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Revista APM

Asociación Psiquiátrica Mexicana

Volumen 5 - Número 2

Editorial

Neuromodulation in Psychiatry: A Call to Professional and Institutional Renewal
Aldana López

Original Article

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Lesley Abril-Medina, et al.

Original Article

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Sobre Nosotros

Asociación Psiquiátrica Mexicana, A.C.

Antecedentes

La **Asociación Psiquiátrica Mexicana, A.C.**, constituida en 1966, es la organización médico-psiquiátrica que agrupa al mayor número de miembros con más de tres mil integrantes en todo el país.

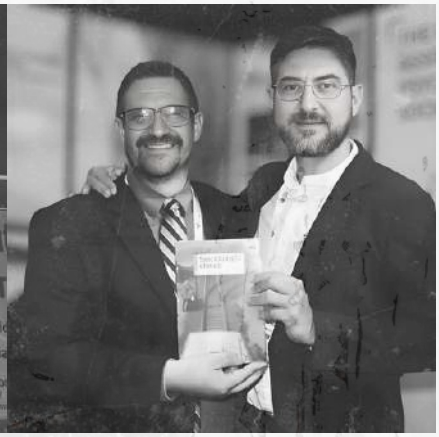
Su finalidad es promover la unidad en esta rama de la medicina, así como incentivar el desarrollo del conocimiento de esta tanto para sus socios como para el público en general; lo anterior, mediante educación continua en temas sobre profesionalismo, ética, práctica clínica, investigación en las ciencias de la salud mental.

Desde su origen, se distingue por el compromiso con contribuir socialmente de manera permanente y con tanto la divulgación como la difusión respecto a esta disciplina de la medicina científica.

Para lograrlo, organiza eventos locales, congresos nacionales, reuniones colegiadas y mantiene una editorial propia en constante expansión, que, al día de hoy, incorpora a este órgano de difusión periódica y la producción literaria de alta calidad.

Además, la institución participa de manera activa en la consolidación de políticas públicas en salud mental, en el fortalecimiento de la enseñanza de la psiquiatría en el rubro universitario, así como en la promoción de una práctica clínica fundamentada en evidencia científica sustentada, ética y humana.

Asimismo, mantiene vínculos de colaboración con organismos nacionales e internacionales, entre ellos la **Asociación Mundial de Psiquiatría**, lo que favorece la proyección de la psiquiatría mexicana y su integración en redes gremiales globales.



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El **Comité Editorial** fue designado al inicio del bienio 2024–2025 por el Dr. Alejandro Molina-López, en su calidad de presidente de la Asociación Psiquiátrica Mexicana, A.C. La composición de este grupo colegiado puede estar sujeta a modificaciones conforme a los estatutos de la Asociación, sin que ello afecte la validez de los procesos editoriales en curso ni la integridad científica de los contenidos publicados.

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La **Revista de la Asociación Psiquiátrica Mexicana, A.C.** se erige como el órgano oficial de difusión del gremio, destinado a difundir conocimiento científico de alta calidad, y constituirse como un referente nacional e internacional en el ámbito de la psiquiatría contemporánea.

Visión

Consolidarse como una publicación de referencia en las ciencias de la salud mental en México y Latinoamérica, con impacto internacional, y sustentada en la excelencia científica, la ética editorial y la innovación.

La **Revista de la Asociación Psiquiátrica Mexicana, A.C.** aspira a ser un espacio de encuentro transdisciplinario que articule la investigación básica, clínica y psicosocial con la práctica profesional, contribuyendo a incentivar la difusión del conocimiento en esta rama de la salud en mejores estándares de atención sanitaria.

Misión

Difundir el conocimiento original, riguroso y actualizado en las ciencias de la salud mental y disciplinas afines mediante un proceso editorial transparente y de calidad que garantice la integridad académica de sus publicaciones.

La **Revista de la Asociación Psiquiátrica Mexicana, A.C.** tiene como misión fomentar el diálogo entre investigadores, clínicos y profesionales de esta rama de la salud, incentivar la formación y educación de nuevas generaciones de investigadores, y promover una comprensión integral de la salud mental en el contexto mexicano y global, respetando la diversidad cultural y las necesidades emergentes de México.

Congreso Mundial de Psiquiatría 2024, organizado con la Asociación Psiquiátrica Mundial y la Asociación Psiquiátrica Mexicana, A.C. En la imagen: Dr. Alejandro Molina López (presidente 2024-2025), Dra. Wannuta Wasserman (directora de la Asociación Psiquiátrica Mundial) y Dr. Juan Ramón de la Fuente (Canciller de México)

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La **Revista APM de la Asociación Psiquiátrica Mexicana, A.C.** se encuentra indexada en Latindex (Directorio y Catálogo v2.0), Google Scholar, ROAD (Directory of Open Access scholarly Resources), LatinREV (FLACSO-Argentina), Scilit, y en OpenAIRE mediante su integración con Zenodo; adicionalmente, mantiene presencia en catálogos y directorios regionales y especializados que consolidan su visibilidad académica en el ámbito de las Ciencias de la Salud Mental, tanto en México como en América Latina, con proyección internacional.

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REVISTA APM
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Editorial

Neuromodulation in Psychiatry: A Call to Professional and Institutional Renewal

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Abstract
This editorial calls for the immediate integration of neuromodulation into psychiatric education and care. It urges professionals and institutions in Mexico and Latin America to update their standards, address ethical and regulatory gaps, and ensure the responsible and widespread implementation to maintain the moral and scientific integrity of psychiatry. Policymakers should develop standardized regulatory guidelines, foster institutional partnerships with global neuromodulation organizations, and require certified training programs to prepare clinicians for emerging advances. Establishing neuromodulation networks among hospitals and clinics will facilitate the rapid exchange of practical experiences and support collaborative problem-solving, thereby accelerating adoption and improving clinical outcomes.

Keywords
Neuromodulation; Psychiatry; Transcranial Magnetic Stimulation

Foreword

The field of neuromodulation has gained a greater presence at international congresses, simultaneously driving the creation of specialized clinical training workshops, professional diploma programs, and residency modules. This trajectory demonstrates a sustained commitment to expanding therapeutic modalities for psychiatrists, moving well beyond a fleeting trend. In 2024, the American Psychiatric Association (APA) formally endorsed Transcranial Magnetic Stimulation (TMS) as a demonstrably safe and evidence-based intervention for treatment-resistant depression. Furthermore, the APA advocated for its integration of neuromodulation into psychiatric residency curricula and encouraged financial support and improved accessibility, thereby reinforcing the clinical legitimacy of neuromodulation.

Developments

Despite such international recognition, many Latin American nations, including Mexico, continue to face significant regulatory challenges, a shortage of specialized training opportunities, and inequitable patient access. For illustration, a 2023 survey found that only 25 percent of psychiatric institutions in Mexico regularly used neuromodulation, citing both high costs and a lack of trained personnel as significant barriers. Regional studies confirm growing interest, evidenced by a steady increase in scholarly publications and clinical trials.

Nevertheless, a segment of clinicians continues to regard neuromodulation as experimental or prohibitively expensive, limiting its availability to patients who are either resistant to or intolerant of standard pharmacological treatments. A noteworthy regional achievement is exemplified by a Mexican startup that reportedly achieved a 90 percent reduction in psychiatric treatment costs in 2023, attracting investment from Mark Zuckerberg's sister. Such innovation underscores the regional potential to make neuromodulation more affordable and accessible.

To effectively address these disparities, comprehensive and multifaceted strategies are essential. These include strengthening continuing medical education, fostering professional collaboration, formally incorporating neuromodulation into psychiatric training programs, and establishing clear national guidelines for the use of neuromodulation. Additionally, editorial initiatives and the development of Latin American policies, such as those promoted by the Latin American Society of Biological Psychiatry, are crucial steps toward standardizing regional practices. Cross-country cooperation is essential for addressing the region's specific needs and ensuring that clinicians have the necessary resources for implementation.

Future Perspective

Looking forward, the trajectory of neuromodulation must advance rapidly through its integration with psychotherapy and the accelerated development of individualized interventions guided by functional neuroimaging and artificial-intelligence-based brain network mapping. Incorporating neuromodulation into psychotherapy can enhance treatment efficacy by aligning therapeutic objectives with brain stimulation protocols, thereby promoting more comprehensive patient care. The use of neuroimaging for individualized intervention design enables clinicians to tailor treatments to distinct brain patterns, optimizing outcomes. The expanding range of clinical indications, including obsessive-compulsive disorder, autism spectrum disorders, chronic pain, cognitive decline, and schizophrenia, further underscores neuromodulation's pivotal and expanding role in contemporary psychiatry (Padberg & George, 2009).

Closing Remarks

In summary, neuromodulation is employed to supplement clinical judgment, not to replace it; this approach requires comprehensive consent, equitable access, and ongoing assessment of long-term effects. Take immediate steps: educate patients thoroughly, introduce subsidies or sliding payment scales, and expand equitable outreach. Embrace innovation with rigorous ethics and strong leadership. The renewed field depends on your action. Neuromodulation serves as a complement to, not a substitute for, clinical judgment. Its responsible implementation requires comprehensive patient consent, a commitment to equitable access, and continuous evaluation of its long-term impacts. Immediate actions are necessary: we must ensure thorough patient education, establish subsidies or sliding payment scales to promote fairness, and actively expand equitable outreach. Moving forward, we must embrace innovation while maintaining rigorous ethical standards and strong leadership. The future of this revitalized field depends on these decisive actions.

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Original Article

Multimodal Hippocampal Spectroscopy and Cognitive Profile in Mesial Temporal Lobe Epilepsy: A Case–Control Study

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Abstract
Introduction. Mesial temporal lobe epilepsy (MTLE) is one of the most common forms of focal epilepsy and a major cause of pharmacoresistance. Hippocampal magnetic resonance spectroscopy (MRS) and multimodal cognitive evaluation allow examination of its metabolic and functional correlates. Objective. To determine whether hippocampal MRS abnormalities differentiate MTLE from healthy controls and to characterize the cognitive profile using the NEUROPSI battery. Materials and Methods. Retrospective case–control study (N = 175; 85 MTLE, 90 controls). Structural MRI, hippocampal MRS, interictal SPECT, EEG/video-EEG, and age- and education-adjusted NEUROPSI were analyzed. Mixed-effects models, logistic regression, and ANCOVA with covariates (age, sex, education) and false-discovery-rate correction were applied. Results. Hippocampal NAA/Cr and NAA/Cho ratios were lower in MTLE than in controls (NAA/Cr: $t(173) = 13.8$, $p < .001$; NAA/Cho: $t(173) = 11.5$, $p < .001$). A significant group × hemisphere interaction ($F(1, 173) = 18.4$, $p < .001$) showed left-sided predominance. Logistic regression for abnormal MRS produced adjusted OR = 8.70 (95 % CI [4.00, 18.80], $p < .001$; AUC = 0.91). NEUROPSI revealed the largest group effect in visuospatial skills ($F(1, 171) = 45.2$, $p < .001$, partial $\eta^2 = 0.21$), followed by attention/concentration and executive functions. Conclusions. Hippocampal MRS detects a distinctive metabolic pattern in MTLE and is associated with a selective cognitive profile affecting visuospatial, attentional, and executive domains, supporting its incorporation into multimodal neuropsychiatric assessment.

