Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Neurological mortality transition in Ecuador, 1997–2024: age-standardized trends and demographic decomposition

Alberth Patricio Muñoz-Gualan

apmunoz2@utpl.edu.ec

Universidad Técnica Particular de Loja

German Geovanny Muñoz-Gualan

Universidad de las Fuerzas Armadas ESPE

Research Article

Keywords: Ecuador, Neurological mortality, Age-standardized mortality, Demographic decomposition, Cerebrovascular disease, Dementia

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11332902/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Neurological mortality transition in Ecuador, 1997–2024: age-standardized trends and demographic decomposition

Alberth Patricio Muñoz-Gualán [a *], German Geovanny Muñoz- Gualán [b].

[a] Department of Health Sciences, Universidad Técnica Particular de Loja (UTPL), Loja, Ecuador

[b] Clinical Medicine Department, Universidad de las Fuerzas Armadas del Ecuador – ESPE, Sangolqui, Ecuador

* Corresponding author at: Department of Health Sciences, Universidad Tecnica Particular de Loja (UTPL), San Cayetano Alto, St Marcelino Champagnat s/n, Loja, Ecuador.

Email address: apmunoz2@utpl.edu.ec

Abstract

Background

Long-term cause-specific neurological mortality trends in Ecuador remain insufficiently characterized. This study examined mortality trends from 1997 to 2024 and quantified the contributions of demographic change and age-specific mortality rates to changes in annual deaths.

Methods

We conducted a nationwide time-series study using national mortality and population data for 1997–2024. Six neurological conditions were examined: cerebrovascular disease, dementia/Alzheimer disease, Parkinson disease, epilepsy/status epilepticus, meningitis, and malignant brain neoplasm. Crude and World Health Organization age-standardized mortality rates were calculated. Temporal trends were assessed using weighted segmented log-linear regression with overdispersion-adjusted inference and bootstrap assessment of breakpoint stability. Changes in annual deaths were decomposed into population growth, age structure, and age-specific mortality-rate effects using a Shapley approach.

Results

Cerebrovascular deaths increased from 2,280 to 4,836, although age-standardized mortality declined by 16.5% (average annual percentage change, −0.85%; 95% confidence interval, −1.29 to −0.40). Dementia/Alzheimer mortality increased markedly (average annual percentage change, +7.73%), with changes in age-specific mortality accounting for the largest share of the increase in deaths. Parkinson mortality also increased (+2.50% annually), whereas epilepsy (−1.33%) and meningitis (−3.12%) declined. For cerebrovascular disease, declining age-specific mortality partly offset strong contributions from population growth and population aging. Sensitivity analyses using three-year endpoints and the pre-pandemic period preserved the main directions.

Conclusions

Neurological mortality in Ecuador underwent a heterogeneous transition. Disease-specific planning should distinguish changes in absolute mortality burden from changes in age-standardized recorded mortality.

Clinical trial number: not applicable.

Keywords: Ecuador; Neurological mortality; Age-standardized mortality; Demographic decomposition; Cerebrovascular disease; Dementia

1. Background

Neurological disorders are a major and growing component of global disease burden. Global Burden of Disease (GBD) Study 2021 estimated that disorders affecting the nervous system affected more than 3 billion people and represented the leading group-level contributor to disability-adjusted life years worldwide [1]. Although age-standardized neurological mortality has declined, population growth and aging continue to increase absolute burden [1].

This transition differs markedly by condition. In the Americas, stroke deaths have increased despite declining age-standardized rates [2]. Epilepsy burden has generally fallen in Latin America and the Caribbean, particularly through lower premature mortality, and meningitis mortality has also declined substantially [3,4]. In contrast, Parkinson disease and dementia have become increasingly important with population aging [5,6], whereas brain and central nervous system cancers have shown rising absolute deaths with comparatively stable age-standardized mortality [7]. These divergent patterns illustrate why mortality counts, crude rates, and age-standardized rates provide complementary information.

Country-specific analyses are needed because demographic change, diagnostic capacity, healthcare access, and death certification vary across health systems. Despite the availability of national vital statistics, long-term evidence distinguishing the contributions of population growth, population aging, and changes in recorded age-specific mortality across major neurological conditions in Ecuador remains limited. Understanding these components may inform disease-specific surveillance, resource allocation, and health-service planning in Ecuador and other Latin American countries undergoing demographic and epidemiological transitions.

National vital statistics can distinguish changes in mortality risk from demographic pressure, and decomposition methods can quantify the contributions of population growth, age structure, and age-specific mortality rates. We therefore examined neurological mortality in Ecuador from 1997 to 2024 for cerebrovascular disease, dementia/Alzheimer disease, Parkinson disease, epilepsy/status epilepticus, meningitis, and malignant brain neoplasm. We assessed crude and age-standardized mortality, long-term segmented trends, changes in cause composition, and the demographic components underlying changes in absolute deaths.

2. Methods

2.1. Study design and data sources

This nationwide time-series study examined cause-specific neurological mortality in Ecuador from 1997 through 2024 using mortality and population data from the Instituto Nacional de Estadística y Censos (INEC). Mortality data were obtained from the national General Death Statistics (*Estadísticas de Defunciones Generales*) [8], which record the underlying cause of death using International Classification of Diseases, Tenth Revision (ICD-10).

For 1997–2007, individual-level annual mortality files were harmonized by year, age, sex, and underlying cause of death. Age was converted to completed years, with deaths before age 1 assigned age 0 and unknown age retained separately. For 2008–2024, national cause-specific mortality tabulations by single year of age were used. Reconstructed annual disease totals matched official INEC totals exactly in all 168 disease-year comparisons (Supplementary Table S1).

