Community Research

Regional disparities in diabetes comorbidity and mortality: a nationwide investigation of provinces in Indonesia

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ABSTRACT

BACKGROUND Diabetes mellitus (DM) remains a major global health challenge, and its burden is intensified by comorbidities, such as obesity, hyperglycemia, and kidney dysfunction. Diverse geography and population, such as Indonesia, create unique provincial variations in DM risk factors, necessitating detailed sub-nationwide analyses to guide policymaking. This study aimed to evaluate regional disparities in diabetes-related mortality and associated risk factors across Indonesian provinces and to examine whether population density influences the distribution of these risk factors.

METHODS We analyzed age-standardized DM mortality and summary exposure values for 9 comorbidities across 34 provinces (GBD 2021), using Pearson's/Spearman's correlations nationally and provincially. Coefficient power was classified as weak (0.01–0.29), moderate (0.30–0.69), or strong (0.70–1.00).

RESULTS At the national scale, DM mortality was moderately associated with high BMI, high FPG, and kidney dysfunction (all R = 0.60; $p<0.001$). Associations were stronger in high-density provinces and negligible in low-density provinces. Across provinces, BMI and FPG were the most consistent correlates of DM mortality while diet-related factors (e.g., sugar intake) showed the largest gradient by density.

CONCLUSIONS These findings support the development of tailored strategies based on population density to effectively reduce diabetes-related mortality. These results indicate that interventions in urban provinces should prioritize curbing sugar intake and reducing obesity prevalence. In intermediate-density regions, the focus should shift to the intensification of management for kidney disease and the optimization of blood pressure control. For low-density provinces, a critical approach involves expanding systematic screening programs and enhancing patient access to healthcare services.

KEYWORDS comorbidity, diabetes, mortality, Indonesia, policy, regional health planning

Diabetes mellitus (DM) is a pressing global health challenge, contributing to over 1.5 million deaths annually and ranking among the top 10 causes of mortality worldwide.[1] Its burden is particularly severe in low- and middle-income countries, where healthcare systems commonly struggle to address this disease's complex comorbidities.[2] Comorbid conditions, such as obesity, hyperglycemia, hypertension, and kidney dysfunction can all accelerate DM progression and significantly increase the risk of mortality.[3] In Indonesia, a geographically and demographically diverse nation with more than 270 million people, the management of DM is exceptionally complex. Its prevalence is also projected to rise sharply in the future, driven by urbanization, dietary shifts, and limited healthcare access, particularly in rural areas.[4]

In 2021, the International Diabetes Federation estimated that there were 19.47 million Indonesian

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adults aged 20–79 years living with diabetes, representing a prevalence of 10.8%.[5] This places Indonesia among the top 10 countries globally for diabetes burden. However, this national figure masks significant variation. To our knowledge, no study has systematically evaluated province-level associations between diabetes mortality and Global Burden of Disease (GBD)-derived risk-exposure metrics across all 34 Indonesian provinces. For example, urban centers such as Jakarta face high rates of obesity and processed food consumption, while these issues are less in provinces with small populations such as Papua, which conversely grapples with inadequate healthcare infrastructure.[6] National health policies commonly fail to account for this heterogeneity, underscoring the need for subnational analyses to inform targeted interventions.

The economic impact of DM in Indonesia is substantial, with both direct medical costs and productivity losses straining the healthcare systems and households.[7] The dual burden of communicable diseases and non-communicable diseases (NCDs) further complicates resource allocation, particularly in less densely populated areas where infectious diseases remain prevalent.[8–10] Moreover, the coronavirus disease 2019 pandemic exacerbated DM management challenges as patients with diabetes face higher risks of severe outcomes.[9] These factors highlight the urgent need to understand the regional variations in DM mortality and its risk factors in Indonesia.

The GBD framework provides standardized summary exposure values (SEVs), which integrate both the prevalence and relative severity of risk-factor exposure into a common population-level metric. These metrics facilitate comparison of risk-exposure profiles across geographic regions and may help identify regional priorities for diabetes prevention and management.[1] This study leveraged the Global Burden of Disease (GBD) Study 2021, a comprehensive epidemiological resource, to examine the correlations between DM mortality and selected GBD-derived risk-exposure metrics across 34 provinces of Indonesia,[11,12] with the primary objective of identifying distinct region-specific risk factor profiles. Such an analysis will be essential to provide granular evidence to Indonesian health ministries and local policymakers, particularly in the context of diabetes. These findings may further offer a methodological framework for other large and diverse nations facing similar subnational health disparities.