Keywords
Epilepsy, Temporal Lobe; Hippocampus; Magnetic Resonance Spectroscopy; Visuospatial Attention; Neuropsychology; Mexico

Introduction

Mesial temporal lobe epilepsy (MTLE) is the most prevalent form of focal epilepsy and one of the principal indications for surgical evaluation when seizures remain drug resistant. Randomized controlled trials and meta-analyses have consistently shown that surgical intervention offers superior seizure control compared with continued pharmacotherapy, whereas approximately one-third of all individuals with epilepsy eventually meet criteria for pharmacoresistance (Kalilani et al., 2018; Wiebe et al., 2001). These figures underscore the critical need for diagnostic strategies that can distinguish pathological hippocampal alterations from normal brain variations. Standard diagnostic assessments integrate clinical semiology, surface electroencephalography (EEG), long-term video-EEG monitoring, and magnetic resonance imaging (MRI); nevertheless, each modality on its presents notable limitations. Routine EEG may fail to record interictal epileptiform discharges due to its restricted spatial sampling, and up to 30 percent of clinically defined MTLE cases display structurally normal hippocampi on MRI (Javidan, 2012; Noachtar & Rémi, 2009). Consequently, incorporating complementary imaging approaches that assess neuronal metabolism and synaptic connectivity becomes indispensable. Proton magnetic resonance spectroscopy (^{1}H-MRS) quantifies metabolites associated with neuronal viability, membrane turnover, and glial proliferation. Previous research has demonstrated consistent ipsilateral reductions of N-acetylaspartate (NAA) and decreased NAA-to-creatine (Cr) and NAA-to-choline (Cho) ratios in MTLE, even in the absence of visible structural abnormalities on MRI (Connelly et al., 1994). The application of multivoxel magnetic resonance spectroscopic imaging (MRSI) further enhances spatial mapping and improves the precision of seizure-focus lateralization (Pan & Kuzniecky, 2015). In parallel, perfusion imaging with interictal single-photon emission computed tomography (SPECT) can detect hypoperfusion within epileptogenic mesial temporal regions, thereby contributing additional functional evidence (von Oertzen et al., 2011). Cognitive assessment provides an indispensable complement to metabolic and electrophysiological data by delineating the functional consequences of hippocampal pathology. The NEUROPSI battery, developed and validated in Mexico, includes age- and education-adjusted normative data, measuring orientation, attention/concentration, coding, memory, language, reading/writing, visuospatial skills, executive functions, and overall performance (Ostrosky-Solís, Ardila, & Rosselli, 1999). Prior studies have indicated that MTLE selectively affects visuospatial and executive domains, patterns consistent with disruption of the hippocampal–parietal network (McAndrews & Cohn, 2012). Therefore, the integration of MRS, MRI, SPECT, EEG, and NEUROPSI within a unified analytic framework enables a multimodal characterization of MTLE that bridges structural, metabolic, and cognitive dimensions. Hence, comparing patients with MTLE against healthy controls provides a direct and reliable means of isolating disease-specific metabolic and cognitive alterations. Evidence from MRS and MRSI studies demonstrates lateralized hippocampal metabolic abnormalities that align with both seizure focus and histopathological findings (Connelly et al., 1994; Pan & Kuzniecky, 2015). Furthermore, EEG and SPECT contribute convergent electrophysiological and perfusion-based markers of epileptogenicity (von Oertzen et al., 2011), while the NEUROPSI battery offers psychometrically validated cognitive measures designed explicitly for Spanish-speaking populations (Ostrosky-Solís et al., 1999). Integrating these modalities increases diagnostic reliability and captures the multidimensional expression of hippocampal dysfunction. In addition, delineating the cognitive profile of Mexican individuals with MTLE contributes culturally contextualized data to the global epilepsy literature. Establishing normative and pathological spectroscopic benchmarks within local populations promotes equitable neurodiagnostic standards and enhances the translational relevance of findings. From a methodological perspective, analyzing continuous metabolic and cognitive variables within a single analytic model minimizes bias arising from dichotomization and aligns with current best practices for reproducible neuroscience (Pan & Kuzniecky, 2015).

Objective

To conduct a systematic review to identify and describe the main risk factors associated with suicidal ideation among medical students in Mexico, thereby providing information to support the design of preventive strategies.

Materials & Method

Hypothesis, Design, Setting & Timeframe

Patients with MTLE would demonstrate significantly lower hippocampal N-acetylaspartate-to-creatine (NAA/Cr) and N-acetylaspartate-to-choline (NAA/Cho) ratios compared with healthy controls, accompanied by poorer performance in visuospatial and attentional NEUROPSI domains. This study employed an observational, retrospective, descriptive, and analytic case–control design based on a secondary review of a clinical database. Data were obtained from comprehensive neuropsychiatric evaluations conducted between August 2022 and March 2023 at the Instituto Nacional de Psiquiatría Ramón de la Fuente Muñiz (Mexico City). Statistical and methodological analyses were performed at the Facultad de Estudios Superiores Zaragoza, Universidad Nacional Autónoma de México (UNAM), between October 2024 and March 2025.

Sample

Participants were selected through non-randomized convenience sampling. Inclusion criteria for the MTLE group were as follows: (1) Diagnosis established by a neurologist or neuropsychiatrist according to the International League Against Epilepsy (ILAE) 2017 operational classification of seizure types and epilepsies (Fisher et al., 2017). (2) Availability of complete datasets encompassing EEG/video-EEG, MRI, hippocampal MRS, SPECT, and NEUROPSI. (3) Adequate technical quality across modalities for analysis. Inclusion criteria for the control group included: absence of neurological, psychiatric, or systemic disorders; no history of substance use; and normal findings on neurological examination, EEG, MRI, and MRS. Exclusion criteria for both groups were: history of traumatic brain injury with loss of consciousness, metabolic or infectious encephalopathy, severe systemic illness, incomplete datasets, or inability to complete neuropsychological evaluation.

Measurement Instruments

Cognitive performance was assessed using the NEUROPSI battery (Neuropsychological Assessment in Spanish), developed and validated in Mexico (Ostrosky-Solís, Ardila, & Rosselli, 1999). This instrument provides age- and education-adjusted normative data, evaluating orientation, attention/concentration, coding, memory, language, reading/writing, visuospatial skills, executive functions, and total performance. Internal consistency coefficients range from Cronbach's $\alpha = 0.86$ to 0.92, interrater reliability exceeds 0.85, and test–retest reliability is $r = 0.88$ (Ostrosky-Solís et al., 1999). Concurrent validity with the Wechsler Adult Intelligence Scale (WAIS) and Halstead–Reitan subtests ranges between $r = 0.70$ and 0.84. In contrast, construct validity has been confirmed in Latin American cohorts (Rosselli, Matute, & Ardila, 2010). The NEUROPSI demonstrates sensitivity of 0.83 and specificity of 0.81 for detecting mild cognitive impairment in epilepsy populations, supporting its external validity.

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Measurement Instruments (Continued)

Structural MRI was obtained using a 3-Tesla scanner equipped with three-dimensional T1-weighted magnetization-prepared rapid gradient-echo (MPRAGE, voxel = 1 mm^3) and coronal T2-weighted sequences aligned to the hippocampal axis. Hippocampal proton magnetic resonance spectroscopy (^{1}H-MRS) employed a point-resolved spectroscopy (PRESS) sequence (repetition time = 2000 ms, echo time = 30 ms) to quantify N-acetylaspartate (NAA), creatine (Cr), and choline (Cho). Spectral quality criteria included a signal-to-noise ratio of ≥ 8, a linewidth of ≤ 0.08 ppm, and a Cramér–Rao lower bound of ≤ 20 percent. Two board-certified neuroradiologists independently verified voxel placement and spectral integrity. Interrater agreement for voxel localization exceeded κ = 0.90, and test–retest coefficient of variation was < 5 percent. Metabolite ratios NAA/Cr and NAA/Cho served as quantitative indicators of neuronal integrity and gliosis (Connelly et al., 1994; Pan & Kuzniecky, 2015). EEG and video-EEG recordings adhered to the international 10–20 system, with a sampling rate of≥ 256 Hz and a standard montage. Recording sessions lasted at least 30 minutes to ensure artifact-free segments were captured. Epileptiform activity was classified according to ILAE standards (Noachtar & Rémi, 2009; Javidan, 2012). All tracings were independently reviewed by two board-certified neurophysiologists, with interrater reliability κ = 0.84 (95% CI (0.78, 0.89). Interictal perfusion SPECT was performed using technetium-99m HMPAO under standardized resting conditions. Images were reconstructed with iterative algorithms and co-registered to the MRI for anatomical correspondence. Regional perfusion asymmetries ≥ 15 percent compared with contralateral homologous regions were deemed abnormal, consistent with established criteria (von Oertzen et al., 2011). Clinical severity was rated using the Clinical Global Impression (CGI) scale, and functional disability was assessed with the World Health Organization Disability Assessment Schedule (WHODAS 2.0, 36 items) (Üstün et al., 2010). Both scales were validated in Spanish, with internal consistency α values of 0.82 for the CGI and 0.90 for the WHODAS 2.0.

Procedure

This investigation was conducted as a secondary analysis of an institutional database. Before accessing the data, the principal investigator obtained formal authorization from the ethics committee. Following approval, the institutional data manager extracted only variables relevant to the present study, removed identifiers, and assigned encrypted alphanumeric codes. Data were anonymized in accordance with international standards, including the General Data Protection Regulation (European Union, 2018) and the Health Insurance Portability and Accountability Act (United States, 1996). The principal investigator and a senior researcher cross-validated data consistency against the original anonymized records. Discrepancies were resolved by consensus. The verified dataset was imported into R Studio (version 2024.09.0 + 382; Posit Software PBC, Boston, MA, USA) for analysis. Only anonymized datasets were used for computation, and all temporary files were deleted after verification was complete. All procedures adhered to the FAIR data principles (Findable, Accessible, Interoperable, Reusable) and institutional quality-assurance standards.

Ethical Aspects

This study adhered to the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013) and national biomedical research regulations (Reglamento de la Ley General de Salud en Materia de Investigación para la Salud, Cámara de Diputados, 2014). The protocol was approved by the Research and Ethics Committee of the Instituto Nacional de Psiquiatría Ramón de la Fuente Muñiz (registry CEI/C/020/2023, CONBIOÉTICA registration). All participants from the original database provided written informed consent, and assent was obtained when applicable. Data were fully anonymized before analysis and processed exclusively by authorized personnel on secure institutional servers.

Statistical Analysis

All analyses were performed in R Studio (version 2024.09.0 + 382; Posit Software PBC, Boston, MA, USA) using R version 4.3.0 (R Core Team, 2024). Descriptive statistics were reported as mean ± standard deviation (SD) or median (interquartile range [IQR]) for continuous variables and as frequency and percentage for categorical variables. Normality was verified using the Shapiro–Wilk test, and homogeneity of variance was assessed with Levene's test. Variables with normal distribution were analyzed using Welch's t test, whereas non-parametric data were examined using the Mann–Whitney U test. Categorical variables were assessed using the chi-square (χ^2) or Fisher's exact tests, as appropriate. All tests were two-tailed with α = .05. Continuous hippocampal metabolite ratios (NAA/Cr and NAA/Cho) were defined as the primary outcomes. Between-group differences were evaluated through linear mixed-effects models (Singmann et al., 2023) with participant as a random intercept and hemisphere as a within-subject factor. Covariates included age, sex, and education. Partial η^2 and 95 percent confidence intervals (CI) were calculated. Binary logistic regression models examined the association between MTLE and abnormal spectroscopy, defined as an NAA/Cr or NAA/Cho ratio of ≤ 1.30. Odds ratios (ORs) and 95 percent CIs were computed using the glm() function. Model calibration was verified via the Hosmer–Lemeshow test (df = 8), and discrimination was quantified using the area under the receiver-operating characteristic curve (AUC). Calibration slope, intercept, and Brier score were also reported. Variance inflation factors (VIF < 2) confirmed the absence of collinearity. Group differences in NEUROPSI domain scores were analyzed through ANCOVA, adjusting for age, sex, and education. Partial η^2 and 95 percent CIs were computed. Multiple testing across domains was corrected using the Benjamini–Hochberg false-discovery rate (FDR) (q < .05) (Benjamini & Hochberg, 1995). Ordinal outcomes, such as CGI severity, were modeled using proportional-odds logistic regression (package MASS), and proportionality was verified via the Brant test (Brant, 1990). Propensity-score weighting (package WeightIt; Greifer, 2024) served as a sensitivity analysis to balance baseline covariates. Diagnostic plots were used to confirm linearity, homoscedasticity, and normality of residuals.