Population denominators were obtained from the INEC *Estimaciones y Proyecciones de la Población de Ecuador, Revisión 2024* [9]. Single-year ages were aggregated into 18 groups (0–4, 5–9, …, 80–84, and ≥85 years). These denominators exactly reproduced all 1,512 corresponding official year-by-sex-by-age population cells (Supplementary Table S2).

2.2. Neurological causes of death

Six conditions were prespecified: cerebrovascular disease (I60–I69), dementia/Alzheimer disease (F01, F03, G30), Parkinson disease (G20), epilepsy/status epilepticus (G40–G41), malignant neoplasm of the brain (C71), and meningitis (A39.0, A87, G00–G03). The analysis therefore represents these six selected neurological conditions rather than all neurological deaths.

2.3. Mortality rates and temporal trends

Annual crude mortality rates were expressed per 100,000 population. Age-standardized mortality rates (ASMRs) were calculated by direct standardization to the WHO World Standard Population [10] using the same 18 age groups; published weights were normalized to sum to one. Deaths with unknown age were excluded from primary age-standardized analyses. Ninety-five percent confidence intervals (CIs) for ASMRs were calculated using the Fay–Feuer gamma method [11].

Temporal trends were assessed using weighted segmented log-linear regression. For each condition, log(ASMR) was modeled as a continuous piecewise-linear function of calendar year. Models with zero to four breakpoints were evaluated, requiring at least four annual observations per segment, and observations were weighted by the inverse variance of log(ASMR). The model with the lowest Bayesian information criterion (BIC) was selected (Supplementary Table S3).

Segment-specific annual percentage changes (APCs) were calculated as:

$$APC = 100\,[\exp(\beta) - 1],$$

where β is the annual log-rate slope. Average annual percentage changes (AAPCs) for 1997–2024 were duration-weighted averages of segment-specific log slopes.

When residual variation exceeded that expected from the supplied rate standard errors, inference was adjusted for overdispersion using the Pearson χ^2-to-residual-degrees-of-freedom ratio, constrained to a minimum of 1. Adjusted APCs and model diagnostics are reported in Supplementary Tables S4–S5.

Breakpoint stability was evaluated using 300 parametric bootstrap replicates per condition, re-estimating breakpoint locations while retaining the selected number of breakpoints. Breakpoint reproducibility and bootstrap AAPCs are reported in Supplementary Tables S6–S7. Observed ASMRs, 95% CIs, fitted trends, and selected breakpoints are shown in Figure 1.

2.4. Demographic decomposition

Changes in absolute deaths were expressed as:

$$D = N \sum_{a} s_a \, r_a$$

where N represents total population size, s_a the proportion of the population in age group a, and r_a the corresponding age-specific mortality rate.

The difference in deaths between 1997 and 2024 was decomposed into population growth, change in age structure, and change in age-specific mortality rates. A Shapley decomposition was used to avoid dependence on substitution order [12]; marginal contributions were averaged across all six possible permutations of the three components. Unknown-age deaths were proportionally redistributed across observed age groups so reconstructed disease totals equaled official counts. Results are reported in Table 2 and Figure 2.

2.5. Cause composition and sensitivity analyses

Annual cause composition was calculated as each condition's percentage of combined deaths across the six selected conditions and is shown in Figure 3.

Two sensitivity analyses were performed. First, the Shapley decomposition was repeated using 1997–1999 and 2022–2024 three-year windows to reduce dependence on single-year endpoints (Supplementary Tables S8–S9). Second, segmented trend analyses were repeated for the pre-pandemic period 1997–2019 (Supplementary Tables S10A–S10C).

All analyses were performed in Python using pandas, NumPy, SciPy, and Matplotlib.

3. Results

3.1. Data validation and overall mortality changes

The analysis covered 28 years and six neurological conditions, yielding 168 disease-year observations. Reconstructed mortality counts matched official INEC totals in all 168 comparisons, and population denominators reproduced all 1,512 official quinquennial-age cells without discrepancy (Supplementary Tables S1–S2).

Between 1997 and 2024, Ecuador's population increased from 11.86 to 17.97 million. Deaths increased for five of the six conditions and declined only for meningitis (Table 1). Dementia/Alzheimer deaths increased from 42 to 1,033 (+2359.5%), Parkinson disease from 60 to 352 (+486.7%), and cerebrovascular disease from 2,280 to 4,836 (+112.1%), whereas meningitis deaths decreased from 134 to 93 (−30.6%).

3.2. Crude and age-standardized mortality trends

Age standardization substantially altered the interpretation of several long-term changes (Table 1; Figure 1). Cerebrovascular crude mortality increased by 40.1%, from 19.22 to 26.92 per 100,000, whereas the ASMR declined by 16.5%, from 30.53 (95% CI, 29.27–31.83) to 25.50 (24.78–26.24). The overdispersion-adjusted AAPC was −0.85% per year (95% CI, −1.29 to −0.40; P<0.001).

Dementia/Alzheimer mortality increased markedly despite age standardization: ASMR rose from 0.59 (0.42–0.79) to 4.75 (4.46–5.05) per 100,000 (+711.1%), with an AAPC of +7.73% per year (95% CI, 7.13–8.34; P<0.001). Parkinson ASMR increased from 0.85 to 1.78 per 100,000 (+110.6%), with an AAPC of +2.50% (1.56–3.44; P<0.001).

In contrast, epilepsy/status epilepticus ASMR declined by 32.3%, from 2.62 to 1.77 per 100,000 (AAPC −1.33%; 95% CI, −1.82 to −0.84; P<0.001), and meningitis declined by 45.4%, from 0.98 to 0.53 (AAPC −3.12%; −3.86 to −2.38; P<0.001). Brain malignant neoplasm ASMR increased

from 1.93 to 2.37 per 100,000, but no sustained overall trend was detected (AAPC +0.31%; −0.39 to 1.02; P=0.39).

