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Adaptation process in newborns at 2,850 and 2,200 meters in the first two hours of life: A multicenter observational study.

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Abstract

Introduction: The transition from intrauterine life confronts the newborn with factors that test their ability to adapt. Quito is located at 2850 masl, with low barometric pressure and a consequent reduction in the partial pressure of oxygen, causing a more extended adaptation period. The objective of this study was to compare the adaptive process of the newborn at 2,850 meters (Metropolitan Hospital) and 2,200 meters (Hospital de los Valles) in the first two hours of life.

Methods: This was an observational, analytical, cross-sectional study with data from 591 patients. The quantitative variables were expressed with dispersion statistics, the qualitative ones with frequencies, and the correlation with Chi ^{2} and OR, with a P value <0.05 for statistical significance (95% CI). Logistic regression was calculated to establish a relationship between variables.

Results: Vital signs showed differences according to height (2850 vs. 2220 masl), heart rate (146 vs. 144 bpm), respiratory rate (54 vs. 56 rpm), and SatO2 (89 vs. 90%). A total of 85.6% of newborns at 2850 masl required oxygen; 79.8% required oxygen for more than two hours, P < 0.05 (OR 4.7, 95% CI 1.333-16.770). A total of 52.6% were male, and 56.9% were born at early term with Apgar scores of 8 at 1 minute (80%) and nine at 5 minutes (94.8%).

Conclusions: The adaptation process to extrauterine life is longer in newborns at higher altitudes, with differences in vital signs and a more significant requirement for oxygen administration.

Keywords: **MeSH**: Asphyxia neonatorum; altitude; parturition; infant, newborn; oxygen saturation.

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Introduction

Birth is the process that allows the fetus to transition from intrauterine life to an independent life, facing a series of physiological events that test the elements that will enable it to adapt healthily. Quito is located at an altitude of 2,850 meters above sea level (masl); at this height, there is lower barometric pressure, and therefore, a reduction in the partial pressure of inspired oxygen is also registered, which will cause a more extended adaptation period [1].

In term pregnancy, adaptation to extrauterine life proceeds effectively. However, this adaptation is usually complex and needs to be evaluated, especially regarding four essential elements: breathing, circulation, and thermoregulation, among others. The circulatory changes after birth depend absolutely on the respiratory process; with lung expansion, the opening of the pulmonary vascular bed occurs, leading to a drop in pulmonary resistance, producing an increase in systemic pressure and a marked elevation of O2 in arterial blood [2].

Depending on the environment, newborns register physiological characteristics, especially at low and high altitudes. In this sense, these differences are relevant in Ecuador since the most important cities are above 2,500 meters, where high frequencies of disorders such as polycythemia, respiratory acidosis, and hypoxemia are observed among newborns. High-altitude settings intensify physiologic changes in hematologic and arterial blood gas parameters [3].

The transition process from intrauterine life to extrauterine life can develop without significant or any difficulty in 90% of newborns, and they may present little or no need for respiratory assistance to regulate their adaptation. Therefore, 9% of newborns require some help, and 1% require advanced resuscitation [4].

The present work was carried out to compare the newborn's adaptive process in two hospitals at different levels of altitude, considering 2,850 meters and 2,200 meters in height, evaluating vital signs in the first two hours of life, for which they established the characteristics of a group of newborns admitted to the Hospital Metropolitano and Hospital de los Valles located in the city of Quito from April 2021 to March 2022.

Materials and methods

Type of Study

The present study is observational and analytical, with cross-sectional observation.

Scenery

This study was conducted at the Hospital Metropolitano (private hospital) located 2,850 meters above sea level in the Belisario Quevedo parish, Av. Mariana de Jesús s/n, Quito. The Hospital de los Valles (private hospital) is located at 2,200 meters above sea level in the parish of Cumbayá, Av. Interoceánica km 12.5 and Av. Florencia 1 2 y, Quito -Ecuador. The study period was from April 1, 2021, to March 31, 2022.

Universe and sample

The Universe comprised all the patients admitted to the Neonatology Unit of the participating institutions during the study period. Within each hospital's statistics, 657 annual births were mentioned in the Metropolitan Hospital and 241 in the Hospital de los Valles. The two populations were added to obtain a single universe with a total of 898 newborns, with which the sample calculation was performed.

Sample: To calculate the model, the formula corresponding to a finite population was used, which is described below:

N = Population size.

= Population standard deviation 0.5 (constant)

Z = 95% confidence level =1.96 e = Sampling error 0.05

n=N2Z2e2N-1+2Z2

n=898·0.521.9620.052898-1+0.521.962

n = 269.4

Total calculated sample size: 270 patients.

