

Centenarians in Colombia: a population-based cohort study on the impact of COVID-19

Claudia Birchenall-Jiménez^{1,2,*}, José Emilio Amoroch-Barrera^{1,3}, Laura Marcela Rodríguez-Ortega^{1,4}, Erika Sanchez-Bolaños^{1,5}, Wilson Giovanni Jiménez-Barbosa⁶, Javier Riascos-Ochoa⁷

Abstract

Objective: This study examines the impact of COVID-19 on the centenarian population in Colombia, highlighting their vulnerability through a detailed demographic analysis.

Material and method: A retrospective cohort study (March 2020 - December 2022) analysed 1,005 affected centenarians. Descriptive statistics, chi-square tests, and Kaplan–Meier survival curves were used.

Results: Of these, 65.47% were females; the mortality rate was 37.1%, which was higher in males (45.24%). The average time from symptom onset to recovery was 26.56 days, and the average time to mortality was 14.33 days. The Kaplan–Meier curve showed greater survival in females ($p=0.0001$); the age-specific curve showed no significant differences ($p=0.084$). Centenarians were concentrated in municipalities in special categories 1 and 6.

Discussion: This study revealed increased mortality among male centenarians, emphasizing the need for extended follow-up due to the prolonged recovery time.

Keywords: Centenarians, COVID-19, mortality, Colombia.

Centenarios en Colombia: un estudio de cohorte poblacional sobre el impacto del COVID-19

Resumen

Objetivo: Este estudio examina el impacto del COVID-19 en la población centenaria en Colombia, resaltando su vulnerabilidad a través de un análisis demográfico detallado.

Material y método: Se realizó un estudio de cohorte retrospectivo (marzo de 2020 - diciembre de 2022) que analizó a 1.005 centenarios afectados. Se emplearon estadísticas descriptivas, pruebas de chi-cuadrado y curvas de supervivencia de Kaplan–Meier.

Resultados: De estos, el 65,47% eran mujeres; la tasa de mortalidad fue del 37,1%, más alta en los hombres (45,24%). El tiempo promedio desde los síntomas hasta la recuperación fue de 26,56 días; hasta la mortalidad, 14,33 días. La curva de Kaplan–Meier mostró una mayor supervivencia en las mujeres ($p=0.0001$); la curva específica por edad no mostró diferencias significativas ($p=0.084$). Los centenarios se concentraron en municipios de categoría especial, 1 y 6.

Discusión: Este estudio revela una mayor mortalidad entre los centenarios masculinos, enfatizando la necesidad de un seguimiento extendido debido al tiempo prolongado de recuperación.

Palabras clave: Centenarios, COVID-19, mortalidad, Colombia.

Introduction

The term “centenarian” refers to individuals who have reached the remarkable milestone of living over 100 years, while the designation “supercentenarians” is reserved for those surpassing the age of 114 years¹. According to data provided by the National Department of Statistics of Colombia (DANE)², in

2020, a total of 23,866 centenarians were recorded in Colombia. This figure decreased in 2021, reaching a total of 22,488 individuals, and by 2022, a further decline was observed, with 20,823 centenarians remaining in the country. Compared with the 2005 census, the number of centenarians has been on the rise in Colombia, and the distribution of centenarians by region shows diverse patterns across the nation³.

1 Intensive Care Department. Hospital Universitario Mayor-Medier. Bogotá D.C., Colombia.

2 Escuela de Medicina y Ciencias de la Salud. Universidad del Rosario. Bogotá D.C., Colombia. <https://orcid.org/0000-0002-4479-8806>

3 <https://orcid.org/0009-0009-5325-5123>

4 <https://orcid.org/0009-0009-1266-6612>

5 <https://orcid.org/0009-0004-7051-3511>

6 Department of Basic Sciences and Modelling, Faculty of Natural Sciences and Engineering. Universidad Jorge Tadeo Lozano. Bogotá D.C., Colombia. <https://orcid.org/0000-0002-0467-0365>

7 Department of Basic Sciences and Modelling, Faculty of Natural Sciences and Engineering. Universidad Jorge Tadeo Lozano. Bogotá D.C., Colombia. <https://orcid.org/0000-0001-6680-8510>

