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Spatial Analysis of Birth Defects in Ecuador

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Abstract

Objectives: This study aimed to assess the geographical distribution of birth defects in Ecuador.

Materials and Methods: This study employed spatial analysis techniques using the records of birth defects from the Ecuadorian Public Health Ministry from January 2015 to December 2019. Morbidity rates, per 1000 newborns, were calculated by birth defect detected and the province of birth, and then the map of its distribution was depicted. The spatial distribution was assessed in each province and canton.

Results: 29 276 confirmed cases born between 2015 and 2019 were registered. The distribution of every disease tends to be different in every canton and birth defect type in Ecuador. The relative rates show a higher incidence in some eastern and highland cantons.

Conclusions: We found a different distribution and rate of birth defects in Ecuador. The higher incidence of birth defects in some cantons should be investigated in future studies, as should environmental factors, consanguineous rates, and genetic polymorphism distribution.

Keywords: Spatial analysis, Birth defects, Ecuador

Introduction

Birth defects refer to a set of alterations of prenatal origin (1) that can be detected during pregnancy, in the neonatal stage, childhood, adolescence, and even in adults (2). To date, over 7000 different birth defects have been identified (3).

They comprise a broad spectrum of disorders and are estimated to affect 3% of all pregnancies globally (4). It is estimated that causes 9% of neonatal deaths around the world. In Latin America, neonatal mortality from this cause reaches 21% (5). There is no precise data about congenital anomalies in Ecuador, because of the lack of active surveillance programs (6). However, it is estimated that the prevalence is approximately 2.9% (7). In 2018, the "Instituto Nacional de Estadísticas y Censos" the Ecuadorian institution in charge of statistics and population data, described birth defects as the second and fourth causes of infant mortality (8).

The risk of birth defects developing, as described in the literature, is related to genetic and environmental factors. However, in most cases, the cause is unknown. Currently, research efforts focus on birth defect causes with the goal of using this information to prevent these conditions in the population (9).

Congenital anomalies can be isolated or multiple, depending on whether they affect one system or several organs. The ICD 10 describes the structural congenital malformations in Chapter XVII (Q00–Q99): "Congenital malformations, deformations, and chromosomal abnormalities." Within each group, there is a sub-classification depending on the clinical presentation (10).

Epidemiological data concerning congenital anomalies that describes the behavior of congenital defects in the population exist in short supply in Ecuador, which denotes an urgent need to study these disorders. It is necessary to know the distribution, and the factors related to birth defects presentation, the types, and the distribution in the country.

Materials and Methods

Study Area and Population

An ecological study was conducted that used distribution and spatial analysis. This study was performed in Ecuador, a country on the west coast of the northern South American continent. Ecuador is divided into four climate zones: the Pacific Coast Line (the coast), the Highlands (the Andes mountains), Amazonia (the eastern region), and the Galapagos Islands. These four regions are divided into 24 provinces and 221 cantons (11).

Data Collection

Data were collected from the registries of public hospitals' admissions between January 2012 and December 2019. The population characteristics, demographic distribution by provinces, and geographic files were got from the "Instituto Nacional de Estadísticas y Censos" website. This institution is the governing body of national statistics, and it generates official statistics for Ecuador.

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Data Analysis

We divided the total number of newborns per 1000 in each province by the cumulative incidence of birth defects attended in Ecuadorian Public Health Ministry hospitals during the study. The spatial analysis units used to prepare thematic maps were provinces and cantons. We performed a spatial distribution of the birth defects and a spatial distribution. Spatial analysis and modeling were performed using geographic information system tools.

Results

This study found 29 276 congenital anomalies treated in hospitals under the Ministry of Public Health from 2015 to 2019. During this time, 1 406 833 births were reported nationwide. The cumulative incidence during the study years is 20.89 × 1000 live births.

Incidence of congenital anomalies in Ecuador throughout the years of study is above 20 per 1000 live births during all the years studied except for the year 2016, when it falls to 16.3 × 1000 live births. Since 2017, the birth defects rate rises continuously to the higher incidence rate of 23.45 × 1000 live births (Figure 1).

There were more cases of the male gender with 55.40%, compared to 44.60% of the female gender (male/female ratio = 1.24). Isolated malformations comprise most of the cases (87.33%) (Table 1).

Malformations of the heart and circulatory system are the most common congenital anomalies, with 20.49% of the total. In female persons, cardiac malformations are the most common anomalies, with 23.13% of cases. However, in males, musculoskeletal system malformations were the leading type, with 21.21% of the total (Table 2).