To ensure a sufficient number of samples, it was decided to add a 15% loss in each of the groups.

Therefore, the final sample size calculated for each group was 156 patients, with a total sample of 312 patients for the study. However, more patients were obtained due to convenience sampling, entering all those who met the established inclusion criteria and obtaining a final sample of 591 patients.

Inclusion criteria

- Term newborn (TNB) (37 – 41 weeks and six days) determined by the Capurro scale.
- Newborn at term by delivery or cesarean section without complications.
- Birth APGAR between 7-10 points at 1 minute and 5 minutes after birth.
- Normal physical examination and adequate weight for gestational age.
- No acute fetal distress.
- No congenital malformations established at birth.
- No neuromuscular problems that alter ventilatory mechanics.
- Mothers who live in the study city for at least six months and who are healthy.
- Normal temperature at birth (36.5 - 37.5)

Exclusion criteria:

- Newborn with congenital anomalies (congenital heart disease) or anatomical malformations of the rib cage.
- Newborn mothers with previous obstetric pathology, such as pregnancy toxemia, diabetes, anemia, placental insufficiency, and third-trimester hemorrhages.
- Multiple pregnancy.
- Newborns under 37 weeks and over 42 weeks of gestation.
- APGAR less than 7 points per minute.
- Temperature less than 36.5°C.
- Mothers coming from another city whose height above sea level is lower than the one studied.

Information collection procedure

Once the research was accepted in each hospital and with the approval of the Ethics Committee for Research in Human Beings of the Pontificia Universidad Católica del Ecuador, the information was registered in the GEMA computer system of each hospital.

Anonymized data were obtained from the clinical history of newborns (form 016-2010 Immediate Newborn Care - MSP and nursing vital signs) (Annex 1, 2, 3) who met the inclusion criteria. These data were recorded in a data collection base (EXCEL Sheet), and the anonymized information was organized according to a unique code assigned to each neonate.

Variables

The following study variables were recorded:

1. Vital signs (heart rate, respiratory rate, oxygen saturation) (dependent).
2. Height of place of birth (independent).
3. Oxygen therapy requirement (conditional).
4. Apgar (intervening).
5. Gestational age (moderating).
6. Sex (confusing).
7. Type of delivery (confusing)

Results analysis plan

Using a database in Excel version 2010, the information obtained from the data collection sheet was refined and later exported to the SPSS V25 program for the respective statistical analysis (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

To determine the normality of the data, the Kolmogorov–Smirnov test was used, and quantitative variables such as the altitude of the place of birth, the adaptation of the newborn (based on vital signs, heart rate, respiratory rate, saturation), and oxygen therapy requirement were assessed. They were expressed as the mean and standard deviation. Qualitative variables such as sex and type of delivery were reported in percentages depending on the normality of the data.

For inferential statistics, in qualitative variables, such as the characteristics of the adaptive oxygen process in newborns, Chi-square was used. For quantitative variables (altitude difference), Student's t test for

two independent groups (parametric) or the Mann–Whitney-Whitney U test (nonparametric) was used. To determine statistical significance, a 95% CI and a *P* <0.05 were considered. A multivariate logistic regression analysis was performed to estimate the effects of the confounding variables, such as sex and type of delivery.

Procedure to guarantee Ethical Aspects

Once the purpose of the research was disclosed and with prior authorization, the information collected was used solely for the analysis and development of the study. The clinical histories were obtained confidentially and not disclosed to people outside this project.

Biases

The principal investigator kept the data with a guide and records approved in the research protocol to avoid possible interviewer, information, and memory biases. Observation and selection bias was avoided by applying the participant selection criteria. All the clinical and paraclinical variables of the previous period were recorded. Two researchers independently analyzed each record in duplicate, and the variables were recorded in the database once their concordance was verified.

Results

Participants

A total of 591 patients were entered into the study. A total of 418 newborns at 2850 masl (Group 1), 173 to 2220 masl (Group 2)

General characteristics of the population

The gestational age registered a mean of 38.5 (SD ± 0.876) weeks, with a minimum of 37 and a maximum of 41.1. The highest frequency was observed in the early-term group, with 56.9% (n= 336) of patients and 52.6% (n= 311) of males.

In the first minute, the Apgar recorded a mean of 7.95 (SD ± 0.456) points, with a minimum value of 7 and a maximum of 9. The highest frequency was 8 points in 80% (n= 473) of the cases. At minute 5, the Apgar recorded a mean of 9.01 (SD ± 0.26) points, with a minimum value of 7 and a maximum value of 10. A total of 25.8% (n= 153) of the patients who required oxygen administration, of whom those who required 1 to 3 liters, were the most frequent with 47.1% (n= 72) and in a time greater than two hours with 61.4% (n= 94) of patients (Table 1).