* Autor para correspondencia:

Correo electrónico: claudia.birchenall@urosario.edu.co

Recibido: 31/03/2024; Aceptado: 24/08/2024

Cómo citar este artículo: C. Birchenall-Jiménez, *et al.* Centenarians in Colombia: a population-based cohort study on the impact of COVID-19. *Infectio* 2024; 28(4): 228-234
<https://doi.org/10.22354/24223794.1200>

The COVID-19 pandemic has left a significant imprint worldwide, impacting public health, the economy, and society. The first case of COVID-19 in Colombia was reported on March 6, 2020⁴, leading to a health and economic crisis that affected various communities. Within the high-risk population, older adults, especially males, particularly those with comorbidities such as cardiovascular diseases, diabetes mellitus, pulmonary conditions, cancer, and liver and kidney diseases, are particularly affected⁵.

The centenarian population is unavoidably relevant in the Colombian context, especially considering the challenges posed by the COVID-19 pandemic. Longevity refers to the ability to survive beyond the specific average age of death for a species⁶. It not only constitutes a remarkable individual achievement but also has significant implications for the healthcare system, public policies, and society.

Studying centenarians offers valuable insights into longevity and adaptability over time. In addition to preserving their legacy, this approach provides information on how they face challenges. Learning from the resilience of centenarians can enhance society's preparedness for future challenges. In this scenario, the impact of COVID-19 on the centenarian population deserves particular attention, considering their vulnerability to diseases and their potential to offer valuable perspectives on the healthcare system's response and the adaptation of public policies in crisis situations⁷.

This research focused on understanding how the COVID-19 pandemic has specifically affected the centenarian population in Colombia. Given that centenarians represent a high-risk group due to their advanced age and potential comorbidities, it is crucial to analyse how the health crisis has influenced their mortality and well-being. Additionally, it is important to consider regional differences in the distribution of the centenarian population and how these differences may have modulated the impact of COVID-19.

Analysing the dynamics of this population in the face of the pandemic will not only allow us to understand the fragility of this demographic segment but also generate ideas about the necessary strategies to preserve the health and well-being of the oldest individuals. In this sense, the present study aimed to describe, through a population cohort analysis, longevity in the context of the COVID-19 health crisis, focusing on the experience of centenarians.

Materials and methods

Study design

A retrospective population cohort study focused on the centenarian population diagnosed with COVID-19 through polymerase chain reaction (PCR) or antigen tests in Colombia was conducted.

Data collection

Demographic information and data related to COVID-19-associated mortality were obtained from the national COVID-19 database compiled by the National Institute of Health of Colombia (INS)⁸. The research period spanned from March 6, 2020, to December 31, 2022.

For geographical distribution, regions in Colombia were considered, categorized as follows: Caribbean, Andean, Pacific, Orinoco, Amazon, and Insular, in accordance with the DANE's division⁹. Municipalities were classified based on current legislation, specifically Law 136 of 1994¹⁰, amended by Law 1551 of 2012¹¹. The latter regulation defines seven categories for municipalities: special, first, second, third, fourth, fifth, and sixth. The assignment of these categories is based on the evaluation of four fundamental criteria: population volume, current income available for discretionary spending, economic importance, and geographical location¹². For the purposes of this research, the year 2022 was used as a reference to ensure precise and updated contextualization.

Statistical analysis

The statistical approach employed methods of descriptive statistics to conduct a detailed analysis of the variables under study. For quantitative variables, central measures such as the mean, median, and percentiles were calculated. Categorical variables are presented as frequencies and percentages. Comparisons between groups were carried out using mean differences for continuous variables and the chi-square test for categorical variables, aiming to identify potential associations or significant disparities. Additionally, a sex-adjusted stratified analysis was performed using odds ratios for a more precise evaluation of relationships in the population, considering confounding factors such as age and sex.

To visually represent the demographic structure, a population pyramid was constructed. A Kaplan–Meier survival curve was created for sex and age, and differences were assessed using the log-rank test. Additionally, a descriptive map illustrating the geographical distribution of COVID-19 cases in centenarians, categorized by municipalities in Colombia, was generated, providing a useful visual tool for identifying regional patterns.

The software used for analysis included STATA 16, R version 4.3.1, and Excel 2019.