Results

A total of 175 participants were analyzed, comprising 85 patients with mesial temporal lobe epilepsy (MTLE) and 90 healthy controls. The mean age in the MTLE group was 42.5 ± 16.2 years (median, 41; interquartile range, 29–55), whereas the control group had a mean age of 39.9 ± 15.0 years (median, 38; interquartile range, 27–50). The age difference was not statistically significant (Welch's t(173) = 1.09, p = .278, Cohen's d = 0.16). Women represented 48.2 percent of the MTLE group and 81.1 percent of the control group (χ^2(1, N = 175) = 26.8, p < .001, φ = 0.39). Mean years of education were 11.2 ± 3.1 for MTLE and 12.4 ± 2.8 for controls (t(173) = 2.80, p = .006, d= 0.42). Consequently, age, sex, and education were retained as covariates in all subsequent models.

All MTLE cases satisfied the ILAE 2017 operational criteria (Fisher et al., 2017). Median disease duration was 4.5 years (IQR = 2–6; range = 1–16). The seizure focus was left-sided in 48 patients (56.5%) and right-sided in 37 (43.5%). Psychiatric comorbidity occurred in 42 participants (49.4%), most frequently depressive disorders (31.8%) and anxiety disorders (20.0%). EEG/video-EEG demonstrated temporal-lobe epileptiform discharges in all MTLE participants; anterior temporal spikes and sharp waves were present in 78 (91.8%). MRI revealed unilateral mesial temporal sclerosis in every patient with MTLE. MRS showed reduced hippocampal metabolite ratios on the affected side, with a mean NAA/Cr ratio of 1.20 ± 0.25 and an NAA/Cho ratio of 1.15 ± 0.20. Contralateral hippocampal ratios were NAA/Cr = 1.60 ± 0.20 and NAA/Cho = 1.45 ± 0.18. Interictal SPECT revealed unilateral mesial temporal hypoperfusion in 76 (89.4%) and bilateral asymmetric hypoperfusion in 9 (10.6%). The mean global NEUROPSI z-score in MTLE was −1.2 ± 0.6 (median = −1.1, IQR = −1.6 to −0.8). Domain-specific z-scores were: visuospatial = −1.5 ± 0.7, attention/concentration = −1.1 ± 0.7, executive = −1.0 ± 0.7, memory = −0.8 ± 0.6, and language = −0.3 ± 0.5. Clinical Global Impression (CGI) severity ratings were mild in 6 patients (7.1%), moderate in 27 (31.8%), marked in 39 (45.9%), and severe in 13 (15.3%). The mean WHODAS 2.0 total score was 42.5 ± 8.7 (median, 43; interquartile range, 36–49). In controls, all EEG, MRI, and SPECT results were within normative limits. Mean hippocampal MRS ratios were NAA/Cr = 1.65 ± 0.15 (median = 1.65, IQR = 1.55–1.75) and NAA/Cho = 1.50 ± 0.12 (median = 1.50, IQR = 1.40–1.60). The global NEUROPSI z-score was −0.1 ± 0.5 (median = 0.0, IQR = −0.4 to 0.3); CGI = "not ill" for all. The mean WHODAS 2.0 score was 27.8 ± 6.9 (median = 28, IQR = 24–33).

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Results (Continued)

Mean NAA/Cr was significantly lower in MTLE (1.20 ± 0.25) than in controls (1.65 ± 0.15), Welch's $t(173) = 13.8$, $p < .001$, Cohen's $d = 2.09$ (95 % CI = 1.70, 2.48). Mean NAA/Cho was also reduced (1.15 ± 0.20 vs. 1.50 ± 0.12), Welch's $t(173) = 11.5$, $p < .001$, $d = 1.76$ (95 % CI = 1.38, 2.15). The mixed-effects model revealed a significant group × hemisphere interaction, $F(1, 173) = 18.4$, $p < .001$, indicating a predominant left-sided reduction in MTLE. Lateralization agreement across EEG, MRI, MRS, and SPECT was $\kappa = 0.82$ (95% CI = 0.74, 0.90). Binary logistic regression for abnormal MRS (ratio ≤ 1.30) yielded unadjusted OR = 9.33 (95% CI = 4.40, 19.80, $p < .001$); adjusted for age, sex, and education, OR = 8.70 (95% CI = 4.00, 18.80, $p < .001$). Hosmer–Lemeshow $\chi^2(8, N = 175) = 5.21$, $p = .736$; AUC = 0.91 (95 % CI = 0.86, 0.95); calibration slope = 0.97; intercept = 0.02; Brier score = 0.06. No collinearity was detected (VIF < 2).

ANCOVA, adjusting for covariates (age, sex, education), showed a main effect of group on visuospatial skills, $F(1, 171) = 45.2$, $p < .001$, partial $\eta^2 = 0.21$ (95% CI = 0.13, 0.29). Attention/concentration demonstrated $F(1, 171) = 17.8$, $p < .001$, $\eta^2 = 0.09$; executive functions, $F(1, 171) = 12.4$, $p = .001$, $\eta^2 = 0.07$. Memory ($F(1, 171) = 6.1$, $p = .014$, $\eta^2 = 0.03$) and coding ($F(1, 171) = 4.8$, $p = .030$, $\eta^2 = 0.03$) did not retain significance after FDR correction ($q > .05$). Orientation, language, and reading/writing domains showed no differences ($p \geq .08$, $\eta^2 < 0.02$). Propensity-score weighting confirmed significant spectroscopy and visuospatial effects (weighted $p < .001$). Ordinal logistic regression for CGI severity produced OR = 5.24 (95% CI = 3.11, 8.82, $p < .001$). The proportional-odds assumption was met (Brant test $p = .64$). WHODAS 2.0 total scores were significantly higher in MTLE than in controls (mean difference = 14.7, 95% CI = 12.1, 17.2, $t(173) = 9.54$, $p < .001$, Cohen's $d = 1.45$). Residual analyses confirmed normality and homoscedasticity; no influential outliers were detected. All tests were two-tailed with $\alpha = .05$, and random seeds were fixed to ensure reproducibility.

Discussion

The current case–control study integrated MRS, structural magnetic resonance imaging (MRI), interictal SPECT, EEG, and the NEUROPSI neuropsychological battery to investigate the metabolic and cognitive correlates of MTLE. The primary hypothesis, positing that hippocampal MRS abnormalities would differentiate MTLE patients from healthy controls, was corroborated. Hippocampal spectroscopy demonstrated a significant reduction in both NAA/Cr and NAA/Cho ratios among patients with MTLE, consistent with neuronal and axonal loss or mitochondrial dysfunction. These observed reductions are congruent with previous findings of ipsilateral NAA depletion in MTLE and its robust association with mesial temporal sclerosis (Connelly et al., 1994; Pan & Kuzniecky, 2015). The detected left-hemisphere predominance aligns with patterns previously described in dominant-temporal cases. Logistic and mixed-effects models evidenced a strong discriminative capacity, affirming that continuous spectroscopic indices serve as sensitive quantitative markers of mesial temporal dysfunction. While causality cannot be established, these metabolic findings lend support to the interpretation of hippocampal energy impairment as a characteristic feature of epileptogenic activity. Cognitively, NEUROPSI performance delineated a selective deficit profile. The domains of orientation, language, and reading/writing remained preserved; attention, concentration, and executive functions showed moderate impairment; and the most pronounced effect was observed in visuospatial skills. This pattern is suggestive of fronto-hippocampal and parietal-frontal network disruption rather than diffuse cortical dysfunction. Comparable cognitive profiles have been reported in MTLE cohorts, where nonverbal and attentional deficits correlate with a loss of hippocampal–parietal connectivity (Helmstaedter, 2017; McAndrews & Cohn, 2012). The preservation of verbal abilities further indicates a lateralization of pathology to the nondominant hemisphere in the majority of cases.

High concordance among EEG, MRI, SPECT, and MRS modalities ($\kappa = 0.82$) underscores the coherence between electrophysiological, metabolic, and structural indicators. This level of agreement parallels that reported in presurgical studies, which have shown 80–85 percent cross-modal consistency (von Oertzen et al., 2011). The present findings reinforce the interpretation that spectroscopic abnormalities correspond to genuine epileptogenic foci, adding diagnostic value when conventional MRI findings are equivocal or absent. The association between hippocampal metabolic reduction and selective cognitive deficits emphasizes the translational potential of spectroscopy in clinical decision-making. MRS can assist clinicians in differentiating MTLE from psychogenic or functional seizure presentations and refining seizure-focus lateralization before surgery.

Quantitative metabolic ratios may also inform prognostic evaluation, aiding in the prediction of postsurgical outcomes. In resource-limited contexts where positron-emission tomography (PET) is unavailable, MRS provides an accessible and non-invasive biomarker that enhances diagnostic accuracy and facilitates individualized presurgical planning (Bonilha et al., 2010).

Future research should advance from single-voxel to multivoxel or whole-brain spectroscopic imaging (MRSI) to capture metabolic gradients throughout limbic and parietal networks. Integration with diffusion-tensor imaging (DTI) and resting-state functional connectivity will elucidate the directional relationships among structural and metabolic abnormalities (Craver, 2007; Pan & Kuzniecky, 2015). Prospective longitudinal studies are warranted to determine whether normalization of NAA ratios after surgery predicts seizure control and cognitive recovery. Developing normative MRS databases for Latin American populations would enhance regional diagnostic precision and support artificial intelligence algorithms for automated classification. Furthermore, combining metabolic and cognitive indices in predictive models could improve presurgical decision-making and long-term prognostic accuracy.

This study's retrospective design limits causal inference and may introduce selection bias inherent to pre-existing datasets. Although the models were adjusted for age, sex, and education, residual confounding cannot be entirely ruled out. The sample size, while statistically adequate, restricted stratification by seizure laterality or degree of pharmacoresistance. Spectroscopy was limited to hippocampal voxels, omitting extratemporal and thalamic regions involved in seizure propagation. The cross-sectional design precluded temporal analysis of metabolic change or treatment response. Additionally, volunteer bias among the controls may have resulted in higher-than-average cognitive performance. Despite these limitations, the present results align with comparable single-center studies and provide a methodological framework for multicenter prospective replication to enhance external validity (Kwan et al., 2011).

The principal strength of this investigation lies in its multimodal design, which integrates metabolic, electrophysiologic, structural, and cognitive datasets within a unified analytic model. Continuous spectroscopic variables preserved quantitative information and avoided distortions produced by dichotomization, consistent with modern neuroimaging standards (Pan & Kuzniecky, 2015). Analytical rigor was ensured through mixed-model diagnostics, false discovery rate control, and independent verification of database integrity. Moreover, the use of NEUROPSI, standardized for Mexican populations, provides culturally contextualized normative benchmarks, thereby enriching regional neuropsychological reference data. Collectively, these features exemplify methodological consistency, in which multiple independent lines of evidence converge toward a coherent explanatory framework (Wilson, 1998).