3.3. Segmented temporal patterns

Segmented models showed heterogeneous trajectories (Figure 1; Supplementary Tables S3–S4). Cerebrovascular mortality declined during 2000–2009 and more rapidly during 2009–2012, remained relatively stable thereafter, and declined again during 2021–2024. Dementia/Alzheimer mortality increased throughout the period, with APCs of +8.89% during 1997–2011 and +6.49% during 2011–2024. However, the 2011 breakpoint was imprecisely localized by bootstrap resampling, supporting interpretation of a persistent increase rather than a discrete transition at a specific year (Supplementary Table S6).

Epilepsy followed a non-monotonic trajectory, with marked earlier declines followed by an increase during 2010–2024 (APC +2.62%; 95% CI, 1.76–3.48; P<0.001). Meningitis declined strongly during 2000–2012 (APC −9.20%; −10.39 to −7.99) and was subsequently approximately stable. Parkinson disease was largely stable during 2006–2021 before increasing during 2021–2024 (APC +7.73%; 3.21–12.44; P<0.001), although the latest breakpoint showed limited temporal stability (Supplementary Table S6). Bootstrap AAPCs closely reproduced the primary estimates (Supplementary Table S7).

3.4. Demographic decomposition and cause composition

The Shapley decomposition showed that changes in absolute deaths reflected different combinations of population growth, age structure, and age-specific mortality rates (Table 2; Figure 2).

For cerebrovascular disease, the increase of 2,556 deaths reflected positive contributions from population growth (+1,423.8 deaths) and age structure (+1,759.5), partly offset by declining age-specific mortality (−627.3). In dementia/Alzheimer disease, the 991 additional deaths were driven primarily by changes in age-specific mortality (+591.2), followed by age structure (+238.4) and population growth (+161.5).

Parkinson disease increased by 292 deaths, with positive contributions from population growth (+70.2), age structure (+97.8), and age-specific mortality (+124.0). For epilepsy, positive demographic contributions (+128.6 from population growth and +39.0 from age structure) were largely offset by declining age-specific mortality (−133.6), producing a net increase of only 34 deaths. Meningitis deaths declined by 41, mainly because the age-specific mortality contribution (−78.3) outweighed population growth (+47.6). Brain malignant neoplasm deaths increased by 258, with positive contributions from all three components.

Cerebrovascular disease remained the largest contributor among the six selected conditions, but its share declined from approximately 76.8% in 1997 to 68.5% in 2024, while dementia/Alzheimer disease increased from 1.4% to 14.6% (Figure 3).

3.5. Sensitivity analyses

The decomposition was robust when single-year endpoints were replaced by 1997–1999 and 2022–2024 three-year windows: the direction of all three components was preserved in all six conditions (Supplementary Tables S8–S9).

Pre-pandemic analyses also supported the principal long-term directions (Supplementary Tables S10A–S10C). During 1997–2019, AAPCs were +7.82% for dementia/Alzheimer disease, −0.64% for cerebrovascular disease, −2.43% for epilepsy/status epilepticus, −3.94% for meningitis,

+1.93% for Parkinson disease, and +1.08% for brain malignant neoplasm. Thus, the principal full-period trends were already evident before 2020, although segment structure and magnitude differed.

4. Discussion

This nationwide study shows that neurological mortality in Ecuador underwent markedly different transitions across conditions between 1997 and 2024. Absolute deaths frequently moved in a different direction from age-standardized mortality, highlighting the distinction between demographic pressure and underlying mortality risk. Cerebrovascular deaths more than doubled despite declining age-standardized mortality; dementia/Alzheimer disease and Parkinson disease increased after age adjustment; epilepsy and meningitis declined; and malignant brain neoplasm showed no sustained overall age-standardized trend. These divergent patterns are consistent with the broader global neurological transition, in which population growth and aging increasingly shape absolute burden even when standardized rates remain stable or decrease [1].

The cerebrovascular findings illustrate this divergence most clearly. Although deaths increased by 112%, ASMR declined by 16.5%, and the decomposition showed that lower age-specific mortality offset approximately 627 deaths that would otherwise have added to strong demographic pressure. Similar patterns have been reported globally and across the Americas, where declining age-standardized stroke mortality coexists with substantial or increasing absolute burden [2,13,14]. Changes in hypertension control, smoking, lipid exposure, acute stroke care, reperfusion therapies, and secondary prevention may have contributed to this favorable trajectory [13–15], but our data cannot attribute the decline to specific interventions.

Dementia/Alzheimer disease showed the strongest adverse trend. ASMR increased from 0.59 to 4.75 per 100,000, and approximately 591 of the 991 additional annual deaths were attributed to changes in age-specific mortality rather than population growth or age structure alone. This mortality-rate component captures changes in recorded age-specific mortality and cannot distinguish genuine epidemiological changes from improvements in diagnostic recognition, death certification, or cause-of-death coding. Therefore, the decomposition results should be interpreted as an accounting of observed mortality changes rather than evidence of a causal increase in disease-specific mortality risk. Global evidence similarly identifies dementia as a rapidly expanding neurological burden, while Latin American studies document considerable heterogeneity by age, education, sex, and residence [5,16]. However, mortality registries do not measure dementia incidence directly. Dementia remains incompletely recorded on death certificates, and ascertainment has changed over time with coding practices, diagnostic recognition, comorbidity, and place of death [17–19]. The Ecuadorian increase should therefore be interpreted as a combination of epidemiological and ascertainment changes rather than as a direct measure of incidence.

The growing dementia signal has important health-system implications. The 2024 Lancet Commission emphasizes prevention across the life course together with timely diagnosis, caregiver support, and integrated health and social care [20]. In Ecuador, these findings support strengthening dementia surveillance and expanding access to geriatric, neurological, cognitive, and community-based services.