Ethical aspects

This study was conducted in accordance with the ethical principles established in the declaration of Helsinki-Fortaleza (Brazil 2013) and following the specific regulations of Colombia, according to resolution 8430 of 1993, article 11, the study is classified as minimal risk, secondary data that were publicly available, anonymized, and open were used to ensure the privacy and confidentiality of the data.

Results

During the period from March 6 2020, to December 31 2022, a total of 6,313,872 cases of COVID-19 were reported in Colombia, with 1,005 affected centenarians identified within the age range of 100 to 114 years, as detailed in Table 1. The average age was 101.82 years, with the living centenarians having an average age of 101.9 years and the deceased having an average age of 101.69 years, with no significant differences between the two means ($p=0.15$). Gender distribution analysis revealed that 65.47% were females ($n=685$), while 34.53% were males ($n=347$). The overall fatality rate was 37.1% ($n=373$), which was significantly greater for males (45.24%, $n=157$) than for females (32.83%, $n=216$) ($p=0.0148$). The adjusted mortality rate was 1.40 (95% CI: 1.26-1.55), and the odds ratio for mortality in males was 1.69 (CI 1.29-2.21).

The mortality rates per 10,000 inhabitants during the years 2020, 2021, and 2022, along with specific variations by sex, are presented below. Substantial variability was observed in the mortality rates throughout the study period. In 2020, the overall rate was 43.57, increasing to 75.15 in 2021, and then decreasing to 48.02 in 2022. According to sex, the mortality rate for men was 45.84 in 2020, increased to 74.88 in 2021, and then decreased to 53.47 in 2022. Moreover, women exhibited a mortality rate of 42.4 in 2020, followed by an increase to 75.33 in 2021 and a decrease to 44.32 in 2022.

The graphical representation of the population pyramid provides detailed insight into how centenarians are distributed by age and gender. A notable predominance of females is highlighted, revealing a demographic structure characterized

Table 1. Percentages by age of centenarians during the COVID-19 pandemic.

Age	Frecuency	Percentage
100	362	36.02
101	226	22.49
102	140	13.93
103	103	10.25
104	69	6.87
105	33	3.28
106	28	2.79
107	11	1.09
108	9	0.9
109	5	0.5
110	7	0.7
111	5	0.5
112	3	0.3
113	1	0.1
114	3	0.3
Total	1.005	100

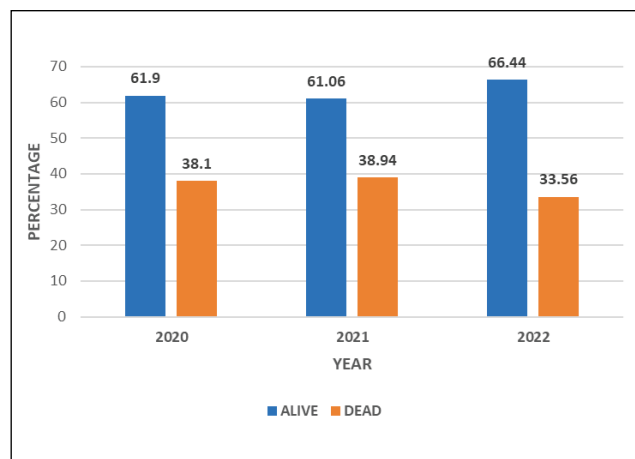


Figure 1. Fatality rate per year during the COVID-19 pandemic. Depicts the fatality rate over the study years. In 2020, it was 38.1%, slightly increasing to 38.94% in 2021 and subsequently decreasing to 33.56% in 2022. Notably, the differences between the percentages did not reach statistical significance ($p=0.309$).

by a broad base and a narrow apex. This design reflects that the majority of the centenarian population is concentrated in the age range of 100 to 104 years, while the supercentenarians, represented at the apex of the pyramid, constitute a smaller proportion of this population segment.

The temporal window from the onset of symptoms to recovery shows notable variability, spanning an interval of 10 to 255 days, with an average of 26.56 days (standard deviation: 30.87). The median is 18 days, while the 25th and 75th percentiles are 14 and 26 days, respectively.