Conclusions

MRS identified a consistent and reproducible metabolic signature of MTLE, characterized by reduced NAA/Cr and NAA/Cho ratios, with a left-hemisphere predominance. The corresponding cognitive profile revealed selective impairments in visuospatial, attentional, and executive domains, confirming the functional impact of disrupted hippocampal–parietal networks. Taken together, these findings demonstrate that hippocampal spectroscopy complements conventional MRI and EEG as part of an integrated diagnostic framework for MTLE. Incorporating spectroscopy into standard evaluation protocols can substantially enhance diagnostic accuracy, guide presurgical planning, and refine prognostic assessment. The present evidence supports MRS as a non-invasive, quantitative biomarker that bridges structural and functional dimensions of epileptic pathology.

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Conclusions (Continued)

Future research should pursue prospective and longitudinal validation of this multimodal framework, examining whether metabolic recovery correlates with postoperative seizure control and cognitive improvement. Expanding spectroscopic reference databases across Latin American populations will enhance regional diagnostic equity and provide the empirical foundation for artificial intelligence-based clinical decision tools. Ultimately, systematic integration of metabolic and neuropsychological indices will advance precision medicine in epilepsy, aligning neuropsychiatric care with reproducible and culturally contextualized scientific standards.

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Original Article

Patterns of Suicide Method Lethality by Sex: A Hospital-Based Pilot Study from Northern Mexico

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Conflicts of Interest
The authors declare no conflicts of interest

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Abstract
Background. Suicide remains a significant public-health concern in northern Mexico. Hospital-based data describing sex-related patterns in suicide methods can inform context-specific research and planning. Objective. This study describes the sociodemographic and clinical characteristics of patients treated for suicidal behavior at a psychiatric hospital in Chihuahua, Mexico. It identifies sex-related patterns in method lethality within a pilot descriptive framework. Materials and Methods. A cross-sectional pilot study analyzed patients admitted between January 2023 and September 2024. Sociodemographic, diagnostic, and behavioral variables were recorded. Psychiatric diagnoses were coded using the International Classification of Diseases, 11th Revision. Suicidal ideation, intent, and lethality were assessed with the Columbia Suicide Severity Rating Scale. Descriptive and comparative analyses were conducted in R Studio 2024. Results. Among the 497 records analyzed, 64% (n = 318) were women. Self-poisoning was the most common suicide method overall. Men more frequently used high-lethality methods, particularly hanging, compared to women. Mood and substance-use disorders were the most frequent diagnoses, with methamphetamine use notably higher among men. No differences by sex were observed in the severity of suicidal ideation or most precipitating factors. Conclusions. This pilot study provides an initial hospital-based profile of suicidal behavior in northern Mexico and highlights sex differences in method lethality. Ongoing, context-specific documentation will be essential to guide future analytical and longitudinal research on suicidal behavior in the region.

Keywords
Suicidal Behavior; Sex differences; Method Lethality; Psychiatric Hospital; Northern Mexico.

Introduction

Suicide remains a significant challenge for global public health. The World Health Organization (2021) estimates that over 700,000 people die by suicide each year, accounting for approximately 1.3% of global deaths. The Global Burden of Disease Study 1990–2016 demonstrates a persistent burden in most regions, despite modest declines in global rates (Naghavi, 2019). These findings underscore the ongoing importance of intentional self-harm as a cause of premature mortality and the necessity for continuous epidemiological surveillance. Psychiatric and psychological research identifies depression, substance use, and psychosocial adversity as the most common factors associated with suicidal behavior (Turecki & Brent, 2016). Reviews indicate that approximately 90% of individuals who die by suicide have at least one diagnosable mental disorder, most often a mood or psychotic disorder (Cavanagh et al., 2003). However, an exclusive focus on psychopathology may overlook the social, cultural, and economic determinants (Kohn et al., 2005). It is therefore essential to integrate both biological and contextual dimensions to achieve a comprehensive understanding of this complex phenomenon.

In Latin America, suicide rates vary widely across countries and socioeconomic strata, reflecting heterogeneous cultural and demographic conditions (Pan American Health Organization [PAHO], 2023). Regional analyses show that Latin-American and Caribbean nations face increasing suicide mortality among adolescents and young adults, emphasizing mental-health disparities and limited access to specialized care (Kohn et al., 2005; PAHO, 2023). Building on this broader regional perspective, within Mexico, suicide mortality has progressively increased in recent decades (Instituto Nacional de Estadística y Geografía [INEGI], 2023). Studies report a predominance of deaths among men but more non-fatal attempts among women, a pattern often described as the gender paradox of suicidal behavior (Schrijvers, Bollen, & Sabbe, 2012). Recent national surveys and hospital-based reports indicate that the northern states, including Chihuahua, maintain suicide rates above the national mean, especially among adolescents and young adults (Borges, Orozco, Benjet, & Medina-Mora, 2020; González-Forteza, Hermosillo-de la Torre, & Jiménez-Tapia, 2020).

Chihuahua consistently ranks among the Mexican states with the highest suicide mortality (INEGI, 2023). Epidemiological analyses suggest that challenges in this region, including socioeconomic instability, alcohol and stimulant consumption, and limited mental health coverage, converge here (Orozco, Gómez, & Mora, 2022). Local health bulletins describe suicides and attempts as concentrated among young adults aged fifteen to thirty-four, a trend also documented internationally (World Health Organization [WHO], 2021). The Hospital Psiquiátrico Dr. Ignacio González Estavillo in Chihuahua City serves as the primary psychiatric referral center for the state, receiving patients from both urban and rural municipalities. Its clinical population provides an opportunity to observe the interaction of psychiatric and contextual variables in suicidal behavior in a northern Mexican setting. Few local studies have characterized the clinical or sociodemographic profiles of these patients.

Suicidal behavior encompasses ideation, planning, attempts, and suicide death, with each phase necessitating distinct evaluation and intervention strategies (Turecki & Brent, 2016). The Columbia Suicide Severity Rating Scale provides a standardized assessment of ideation and lethality, facilitating cross-study comparisons (Posner et al., 2011). Identification of individuals with recent suicide attempts is essential, as prior suicidal acts are among the strongest predictors of future attempts (Macalli et al., 2021). Gender differences in suicidal behavior are well established: men are more likely to use lethal methods, while women report more frequent attempts (Schrijvers et al., 2012). Alcohol and stimulant use are associated with impulsive and recurrent suicidal behavior (Pigoni et al., 2024). In northern Mexico, methamphetamine use has increased substantially and is linked to higher rates of admissions for suicide attempts (Orozco et al., 2022).

Although many studies address social determinants, interpersonal stressors such as family conflict, isolation, and intimate-partner violence are the most consistent contextual variables in Latin America (García-Montes & Pérez-Álvarez, 2022). These factors frequently coexist with limited access to treatment, economic vulnerability, and poor continuity of care (Kohn et al., 2005; PAHO, 2023). Few peer-reviewed studies have described the sociodemographic and clinical characteristics of patients with suicidal behavior in Chihuahua. Most available data are derived from mortality registries that lack diagnostic and psychosocial information. Descriptive, hospital-based evidence can establish parameters for further research. In this context, the current pilot study describes the sociodemographic and clinical characteristics of patients admitted for suicidal behavior at the Hospital Psiquiátrico Dr. Ignacio González Estavillo between 2023 and 2024. This project represents the initial phase of a broader investigation into suicide-risk factors in northern Mexico. By integrating demographic, diagnostic, and contextual data, the study seeks to generate baseline information to inform future analytical and preventive research.

Objectives

This study aims to describe the sociodemographic and clinical characteristics of patients treated for suicidal behavior at a psychiatric hospital in Chihuahua, Mexico, and to identify sex-related patterns in method lethality within a pilot descriptive framework.

Materials and Methods

Study Design and Period

This study employed a cross-sectional, descriptive, and observational design, analyzing clinical records of patients admitted for suicidal behavior to the Hospital Psiquiátrico Dr. Ignacio González Estavillo in Chihuahua City, Mexico. The study period spanned from January 2023 to September 2024 and included all records that met the inclusion criteria. This research represents the initial phase of a pilot project designed to generate preliminary hospital-based data to inform future analytical and preventive studies on suicide-risk factors in northern Mexico (Leon, Davis, & Kraemer, 2011).

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Sample

The study population comprised all available records of patients admitted during the study period who exhibited suicidal behavior, defined as self-inflicted acts or preparatory behaviors with evidence of intent to die, or who expressed suicidal ideation at admission. Inclusion criteria were: (a) complete medical records in the electronic registry, (b) age ≥ 12 years, and (c) at least one psychiatric or psychological evaluation documented during hospitalization. Exclusion criteria were: (a) incomplete or illegible records, (b) admission for non-suicidal self-injury without intent to die, and (c) duplicate files of repeated admissions, retaining only the first episode for analysis.

Measurement Instruments

Data were extracted using a structured form created by the research team, which included sociodemographic, clinical, and behavioral variables. Sociodemographic information comprised age, sex, marital status, education, occupation, and municipality of origin. Clinical data included primary and secondary psychiatric diagnoses coded under the International Classification of Diseases for Mortality and Morbidity Statistics (11th Revision) (ICD-11; World Health Organization [WHO], 2019). Suicidal behavior was assessed with the Columbia Suicide Severity Rating Scale (C-SSRS; Posner et al., 2011), which classifies suicidal ideation, intent, and lethality on standardized ordinal scales. The Spanish validation demonstrated excellent internal consistency (Cronbach's α = 0.94) and strong convergent validity with measures of depression and hopelessness (Al-Hassan, Sánchez-García, & González-Ramírez, 2014). An additional computer-automated validation confirmed its reliability and ease of application in clinical settings (Mundt et al., 2013). Behavioral variables included the method of self-harm, degree of medical lethality, and precipitating factors such as family conflict, interpersonal loss, or economic stress. Psychiatric diagnoses, prior treatment, and substance use were recorded according to hospital protocols.

Ethical Aspects

The protocol was reviewed and approved by the Research and Bioethics Committee of the Hospital Psiquiátrico Dr. Ignacio González Estavillo (Approval ID HPIE-2024-SUIC-01). Data were analyzed in accordance with the Declaration of Helsinki (World Medical Association [WMA], 2013) and the Reglamento de la Ley General de Salud en materia de investigación para la salud (Cámara de Diputados, 2014). Because the analysis used anonymized secondary information, individual consent was not required under the conditions approved by the institutional bioethics committee. The research team maintained confidentiality and restricted access to authorized investigators.

Procedure

The research team collaborated with the hospital's Department of Teaching and Research to obtain supervised access to clinical records. Two trained evaluators independently reviewed and coded each record. Discrepancies were resolved by consensus, with the principal investigator re-examining unresolved cases. Records were anonymized and stored in an encrypted database. Data extraction followed a structured sequence: verification of eligibility criteria, removal of identifying information, collection of sociodemographic and clinical variables, classification of suicidal behavior according to C-SSRS categories, and preparation of a clean dataset. Variables such as substance use, prior treatment, and psychiatric diagnosis were cross-checked for consistency.

Statistical Analysis

Descriptive statistics summarized the data. Categorical variables were presented as absolute frequencies and percentages, and continuous variables as means ± standard deviations when approximately typical or as medians with interquartile ranges otherwise. Normality was assessed with the Shapiro–Wilk test and homogeneity of variance with Levene's test. Group comparisons used chi-square or Fisher's exact tests for categorical variables and independent-samples t-tests or Mann–Whitney U tests for continuous variables, as appropriate. All analyses were two-tailed, with a nominal significance threshold of $p < 0.05$. Results were interpreted in descriptive terms consistent with the pilot design. Analyses were performed in R Studio 2024 (R Foundation for Statistical Computing, Vienna, Austria) following current guidelines for reproducible biostatistics (Wickham, 2023). No multivariate modeling was conducted; the analysis focused on frequencies and distributions to describe the sample and assess the feasibility of variable collection for future phases.