Higher cumulative incidence of congenital anomalies is found in the central and northern regions of the highlands, the central region of the eastern, and the insular region. Canton distribution is similar, with the highest rates in the same areas (Figure 2).

We can observe that the provinces of Pastaza, Galapagos, Carchi, and Napo present the highest cumulative incidence of malformations. The highest incidence is in Pastaza, with 54.29 × 1000 live births. The province of Orellana is the one with the lowest incidence of 11.93 × 1000 live births. This information differs from that observed by cantons. Here appeared clusters that do not appear on the map of the provinces. Baños de Agua Santa, a canton in the province of Tungurahua, is the canton with the highest incidence in the country (71.57 per 1000 live births). Other cantons like San Cristobal in Galapagos province, Guachapala in Azuay province, Mera in Pastaza Province, and Quijos in Napo Province, presented a cumulative incidence greater than 60 per 1000 live births. This map also highlights Rocafuerte, a canton in the Manabí Province, with the highest incidence of congenital anomalies on the country's coast.

The lowest incidence of malformations was found in the province of Francisco de Orellana, in eastern Ecuador. However, it is surrounded by areas with a high incidence of congenital anomalies. If we observe the distribution of incidents in this province by cantons, three of the four cantons that make up the Province of Orellana have a very low incidence. Oña, in the province of Azuay, is the only one that did not report congenital anomalies in hospitals of the Ministry of Public Health during the period studied. General Antonio Elizalde and Marcelino Maridueña, in the province of Guayas, and Mocache in Los Ríos Province, presented an incidence rate of less than 5 × 1000 live births.

The highest incidences of congenital malformations of the nervous system (ICD-10: Q00-Q07) were in some cantons in the south of the Ecuadorian highlands and

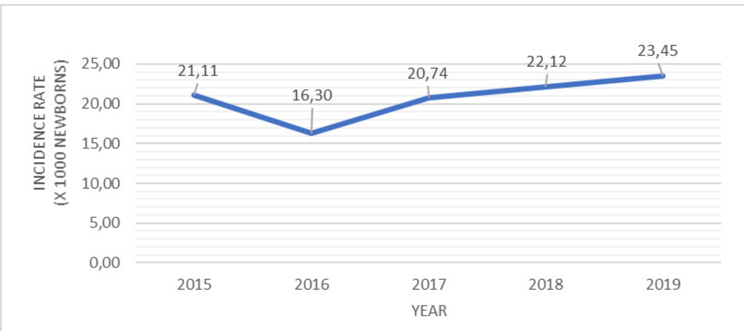


Figure 1. The Annual Incidence of Birth Defects in Ecuador from 2015 to 2019

Table 1. Birth defects in Ecuador From 2015 to 2019 According to Type and Gender

Birth Defect Type	Gender				Total	%
	Female	%	Male	%		
Isolated birth defects	11 287	86.44	14 281	88.06	25 568	87.33
Multiple birth defects	1771	13.56	1937	11.94	3708	12.67
Total	13 058	100	16 218	100	29 276	100

Table 2. Birth Defects in Ecuador From 2015 to 2019 According to Type and Gender

ICD 10 Clasification	Gender				Total	%
	Female	%	Male	%		
Congenital malformations of the nervous system (Q00-Q07)	1757	13.46	1817	11.20	3574	12.21
Congenital malformations of the eye, ear, face, and neck (Q10-Q18)	1276	9.77	1574	9.71	2850	9.73
Congenital malformations of the circulatory system (Q20-Q28)	3020	23.13	2980	18.37	6000	20.49
Congenital malformations of the respiratory system (Q30-34)	248	1.90	360	2.22	608	2.08
Cleft lip and cleft palate (Q35-Q37)	730	5.59	986	6.08	1716	5.86
Other congenital malformations of the digestive system (Q38-Q45)	1057	8.09	1808	11.15	2865	9.79
Congenital malformations of genital organs (Q50-Q56)	327	2.50	478	2.95	805	2.75
Congenital malformations of the urinary system (Q60-Q64)	463	3.55	838	5.17	1301	4.44
Congenital malformations of the musculoskeletal system (Q65-Q79)	2409	18.45	3440	21.21	5849	19.98
Other congenital malformations (Q80-Q89)	616	4.72	747	4.61	1363	4.66
Chromosomal abnormalities, not elsewhere classified (Q90-Q99)	1155	8.85	1190	7.34	2345	8.01
Total	**13 058**	**100**	**16 218**	**100**	**29 276**	**100**

the central region of Amazonia. Call the attention that the higher rates were found in the cantons of Sevilla de Oro, San Fernando, and Giron. These provinces belong to Azuay province (Figure 3).