On the other hand, the period from the onset of symptoms to mortality ranged from 0 to 136 days, with an average of 14.33 days (standard deviation: 12.58). The median is 12 days, and the 25th and 75th percentiles are 6 and 19 days, respectively. The analysis of the Kaplan–Meier curve, specifically focused on the sex variable, yielded significant results, demonstrating that females exhibit a considerably longer survival time compared to males ($p=0.0001$) (Figure 3).

Survival analysis was conducted by constructing a Kaplan–Meier curve based on age, with no significant differences in survival observed ($p=0.084$), as detailed in Figure 4.

Regarding ethnic affiliation, it is noteworthy that mestizos and whites constitute the predominant group, accounting for 97.41%. In contrast, individuals of Black descent represent 1.59%, followed by 0.9% of Indigenous individuals and 0.1% of Raizal ancestry.

The distribution of centenarians by department and the mortality rate per 100,000 inhabitants are presented in Table 2. Additionally, detailed data for each category are available in the Appendix.

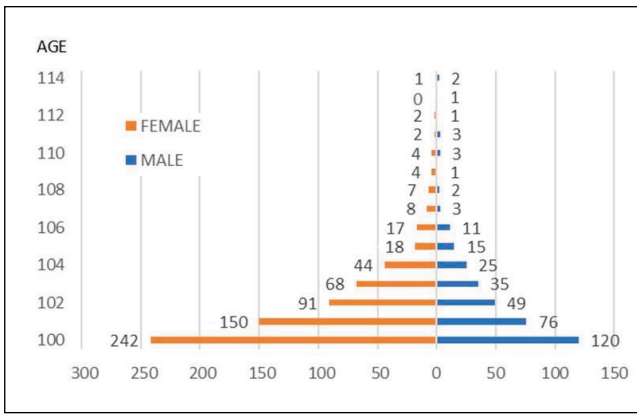


Figure 2. Population pyramid of centenarians during the COVID-19 pandemic.

The analysis of centenarian distribution according to municipality categories revealed that 19.4%, 6.17%, 2.79%, 3.08%, 3.58%, 19.1%, and 45.87% of the participants were classified as category 1, category 2, category 3, category 4, category 5, and category 6, respectively. The most significant concentration is observed in special districts, followed by municipalities categorized as 1 and 6 (Figure 5).

In the special districts, a notable concentration of centenarians is observed, with Bogotá being the city with the highest density, followed by Medellín, Cali, and Cartagena. Among the first-category municipalities, centenarian populations are identified in places such as Bucaramanga, Ibagué, Manizales, Pasto, Pereira, Neiva, Santa Marta, Cúcuta, Soacha, Villavicencio, Montería, Valledupar, Armenia, and Bello.

For the sixth-category municipalities, notable locations include Baranoa, Anolaima, San Juan del Cesar, Villanueva, Arjona, El Colegio, Guaduas, Mompós, Pamplona, San Andrés, Santa-fé de Antioquia, Sevilla, and Arbeláez.

Figure 5 presents a spatial representation of the distribution of COVID-19 cases among centenarians across the Colombian territory, categorized by municipality. The visualization

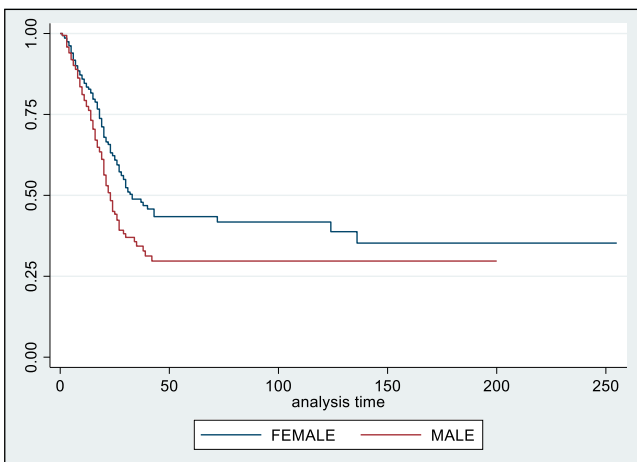


Figure 3. K-M survival curve according to sex.

reveals a notable concentration in the Andean and Caribbean regions, while the presence in the Pacific region is less pronounced. The scarcity of centenarians in the Pacific coastal region contrasts with the higher concentration along the Caribbean coast. Cases are also observed in the insular region, with a complete absence of cases in the Orinoco and Amazon regions. The municipalities with the highest concentration of centenarian cases in Colombia were categorized as special, first, and sixth categories.