METHODS

Data source and ethical considerations

This ecological, cross-sectional study analyzed publicly available aggregate data from the GBD 2021 study. The GBD uses standardized statistical modeling and multiple data sources, including vital registration, surveys, census, and administrative health data to generate annual estimates of disease burden and risk exposure by location, age, sex, and year. For the present analysis, we extracted data for all 34 provinces in Indonesia from the GBD 2021 results tool.

The outcome variable was the 2021 age-standardized mortality rate for DM. The exposure variables were the 2021 SEVs for selected GBD-defined diabetes-related risk factors, namely high body mass index(BMI), high fasting plasma glucose (FPG), high systolic blood pressure (SBP), kidney dysfunction, high low-density lipoprotein cholesterol, diets high in sugar-sweetened beverages, processed meat, and red meat, and tobacco smoking. The SEV is a population-level metric ranging from 0 to 100, reflecting both the prevalence and severity of exposure in relation to its associated health risk. Therefore, these variables should not be interpreted as patient-level comorbidities or mean biomarker values among individuals with diabetes; instead, they should represent the province-level risk-exposure profiles in the general population.

To minimize any temporal mismatch, both DM mortality outcomes and all risk factor exposure variables were extracted for the same calendar year (2021). Accordingly, the analysis evaluated contemporaneous correlations at the provincial level, and did not establish a temporal sequence or causality. District-level analysis was not conducted, as the dataset used in this study was consistently extracted at the provincial level across all variables of interest. The data were accessed in October 2023. Because this study used de-identified and publicly available secondary data, informed consent for participation was not required. Ethical exemption was granted by the Committee on Institutional Review Board/Health Research Ethics of the National Cardiac Center Harapan Kita Hospital (No. DP.04.03/KEP199/EC122/2025).

Variable definition and subgroup analysis

The dependent variable was the provincial age-standardized mortality rate of DM in 2021. The independent variables were set as the provincial 2021 SEVs for the selected GBD risk factors. In the present study, "high body mass index," "high fasting plasma glucose," "high systolic blood pressure," and "kidney dysfunction" were defined following the operational definitions used by GBD 2021. As these indicators were obtained directly from the GBD, they were not recalculated as mean clinical measurements or as the prevalence of diagnosed obesity, hyperglycemia, hypertension, or kidney disease at the individual level. Instead, they were analyzed as standardized province-level risk exposure metrics derived from the GBD framework. For subgroup analysis, provinces were categorized as high (≥1,000 inhabitants/km^2), intermediate (100–999 inhabitants/km^2), or low (<100 inhabitants/km^2) based on population density.

Statistical methods

A normality test (Shapiro–Wilk) was conducted to assess data distribution. Pearson's and Spearman's correlation coefficients were used for normally and non-normally distributed data, respectively. The correlation coefficients (r) were interpreted as weak (0.01–0.29), moderate (0.30–0.69), or strong (0.70–1.00). All statistical analyses were conducted using SPSS software version 23 (IBM Corp., USA). As this study was an ecological analysis of aggregated population-level data (N = 34 provinces), a formal a priori sample size calculation was not applicable.

RESULTS

National-level findings

At the national level, DM mortality was most consistently correlated with the established metabolic and renal risk exposure metrics (Tables 1 and 2). High BMI, high FPG levels, kidney dysfunction, high SBP, and processed meat intake demonstrated statistically significant positive correlations, whereas high sugar intake, high LDL cholesterol level, and tobacco smoking showed weaker but significant associations. Red meat intake was not significantly correlated with DM mortality. These findings indicate that the national pattern is predominantly driven by metabolic and renal exposure, whereas several dietary and lifestyle factors appear to contribute more modestly and may vary more substantially by province.