With congenital malformations of the eye, ear, face, and neck (ICD-10: Q10-Q18), the highest incidences were found in Guachapala in Azuay, Pastaza in the same name province, and Rocafuerte in Manabi. Along with clusters in the highlands and the eastern central region, and the northern region of Amazonia.

Congenital malformations of the circulatory system (ICD-10: Q20-Q28) were found in Mejia (Pichincha), Mera (Pastaza), and Quijos (Napo). Clusters were seen in the north-central region of the eastern and the highlands of the country.

Congenital malformations of the respiratory system

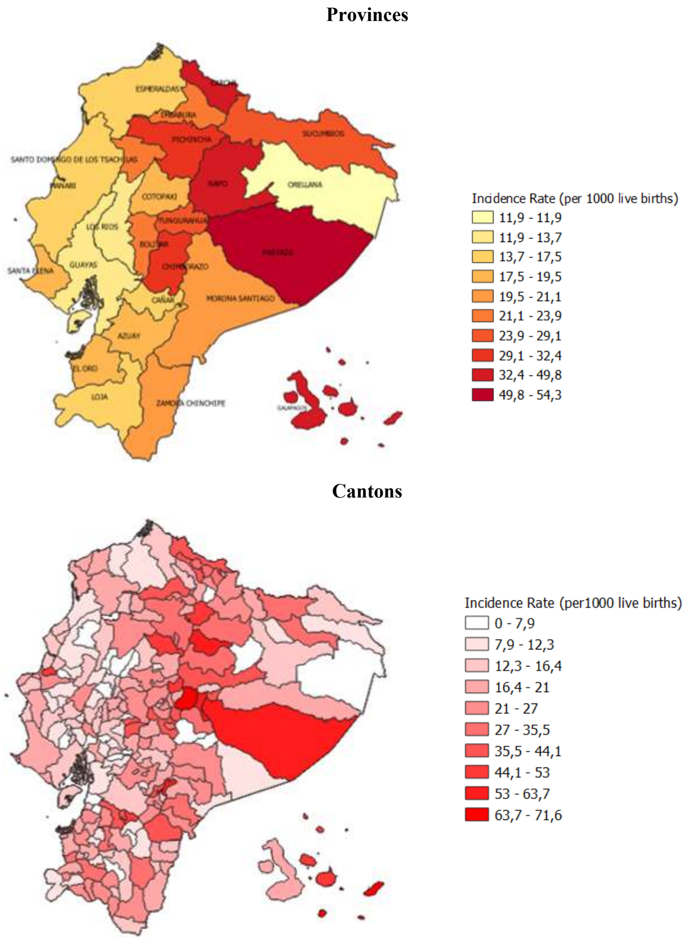
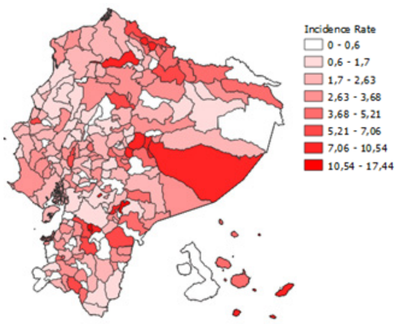
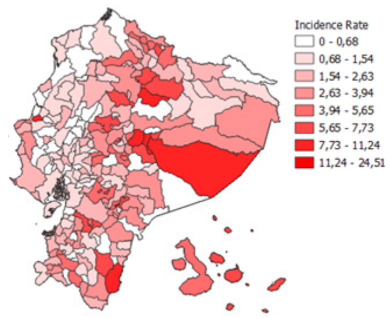


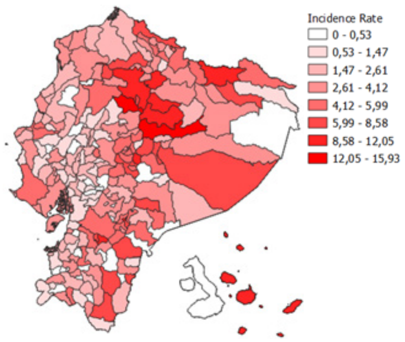
Figure 2. Birth Defects Cumulative Incidence by Provinces and Cantons in Ecuador From 2015 to 2019.