Results

The study analyzed 497 records of patients treated for suicidal behavior at the Hospital Psiquiátrico Dr. Ignacio González Estavillo in Chihuahua, Mexico. The data reflect the hospital population during the study period, not the general population. The mean age was 30 years (SD = 9; range = 13–62). Females represented 64% (n = 318) and males 36% (n = 179). Among females, the mean age was 28 years (SD = 8), and among males, 33 years (SD = 10). Most patients were single (58%), followed by married or cohabiting (29%) and divorced or widowed (13%). Nearly half (47%) had completed secondary school, one-third (33%) had finished high school, 12% had university or technical education, and 8% lacked formal schooling. Unemployment rates were 42%, informal work accounted for 36%, and formal employment made up 22%. Urban residents comprised 67%, and rural residents 33%. The mean hospital stay was 7.3 days (SD = 3.1). Admissions through the emergency department accounted for 89%. Previous psychiatric hospitalization occurred in 18%, and 41% had received outpatient psychiatric treatment before admission.

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Among patients with available treatment information (n = 203), 58% had previously received care at the same institution, while 42% had been treated elsewhere. Antidepressants were the most common medication (48%), followed by benzodiazepines (22%) and antipsychotics (18%). Twelve percent received non-pharmacological interventions, such as psychotherapy or crisis counseling. Some records noted irregular follow-up or medication discontinuation before the index event, although documentation was inconsistent. No significant sex differences were found in previous treatment type ($p > .050$). Mood disorders were the most common primary diagnosis (47%, n = 233), followed by anxiety (22%, n = 109), psychotic disorders (16%, n = 80), and substance-use disorders (10%, n = 49). The remaining 5% (n = 26) included personality or neurodevelopmental conditions. Among those with mood disorders, major depressive disorder accounted for 78% (n = 182). Diagnostic distribution did not differ significantly by sex ($p > .050$). Approximately one third of cases had comorbid mood and substance-use disorders, often associated with prior suicide attempts, though this was not statistically significant ($p > .050$).

A previous suicide attempt was documented in 31% (n = 154). Of these, 56% (n = 86) had one prior effort, 28% (n = 43) had two, and 16% (n = 25) had three or more. Self-poisoning was the most frequent method (58%, n = 288), followed by hanging (19%, n = 95), cutting or sharp-object injury (13%, n = 65), and jumping from a height (5%, n = 24). Other methods, including firearms, accounted for 5% (n = 25). Men used high-lethality methods more often, particularly hanging. Other comparisons by sex were not significant ($p > .050$).

The mean lethality score measured with the Columbia Suicide Severity Rating Scale was 2.8 (SD = 0.9) on a 0–5 scale. Across age groups, younger patients (13–24 years) tended to use self-poisoning, while hanging was more frequent among adults over 30 years. This pattern was not statistically significant, but it suggests an age-related distribution that merits further evaluation in future analyses. Self-poisoning events often involved medications prescribed within the same or previous treatment episodes, primarily antidepressants or anxiolytics.

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Results (Continued)

Among patients diagnosed with substance-use disorders (n = 109), alcohol use predominated (63%, n = 69), followed by methamphetamine (19%, n = 21) and cannabis (11%, n = 12). Polysubstance use occurred in 7% (n = 7). Methamphetamine use was more common among men, while alcohol use was evenly distributed across sexes. Cannabis use was infrequent and showed no meaningful difference ($p > .050$). No age-related variations were found for the type of substance used ($p > .050$). Several records mentioned acute intoxication at admission, particularly among those with stimulant use, though these notes were descriptive and not quantified systematically. According to the C-SSRS, 44% (n = 219) presented severe suicidal ideation (with plan and intent), 38% (n = 189) moderate (active thoughts without plan), and 18% (n = 89) passive (wish to die). The comparison of ideation severity by sex was not statistically significant ($p > 0.050$), nor were there any differences by age group ($p > 0.050$). In numerous records, clinicians described fluctuating intent and ambivalence toward death, often influenced by interpersonal crises or substance intoxication.

Precipitating factors were documented in 92% (n = 457) of records containing contextual data. Family conflict was reported in 38% (n = 173), social isolation in 24% (n = 109), economic difficulties in 17% (n = 78), intimate-partner violence in 11% (n = 50), and recent bereavement in 7% (n = 32). Violence was more frequent among female patients. No significant differences by sex were found for other factors ($p > .050$). Younger participants more frequently cited peer or familial conflict, while adults referred to economic or relational stressors. At discharge, 73% (n = 363) continued outpatient psychiatric care at the same institution, 18% (n = 89) were referred to primary-care programs, and 9% (n = 45) were lost to follow-up. Most discharges included prescriptions for antidepressants or mood stabilizers. Follow-up adherence could not be verified beyond available documentation. No in-hospital fatalities were recorded during the study period. All patients were clinically stabilized before discharge.

Discussion

This pilot study characterized the sociodemographic and clinical features of patients treated for suicidal behavior at a psychiatric referral hospital in Chihuahua, Mexico. The hospital population was composed primarily of young adults, with a higher proportion of women. Mood disorders were the most frequent diagnoses, followed by substance use and anxiety disorders. Self-poisoning was the predominant suicide method, while men more often used high-lethality methods, particularly hanging.

Methamphetamine use was more common among men, and intimate-partner violence was reported more frequently among women. No differences were observed in the severity of suicidal ideation or in most precipitating factors. These findings provide an initial descriptive profile of suicidal behavior within a hospital population in northern Mexico. The predominance of young female patients with mood disorders aligns with national data from the Instituto Nacional de Estadística y Geografía (INEGI, 2023) and prior hospital-based studies conducted across Mexico (Borges, Orozco, Benjet, & Medina-Mora, 2020). Similar trends have been documented in Latin America, where affective disorders remain central to suicidal behavior (Turecki & Brent, 2016; Pan American Health Organization [PAHO], 2023).

The frequent use of self-poisoning corresponds with global evidence showing that accessibility to toxic agents influences method choice (World Health Organization [WHO], 2021). The greater use of high-lethality methods among men aligns with findings from international meta-analyses describing gender differences in suicide lethality (Macalli et al., 2021; Schrijvers, Bollen, & Sabbe, 2012). In contrast, the absence of significant differences in suicidal ideation severity by sex diverges from national surveys indicating higher ideation among women (INEGI, 2023; González-Forteza, Hermosillo-de la Torre, & Jiménez-Tapia, 2020). These variations likely reflect the characteristics of hospital samples and documentation differences rather than contradictory behavioral patterns.

The coexistence of substance-use disorders, mainly alcohol and stimulants, parallels international literature linking stimulant used to impulsive and recurrent suicidal acts (Borges et al., 2017; Pigoni et al., 2024). The higher frequency of methamphetamine use among men is consistent with regional data for northern Mexico (Orozco, Gómez, & Mora, 2022). Although alcohol and cannabis use did not differ by sex, their prevalence parallels national data identifying these substances as the most accessible among individuals with suicidal behavior (Borges et al., 2020).

The proportion of patients previously engaged in psychiatric treatment aligns with observations in tertiary hospitals in central Mexico and other Latin American settings (Leon, Davis, & Kraemer, 2011; López-Castillo, Cortés-Alvarez, & Becerra-Pérez, 2021). This recurrence suggests a clinical phenomenon that persists despite prior contact with mental health services. Likewise, the distribution of psychosocial stressors, such as family conflict and social isolation, agrees with reviews describing interpersonal and economic pressures as recurrent contextual factors in suicidal behavior (García-Montes & Pérez-Álvarez, 2022; PAHO, 2023). The lack of significant differences for education level, area of residence, and economic difficulties contrasts with broader epidemiological studies reporting associations between low education, rural living, and suicide risk (Kohn et al., 2005; INEGI, 2023). Within this pilot framework, such discrepancies likely reflect sample size and heterogeneity in records.

This pilot study has several limitations related to scope and data availability. The analysis was restricted to a single psychiatric institution and does not represent the broader population. The retrospective design relied on clinical records, which may not capture all psychosocial variables relevant to suicidal behavior. Specific dimensions, such as socioeconomic status, ethnicity, barriers, or delays in accessing care, treatment type, or adherence, were not included in this pilot phase but may be addressed in future studies. Dividing the sample by sex reduced statistical power for subgroup analyses, a standard limitation in pilot descriptive research. The descriptive design serves as an initial step for defining parameters to guide analytical designs in subsequent phases. A principal strength of this pilot study is its contribution to documenting suicidal behavior as a critical issue for mental-health sciences in a state with persistently elevated suicide mortality.

By providing structured information from a regional psychiatric population, this work supplies data necessary to contextualize the problem and to encourage further investigation across methodologies and disciplines. The integration of clinical, behavioral, and contextual variables generates evidence that can serve as a foundation for academic and public health initiatives to study populations at risk with greater depth and precision. Future research phases should incorporate multicenter and longitudinal approaches to evaluate temporal trajectories and continuity of care. A broader inclusion of sociocultural, environmental, and clinical variables will enhance the understanding of vulnerability profiles. Prospective designs may examine adherence, accessibility, and treatment response. Collaboration between psychiatric institutions and community services may facilitate the development of preventive strategies tailored to the contextual characteristics identified in this pilot study.

Conclusions

This pilot study identified a higher frequency of high-lethality suicide methods, particularly hanging, among men treated for suicidal behavior in Chihuahua, Mexico. Although women accounted for the majority of hospital admissions, men more frequently employed highly lethal methods, indicating differential exposure to fatal outcomes. The hospital population primarily consisted of young adults with mood and substance-use disorders and recurrent psychosocial stressors, such as family conflict and social isolation. These findings provide an initial description of suicidal behavior among patients treated in a regional psychiatric setting and underscore the necessity of ongoing documentation and analysis through systematic, context-specific research. In a state where suicide mortality continues to rise, expanding empirical evidence will be essential for maintaining academic, clinical, and public-health focus on high-risk populations and for promoting sustained scientific investigation into this complex mental-health issue.

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Comparative Review

Comparative Review of Machine Learning Algorithms for Suicide-Risk Prediction and Prevention

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Conflicts of Interest
The author declares no conflicts of interest

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Abstract
Introduction: According to the World Health Organization (2021), suicide is a primary global public-health concern responsible for nearly 700,000 deaths each year and accounting for about 1,3 percent of all global mortality. It ranks among the leading causes of death in people aged 15–29 years. Objective: To identify, evaluate, and synthesize current evidence on the performance of machine-learning algorithms applied to suicide-risk prediction and prevention, an increasingly important global mental-health concern. Materials and Methods: A comparative review was conducted using the keywords "machine learning," "suicide," "classification," and "data processing" across major scientific databases. Approximately 30 studies were analyzed to compare algorithmic models, data-processing approaches, training methods, evaluation metrics, and dataset characteristics. Results: The machine-learning algorithms reviewed included artificial neural networks, random forests, probabilistic models, clustering approaches such as k-nearest neighbors, and linear classifiers like logistic regression and support vector machines. Across studies, ensemble models (random forest, bagging, and voting) achieved the highest reported F1 scores (around 0.9, with a range of 0.84–0.96) and consistent accuracy. Deep architectures, such as LSTM + CNN, demonstrated exceptional performance (F1 ≈ 0.93) in sequential text analysis. Simpler algorithms showed variable performance depending on dataset balance and quality. Conclusions: No single algorithm is universally optimal for predicting suicide risk. Model selection should be guided by data structure, computational resources, and clinical interpretability rather than algorithmic novelty. Hybrid models that combine explainability with precision, supported by ethical frameworks that emphasize transparency, privacy, and bias mitigation, are essential for the safe and equitable implementation within mental-health systems. These findings support the integration of explainable artificial intelligence models into suicide-prevention and mental-health-surveillance programs.