Parkinson disease also showed an unfavorable long-term pattern in recorded mortality, with age-standardized mortality rates more than doubling and all three Shapley decomposition components contributing positively to the observed increase in annual deaths. This is consistent with global increases in Parkinson disease burden [6] and substantial prevalence reported across Latin America

[21]. Under-recording on death certificates remains important, however, because Parkinson disease is frequently omitted even among clinically diagnosed cases [22]. The apparent post-2021 acceleration should therefore be interpreted cautiously, particularly because the final segment was short and its breakpoint less stable than several earlier changes.

Epilepsy followed a different trajectory. Overall ASMR declined by approximately one-third, and lower age-specific mortality nearly offset the additional deaths expected from population growth and age-structure change. This is consistent with both GBD estimates and Latin American analyses showing reductions in premature epilepsy mortality [3,23]. Although the segmented model suggested an increase after approximately 2010, the full-period and pre-pandemic AAPCs remained negative. This recent increase is therefore better considered a surveillance signal than evidence of a confirmed reversal.

Meningitis showed the most favorable transition, with ASMR declining by approximately 45% and reductions in age-specific mortality outweighing demographic growth. This agrees with global evidence of declining meningitis mortality and reductions in several vaccine-preventable causes [4]. Expanded immunization, antimicrobial treatment, earlier diagnosis, and improvements in acute care are plausible contributors. Population-level mortality benefits after pneumococcal conjugate vaccine introduction have also been demonstrated in Latin America, including Ecuador, although those analyses focused on pneumonia rather than meningitis specifically [24].

For malignant brain neoplasm, absolute deaths increased substantially, but the overall AAPC was not significantly different from zero after overdispersion adjustment. Population growth and age structure accounted for most of the increase. Similar patterns have been reported globally, with rising absolute brain and CNS cancer deaths but smaller or heterogeneous changes in age-standardized mortality [7]. Regional studies also highlight substantial variability in incidence,

mortality, diagnostic ascertainment, and registry completeness across Central and South America [25].

Taken together, these results show why neurological mortality should not be represented by a single aggregate trend. Cerebrovascular disease reflects declining recorded age-specific mortality under strong demographic pressure; dementia and Parkinson disease show increasing standardized mortality; epilepsy and meningitis show long-term improvement; and malignant brain neoplasm remains comparatively stable after standardization. The changing cause composition is therefore not simply a consequence of population aging but also reflects opposing disease-specific mortality trends.

4.1. Limitations and strengths

Several strengths support the findings. The study covered 28 consecutive years of national data, used a single contemporary population revision, reproduced all 168 official disease-year mortality totals and all 1,512 population validation cells, and combined age standardization with weighted segmented regression, overdispersion adjustment, bootstrap assessment, and Shapley decomposition. Sensitivity analyses using three-year endpoints and the pre-pandemic period preserved the principal directions.

Important limitations remain. Exact agreement with INEC totals confirms computational reproducibility but cannot correct deaths that were never registered or inaccurately certified. Moreover, the mortality-rate component of the Shapley decomposition cannot separate changes in underlying disease mortality from temporal changes in cause-of-death ascertainment and coding practices. Previous work has documented geographic and demographic inequalities in Ecuadorian mortality-data completeness and quality [26]. Underlying-cause mortality may also underestimate

dementia and Parkinson disease [17–19,22], and improvements in diagnostic access and certification may contribute to temporal increases. The six conditions do not encompass all neurological mortality, and historical data did not permit consistent sex-specific age-standardized analyses across the entire period. Finally, segmented regression identifies statistical slope changes rather than causal historical breakpoints, and the ecological design cannot attribute trends to specific policies, treatments, or exposures.

From a public-health perspective, the findings support disease-specific planning rather than a uniform neurological strategy. Cerebrovascular prevention and acute-care capacity remain essential despite declining standardized mortality; dementia and Parkinson disease increasingly require chronic neurological, geriatric, rehabilitation, caregiver, and social-care services; and gains in epilepsy and meningitis should be preserved. Stronger mortality certification, multiple-cause analyses, and linkage with clinical and administrative data would improve future neurological surveillance.

5. Conclusions

Between 1997 and 2024, Ecuador experienced a heterogeneous transition in neurological mortality. Cerebrovascular deaths increased despite declining age-standardized mortality, whereas dementia/Alzheimer and Parkinson disease showed rising standardized mortality and positive contributions from changing age-specific rates. Epilepsy and meningitis showed long-term improvements, while malignant brain neoplasm mortality remained comparatively stable after age standardization.

These patterns were robust across segmented models, bootstrap analyses, demographic decomposition, three-year endpoint sensitivity analyses, and pre-pandemic analyses. Neurological

health planning in Ecuador should therefore distinguish absolute mortality burden from changes in recorded age-standardized mortality and adopt disease-specific priorities, combining continued cerebrovascular prevention with expanding neurodegenerative-disease care and stronger population surveillance.

List of abbreviations

AAPC: Average annual percentage change.

APC: Annual percentage change.

ASMR: Age-standardized mortality rate.

BIC: Bayesian information criterion.

CI: Confidence interval.

CNS: Central nervous system.

GBD: Global Burden of Disease.

ICD-10: International Classification of Diseases, Tenth Revision.

INEC: Instituto Nacional de Estadística y Censos (National Institute of Statistics and Censuses).

WHO: World Health Organization.

Declarations

Ethics approval and consent to participate

This nationwide study involved secondary analysis of publicly available, de-identified mortality records and aggregate population estimates from Ecuador's Instituto Nacional de Estadística y

Censos (INEC). No directly identifying information was accessed, and no individuals were contacted.

Clinical trial registration

Clinical trial number: not applicable. This study was a retrospective analysis of publicly available national mortality and population data and did not involve any clinical intervention or prospective assignment of participants.

Consent for publication

Not applicable. The manuscript contains no individually identifiable information.