Table 1. Correlation between DM mortality rate and comorbidities in Indonesian provinces

Comorbidity	r	*p*
High sugar intake	0.20	**<0.001**
High BMI	0.60	**<0.001**
High FPG	0.60	**<0.001**
High LDL-C	0.20	**<0.001**
High SBP	0.40	**<0.001**
Kidney dysfunction	0.60	**<0.001**
Tobacco smoking	0.10	**0.046**
Processed meat intake	0.30	**<0.001**
Red meat intake	0.02	0.542

BMI=body mass index; DM=diabetes mellitus; FPG=fasting plasma glucose; LDL-C=low-density lipoprotein cholesterol; SBP=systolic blood pressure

Table 2. Correlation coefficients (r) between diabetes mortality and selected GBD-defined risk exposures by population-density groups

GBD-defined risk exposure	Population-density groups			
	National	High	Intermediate	Low
High sugar intake	0.20	0.64	0.29	*
High BMI	0.60	0.91	0.57	0.56
High FPG	0.60	0.27	0.46	0.35
High LDL-C	0.20	0.45	0.28	0.38
High SBP	0.40	0.36	0.47	0.06*
Kidney dysfunction	0.60		0.52	0.61
Tobacco smoking	0.10	0.23	0.04*	
Processed meat intake	0.30	0.62	0.38	0.23
Red meat intake	0.02*	0.37	0.07*	

BMI=body mass index; DM=diabetes mellitus; FPG=fasting plasma glucose; GBD=Global Burden of Disease; LDL-C=low-density lipoprotein cholesterol; SBP=systolic blood pressure
*Not significant

Provincial variability

Beyond the national average, provincial analyses revealed significant heterogeneity in the correlation between risk factors and DM mortality. For example, in highly urbanized provinces, the correlations were substantially stronger than the national average, while other provinces showed weaker or even negative correlations (e.g., North Sulawesi). This finding underscores the limitations of national-level analysis.

Table 3. Comorbidity correlative power with DM mortality according to province in Indonesia

Provinces	Sugar intake	BMI	FPG	LDL	SBP	Kidney disease	Tobacco smoking	Processed meat	Red meat
Aceh	0.65	0.99	0.78	0.74	0.99	0.90	0.37	0.81	−0.11*
Bali	0.70	0.94	0.26*	0.80	0.85	−0.80	−0.14*	0.71	0.43
Bangka Belitung Island	0.67	0.98	0.69	0.68	0.98	0.53	0.60	0.78	0.30*
Banten	0.68	0.99	0.49	0.62	0.99	0.31*	0.40	0.80	0.24*
Bengkulu	0.76	0.98	0.42	0.71	0.69	−0.01*	0.24*	0.79	0.34*
Central Java	0.80	0.99	0.79	0.64	0.93	0.10*	0.20*	0.82	0.41
Central Kalimantan	0.92	0.99	0.62	0.68	0.61	−0.81	0.42	0.88	0.39
Central Sulawesi	0.97	0.98	0.50	0.77	0.98	0.27*	0.06*	0.82	0.53
East Java	0.96	0.99	0.83	0.69	0.91	−0.12*	−0.10*	0.86	0.52
East Kalimantan	0.85	0.98	0.88	0.98	0.85	0.75	0.19	0.89	0.57
East Nusa Tenggara	0.62	0.73	0.48	0.87	0.69	−0.17*	−0.44	0.48	0.67
Gorontalo	0.68	0.99	0.72	0.57	0.99	0.90	−0.41	0.78	0.27*
Indonesia (national estimate)	0.89	0.99	0.77	0.90	0.99	−0.35	0.49	0.85	0.45
Jakarta	0.99	0.99	0.92	0.99	0.99	0.76	−0.63	0.97	0.69
Jambi	0.90	0.99	0.71	0.73	0.99	−0.23*	−0.17*	0.86	0.52
Lampung	0.96	0.99	0.47	0.71	0.95	−0.50	0.15*	0.85	0.47
Maluku	−0.22*	0.89	0.47	0.67	0.70	−0.61	−0.59	0.73	−0.30*
North Kalimantan	0.89	0.96	0.89	0.91	0.96	−0.63	0.33*	0.93	0.62
North Maluku	0.53	0.93	0.55	0.93	0.93	−0.71	0.37	0.72	−0.11
North Sulawesi	−0.78	−0.78	−0.45	−0.36	−0.79	0.80	0.24*	−0.93	−0.45
North Sumatera	0.92	0.99	0.51	0.73	0.84	0.18*	0.47	0.83	0.48
Papua	0.74	0.97	0.69	0.97	−0.25*	0.64	−0.17*	0.83	0.27*
Riau	0.72	0.99	0.85	0.83	0.93	−0.25*	0.30*	0.83	0.39
Riau Islands	0.94	0.71	0.90	0.55	0.73	−0.50	−0.04*	0.73	0.72
South Kalimantan	0.88	0.98	0.58	0.64	0.87	−0.80	0.22*	0.82	0.33*
South Sulawesi	0.91	0.99	0.58	0.69	0.73	−0.05*	0.46	0.85	0.36
South Sumatera	0.75	0.99	0.69	0.69	0.89	−0.80	0.43	0.85	0.40
Southeast Sulawesi	0.75	0.96	0.61	0.96	0.92	−0.59	0.37	0.76	0.51
West Java	0.75	0.99	0.38	0.99	0.92	−0.89	0.99	0.81	0.35
West Kalimantan	0.84	0.99	0.51	0.67	0.99	−0.89	−0.04*	0.81	0.33*
West Nusa Tenggara	0.99	0.99	0.73	0.79	0.99	0.85	−0.46	0.87	0.54
West Papua	0.66	0.97	0.69	0.97	0.97	0.23*	0.87	0.78	0.42
West Sulawesi	0.58	0.68	0.35	0.91	0.68	−0.09*	−0.32*	0.46	0.56
West Sumatera	0.97	0.99	0.54	0.70	0.83	−0.89	0.43	0.87	0.48
Yogyakarta	0.89	0.96	0.51	0.77	0.57	0.33*	−0.43	0.76	0.47