Discussion

This study focused on a particularly relevant group during the COVID-19 pandemic: centenarians affected by the virus. By examining the experiences of those who have reached a hundred years, we gain a unique perspective that highlights the complex interaction between longevity and vulnerability to diseases. Significant differences have been identified between women and men in aspects such as life expectancy, disability, mortality, and longevity, with these disparities being even more pronounced during the COVID-19 pandemic¹³. The increased mortality among male centenarians due to COVID-19 is multifactorial, likely attributed to a combination of biological factors, comorbidities, and access to healthcare. COVID-19 infection triggers an exacerbated inflammatory response known as a cytokine storm, and individuals of advanced age appear to be more susceptible to its adverse effects. However, in centenarians, this immune response is considerably attenuated. Despite this attenuation, a gender disparity in mortality persists among centenarians affected by COVID-19. It has been hypothesized that men may have a genetic predisposition to higher interleukin-6 production, which could have counterproductive implications for longevity¹⁴. Additionally, hypotheses regarding HLA genes suggest weak immune and antiviral responses in centenarians¹⁵.

A study conducted in South America demonstrated that trained immunity induced by influenza vaccination improved the survival of centenarians with respect to COVID-19. Additionally, survivors of the 1918 influenza pandemic were found to

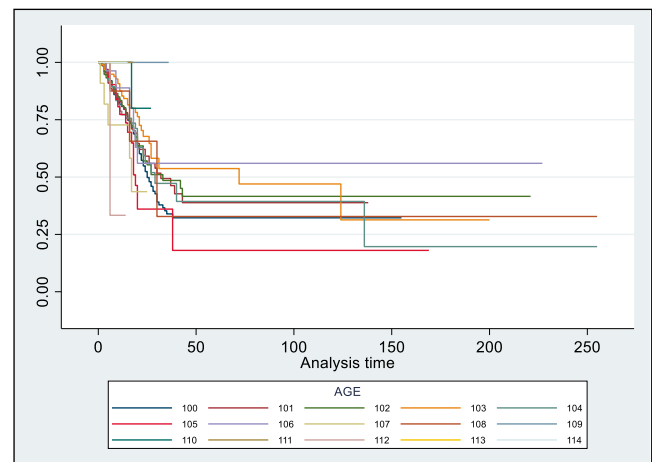


Figure 4. K-M survival curve according to age.

Table 2. Distribution of centenarians by department and mortality rate per 100.000 inhabitants.

Department	Alive	Dead	Total	Mortality rate:100.000
ANTIOQUIA	86	58	144	0.86
ARAUCA	1	0	1	0
ATLANTICO	24	12	36	0.44
BARRANQUILLA	47	19	66	0.73
BOGOTA	127	65	192	0.83
BOLIVAR	11	11	22	0.5
BOYACA	18	9	27	0.71
CALDAS	12	6	18	0.58
CAQUETA	4	2	6	0.48
CARTAGENA	20	10	30	0.48
CASANARE	3	0	3	0
CAUCA	6	7	13	0.46
CESAR	5	6	11	0.45
CHOCO	6	1	7	0.17
CORDOBA	14	11	25	0.59
CUNDINAMARCA	34	22	56	0.68
GUAJIRA	10	6	16	0.61
HUILA	8	11	19	0.96
MAGDALENA	1	4	5	0.28
META	11	3	14	0.27
NARIÑO	17	11	28	0.66
NORTE SANTANDER	13	6	19	0.36
PUTUMAYO	4	1	5	0.27
QUINDIO	10	3	13	0.54
RISARALDA	13	6	19	0.62
SAN ANDRES	2		2	0
SANTANDER	26	19	45	0.82
STA MARTA D.E.	3	8	11	0.74
SUCRE	9	6	15	0.62
TOLIMA	15	9	24	0.66
VALLE	72	41	113	0.89

possess neutralizing antibodies derived from B cells. These findings underscore the importance of long-term immunological memory and its influence on the response to infectious diseases¹⁶.