Availability of data and materials

The mortality records and population estimates analysed in this study are publicly available from Ecuador's Instituto Nacional de Estadística y Censos (INEC), as detailed in the data-source references. The analytical code and non-restricted derived datasets supporting the findings are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific funding from public, commercial, or not-for-profit funding agencies.

Authors' contributions

APMG contributed to conceptualization, methodology, investigation, formal analysis, data curation, project administration, software development and writing of the original draft. GGMG contributed to conceptualization, supervision, and reviewing and editing the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Steinmetz JD, Seeher KM, Schiess N, et al. Global, regional, and national burden of disorders affecting the nervous system, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Neurol*. 2024;23(4):344-381. doi:10.1016/S1474-4422(24)00038-3

2. Martinez R, Muñoz-Venturelli P, Ordunez P, et al. Risk and impact of stroke across 38 countries and territories of the Americas from 1990 to 2021: a population-based trends analysis from the Global Burden of Disease Study 2021. *The Lancet Regional Health - Americas*. 2025;43:101017. doi:10.1016/j.lana.2025.101017

3. Feigin VL, Vos T, Nair BS, et al. Global, regional, and national burden of epilepsy, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Public Health*. 2025;10(3):e203-e227. doi:10.1016/S2468-2667(24)00302-5

4. Wunrow HY, Bender RG, Vongpradith A, et al. Global, regional, and national burden of meningitis and its aetiologies, 1990–2019: a systematic analysis for the Global Burden of

Disease Study 2019. *Lancet Neurol*. 2023;22(8):685-711. doi:10.1016/S1474-4422(23)00195-3

5. Duan Y, Han C, Zheng H, Yu J, Luo M. Global, regional, and national burden of Alzheimer's disease and other dementias from 1990 to 2021: findings from the Global Burden of Disease Study 2021. *Front Aging Neurosci*. 2025;17. doi:10.3389/fnagi.2025.1678212

6. Li M, Ye X, Huang Z, Ye L, Chen C. Global burden of Parkinson's disease from 1990 to 2021: a population-based study. *BMJ Open*. 2025;15(4):e095610. doi:10.1136/bmjopen-2024-095610

7. Zhou J, Gu L, Du F, et al. The global, regional, and national brain and CNS cancers burden and trends from 1990 to 2021. *Sci Rep*. 2025;15(1):19228. doi:10.1038/s41598-025-04636-7

8. INEC. Registro Estadistico de Defunciones Generales. Instituto Nacional de Estadística y Censos (INEC). 2024. Accessed September 16, 2026. https://www.ecuadorencifras.gob.ec/defunciones-generales/

9. INEC. Estimaciones y Proyecciones de Poblacion, Nacional, Provincial, Cantonal, Revision 2024. Instituto Nacional de Estadística y Censos (INEC). 2024. Accessed September 16, 2026. https://www.ecuadorencifras.gob.ec/estimaciones-y-proyecciones-de-poblacion-revision-2024/

10. Omar BA, Cynthia BP, Alan DL, Christopher JM, Rafael L, Mie I. Age standardization of rates: a new WHO standard. GPE Discussion Paper Series No. 31. Geneva: World Health Organization. 2001. Accessed September 16, 2026. https://cdn.who.int/media/docs/default-

source/gho-documents/global-health-estimates/gpe_discussion_paper_series_paper31_2001_age_standardization_rates.pdf

11. Fay MP, Feuer EJ. Confidence intervals for directly standardized rates: a method based on the gamma distribution. *Stat Med*. 1997;16(7):791-801. doi:10.1002/(sici)1097-0258(19970415)16:7<791::aid-sim500>3.0.co;2-#

12. Cheng X, Tan L, Gao Y, Yang Y, Schwebel DC, Hu G. A new method to attribute differences in total deaths between groups to population size, age structure and age-specific mortality rate. *PLoS One*. 2019;14(5):e0216613. doi:10.1371/journal.pone.0216613

13. Feigin VL, Abate MD, Abate YH, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Neurol*. 2024;23(10):973-1003. doi:10.1016/S1474-4422(24)00369-7

14. He Q, Wang W, Zhang Y, et al. Global, Regional, and National Burden of Stroke, 1990–2021: A Systematic Analysis for Global Burden of Disease 2021. *Stroke*. 2024;55(12):2815-2824. doi:10.1161/STROKEAHA.124.048033

15. Brauer M, Roth GA, Aravkin AY, et al. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *The Lancet*. 2024;403(10440):2162-2203. doi:10.1016/S0140-6736(24)00933-4

16. Ribeiro F, Teixeira-Santos AC, Caramelli P, Leist AK. Prevalence of dementia in Latin America and Caribbean countries: Systematic review and meta-analyses exploring age, sex, rurality, and education as possible determinants. *Ageing Res Rev*. 2022;81:101703. doi:10.1016/j.arr.2022.101703

17. Wolters FJ, Harteloh PPM, van Rooij FJA, et al. Diagnostic value of death certificates for case ascertainment of dementia: A population-based assessment of mortality registry data. *Journal of Alzheimer's Disease*. 2026;110(3):1428-1437. doi:10.1177/13872877261423958

18. Perera G, Stewart R, Higginson IJ, Sleeman KE. Reporting of clinically diagnosed dementia on death certificates: retrospective cohort study. *Age Ageing*. 2016;45(5):667-672. doi:10.1093/ageing/afw077

19. Ahmad S, Carey IM, Harris T, Cook DG, DeWilde S, Strachan DP. The rising tide of dementia deaths: triangulation of data from three routine data sources using the Clinical Practice Research Datalink. *BMC Geriatr*. 2021;21(1):375. doi:10.1186/s12877-021-02306-7