The recording of vital signs broken down by height showed that the heart rate was higher than 2850 masl in 30 minutes, 1 hour, and 2 hours, with a mean of 146.05 (SD ± 13.15), 141.2 (SD ± 13.39) and 137.78 (SD ± 11.96), respectively.

Table 1. Characteristics of Sociodemographic and clinical patients participants of the study

Characteristics	Frequency	(%)
Age gestational		
37-38.6 SG	336	56.9
39-40.6 SG	253	42.8
41-41.6 SG	2	0.3
Sex		
Women	280	47.4
Man	311	52.6
Apgar 1 minute		
7	72	12.1
8	473	80.0
9	46	7.8
Apgar 5 minutes		
7	3	0.5
8	7	1.2
9	560	94.8
10	21	3.6
Request of oxygen		
Yeah	153	25.8
No	438	74.1
Amount of oxygen		
Less of 1 liter	43	28.1
1-3 liters	72	47.1
Further of 4 liters	38	24.8
Duration of the administration ofoxygen		
< 2 hours	59	38.6
> 2 hours	94	61.4

In all cases, the decrease in the recorded figures was progressive from the first measurement up to two hours. Regarding respiratory frequency, at 30 minutes, it was higher than 2,200 masl with an average of 56.32 rpm (SD ± 5,447); in the first hour, it was 54.62 (SD ± 4,322); and at two hours, it was slightly higher than 2,220 masl with 53.57 (SD ± 3.973). Oxygen saturation was consistently higher in newborns at 2,220 masl, registering 90.08% (SD ± 8,966) at 30 minutes, 93.6% (SD ± 2,676) at one hour, and 93.4% (SD ± 2,104) at two hours of life. (Table 2).

It was found that newborns at 2,850 masl registered an average oxygen use of 9.58 hours, a figure more significant than that required by newborns at 2,220 masl registered in 4.09 hours (Table 2).

Table 2. Heart rate and saturation of study participants.

Variables		G1 (2850 masl) No.=418	G2 (2220 masl) No.=173
Heart rate (Bpm)	30 min	146 ± 13	144 ± 18
	60 min	141 ± 13	140 ± 17
	120 min	138 ± 12	136 ± 14
SatO2 (%)	30 min	89.2 ± 6.4	90.1 ± 9.0
	60 min	92.8 ± 2.5	93.6 ± 2.7
	120 min	93.3 ± 2.2	93.4 ± 2.1
Oxygen	Hours of use	9.58 ± 18.7	4.09 ± 6.02

Bpm: beats per minute

Bivariate analysis

Patients born at 2850 masl required oxygen in 85.6% (n= 131) of cases, while 14.4% (n= 22) of patients were administered oxygen to those taken at 2220 masl. A statistically significant association was found between these variables with a *P value* < 0.05 (OR 3.133 95% CI 1.914-5.128) (Table 3).

Table 3. Association between oxygen requirement and height at birth.

Range of height	Request of oxygen					
	Yeah No. =153 (%)	No No.=438 (%)	Chi ^{2}	*P*	OR	CI 95%
G1 (2850 masl)	131 (85.6%)	287 (65.5%)	22.1	<0.001	3.133	1914-5128
G2 (2220 masl)	22 (14.4%)	151 (34.5%)				

Table 4. Association between time of oxygen requirement and height at birth.

Range of height	Request of Oxygen					
	Less than 2 hours No.=59 (%)	more than 2 hours, No.=94 (%)	Chi ^{2}	P	OR	CI 95%
G1 (2850 masl)	56 (94.9%)	75 (79.8%)	6,738	0.009	4.729	1.333-16.770
G2 (2220 masl)	3 (5.1%)	19 (20.2%)				

Of the total sample of patients, 153 required oxygen; 94 were administered for more than 2 hours. In this group, 79.8% (n= 75) of the patients were born at 2850 masl), while those born at 2220 masl were administered to 20.2% (n= 19) of patients during this time. A statistically significant association was found between these variables with a *P value* < 0.05 (OR 4.729 95% CI 1.333-16.77) (Table 4).

