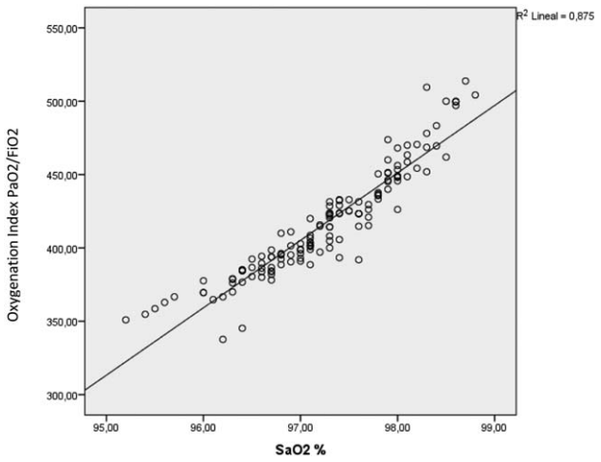

Figure 1. Relationship between oxygenation index and SaO_2%.
Source: Authors.

Discussion

The arterial blood gas measurement is an instant report of the oxygenation status, the ventilation condition, and the internal acid–base balance; it is an indispensable quick test in the clinical care of patients with respiratory disease, acute or chronic pulmonary conditions, or metabolic disorders.[9] According to the geographic location, and as result of the changes in bp due to the different altitudes above sea level, the information about the normal blood gases parameters should be available as a tool in daily clinical practice.

In our study conducted in young individuals without pulmonary disease, non-smokers, and at rest, we identified pH values ranging from 7.43 to 7.45; PaO_2 values between 86.23 and 88.83; $PaCO_2$ values from 32.64 to 33.87; and SaO_2% values ranging from 97.13 to 97.38. No gender or age differences were found. Studies conducted at altitudes similar to Armenia's, such as the study conducted by Ortega et al[8] in the city of Medellin, suggested that the reference values for healthy adults aged 20 to 45 were as follows: pH 7.42, PaO_2 80.82 mm Hg, $PaCO_2$ 31.68 mm Hg, and HCO_3^- 20.37 mEq/L.

Over the course of the review, several studies conducted in Bogotá, Colombia, located at an altitude of 2.640-m above sea level and with a bp of 560 mm Hg, have established the normal values for various age groups, indicating average normal pH values between 7.36 and 7.47; $PaCO_2$ values between 29 and 35, PaO_2 values of 60 to 69, and SaO_2 values of 90 to 93.8.[20–22]

At a higher altitude, in Huancayo (Peru), located at 3249-m above sea level, and in Cusco at 3350-m above sea level, the bps were 535 and 530 mm Hg, respectively. The following average normal values are available: pH 7.4 to 7.5, $PaCO_2$ between 23.0 and 35.3, PaO_2 of 59.5 to 72.9, and SaO_2 91.7% to 96.1%[18]; furthermore, the Cusco study also found a 0.122 drop in PaO_2 and a 0.05% decline in SO_2 per each year of life.[23]

When comparing our findings against studies conducted in Bogotá and Peru,[24,25] differences in PaO_2 between 18 and 26 mm Hg less than Armenia were identified; the PCO_2 is between 2.0 and 2.7-mm Hg higher in our city, and SaO_2% is between 3.6% and 6.2% higher also. Likewise, the comparison against the study conducted in Medellin[8] at an altitude of 1538-m above sea level, showed very similar results, although in Armenia, the PaO_2 and HCO_3^- values were somewhat higher.

The oxygenation index (PaO_2/FIO_2) in the study population showed values in the normal range; this indicator is still important as a diagnostic and severity staging criterion in the acute respiratory distress syndrome, and is a marker for evolution and survival.[26]

In conclusion, this study provided arterial blood gases values at 1600-m above sea level—the geographic location of Armenia. These measurements can be used as a reference for the young, healthy population, with no risk factors for pulmonary disease, and free of any lung pathology. As described in the physiology, the results are significantly different from those reported at sea level and at higher altitudes. The results from this study represent a fundamental tool for the diagnosis, staging, and management of patients with acute or chronic pulmonary disease.

Ethical responsibilities

Protection of persons and animals. the authors declare that no experiments in humans or in animals were conducted for this research.

Confidentiality of information. the authors declare that they have followed the protocols established by their institution on the disclosure of patient information.

Right to privacy and informed consent. the authors declare that this article contains no patient data.

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Conflicts of interest

The authors have no conflicts of interest to disclose.

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