20. Livingston G, Huntley J, Liu KY, et al. Dementia prevention, intervention, and care: 2024 report of the Lancet standing Commission. *The Lancet*. 2024;404(10452):572-628. doi:10.1016/S0140-6736(24)01296-0

21. Kim DJ, Isidro-Pérez AL, Doering M, et al. Prevalence and Incidence of Parkinson's Disease in Latin America: A Meta-Analysis. *Movement Disorders*. 2024;39(1):105-118. doi:10.1002/mds.29682

22. Benito-León J, Louis ED, Villarejo-Galende A, Romero JP, Bermejo-Pareja F. Under-reporting of Parkinson's disease on death certificates: A population-based study (NEDICES). *J Neurol Sci*. 2014;347(1-2):188-192. doi:10.1016/j.jns.2014.08.048

23. Pacheco-Barrios K, Navarro-Flores A, Cardenas-Rojas A, et al. Burden of epilepsy in Latin America and The Caribbean: a trend analysis of the Global Burden of Disease Study 1990

– 2019. *The Lancet Regional Health - Americas*. 2022;8:100140. doi:10.1016/j.lana.2021.100140

24. de Oliveira LH, Shioda K, Valenzuela MT, et al. Declines in Pneumonia Mortality Following the Introduction of Pneumococcal Conjugate Vaccines in Latin American and Caribbean Countries. *Clinical Infectious Diseases*. 2021;73(2):306-313. doi:10.1093/cid/ciaa614

25. Piñeros M, Sierra MS, Izarzugaza MI, Forman D. Descriptive epidemiology of brain and central nervous system cancers in Central and South America. *Cancer Epidemiol*. 2016;44:S141-S149. doi:10.1016/j.canep.2016.04.007

26. Peralta A, Benach J, Borrell C, et al. Evaluation of the mortality registry in Ecuador (2001–2013) – social and geographical inequalities in completeness and quality. *Popul Health Metr*. 2019;17(1):3. doi:10.1186/s12963-019-0183-y

Tables

Table 1. Temporal changes in mortality for six neurological conditions in Ecuador, 1997–2024.

Condition	Deaths 1997	Deaths 2024	Deaths change (%)	Crude rate 1997	Crude rate 2024	Crude rate change (%)	ASMR 1997 (95% CI)	ASMR 2024 (95% CI)	ASMR change (%)	AAPC (95% CI)	P value
Brain malignant neoplasm	165	423	156.36	1.39	2.35	69.30	1.93 (1.64 to 2.27)	2.37 (2.15 to 2.61)	22.91	0.31 (-0.39 to 1.02)	0.39

Cerebrovascular disease	2280	4836	112.11	19.22	26.92	40.07	30.53 (29.27 to 31.83)	25.50 (24.78 to 26.24)	-16.47	-0.85 (-1.29 to -0.40)	<0.001
Dementia/Alzheimer	42	1033	2359.52	0.35	5.75	1524.21	0.59 (0.42 to 0.79)	4.75 (4.46 to 5.05)	711.08	7.73 (7.13 to 8.34)	<0.001
Epilepsy/status epilepticus	288	322	11.81	2.43	1.79	-26.17	2.62 (2.31 to 2.96)	1.77 (1.58 to 1.98)	-32.30	-1.33 (-1.82 to -0.84)	<0.001
Meningitis	134	93	-30.60	1.13	0.52	-54.17	0.98 (0.81 to 1.18)	0.53 (0.43 to 0.65)	-45.40	-3.12 (-3.86 to -2.38)	<0.001
Parkinson disease	60	352	486.67	0.51	1.96	287.42	0.85 (0.64 to 1.09)	1.78 (1.60 to 1.98)	110.63	2.50 (1.56 to 3.44)	<0.001

Crude and age-standardized mortality rates are expressed per 100,000 population. ASMRs were calculated by direct standardization to the WHO World Standard Population. AAPCs were estimated using weighted segmented log-linear regression. Confidence intervals and P values were adjusted for residual overdispersion using the Pearson χ^2-to-residual-degrees-of-freedom ratio, with the dispersion factor constrained to a minimum of 1.

Table 2. Shapley decomposition of the change in annual deaths between 1997 and 2024.