According to the Wald statistic (Table 5), the variables that made the most significant contribution to the oxygen requirement use prediction model were Apgar at 1 and 5 minutes, heart rate and respiratory rate at 30 minutes, respiratory rate at 2 hours, oxygen saturation at 30 minutes, gestational age and height of 2850 masl. Of these variables and based on the results of the p-value, only the oxygen saturation at 30 minutes and the altitude of 2850 masl allow us to predict the

oxygen requirement during adaptation to extrauterine life; that is, no relationship was observed between the sex of the newborn and the type of delivery with oxygen saturation.

Table 5. Model of regression Logistics with the variables in the equation.

	B.	Mistake stand-ard	Wald	gl	Next. (p)	Exp (B)
Childbirth (1)	0.464	0.467	0.985	1	0.321	1.590
Sex (1)	0.017	0.315	0.003	1	0.957	1.017
Apgar 1 min	-1.078	0.802	1.806	1	0.179	0.340
Apgar 5 min			2.359	3	0.501	
CF 30 min	-0.013	0.012	1.088	1	0.297	0.987
CF 1 hour	0.000	0.013	0.000	1	0.990	1.000
CF 2 hours	0.004	0.014	0.087	1	0.769	1.004
FR 30 min	-0.054	0.037	2.160	1	0.142	0.947
FR 1 hour	0.047	0.047	0.995	1	0.318	1.048
FR 2 hours	-0.093	0.051	3.266	1	0.071	0.912
SatO2 30 min	0.443	0.041	118.141	1	<0.001	1.558
SatO2 1 hour	-0.062	0.063	0.955	1	0.328	0.940
SatO2 2 hours	-0.006	0.074	0.006	1	0.940	0.994
G.E. range			4.934	2	0.085	
Height (1)	-2.335	0.499	21.901	1	<0.001	0.097
Constant	-6.269	27134.288	0,000	1	1.000	0.002

Discussion

The adaptive process of 591 newborns in their first two hours of life was compared, of which 70.1% were admitted at the Metropolitan Hospital at 2,850 meters above sea level and 29.3% at the Hospital de los Valles located at 2,200 meters in the city of Quito during the study period.

In the total sample, the vital signs presented a series of variations according to the time in which they were quantified, beginning the recording of the measurements from the first 30 minutes after birth, then in the first hour and second hour, according to research by authors such as [5, 6], who affirm that the adaptive processes from intrauterine to extrauterine life occur in the minutes following delivery and are considered vitally important for survival. In addition, per [6], it is vital to understand how the process of this transition develops, as well as the changes involved in it, since this analysis facilitates the recognition of minor differences that appear that directly influence the final result. of birth.

Information was collected about vital signs such as heart rate, respiratory rate, and oxygen saturation, established as the central immediate adaptations to which the newborn is exposed, considering that a lower partial pressure of oxygen in high areas negatively influences this adaptation period, according to [7], [6] and [8].

Regarding heart rate, in this study, the highest mean was recorded in the first half hour with 145.24 bpm, the respiratory rate was higher in the first 30 minutes with a standard of 54.4 rpm, and regarding

oxygen saturation, higher figures were recorded at two hours of life with an average of 93.4%. This aspect agrees with what was reported in previous papers [9, 10], which state that the main changes in the birth transition include increased cardiac output and increased oxygenation.

The analysis of the vital signs related to the height allowed shows that the heart rate was higher than 2850 masl in the 30 minutes, 1 hour, and 2 hours with an average of 146.05, 141.2, and 137.78 bpm, respectively. In all cases, the decrease in the registered figures was progressive from the first measurement to two hours. In this sense, [11] and authors such as [8] affirm that the neonatal heart rate of 100 bpm can be considered the threshold for a successful immediate neonatal transition to extrauterine life and serves as a guide for neonatal resuscitation. Furthermore, according to [9] and [12], a healthy newborn can take several minutes to reach values above 100 bpm.

The patients in this study presented a higher respiratory rate in the first 30 minutes of life among those born at 2200 masl, with an average of 56.32 rpm, which later decreased to 54.62 and 53.57 rpm in the following measurements at the first and second hours, respectively. In these periods, the respiratory rate measurements remained lower among those born at 2850 masl, with 53.6, 53.7 and 53.6 rpm, respectively. According to [14], the first period of reactivity lasts longer in newborns at higher altitudes, which will be expressed in irregular breathing related to the development of hypoxia due to height. According to these organisms, the transition period will significantly differ according to birth height. However, in our study, it was possible to show that the respiratory rate had minimal variation between the two study groups.