Keywords
Artificial intelligence; Machine learning; Mental health; Prevention; Suicide.

Introduction

According to the World Health Organization (2021), suicide is a primary global public-health concern responsible for nearly 700,000 deaths each year and accounting for about 1.3 percent of all global mortality. It ranks among the leading causes of death in people aged 15–29 years. The phenomenon arises from the convergence of biological, psychological, and sociocultural factors that interact dynamically across the life course (Somé, Noormohammadpour, & Lange, 2024). These interactions encompass psychiatric comorbidity, neurocognitive vulnerability, environmental adversity, and sociostructural determinants such as stigma, inequality, and access to mental-health services (Turecki & Brent, 2016).

Because these determinants do not operate linearly, their combined influence defies the assumptions of classical causal inference, complicating predictive accuracy. Traditional statistical and screening approaches—most notably logistic regression models and structured clinical interviews—remain indispensable in psychiatric assessment but are limited by linear assumptions and reduced dimensionality. Their capacity to predict suicidal behavior diminishes when interdependent variables evolve nonlinearly across heterogeneous datasets (Walsh, Ribeiro, & Franklin, 2017).

These constraints have prompted exploration of computational paradigms capable of identifying high-order interactions and latent structures that conventional models overlook. Advances in artificial intelligence and machine learning have introduced alternative methodologies that analyze complex, multivariate data without requiring explicit programming rules (Nordin, Zainol, & Zurinahni, 2021). Machine-learning models have been applied to a broad range of data sources, including electronic health records, neuroimaging, psychometric scales, and social media text, to detect latent patterns associated with suicide risk (Tadesse, Lin, Xu, & Yang, 2019; Pigoni, Perna, Cavedini, & Caldiroli, 2024).

By revealing subtle associations among disparate variables, these algorithms can augment conventional clinical reasoning and improve early detection (Macalli, Navarro, Orri, Ouellet-Morin, & Geoffroy, 2021). Nevertheless, algorithmic prediction should be regarded as a complement rather than a replacement for professional judgment. The epistemic strength of these systems lies in statistical detection, rather than causal explanation, which necessitates ongoing clinical interpretation and ethical oversight (Somé et al., 2024; WHO, 2021). From an epistemological and ethical standpoint, integrating predictive algorithms into psychiatry requires reconciling quantitative modeling with the interpretive logic of clinical practice. Predictive systems trained on biased or unrepresentative data may replicate structural inequities, while opaque "black-box" architectures can obscure accountability for diagnostic error (Adadi & Berrada, 2018; Gillum, 2023). Consequently, the responsible adoption of these tools demands transparency, fairness, and respect for patient autonomy.

As the WHO (2021) has emphasized, artificial intelligence applications in healthcare must ensure data privacy and human oversight to prevent algorithmic harm. Given the proliferation of studies employing machine learning for suicide-risk assessment, a critical synthesis of their methodologies and ethical implications is essential. Comparative analysis can determine which algorithms achieve reliable predictive performance, under what conditions of data balance and representativeness, and within what normative limits they can be safely integrated into policy and clinical decision-making. Establishing such an evidence base will enable the ethically coherent incorporation of artificial-intelligence models into suicide-prevention frameworks, strengthening both diagnostic precision and the public-health response.

Objectives

This review synthesized and critically compared machine-learning algorithms applied to suicide-risk prediction and prevention. It examined methodological architectures, data-processing procedures, and evaluation metrics; analyzed comparative performance across clinical, textual, and sociodemographic datasets; and discussed the ethical, epistemological, and operational implications of applying artificial-intelligence systems within psychiatry and public health. The overarching purpose was to develop an integrated framework that balances algorithmic precision with clinical interpretability, ensuring that predictive technologies operate as complements—not substitutes—for human discernment in the prevention of self-directed violence.

Materials and Methods

Study Design and Scope

This narrative review analyzed and compared machine-learning algorithms used for predicting and preventing suicide risk. The objective was an analytic and ethical synthesis rather than a quantitative meta-analysis. Approximately thirty scientific and dissemination articles were reviewed to describe algorithms, data-processing techniques, training strategies, evaluation metrics, and dataset characteristics. Because the of the objetives, the review was framed to foreground contextual variables that may influence model behavior and external validity.

Search Strategy

Searches were conducted between January 2024 and March 2025 in PubMed, ScienceDirect, and Research Rabbit, with complementary screening in openly accessible repositories to identify gray literature where appropriate. To preserve the author's original intent and bilingual scope, we used English and Spanish terms, including: machine learning, suicide, classification, data processing, suicide prevention, así como aprendizaje automático, suicidio, clasificación y procesamiento de datos. Searches were limited to publications from 2017 onward in English or Spanish that reported at least one algorithmic evaluation related to suicide risk detection, prediction, or prevention.

They provided quantitative metrics such as F1 score, accuracy, sensitivity, or precision. Editorials, purely theoretical papers, and studies without algorithmic analysis were excluded. Studies were eligible if they implemented and evaluated a machine-learning model on clinical, textual (e.g., social media), or sociodemographic data for suicide-related outcomes and reported evaluable performance metrics. For each included article, we extracted the following information: population and data provenance, dataset size and class balance, algorithmic architecture, training and validation procedures, and the primary metrics reported. We also recorded whether the authors discussed sources of bias related to database design, population composition, or geographic region, since these factors can systematically affect performance estimates and generalizability.

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Ethical Aspects

In line with the original manuscript, the review paid particular attention to contextual covariates that can confound algorithmic outputs or their interpretation in practice, including social variables, polypharmacy, sociodemographic characteristics, health-care access, and family factors. These dimensions were documented whenever reported and were later used to qualify narrative interpretations of performance. Consistent with good clinical practice, we reiterate that algorithmic predictions are not absolute determinations and require the application of professional judgment. This review used only secondary, publicly available information and did not involve human participants or identifiable data; therefore, institutional review board approval was not required. Procedures conformed to the Declaration of Helsinki and to the editorial and research-integrity standards of COPE and ICMJE (World Medical Association, 2013).

Analytic Plan

Two reviewers independently screened titles, abstracts, and full texts. Disagreements were resolved by consensus. Given the heterogeneity of populations, inputs, feature engineering, and outcome definitions, we synthesized findings qualitatively rather than statistically and avoided direct cross-study numeric comparisons that could imply false equivalence. Algorithms were grouped conceptually (for example, linear classifiers, kernel methods, probabilistic models, tree-based and ensemble methods, and deep-learning architectures) to clarify patterns of use, typical data contexts, and common pitfalls. Performance values were summarized descriptively, with an emphasis on consistency across settings, explicit handling of class imbalance, and the presence of explainability or bias-mitigation procedures. All search procedures, inclusion criteria, and data-extraction steps were documented in a reproducibility log, which is available upon reasonable request. A random 20 percent of extracted records was cross-checked to verify consistency. Descriptive tabulations were produced in Microsoft Excel 2021. No inferential meta-analytic modeling was attempted because of metric and design heterogeneity.

Results

The studies reviewed displayed substantial heterogeneity in design, data source, and reporting metrics, which preclude direct quantitative comparison. Nevertheless, consistent patterns of algorithmic performance were identifiable across methodological families. Reported F1 scores ranged approximately from 0.56 to 0.96, accuracy values from 0.55 to 0.96, and sensitivity between 0.57 and 0.94, depending on data quality, population characteristics, and class balance. These values should be interpreted as indicative rather than definitive benchmarks. Table 1 depicts the study's general findings. Among traditional models, logistic regression demonstrated moderate yet stable predictive capacity, with F1 values near 0.80 in structured clinical datasets (Nordin, Zainol, & Zurinahni, 2021). Its performance declined in unbalanced or small samples, confirming dependence on linear separability and feature homogeneity. Decision-tree algorithms achieved comparable accuracy (≈ 0.82) and were frequently highlighted for interpretability and simplicity, qualities that facilitate their clinical translation (Tang et al., 2024). Support-vector machines consistently achieved robust results across heterogeneous data environments, with reported F1 scores ranging from 0.79 to 0.95 and sensitivity reaching up to 0.92, particularly in text-based corpora derived from online platforms such as Reddit (Tadesse, Lin, Xu, & Yang, 2019). Their capacity to manage high-dimensional feature spaces explains their frequent inclusion in hybrid architectures. Naïve Bayes classifiers, although computationally efficient and well-suited for textual data, yielded lower F1 values (≈ 0.78) due to the independence assumption; however, they remained helpful in baseline classification. Within ensemble frameworks, random forest models consistently reported high and stable performance (F1 ≈ 0.84–0.96) across both clinical and population survey data (Somé, Noormohammadpour, & Lange, 2024). Bagging and voting ensembles achieved similar metrics (≈ 0.92 for both F1 and accuracy), reinforcing the robustness of aggregated decision processes. Gradient-boosting and XGBoost models performed comparably (F1 ≈ score 0.76–0.94), but they exhibited sensitivity to hyperparameter tuning and class imbalance (Tang et al., 2024). Despite technical complexity, these algorithms demonstrated greater resilience to noisy or incomplete datasets.

Among deep-learning models, artificial neural network architectures achieved F1 scores ranging from 0.84 to 0.87, particularly in structured medical datasets (Servi et al., 2023). Combined frameworks, such as long short-term memory networks integrated with convolutional neural networks (LSTM + CNN), obtained the highest reported results (F1 ≈ 0.92–0.93; accuracy ≈ 0.90–0.93) when applied to sequential textual data from social media sources (Tadesse et al., 2019). Transformer-based models, including BERT and its derivatives, yielded moderate but promising outcomes (F1 ≈ 0.65–0.73) and showed potential for improvement through fine-tuning on domain-specific corpora (Grimland et al., 2024). Despite the wide dispersion of metrics, several regularities emerged. Ensemble and deep-learning models exhibited greater stability and resistance to overfitting than single-algorithm methods. Simpler approaches, such as logistic regression and decision trees, retain practical relevance due to their interpretability, particularly in clinical environments where transparency is essential. Conversely, almost one-third of studies failed to report sufficient methodological detail to assess reproducibility or control bias, thereby limiting external validity and comparability across research groups. Taken together, the evidence suggests that predictive success in suicide-risk modeling depends less on algorithm type than on dataset representativeness, preprocessing quality, and the ethical handling of sensitive information. The results underscore the need for standardized reporting frameworks and open data practices to enhance methodological comparability and enable clinical validation of machine-learning applications in mental health care.

Discussion

The collective analysis of the reviewed studies reveals that the predictive performance of machine-learning algorithms for suicide-risk assessment varies across model families but follows identifiable trends. Ensemble and hybrid deep-learning models achieved the highest reported metrics within the datasets analyzed, supporting prior evidence that aggregation and hierarchical feature extraction improve stability and generalization (Somé, Noormohammadpour, & Lange, 2024; Tadesse, Lin, Xu, & Yang, 2019). Nevertheless, their apparent superiority depends primarily on dataset representativeness, preprocessing quality, and class balance rather than on algorithm type alone. Classical statistical models, such as logistic regression and decision trees, remain relevant in contexts that require interpretability. Their transparency facilitates clinical use, although their predictive capacity declines in heterogeneous or unbalanced samples (Tang et al., 2024). These results align with comparative research indicating that methodological rigor and appropriate feature selection have greater influence on performance than computational complexity (Macalli, Navarro, Orri, Ouellet-Morin, & Geoffroy, 2021). Overall, the findings suggest that machine learning in psychiatry should be understood as an extension rather than a replacement of existing analytical paradigms. Its value lies in enhancing sensitivity to complex interactions rather than in producing deterministic predictions.