Mortality was significantly higher in men (45.25%) compared to women (32.83%). The odds ratio for mortality in males was 1.69 (95% CI: 1.29–2.21), indicating that men were more likely to die than women.

In the first wave of the pandemic in 2020, centenarians over 101 years old exhibited greater resistance to COVID-19, possibly related to the 1918 Spanish flu pandemic. Despite these findings, the specific mechanisms supporting this resistance are still unknown, underscoring the complexity of the infection response in various demographic groups. These results emphasize the importance of additional research to fully understand the disparities observed in the response to COVID-19 infection in the centenarian population^{17,18}.

The fatality rate in the studied population reached 37.5%, while in previous research conducted in a population with an average age of 91 years, a percentage of 33.6% was recorded. These findings suggest an increase in mortality associated with age¹⁹, hinting at the possibility of greater vulnerability or severity of the disease among the oldest population.

Mortality did not significantly change over time, indicating a lack of significant changes over time. Notably, the COVID-19 vaccination plan in Colombia started on February 17, 2021²⁰. This observation underscores the need for additional studies to assess vaccine implementation and its effectiveness in this population. Additionally, the results show that the time window from the onset of symptoms to recovery or mortality is variable. The median recovery window was 18 days, but 25% of individuals recovered in less than 14 days, and 75% recovered in less than 26 days, similar to other studies where the recovery time was 23.5 ± 9.9 days, indicating wide variability in the duration of recovery²¹. The median mortality window is 12 days, but 25% of individuals die in less than 6 days, and 75% die in less than 19 days. In the general population, the median number of days until mortality is 19 days after the onset of symptoms²². These results suggest that disease progression is unpredictable, and patients should be closely monitored for at least 26 days after the onset of symptoms.

The ethnic affiliation in the studied population is predominantly mestizo and white, and these results align with existing evidence showing that the Colombian population is largely composed of this demographic²³.

In Colombia, municipalities are classified into three groups, namely large municipalities, intermediate municipalities, and basic municipalities, considering factors such as population, current income, and geographical location^{10,11}. Large municipalities include those in the special category and the first

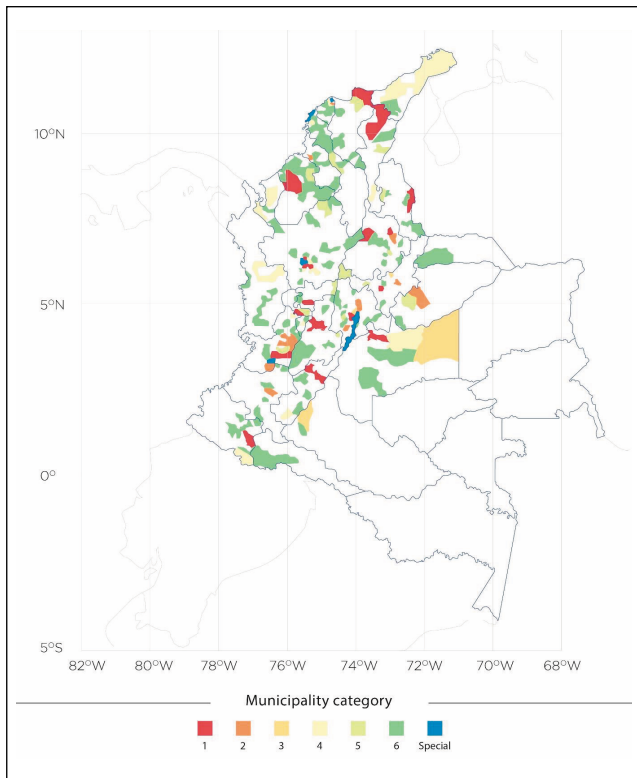


Figure 5. Map of COVID-19 cases among centenarians by municipality category.

category. Intermediate municipalities encompass the second, third, and fourth categories, while basic municipalities include the fifth and sixth categories.

During the COVID-19 pandemic, the centenarian population was mainly concentrated in large municipalities and basic municipalities. These results highlight the disparity in the distribution of infected centenarians according to municipal classification, emphasizing the importance of considering the specificities of each category to understand longevity in different geographical contexts.