The record of oxygen saturation was higher in all newborns at 2220 masl, with descriptions of 90.08%, 93.6%, and 93.4%, progressively according to the measurement time (30 minutes, 1 hour, and 2 hours), while at 2850 masl, the measurements were 89.19%, 92.81%, and 93.33%, all below the newborns at a lower altitude. This aspect is mentioned by [3], who states that at higher altitudes, newborns are more likely to present hypoxemia; in addition, high-altitude settings intensify physiological changes in hematological and arterial blood gas parameters; therefore, it is common to expect that this saturation registers lower figures compared to those born closer to sea level.

Previous studies have described that the higher the altitude is, the lower the partial pressure of oxygen [7], which is reflected in a decrease in saturation. Regarding measured oxygen saturation values above 90%, they are more likely to have a successful extrauterine adaptation [6, 9]. It has been described that the newborn takes between 8 and 10 minutes to achieve a stable saturation of over 90%. % [10].

In this study, the need for oxygen was evaluated according to the height of the place of birth during the first two hours of the newborn's life; in this regard, a significant association was evidenced between the requirements of the administration to the patients born at 2850 masl (85.6%) compared with those born at 2220 masl (14.4%). These results agree with a previous report [1], which assures that the city of Quito, located at 2850 masl, presents a low barometric pressure, which generates a reduction in the partial pressure of inspired oxygen, which will cause a longer period of adaptation in the newborn. In this regard, in a previous study [14], neonatal resuscitation in newborns at 2,240 meters using room air was a safe procedure, demonstrating the unnecessaryness of resuscitation by administering oxygen.

A significant association was evidenced between the time of oxygen administration and the height of the place of birth; specifically, a group of 153 patients required oxygen administration, and among these, those admitted to institutions at 2850 masl registered an average use of oxygen of 9.58 hours. Among these, 75 patients received oxygen for more than two hours, a figure higher than that reported by newborns at 2220 masl with an average of 4.09 hours, of which 19 patients received it for more than two hours. These results agree

with the indications of [4], who reported that in 90% of births, the transition from intrauterine to extrauterine life can develop without any difficulty; however, a minority group of patients, at least 9%, will need some respiratory assistance to regulate their adaptation.

A total of 61.4% of the newborns in this study who required oxygen received it for more than two hours and 24.8% at a rate of more than 4 liters per minute. In this regard, according to what was reported in previous studies [15, 16], hyperoxia is a risk factor for developing oxidative stress, which in turn can generate an inflammatory response at the alveolar level with the consequence of long-term lung damage. In this sense, one article [17] warns about reducing unnecessary use of oxygen due to its adverse effects and the impact on public health spending.

Regarding the issue of oxygen requirement by this group of newborns, [5] states that oxygen supplementation is related to a failed or incomplete transition of the newborn from intrauterine to extrauterine life.

According to the calculated logistic regression, no relationship was observed between the sex of the newborn and the type of delivery with oxygen saturation, results that agree with the findings of Bancalari et al. [18], who report that no differences were found in their research statistically relevant between sex and type of delivery concerning oxygen saturation or heart rate.

In the first minute, the Apgar recorded an average of 7.95 points, with a minimum value of 7, and at minute 5, the Apgar recorded an average of 9.01 points, with a minimum value of 7. According to [19], these values can be estimated as measuring. In contrast, a score of 4 to 6 can be considered moderately abnormal, and 0 to 3 is low for both term and late preterm infants. Therefore, all infants in this study fell within the normal range and without a risk of mortality, according to [20].

References

Conclusions

Regarding the proposed hypothesis, it is confirmed that the adaptive process of newborns at 2,850 meters is longer than that of newborns at 2,200 meters in the first two hours of life, with differences in vital signs and oxygen administration requirements.

Abbreviations

SG: Weeks of gestation.

Supplementary information

No supplementary materials are declared.

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Author contributions

Janina Tatiana Ullauri Betancourt: Conceptualization, data curation, formal analysis, fundraising, research, writing - original draft.
Jenny Paola Zurita Guerra: Methodology, project administration, resources, software, supervision, validation, visualization, writing – review, and edition.
Huáscar Gabriel Contreras Pierola: Methodology, project administration, resources, software, supervision, validation, visualization.
All the authors have read and approved the final version of the manuscript.

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Availability of data and materials

Data collected from medical files are not publicly available due to patient confidentiality but are available through the corresponding author under clearly justified academic requests.

Statements

Ethics committee approval and consent to participate

This study was approved by the Ethics Committee for Research in Human Beings of the Pontificia Universidad Católica del Ecuador and the directives of each participating hospital. The tutors of the participants signed the consent to participate.

Publication Consent

Not required when patient-specific images, radiographs, and studies are not published.

Conflicts of interest

The authors declare they have no conflicts of interest.

Author Information

Not declared.

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