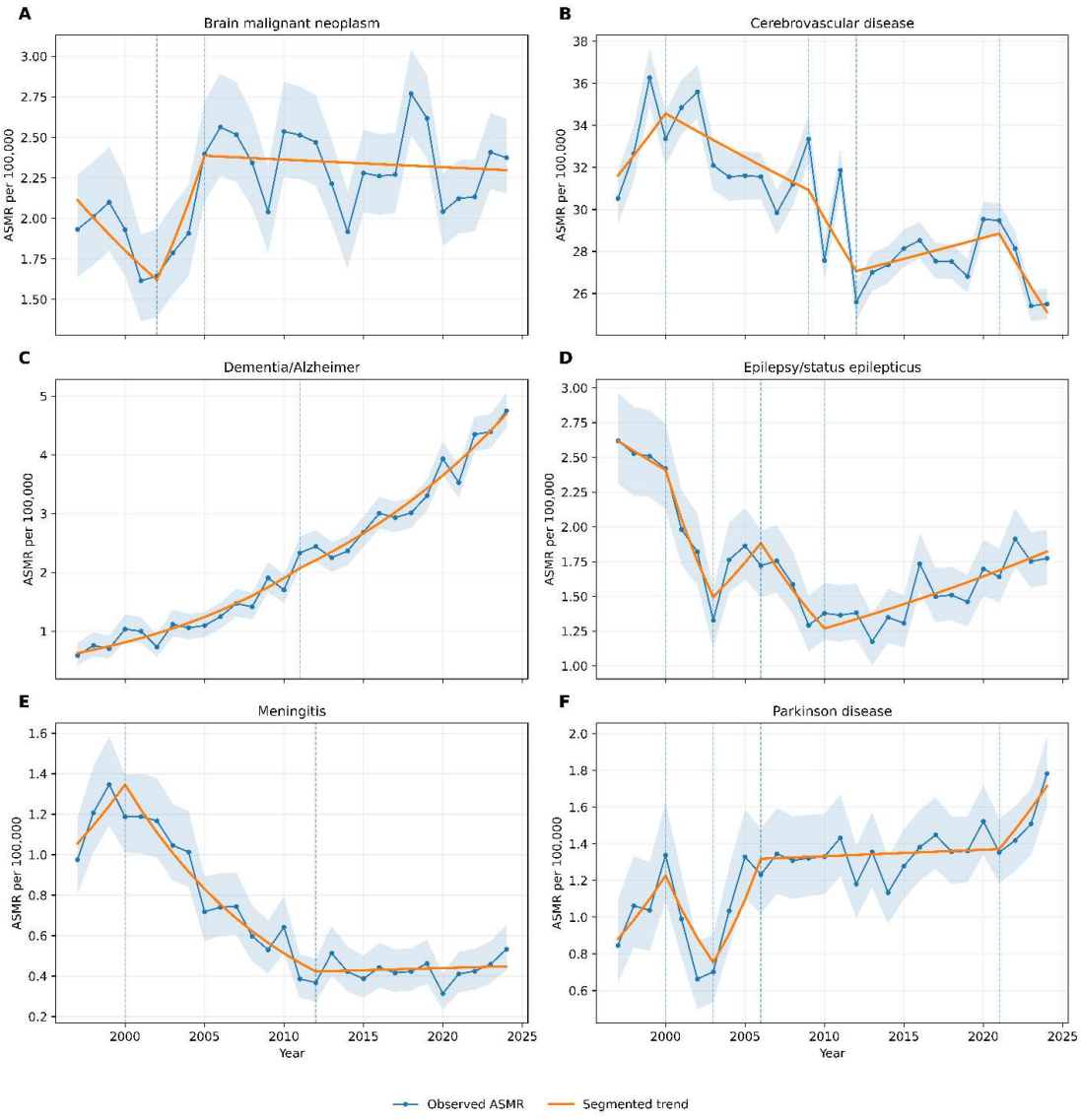
Condition	Deaths 1997	Deaths 2024	Net change	Population growth effect	Age-structure effect	Age-specific mortality-rate effect
Brain malignant neoplasm	165	423	258	113.2	88.0	56.8
Cerebrovascular disease	2280	4836	2556	1423.8	1759.5	-627.3
Dementia/Alzheimer	42	1033	991	161.5	238.4	591.2
Epilepsy/status epilepticus	288	322	34	128.6	39.0	-133.6

Meningitis	134	93	-41	47.6	-10.3	-78.3
Parkinson disease	60	352	292	70.2	97.8	124

The observed change was decomposed into contributions from population growth, changes in age structure, and changes in age-specific mortality rates. Positive values indicate contributions toward higher mortality counts; negative values indicate mortality reductions. Components may act in opposite directions.

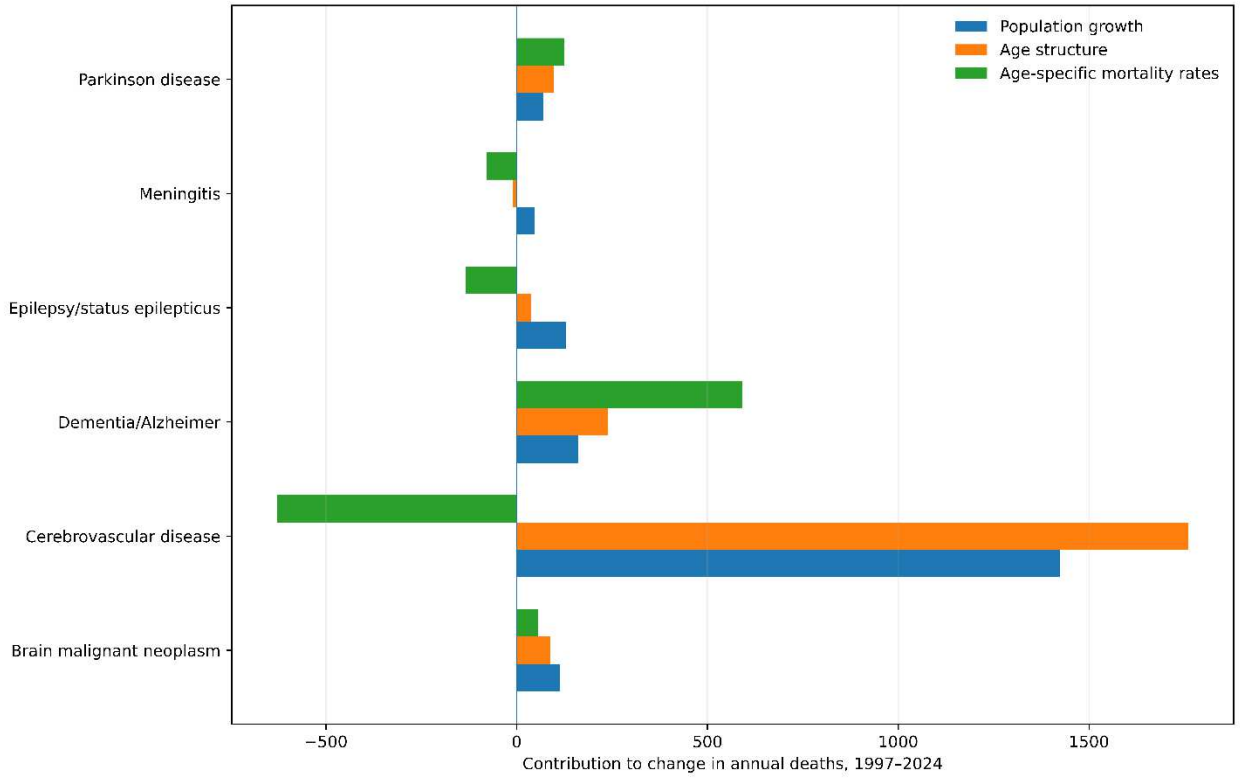
Figures

Figure 1. Age-standardized mortality trends for six selected neurological conditions in Ecuador, 1997–2024.