The relevance of this categorization is emphasized in terms of improving the state's response in providing social goods and services²⁴. It is noteworthy that a high percentage of centenarians are found in sixth-category municipalities, identifying a risk because these municipalities have a low level of taxation and lower complexity in healthcare provision²⁵. As part of public policy for elderly people, it is important to create space for centenarians, as this is a necessary factor for society

Considering the prospect of a potential increase in the number of centenarians in the future, it is imperative to reflect on the lessons learned during the COVID-19 pandemic to enhance the management of this population in the face of potential emerging infectious diseases. This study revealed a high mortality rate, especially in men. No significant differences in survival were found among the different age groups.

The age of centenarians does not appear to be a determining factor in the survival of COVID-19 patients, although additional studies with larger samples are needed to confirm this finding. The variability in the symptom-to-recovery window and the concentration in certain municipalities underscore the vulnerability of this population, emphasizing the need for specific strategies in healthcare and public policies to address their needs.

This study has several limitations that should be considered when interpreting the results. First, the absence of information on clinical comorbidities limits the ability to fully adjust for factors that may influence COVID-19-associated mortality. Additionally, the retrospective design of the study introduces potential biases related to the quality and accuracy of the recorded data, as well as the reliance on secondary records, which may affect the completeness and accuracy of the information. Differences in the categorization of municipalities and regions, based on current legislation and economic and geographical criteria, may introduce variability that affects the interpretation of results at the regional level.

Ethical considerations

Protection of persons and animals. The authors declare that no experiments have been conducted on humans or animals for this research.

Protection of Vulnerable Populations. Not applicable.

Confidentiality. The authors declare that they have followed the protocols of their workplace regarding the publication of patient data.

Privacy. Not applicable.

Financing. Not applicable.

Conflict of interests. The authors declare that they have no conflicts of interest.

Acknowledgments. Not applicable.

Authors' contributions. CBJ managed project administration, performed the statistical analysis, and wrote the manuscript. JA, ES, and LR contributed to the literature review and investigation. WJ contributed to the methodology. JRO conducted the statistical analysis. All authors contributed to, read, and approved the submitted version of the manuscript.

References

- Gutiérrez WA, Samudio ML, Cano CA. Caracterización de las personas centenarias atendidas en el Hospital Universitario San Ignacio de enero del 2005 a diciembre del 2012. *Univ Médica*. 2015;56(3):268-274.
- Personas mayores de 100 años en Colombia - 70 Años del DANE: Un Legado Estadístico [Internet]. [citado 20 de enero de 2024]. Disponible en: <https://dane70.dane.gov.co/index.php/los-hitos/censos/personas-mayores-de-100-anos-en-colombia>

