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Machine learning to investigate policy-relevant social determinants of health and suicide rates in the United States

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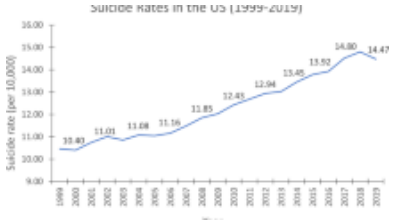
Abstract

This study aimed to categorize county clusters of multidimensional social determinants of health (SDOH) using unsupervised machine learning and to analyze their association with county-level suicide rates, considering temporal, geographic and demographic variation. We analyzed aggregated SDOH data across 3,018 US counties for 2009, 2014 and 2019, which were linked to county-level suicide rates from the National Vital Statistics System. We identified three distinct SDOH clusters: 'REMOTE' (rural, elderly, marginalized environments, old housing, traditional systems, empty houses), 'COPE' (complex family dynamics, high consumption of health services, poverty, extreme heat) and 'DIVERSE' (dense, immigrant rich, environmentally challenged, economically unequal, racial/ethnic diversity, saturated health care, expensive housing). We used negative binomial regression after identifying clusters to estimate the associations between county-level SDOH clusters and suicide rates. Compared with other clusters, REMOTE was associated with higher overall suicide rates, particularly among men; COPE showed elevated suicide rates among whites; and DIVERSE exhibited increased rates among women and Black and Hispanic populations. The distribution of suicide rates across US states corresponded to the variations in SDOH cluster distribution within each state. These findings provide a foundation for

designing more effective, data-driven suicide prevention strategies tailored to specific regional and demographic contexts.



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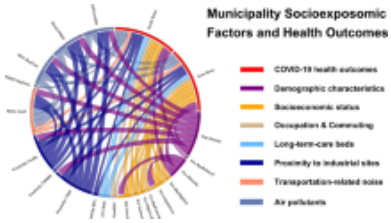

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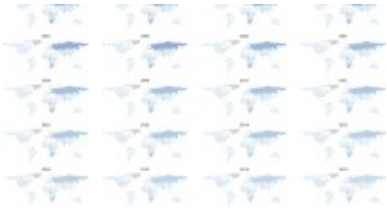

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Data availability

All raw data in this study are publicly available and can be retrieved from the US National Center for Health Statistics, US Centers for Disease Control and Prevention Mortality Data (https://www.cdc.gov/nchs/nvss/deaths.htm) and US Agency for Healthcare Research and Quality Social Determinants of Health Database (https://www.ahrq.gov/sdoh/data-analytics/sdoh-data.html).

Code availability

Data analysis was performed using R version 4.4.2, leveraging several specialized packages to ensure robust and reproducible results. The 'NbClust' package (version 3.0.1) was used to determine the optimal number of clusters, while 'cluster' (version 2.1.6) facilitated clustering techniques and visualization. Core statistical computations and modeling were conducted using the 'stats' package (version 3.6.2). For regression modeling, including elastic net and regularization, the 'glmnet' package (version 4.1.8) was employed. In addition, geographically weighted regression was implemented using the 'spgwr' package (version 0.6-37). Code is available at github.com/X-PLORE-Lab/sdoh_clustering_suicide.

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responsibility for the integrity of the data and the accuracy of the data analysis. Y.X. and Y.M. have made equal contributions.

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Ethics declarations

Competing interests

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Supplementary information

Supplementary Information

Supplementary Figs. 1–9, Tables 1–20, Results 1–3 and Methods 1–7.

Reporting Summary

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