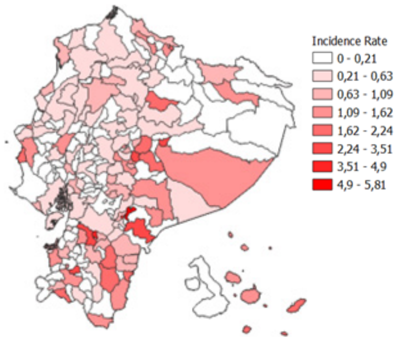
Congenital malformations of the nervous system



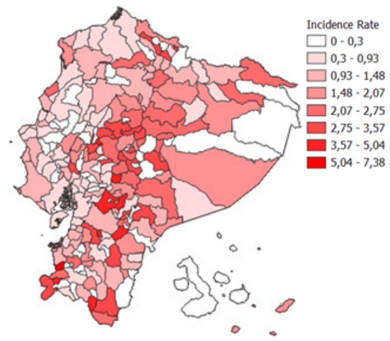
Congenital malformations of the eye, ear, face, and neck



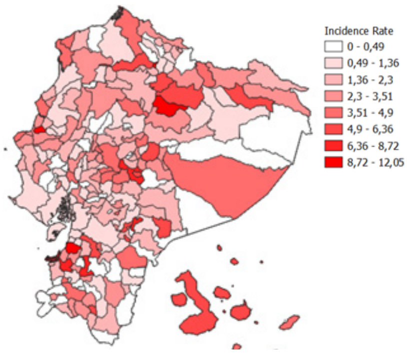
Congenital malformations of the circulatory system



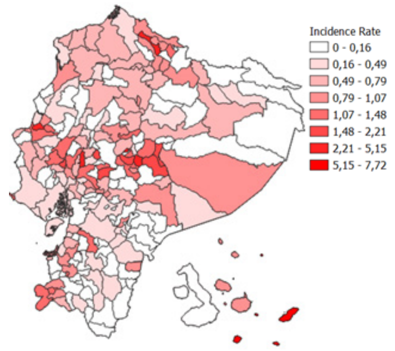
Congenital malformations of the respiratory system



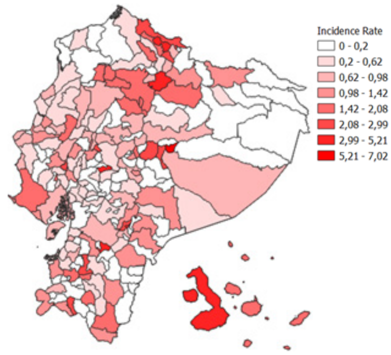
Cleft lip and cleft palate



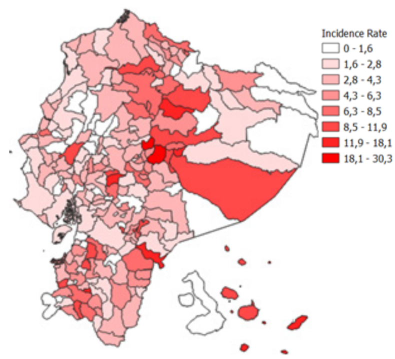
Other congenital malformations of the digestive system



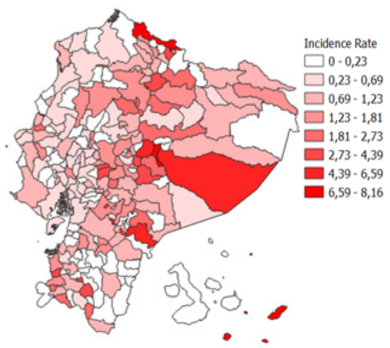
Congenital malformations of genital organs



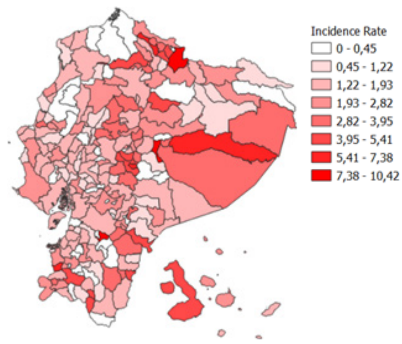
Congenital malformations of the urinary system



Congenital malformations of the musculoskeletal system



Other congenital malformations



Chromosomal abnormalities, not elsewhere classified

Figure 3. Birth Defects Cumulative Incidence by Provinces and Cantons by type disorder, 2015–2019

(ICD-10: Q30-Q34) presented spatial collections in cantons of the south and the central part of the eastern region. Here we can observe that Sevilla de Oro, Guachapala, and San Fernando, three cantons of the Azuay Province, presented the higher rates of the country.