From a clinical perspective, predictive models can complement risk-assessment protocols by identifying statistical patterns that may be overlooked in subjective evaluations. Their outputs must be interpreted probabilistically and contextualized within the patient's biopsychosocial environment. Models with high sensitivity but modest specificity may be useful for early triage and resource prioritization, whereas highly specific algorithms could inform more individualized interventions. Methodologically, the field requires harmonization of evaluation criteria and documentation of datasets. Differences in F1, accuracy, and sensitivity values among studies often reflect inconsistent reporting of sample composition, feature engineering, and validation strategies. The creation of standardized, open, and demographically diverse databases would allow independent replication and reduce publication bias. Future studies should report complete methodological parameters, including cross-validation procedures, hyperparameter tuning, and class-balance strategies. The integration of predictive algorithms into practice introduces epistemological and ethical challenges that extend beyond technical validation. Predictive models operate within a probabilistic logic that complements but cannot substitute the interpretive reasoning inherent to psychiatry. Transparency and explainability are essential to preserve accountability and clinician trust (Adadi & Berrada, 2018).

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Discussion (Continued)

Moreover, data used to train algorithms may encode structural inequities; without corrective measures, these systems risk perpetuating discrimination or reinforcing social bias (Gillum, 2023). Ethically, suicide-risk prediction must adhere to the principles of beneficence, non-maleficence, autonomy, and justice. Governance frameworks should ensure informed consent, data privacy, and equitable representation of vulnerable populations. As emphasized by the World Health Organization (2021), human oversight remains indispensable: artificial intelligence can inform decision-making but cannot replace the clinician's moral responsibility or contextual understanding.

The heterogeneity of study designs and outcome definitions limits the conclusions of this review. Most included studies were retrospective and exploratory, with variable sample sizes and incomplete descriptions of bias-control procedures. The absence of standardized reporting precluded formal meta-analysis. Additionally, publication bias toward positive findings may have inflated apparent accuracy. These constraints warrant cautious interpretation and highlight the need for prospective, preregistered, and methodologically transparent investigations. Future research should focus on developing explainable, interpretable, and ethically validated models that can be integrated into clinical workflows. Interdisciplinary collaboration among psychiatrists, data scientists, and ethicists will be crucial to strike a balance between predictive accuracy and fairness and accountability. Beyond algorithmic innovation, priority should be given to post-deployment auditing, continuous monitoring of performance drift, and cultural adaptation to local contexts. Building multilingual and region-specific datasets could reduce cultural bias and improve model generalization for populations. In the long term, artificial intelligence systems for suicide prevention should evolve from isolated predictive tools into integrated components of comprehensive mental health frameworks that combine digital analytics, psychosocial support, and population-level policy interventions.

Conclusions

This review demonstrates that the predictive performance of machine-learning algorithms for suicide risk assessment is highly context-dependent and shaped more by dataset composition, feature engineering quality, and validation rigor than by algorithmic novelty. Ensemble and deep-learning models consistently produced the highest reported metrics within the analyzed studies; however, their effectiveness remains contingent on data representativeness, ethical design, and transparent evaluation. Classical models such as logistic regression and decision trees, while less complex, continue to provide clinically interpretable frameworks that preserve conceptual clarity and facilitate integration into psychiatric settings. The results collectively indicate that algorithmic innovation alone is insufficient to advance suicide prevention. Predictive technologies must be embedded within multidisciplinary frameworks that incorporate clinical expertise, ethical oversight, and cultural sensitivity to ensure effective implementation. The strength of artificial intelligence lies not in replacing clinical judgment but in supporting it, expanding the capacity of professionals to recognize risk patterns that may otherwise remain hidden. Ethical responsibility is central to the development and application of these systems. Algorithms trained on unbalanced or biased datasets may perpetuate inequities, misclassify vulnerable individuals, or contribute to stigma if their outputs are interpreted without context. Compliance with international ethical standards, continuous model auditing, and open reporting of performance metrics are indispensable to ensure safety, transparency, and accountability. Looking forward, the path toward responsible implementation requires harmonized reporting practices, creation of multilingual and demographically inclusive databases, and sustained collaboration between data scientists, clinicians, and ethicists. Integrating explainable and interpretable models into public-health infrastructures could enable earlier intervention, optimize resource allocation, and strengthen suicide-prevention strategies across clinical and community levels. In summary, the application of machine learning to suicide prevention represents both a methodological advance and an ethical challenge. Its promise depends on maintaining a balance between predictive precision and human understanding. Only through this equilibrium can artificial intelligence become a reliable and compassionate ally in the global effort to reduce self-directed violence and safeguard mental health.

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Ecological Analysis

A Pre-Epidemic Analysis of Jalisco's Spatial-Temporal Baseline Suicide Mortality

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Conflicts of Interest.
The author declares no conflicts of interest.
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Abstract
Introduction. Suicide is a significant public health concern in Jalisco, Mexico, with notable variation across demographic and geographic groups. This study addresses the need for a detailed spatial and temporal analysis of suicide mortality before the COVID-19 pandemic, providing a baseline for future comparisons. Objectives. The primary objective was to characterize the spatial and temporal patterns of suicide mortality in Jalisco from 2015 to 2019, focusing on sex- and region-specific differences. The study aimed to identify high-risk clusters, demographic disparities, and areas of persistent elevated mortality to inform targeted interventions. Materials and Methods. An ecological, exploratory study was conducted using depersonalized suicide mortality records from 2015 to 2019. Analyses were performed at the state and municipal levels, with mortality rates calculated per 100,000 inhabitants aged 10 years or older. The study utilized official sources for mortality and population data. Spatial patterns were assessed through choropleth mapping and statistical classification methods, and a multidisciplinary team validated the results. Results. A total of 2,837 suicide deaths were documented: 2,277 among men (80.2%) and 560 among women (19.8%). The overall mortality rate was 8.4 per 100,000 inhabitants, with 12.2 for men and 3.4 for women. Suicide rates increased in both sexes, more markedly among men. Female mortality peaked in northern municipalities, while male mortality was highest in the Tamazula, Autlán, and Colotlán health regions. High-mortality clusters remained stable over the five years. Contributing factors may include socioeconomic disparities, limited access to mental health services in rural areas, and cultural stigmas. Conclusions. These findings establish a robust pre-pandemic baseline for monitoring changes, supporting targeted public health interventions, and guiding equitable allocation of mental health resources.

Keywords
Suicide; Mortality; Spatial analysis; Mental health; Epidemiology; Mexico.

Introduction

Suicide represents a significant global public health issue. According to the World Health Organization (WHO), approximately 700,000 individuals die by suicide annually, accounting for over 1.3 percent of all deaths (World Health Organization [WHO], 2021a). For each completed suicide, an estimated 20 non-fatal attempts occur, highlighting the scale of the problem (WHO, 2021b). The interplay of psychological, biological, and social determinants renders suicide a highly multifactorial and context-dependent phenomenon. In Mexico, suicide mortality has exhibited a persistent and progressive increase over the past four decades, with rates rising from 1.13 per 100,000 inhabitants in 1970 to 6.2 per 100,000 in 2021 (Instituto Nacional de Estadística y Geografía [INEGI], 2021). While various sociocultural and economic factors contribute to this trend, several studies indicate that the COVID-19 pandemic may have exacerbated pre-existing vulnerabilities by increasing depressive symptoms, anxiety, and adjustment disorders in the general population (WHO, 2022). This challenge is intensified in a society experiencing rapid demographic transition, where more than 68 percent of mental disorders occur among individuals aged 50–64 years (Kohn et al., 2005; Borges et al., 2004; Rodríguez et al., 2009). In Jalisco, one of Mexico's most populous and economically active states, suicidal behavior has paralleled the national upward trend. The regional health system, led by the Jalisco Institute of Mental Health (SALME) and the Jalisco State Health Secretariat, has prioritized suicide prevention and mental health promotion (Pan American Health Organization [PAHO], n.d.). Despite considerable research on suicide rates nationally and globally, a gap exists in understanding detailed spatial and temporal patterns of suicide mortality specific to Jalisco. Previous studies have not comprehensively mapped the geographic variations or assessed how these might inform targeted preventive measures within the region. This study fills this gap by employing spatial epidemiology techniques to identify disparities in mental health service coverage and mismatches between population needs and available infrastructure (Frerichs, n.d.; Wagner, n.d.). Cartographic methods, such as thematic and choropleth mapping, facilitate the visualization of spatial and temporal variations in suicide mortality at municipal, regional, and national levels. These approaches enable the detection of emerging hotspots, assessment of health inequities, and monitoring of mental health indicators over time (INEGI, 2023). Additionally, geospatial analysis supports the design of targeted interventions by incorporating contextual determinants such as rurality, socioeconomic status, and access to specialized care. Previous research in Mexico has demonstrated the value of spatial analysis for identifying public health priority areas. Studies employing similar methodologies for other health outcomes, including those by González Castañeda and Ramos Herrera (2018) and Alcántara Ayala and Graue Wiechers (2011), emphasize the importance of geoinformation systems for health policy and planning. Building on these foundations, the present study utilizes a spatiotemporal ecological design to characterize suicide mortality in Jalisco during the pre-pandemic period.

Objectives

The primary objective is to establish a territorial baseline of suicide mortality from 2015 to 2019, serving as a reference for evaluating the impact of the COVID-19 pandemic on mental health outcomes. By integrating spatial, temporal, and demographic dimensions, this approach enables a comprehensive analysis of the geographic heterogeneity of suicide mortality, informing the development of regionally tailored prevention strategies.

Materials and Methods

Design, Setting and Period

An ecological exploratory study was conducted using suicide mortality records from Jalisco, Mexico, covering the years 2015 to 2019. Analyses were performed at both state and municipal levels, incorporating a territorial perspective to estimate aggregated indicators and identify spatial patterns. As only secondary, depersonalized data sources were utilized, research or bioethics committee approval was not required. The study adhered to the principles of the Declaration of Helsinki and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (von Elm et al., 2007).

Methodological Framework

The methodological framework was based on the approach proposed by González et al. (2016) for health atlas development, encompassing variable definition, data collection and processing, base map construction, thematic map creation and interpretation, and analytical evaluation of results. Data sources included the Jalisco Institute of Mental Health (SALME), the National Institute of Statistics and Geography (INEGI), the Jalisco State Health Secretariat, and the National Population Council (CONAPO). Variables analyzed comprised sex, age, year, and municipality of death occurrence. Records were aggregated by municipality to estimate crude and age-adjusted mortality rates by year. The numerator was the total number of suicide deaths recorded by INEGI, classified by sex, age group (10 years or older), year, and municipality of occurrence. The denominator was the mid-year population aged 10 years or older, disaggregated by sex and municipality, according to official projections from CONAPO (Consejo Nacional de Población, n.d.). The threshold of 10 years was selected because it was the minimum age reported among suicide cases. Three indicators were derived: the overall suicide-mortality rate for Jalisco during 2015–2019; the annual average rate by sex and year; and the municipal-specific average rate by sex and year. All values were expressed per 100,000 inhabitants aged 10 years or older.