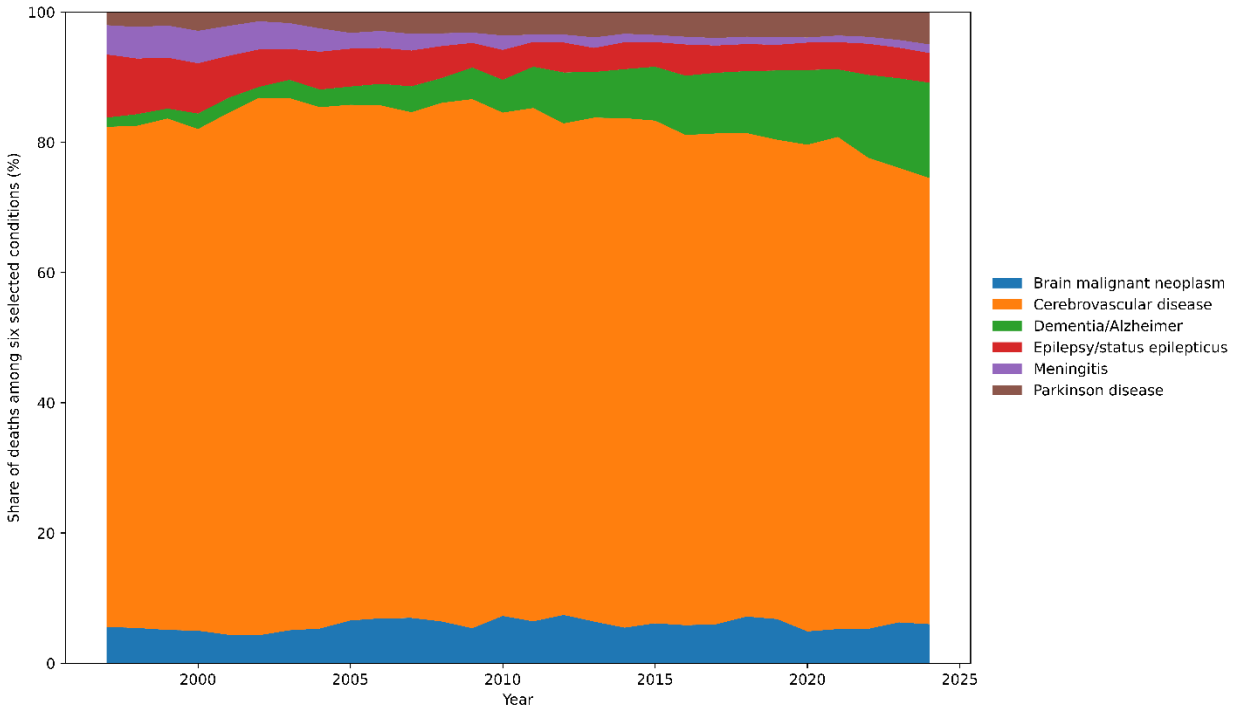
Annual age-standardized mortality rates (ASMRs) per 100,000 population were calculated by direct standardization to the WHO World Standard Population. Points and connecting lines represent observed annual ASMRs, and shaded areas indicate 95% confidence intervals calculated using the Fay–Feuer gamma method. Solid fitted lines represent weighted segmented log-linear regression models selected using the Bayesian information criterion (BIC), and vertical dashed lines indicate selected breakpoints. Panels show (A) brain malignant neoplasm, (B) cerebrovascular disease, (C) dementia/Alzheimer, (D) epilepsy/status epilepticus, (E) meningitis, and (F) Parkinson disease. Breakpoint stability was evaluated using parametric bootstrap resampling and is reported in the Supplementary Material. Note that y-axis scales differ across panels.

Figure 2. Shapley decomposition of changes in annual deaths for six selected neurological conditions in Ecuador, 1997–2024.



Changes in annual deaths between 1997 and 2024 were decomposed using a Shapley approach into contributions from population growth, changes in population age structure, and changes in age-specific mortality rates. Positive values indicate contributions toward an increase in annual deaths, whereas negative values indicate contributions toward a reduction in deaths. For each condition, the three components sum exactly to the observed net change in annual deaths. A sensitivity analysis comparing three-year windows (1997–1999 vs 2022–2024) preserved the direction of all three components in all six conditions.

Figure 3. Changing cause composition of mortality among six selected neurological conditions in Ecuador, 1997–2024.



The 100% stacked-area plot shows the annual proportional distribution of deaths across the six neurological conditions included in the analysis. Percentages were calculated relative to the total number of deaths from these six selected conditions in each year; therefore, the figure describes

484 changes in the composition of the analytic set and should not be interpreted as the distribution of
485 all neurological deaths in Ecuador. Cerebrovascular disease remained the largest component
486 throughout the study period, while the relative contribution of dementia/Alzheimer disease
487 increased over time.

488 **Additional files**

489 **Additional file 1**

490 File name: Additional_file_1.docx

491 Title: Supplementary tables for neurological mortality trends and demographic decomposition in
492 Ecuador, 1997–2024.

493 Description: Supplementary Tables S1–S10C, including validation of mortality counts and
494 population denominators, segmented regression model selection and diagnostics, bootstrap
495 analyses, demographic decomposition sensitivity analyses, and pre-pandemic mortality trends.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.docx