BMI=body mass index; DM=diabetes mellitus; FPG=fasting plasma glucose; LDL=low-density lipoprotein, SBP=systolic blood pressure
*Not significant

The detailed, province-by-province correlation data are provided in Table 3.

Subgroup analyses by population density

Subgroup analyses by population density revealed that the relationship between provincial risk-exposure profiles and DM mortality differed across the density strata (Table 4). High-density provinces showed a more pronounced correlation pattern, particularly for lifestyle- and adiposity-related exposures, while intermediate-density provinces showed more balanced associations across metabolic,

Table 4. Comorbidity correlative power with DM mortality in Indonesian urban (population density ≥1,000/Km^2), suburban (population density 100–999/Km^2) and rural (population density <100/Km^2) provinces

Provinces	Sugar intake	BMI	FPG	LDL	SBP	Kidney disease	Tobacco smoking	Processed meat	Red meat
High density*	0.64	0.91	0.27	0.45	0.36	−0.49	0.23	0.62	0.37
Intermediate density†	0.29	0.57	0.46	0.28	0.47	0.52	0.04§	0.38	0.07§
Low density‡	−0.04§	0.56	0.35	0.38	0.06§	0.61	−0.30	0.23	−0.15

BMI=body mass index; DM=diabetes mellitus; FPG=fasting plasma glucose; LDL=low-density lipoprotein; SBP=systolic blood pressure
*Provinces classified as high density were Banten, Central Java, Jakarta, West Java, and Yogyakarta; †provinces classified as intermediate density were East Java, Bali, West Nusa Tenggara, Lampung, Riau Islands, North Sumatera, South Sulawesi, North Sulawesi, West Sumatera, East Nusa Tenggara, South Kalimantan, Gorontalo, and Bengkulu; ‡provinces classified as low density were South Sumatera, Aceh, Bangka Belitung, West Sulawesi, Riau, Jambi, Southeast Sulawesi, Central Sulawesi, North Maluku, Maluku, West Kalimantan, East Kalimantan, Central Kalimantan, Papua, West Papua, North Kalimantan; §not significant

renal, and blood pressure (BP)-related exposures. In low-density provinces, the correlation pattern was less consistent and included several weak or nonsignificant associations. This divergence indicates that DM mortality may be shaped by different mechanisms across Indonesia, which may require stronger lifestyle and obesity prevention strategies. Intermediate areas may benefit from intensified renal and BP management, while low-density provinces may require improved diagnostic coverage, screening, and access to care before epidemiological patterns can be interpreted with greater confidence.