Cleft lip and cleft palate (ICD-10: Q35-Q37) clusters were found in the highland region. In particular, in the southern towns of the country. The three cantons with the highest incidences were Las Lajas (El Oro), Pindal (Loja), and Pallatanga (Chimborazo). Other congenital malformations of the digestive system (ICD-10: Q38-Q45) presented higher rates groups in the eastern, north, and south coast and the centric region of the highlands. Quijos (Napo), Rocafuerte (Manabí), and Guabo (El Oro) were the three cantons with higher rates.

San Cristobal (Galapagos), Rocafuerte (Manabí), and Mira (Carchi) were the cantons with the higher rates of congenital malformations of genital organs (ICD-10: Q50-Q56). In this type of malformation, we observe a different distribution with clusters in the highland central region and the coast of the country. The highest incidence of congenital malformations of the urinary system (ICD-10: Q60-Q64) defines spatial groups in the northern and central regions of the highlands and the Galapagos Islands. Santa Clara in Pastaza, Isabella in Galapagos, and Guachapala in Azuay presented higher incidences.

Baños de Agua Santa and Pillaro in Tungurahua and Quijos in Napo described the higher incidences of congenital malformations of the musculoskeletal system (ICD-10: Q65-Q79). Spatial collections were found in the eastern central region and the north of the highlands.

Other congenital malformations (ICD-10: Q80-Q89), have higher incidences in Mera (Pastaza) Tulcan (Carchi), and San Cristobal (Galapagos). Spatial clusters were observed in the highlands and the eastern region, and several Galapagos islands.

Chromosomal abnormalities, not elsewhere classified (ICD-10: Q90-Q99), in this group, the highest incidences were found in the highlands and eastern center. Besides, the northern and southern border of the highlands. Sucumbios in the same name province, Mera in Pastaza and Giron in Azuay, presented the higher incidences.

Discussion

The incidence of congenital anomalies described internationally is between 20 and 30 per 1000 live births (12). The cumulative incidence in this study is 20.89 × 1000 live births. However, it is much higher than that described in the 2011 publication made by the Latin America Collaborative Study (ECLAMC). This study described a prevalence of 1.4%, reported as the lowest in Latin America (13). This data is extremely important because the incidence of the study published in 2011 is very low and does not adequately highlight the real importance of congenital anomalies in Ecuador.

Lary and Paulozzi describe in 2001 the behavior of congenital malformations in different sexes; they report a higher frequency of the male gender with 59.17%, compared to the female gender with 40.83% (14). The present study also describes a higher number of cases in the male gender (55.40%), compared to the female gender (55.40%).

The incidence in the province of Pastaza is 54.29 × 1000 live births. This rate is significantly higher than the ECLAMC estimate of 27 1000 live births in Latin America (13). Although less marked, the provinces of Galapagos, Carchi, and Napo have a higher incidence. In the case of the cantons of Baños de Agua Santa (Tungurahua), San Cristóbal (Galapagos), Guachapala (Azuay), Mera (Pastaza), and Quijos (Napo), they present a cumulative incidence greater than 60 per 1000 live births.

A very low incidence compared to the country's average is the incidence in Orellana, 11.93 × 1000, similar is the case in the cantons like Oña in Azuay, General Antonio Elizalde, and Marcelino Maridueña in Guayas, whose incidence is very low compared to the average for the country and Latin America. In this case, we consider the scarce health records in this area as a possible cause.

In a study conducted in Mexico, in 2010, congenital malformations of the musculoskeletal system accounted for a higher percentage of cases (15), similar is the case in Ecuador in male patients. In our study, congenital malformations of the circulatory system were the leading type of birth defect in females and the second one in males. Similar data is described in Europe, where congenital malformations of the circulatory system are the leading birth defect type (16).

Wu et al reported a study in China where they used spatial analysis to examine the behavior of congenital anomalies in the population. The authors found that certain areas had a higher density of disorders compared to others (17). Our study found a varied density in different areas of the country.