Analytic Plan

Mortality rates were classified using the Dalenius–Hodges equal-interval method (Dalenius & Hodges, 1959), which minimizes within-group variance and maximizes between-group differences to produce statistically consistent classes. Mortality values were categorized into five ordinal groups: very low, low, medium, high, and very high mortality rates. Spatial representation employed choropleth mapping, supplemented by graphs and tables. The official health region divisions established by the Jalisco Health Secretariat, along with municipal boundaries, served as regional analytical units to identify areas of elevated risk and concentration. Cartographic processing was conducted in QGIS (version 3.34, Open-Source Geospatial Foundation) using official municipal polygons projected in the Mexican Lambert Conformal Conic coordinate system. Sequential color gradients, ranging from blue to red, represented increasing mortality intensity. Temporal trends were visualized using line and bar charts that displayed annual variations by sex. Descriptive analyses were performed in IBM SPSS Statistics 29.0 (IBM Corp., Armonk, NY, USA) and verified in R Studio (Posit Software PBC, Boston, MA, USA).

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Analytic Plan (Continued)

A multidisciplinary team of psychiatrists, epidemiologists, and geographers reviewed the maps and graphs to ensure geographic coherence and interpretive accuracy. The databases underwent a two-stage verification process. Initially, mortality totals were cross-checked between INEGI and Jalisco State Health Secretariat records to ensure numerical consistency. Subsequently, geographic identifiers were validated by comparing municipality names, numeric codes, and coordinates. Outliers and anomalous values were manually inspected to eliminate transcription errors. Data cleaning and transformation—including harmonization of variable names, conversion of text fields, and removal of missing or duplicate records—were systematically documented in a reproducibility log maintained on the institutional server of SALME.

Ethical Aspects

Because aggregated public data were analyzed, informed consent was not applicable. The study complied with national biomedical research regulations contained in the Reglamento de la Ley General de Salud en Materia de Investigación para la Salud (Cámara de Diputados, 2014) and with international data-protection frameworks, including the General Data Protection Regulation (European Union, 2018).

Results

Between 2015 and 2019, 2,837 suicide deaths were recorded in Jalisco, with 80.2% (n = 2,277) among men and 19.8% (n = 560) among women. The overall suicide mortality rate was 8.4 per 100,000 inhabitants aged 10 years or older, surpassing the national average for the same period (Instituto Nacional de Estadística y Geografía [INEGI], 2021). Sex- and year-specific rates indicated a gradual increase among men from 2015 to 2017, peaking at 17.7 per 100,000, followed by a 5.5-point decline in 2018 and stabilization in 2019. Female mortality remained relatively stable, fluctuating around 3.5 per 100,000. The male-to-female ratio remained approximately 4 to 1, underscoring the persistent predominance of male suicide mortality. Age-specific analysis showed that individuals aged 20–29 and 30–39 years accounted for over 45% of all suicides, indicating a disproportionate vulnerability among young adults. At the state level, suicide mortality exhibited marked geographic heterogeneity. Municipal analysis identified distinct high-risk clusters and stable low-mortality areas. Among men, the highest average municipal rate was recorded in Ejutla (70.5 per 100,000 men aged 10 years or older) within the Autlán health region. Other municipalities in Tamazula, Ciudad Guzmán, and Autlán also showed elevated rates, ranging from 80.9 to 234.2 per 100,000 depending on the year. Early in the study period, the highest mortality rates were concentrated in the southwest corridor, including Ejutla, Tuxcacuesco, El Limón, and Tonaya. In 2018–2019, new clusters emerged in the central-southern region, notably Tizapán el Alto and Acatlán de Juárez, extending into Los Altos (San Miguel el Alto and Yahualica de González Gallo). This pattern indicated a gradual eastward expansion of elevated male mortality. Occasional peaks were also observed in northern municipalities such as Huejúcar and Santa María de los Ángeles.

In contrast, several industrial-corridor localities, including El Salto, Zapotlanejo, and Ocotlán, maintained consistently low rates below 5 per 100,000. For women, the spatial distribution differed, with the highest average mortality rates clustered in the northern region, particularly within the Colotlán health district (17.7 to 28.3 per 100,000 women aged 10 years or older). In certain years, municipalities in the Colotlán and Ameca regions exhibited extreme values, ranging from 58.5 to 88.6 per 100,000, forming isolated but significant female mortality hotspots. Choropleth maps and related figures demonstrated persistent regional disparities, confirming the presence of spatially stable clusters of elevated mortality and municipalities with consistently minimal rates. Suicide mortality showed an overall upward trend during the study period, with a more pronounced increase among men. Female mortality fluctuated slightly but did not show major inflection points. Temporal patterns indicated intensification until 2017, followed by partial stabilization. These changes corresponded with the emergence of new regional clusters. Possible explanatory factors include socioeconomic disparities, changes in mental health policy, and shifts in public awareness and attitudes. Economic instability and limited access to mental health care in rural areas may have contributed to rising suicide rates, especially among men. Policy changes and public awareness campaigns may have influenced the stabilization in later years. Although causal relationships with socioeconomic or environmental factors cannot be established within the current framework, these hypotheses merit further investigation.

Male mortality predominated across all years and regions, accounting for four-fifths of total deaths. This disparity is consistent with international findings from the World Health Organization (2021a), which highlight the higher lethality of methods used by men and their lower engagement with preventive and psychiatric services compared to women. In Jalisco, male mortality exhibited concentrated geographic clustering in rural areas, while female mortality was more dispersed but consistently elevated in the northern highlands. Age-specific analysis confirmed that adults aged 20–39 years were the most affected in both sexes, underscoring the need to prioritize preventive strategies for young and middle-aged populations.

Discussion

This spatiotemporal ecological analysis established a pre-pandemic baseline of suicide mortality in Jalisco from 2015 to 2019. The data demonstrated pronounced geographic heterogeneity, persistent sex differences, and a distinct age-specific concentration among young adults. The overall rate of 8.4 per 100,000 inhabitants exceeded the national average and exhibited a steady upward trend, particularly among men. Municipal clusters of elevated mortality were concentrated in the southwestern and northern regions, while the metropolitan corridor consistently maintained low rates. The geographic distribution of suicide mortality in Jalisco highlights the influence of social structure, access to care, and regional development. High-rate municipalities for men in the southwest, such as Ejutla and Tamazula, share features including rural isolation, limited psychiatric services, and socioeconomic disadvantage. These factors are consistent with prior findings that rural populations often experience higher suicide mortality due to restricted health-service coverage and persistent stigma surrounding mental illness (Hirsch, 2006). In contrast, metropolitan and industrial municipalities maintained low and stable rates, aligning with evidence that regions with robust health infrastructure and economic diversity have lower suicide risk (Helbich et al., 2020). The eastward and central expansion of high-mortality clusters toward the end of the study period suggests increasing vulnerability in previously unaffected areas, potentially reflecting migration dynamics and unequal resource distribution. While causality cannot be established, the spatial persistence of clusters indicates that suicide in Jalisco is a territorially structured phenomenon rather than a result of random variation. The predominance of male mortality, with a ratio of approximately 4 to 1, is consistent with global evidence that men tend to use more lethal methods and engage less frequently with preventive or psychiatric services (World Health Organization [WHO], 2021a; Overholser et al., 2012). The concentration of deaths among individuals aged 20–39 years identifies a critical demographic in which impulsivity, substance use, and early-onset affective disorders converge (Nock et al., 2008). These findings underscore the importance of developing sex- and age-specific prevention strategies that address occupational stress, substance-use prevention, and community-based crisis support. Spatial epidemiology offers a robust framework for identifying local disparities and prioritizing interventions where the need is greatest. The results of this study can inform the Jalisco State Mental Health Program by identifying municipalities requiring additional outreach, telepsychiatry coverage, or gatekeeper training. Incorporating these geographic indicators into surveillance systems would support targeted resource allocation and ongoing monitoring of suicide mortality trends.

This study has several limitations inherent to ecological designs. The use of aggregated data prevents inference at the individual level and may obscure within-area heterogeneity. Variables such as psychiatric history, socioeconomic status, and substance use were unavailable and thus not controlled for. Misclassification of deaths is possible, as suicide is subject to cultural and administrative underreporting, as documented in national analyses (INEGI, 2021). To mitigate these limitations, careful attention was given to cross-verifying data sources to reduce misclassification and increase data reliability. Moreover, spatial and temporal variability have been explicitly accounted for in the design to minimize possible biases. Future studies could incorporate individual-level data when available and tools like multilevel modeling to account for nested data structures, thereby providing more nuanced insights. Despite these limitations, the ecological approach is appropriate for descriptive spatial epidemiology and for generating hypotheses to be tested with individual-level data in future research. A key strength of this research is the integration of temporal, demographic, and spatial dimensions within a unified analytic framework. The use of standardized cartographic methods, verified population denominators, and cross-checked mortality records ensured the reliability of the data. Employing official health-region boundaries enhanced interpretability for policy applications, while multidisciplinary validation by psychiatrists, epidemiologists, and geographers increased the analytic rigor. Establishing a statistically consistent pre-pandemic baseline provides a foundation for evaluating post-COVID-19 changes and long-term suicide mortality trends in Jalisco.

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Discussion (Continued)

Future research should expand the analysis to include pandemic and post-pandemic years to evaluate the effects of social confinement, economic stress, and service reorganization on suicide patterns. Multilevel modeling may quantify associations between contextual determinants, such as unemployment, social fragmentation, and health-care accessibility, and suicide risk at municipal and regional levels. Incorporating geospatial regression and Bayesian hierarchical models would facilitate more precise identification of persistent hotspots. Key research questions include determining the most effective interventions for reducing suicide rates in high-risk areas and understanding how socioeconomic disruptions influence suicidal behaviors across regions. Further studies should investigate causal pathways, including the impact of mental health policies on suicide risk mitigation. At the policy level, these findings should inform the development of regionally tailored suicide-prevention strategies. Integrating geographic information systems into mental health surveillance could enhance early detection of emerging clusters and enable dynamic resource allocation. Sustained collaboration among the Jalisco Institute of Mental Health, the Mexican Social Security Institute, and academic institutions such as the University of Guadalajara will be critical for ongoing monitoring and research translation.

Conclusions

This spatiotemporal analysis offers a comprehensive characterization of suicide mortality in Jalisco during the five years preceding the COVID-19 pandemic. The study identified persistent territorial disparities, pronounced sex differences, and a marked concentration of deaths among young adults. Suicide mortality was consistently higher among men, particularly in rural regions of the southwest and north, while female mortality showed smaller but stable clusters in the northern highlands. The sustained presence of these spatial patterns from 2015 to 2019 indicates that suicide in Jalisco is driven by structural, geographically dependent dynamics rather than random fluctuations. Establishing a pre-pandemic baseline was crucial for understanding the interplay between geographic and demographic factors and broader social determinants. These findings provide a foundation for comparative assessments of changes during and after the pandemic. Identifying municipalities and regions with recurrently high mortality rates supports the implementation of geographically targeted prevention strategies and improved service distribution. At the health-policy level, the results highlight the need to strengthen surveillance systems that integrate geographic information, sociodemographic data, and real-time mortality monitoring. Regional mental health networks should prioritize community-based interventions, crisis hotlines, and early detection programs tailored to the cultural and socioeconomic context of each municipality. Collaboration among academic institutions, government agencies, and public health organizations will be critical to sustaining these efforts and translating data into effective prevention measures. In summary, suicide mortality in Jalisco constitutes a territorially structured and demographically differentiated public health challenge. Integrating spatial epidemiology with mental health policy provides a pragmatic framework for reducing preventable deaths and improving psychosocial well-being across the state. Continuous monitoring, intersectoral coordination, and evidence-based action are essential for achieving measurable progress in suicide prevention and ensuring equitable access to care for all communities in Mexico.

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