3. Rosselli D. Yucumá D. Polanía MJ. Machado JC. Distribución geográfica de los centenarios en Colombia: un análisis de tres bases de datos. *Meta*. 2017;23(10):13. doi.org/10.15446/revfacmed.v65n3.59505.
4. Rosselli M. Covid-19 en Colombia: los primeros 90 días. *Acta Neurológica Colomb*. 2020;36(2):1-6. doi.org/10.22379/24224022287
5. Noor FM, Islam MM. Prevalence and associated risk factors for mortality among COVID-19 patients: a meta-analysis. *J Community Health*. 2020;45(6):1270-82. DOI: 10.1007/s10900-020-00920-x
6. De Benedictis G. Franceschi C. The unusual genetics of human longevity. *Sci Aging Knowl Environ*. 2006;2006(10):pe20-pe20. DOI: 10.1126/sageke.2006.10.pe20
7. Caruso C. Accardi G. Aiello A. Calabrò A. Ligotti ME. Candore G. Centenarians born before 1919 are resistant to COVID-19. *Aging Clin Exp Res*. 2023;35(1):217-20. DOI: 10.1007/s40520-022-02287-6
8. Coronavirus Colombia [Internet]. [citado 20 de enero de 2024]. Disponible en: <https://www.ins.gov.co/Noticias/Paginas/Coronavirus.aspx>
9. Regiones geográficas. [Internet]. [citado 7 de febrero de 2024]. Disponible en: https://geoportal.dane.gov.co/servicios/atlas-estadistico/src/Tomo_1_Demografico/%E2%80%A2regiones-geogr%C3%A1ficas.html
10. LEY 136 DE 1994 [Internet]. [citado 20 de enero de 2024]. Disponible en: <https://www.suin-juriscol.gov.co/viewDocument.asp?id=1648916>
11. Ley 1551 de 2012 - Gestor Normativo - Función Pública [Internet]. [citado 20 de enero de 2024]. Disponible en: <https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=48267>
12. ¿Con base a qué criterios se establece la categoría de un municipio en Colombia? [Internet]. [citado 20 de enero de 2024]. Disponible en: <https://www.construyendomeritos.com/blog/con-base-a-que-criterios-se-establece-la-categoria-de-unmunicipio-en-colombia>
13. Marcon G. Tettamanti M. Capacci G. Fontanel G. Spanò M. Nobili A. et al. COVID-19 mortality in Lombardy: the vulnerability of the oldest old and the resilience of male centenarians. *Aging*. 2020;12(15):15186. DOI: 10.18632/aging.103872.
14. Bonafè M. Olivieri F. Cavallone L. Giovagnetti S. Marchegiani F. Cardelli M. et al. A gender-dependent genetic predisposition to produce high levels of IL-6 is detrimental for longevity. *Eur J Immunol*. 2001;31(8):2357-61. DOI: 10.1002/1521-4141(200108)31:8<#60;2357::aid-immu23578#62;3.0.co;2-x
15. Guerini FR. Cesari M. Arosio B. Hypothetical COVID-19 protection mechanism: hints from centenarians. *Immun Aging*. 2021;18(1):1-5. Doi.org/10.1186/s12979-021-00226-z
16. De Castro MV. et al. The oldest unvaccinated Covid-19 survivors in South America. *Immun Aging*. 2022;19(1):57.
17. Caruso C. Marcon G. Accardi G. Aiello A. Calabrò A. Ligotti ME. et al. Role of Sex and Age in Fatal Outcomes of COVID-19: Women and Older Centenarians Are More Resilient. *Int J Mol Sci*. 2023;24(3):2638. doi: 10.3390/ijms24032638
18. Poulain M. Chambre D. Pes GM. Centenarians exposed to the Spanish flu in their early life better survived to COVID-19. *Aging*. 2021;13(18):21855. doi: 10.18632/aging.203577
19. Kashtanova DA. Erema VV. Gusakova MS. Sutulova ER. Yakovchik AY. Ivanov MV. et al. Mortality and survival in nonagenarians during the COVID-19 pandemic: Unstable equilibrium of aging. *Front Med*. 2023;10:1132476. doi.org/10.3389/fmed.2023.1132476
20. Vacunación contra COVID-19 [Internet]. [citado 7 de febrero de 2024]. Disponible en: <https://www.minsalud.gov.co/salud/publica/Vacunacion/Paginas/Vacunacion-covid-19.aspx>
21. Mizrahi B. Shilo S. Rossman H. Kalkstein N. Marcus K. Barer Y. et al. Longitudinal symptom dynamics of COVID-19 infection. *Nat Commun*. 2020;11(1):6208. DOI: 10.1038/s41467-020-20053-y
22. Sousa G. Garces T. Cestari V. Florêncio R. Moreira T. Pereira M. Mortality and survival of COVID-19. *Epidemiol Infect*. 2020;148. DOI: 10.1017/S0950268820001405
23. Grupos étnicos información técnica [Internet]. [citado 10 de febrero de 2024]. Disponible en: <https://web.archive.org/web/20200408132304/https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/grupos-eticos/informacion-tecnica>
24. Duque Cante N. Importancia de la categorización territorial para la descentralización y las relaciones intergubernamentales en Colombia. *Rev Derecho Estado*. 2017;(38):67-95. DOI:https://doi.org/10.18601/01229893.n38.03.
25. Delgado Ruiz ST. Cárdenas Pinzón JI. Fuentes López HJ. Los municipios de sexta categoría de Colombia (2000-2016): entre la autonomía y la dependencia. *Apunt CENES*. 2020;39(69):137-67. doi.org/10.19053/01203053.v39.n69.2020.10172.