The Zoning-Microbiome Integration Model (ZMIM): A Novel Framework for Quantifying the Biological Impact of Zoning Policies on Native Hawaiian and Pacific Islander Cardiometabolic Health and Gut Microbiome

Sugimoto, Elle (School: Iolani School)

Native Hawaiian and Pacific Islanders (NHPI) suffer disproportionately from cardiometabolic health conditions, with diabetes mortality rates 3.32 times higher than the general population, yet only 3% of minority-centered studies disaggregate NHPI data. This research developed the Zoning-Microbiome Integration Model (ZMIM), a novel framework quantifying relationships between zoning policies, gut microbiome composition, and cardiometabolic health in NHPI communities on O'ahu. The study combined Hawai'i Geographic Information System zoning data with health measurements and gut microbiome profiles (n=1,656), using machine learning to identify patterns across residential versus non-residential environments. Results revealed that NHPI individuals in residential zones exhibited reduced gut microbial diversity (median: 0.155) alongside elevated BMI (coefficient: 4.737, $P<0.01$) and A1c levels. Educational attainment emerged as a significant protective factor specifically within residential zones (coefficient: -0.858, $P<0.01$) but not in non-residential areas, suggesting education provides differential health benefits depending on zoning context. SHAP analysis identified mixed-use proximity as the highest-ranked zoning feature affecting gut microbiome diversity (importance: 0.172), appearing in top predictors in 92% of bootstrap samples. The ZMIM framework provides a standardized methodology for quantifying how zoning policies impact health through gut microbiome alterations, offering a replicable approach for examining similar relationships in other indigenous communities and identifying early biological indicators of environmental exposures before clinical manifestations appear.

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