Some important patterns are found in the malformations' distribution. Sometimes, like congenital malformations of the nervous system, malformations of the eye, ear, face, and neck, malformations of the musculoskeletal system, and other congenital malformations, clusters seem similar to the clusters of total distributions. Other types of malformations, such as those of the circulatory and respiratory systems, cleft lip and palate, digestive system, genital organs, urinary system, and distribution of chromosomal abnormalities, are distinct.

Congenital anomalies result from gene-environment interactions. Environmental causes are endogenous and exogenous and can be physical, chemical, or biological teratogens (18). The individual is most vulnerable to teratogens during organogenesis, which occurs between the third and eighth weeks of gestation (19).

Cluster detection is useful for localizing health research and presenting disease distribution trends. It helps to study environmental, genetic, or lifestyle differences in the etiology of the disease (20). Cuartas et al. propose that there are some reasons for the unequal distribution of congenital anomalies, among them social inequity and environmental variants (21).

Highland living is associated with a higher risk of birth defects like cleft lip, microtia, and malformations of the face and neck (22). Cardiac malformations had also been linked with hypoxia in the highland population (23). Our study described a higher incidence of cleft lip and cleft palate in cantons in the Highlands. Cardiac and circulatory defects occurred with a higher incidence in the cantons of the northern highlands and Amazonia. It could be related to facilities for health access in these populations.

An example of socioeconomic inequity is teenage pregnancy. Ecuador has a teenage pregnancy rate of 76. This rate is higher than the average for America (24). This factor is determinant in the production of congenital malformations (25).

Although there is great difficulty in measuring environmental pollutants (dose, time, and effect), the association between fetal alterations with environmental pollutants has been described for a long time (26). In 1997, Croen et al analyzed the geographical location and the possible association of chemical pollutants with congenital anomalies, finding a relative risk of 2 of presenting congenital anomalies in areas with environmental contamination (27).

There had been several studies that assess the impact of exposure to environmental pollutants on reproductive health. Some of the most studied are pesticides (28-30), metals and mining activities (31-33), and organic solvents (34-37). Being this type of large-scale economic activities very common in various regions of the country.

Environmental differences and health access are strongly related to the health of the mother and child. We can study these differences through geographic analysis (38). All these relationships occur in a social context and a specific place (39). That is an important issue when the health system plans interventions in places with spatial clusters of genital malformations, like the central region of the coast and the highlands. Therefore, finding clusters with a high incidence of malformations is important to plan new local studies that allow discovering the reason why there is a higher frequency in certain populations and planning public health strategies at the local level.

The epidemiological surveillance system collects relevant and necessary information about health conditions for health decision-making 38. The prevalence of congenital anomalies in countries with developing economies is underestimated, mainly because of a deficiency in diagnostic capacity and an inadequate registry of these disorders (6).

Limitations of the Study

A limitation of the study is that the data collected came from the public health care system and did not include data from other care subsystems, because there is no systematic surveillance of congenital anomalies in Ecuador.

Conclusions

Birth defect spatial distribution in Ecuador showed a higher cumulative incidence in cantons in the central and northern regions of the highlands and the central region of the east. We suggest that the lower rates are due to healthcare coverage and registry quality differences. Higher rates could be primarily because of environmental factors like teratogenic products and genetic differences, like ethnicity and consanguinity. This study provides recent epidemiological data on birth defects in Ecuador; this information is useful for those providing and planning services and, hopefully, starting a national birth defect registry program in Ecuador.

Authors' Contribution

Conceptualization: Elvira Palacios.
Data curation: Juan Pozo-Palacios.
Formal analysis: Giannina Zamora, Juan Pozo-Palacios.
Funding acquisition: Juan Pozo-Palacios.
Investigation: Juan Pozo-Palacios, Giannina Zamora, Elvira Palacios.
Methodology: Giannina Zamora, Elvira Palacios.
Project administration: Juan Pozo-Palacios.
Resources: Juan Pozo-Palacios.
Software: Giannina Zamora.
Supervision: Giannina Zamora.
Validation: Giannina Zamora, Elvira Palacios.
Visualization: Juan Pozo-Palacios.
Writing–original draft: Juan Pozo-Palacios.
Writing–review & editing: Giannina Zamora, Elvira Palacios.

Conflict of Interests

Authors declare that they have no conflict of interests.

Ethical Issues

The study was ethically approved by COBIAS - Universidad de Cuenca, ensured data confidentiality, and no ethical dilemmas were identified.

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