DISCUSSION

The moderate national correlations between DM mortality and high BMI, high FPG levels, and kidney dysfunction identified in this analysis are consistent with the global epidemiological evidence, underscoring their pivotal roles in DM-related complications.[13] These findings corroborate studies demonstrating that obesity and hyperglycemia are the primary drivers of DM progression, with kidney dysfunction exacerbating the mortality risk through mechanisms such as diabetic nephropathy.[14] However, the pronounced provincial variability observed in the present study highlights the limitations of uniform health policies in addressing diverse epidemiological landscapes, such as that of Indonesia. This heterogeneity necessitates a nuanced and region-specific approach to public health interventions, tailored to the unique risk profiles of each province.

In urban provinces such as Jakarta, West Java, and Yogyakarta, near-perfect correlations (R≥0.99, p<0.001) between DM mortality and lifestyle-related comorbidities, including high sugar intake, BMI, and LDL cholesterol, reflect the adverse consequences of rapid urbanization. Urbanization commonly precipitates lifestyle changes, such as increased consumption of energy-dense, nutrient-poor foods, reduced physical activity due to sedentary occupations, and reliance on motorized transport.[15] One meta-analysis by Imamura et al[16] found that each additional daily serving of sugar-sweetened beverages increases type 2 diabetes risk by 18% (95% confidence interval: 9–28%), providing robust evidence for targeting dietary interventions in urban settings. Moreover, urban areas may have higher diagnosis rates owing to superior healthcare screening; however, this does not necessarily translate to effective management, particularly if healthcare systems are overburdened or socioeconomic disparities limit access to quality care within these urban populations.[8] For example, in line with our findings, a previous study reported a significantly higher prevalence of DM in Indonesian urban areas driven by elevated BMI and physical inactivity.[17]

In contrast, the negative correlations observed in North Sulawesi (r = −0.78 to 0.79, p<0.001) between high sugar intake and high SBP are particularly intriguing, indicating the presence of protective factors that mitigate DM mortality despite higher exposure to these risk factors. This counterintuitive finding may be attributed to dietary patterns rich in fish and seafood, which are prevalent in North Sulawesi and provide omega-3 fatty acids, known for their anti-inflammatory properties and cardiovascular benefits.[18] One cross-sectional study in Indonesia identified a traditional dietary pattern characterized by fish, vegetables, and fruits that was associated with

lower odds of hypertension, indicating that certain traditional dietary patterns may confer cardiometabolic benefits.[19] These findings warrant further investigation through cohort studies to elucidate the underlying mechanisms and identify scalable protective strategies. Provinces with lower population densities, such as Papua and Maluku, which showed weaker or non-significant correlations with comorbidities as compared to denser regions, present different epidemiological contexts. In these regions, infectious diseases, such as malaria, tuberculosis, and dengue fever, commonly dominate health priorities, potentially overshadowing NCDs, such as DM.[20] Limited healthcare infrastructure, including shortages of diagnostic tools and trained personnel, may lead to the underdiagnosis and underreporting of DM cases, attenuating observed correlations.[21] Additionally, traditional diets in some rural areas, which may include fewer processed foods, could reduce the prevalence of DM risk factors compared to urban settings. However, the lack of any strong correlation may not imply a lower DM burden. Instead, it highlights the need for improved data collection and healthcare access to accurately assess and address DM in these regions.

These findings indicate a decentralized density-specific approach for DM management. In high-density provinces where lifestyle factors (high BMI, sugar intake) are strongly correlated with mortality, policies must prioritize lifestyle modifications. This includes fiscal interventions, such as sugar taxes (as demonstrated in Mexico),[22] and urban planning that promotes physical activity (e.g., pedestrian-friendly zones, public parks). Mass media campaigns promoting glycemic control are vital in urban settings.

Conversely, in low-density provinces, it is imperative that healthcare infrastructure gaps be overcome. Efforts should focus on expanding screening and diagnostic tools in primary care. Given personnel limitations, the empowerment and training of community health workers ('cadres') is a critical strategy for providing basic DM care, education, and prevention. Establishing recurring health-screening events will be necessary once the foundational infrastructure and workforce capacity are in place.

The economic burden of DM in Indonesia is substantial. National insurance claims data from 2016 showed a cost of USD 576 million, primarily for complications, underscoring the need for resource optimization.[23] Effective DM management requires integration into Indonesia's broader healthcare system by leveraging the *Jaminan Kesehatan Nasional* (JKN) program. Interventions must additionally consider social determinants such as poverty and education, which significantly influence risk and access. The variability observed in Indonesia mirrors challenges in other diverse nations, such as India and Brazil, thus reinforcing the global need for localized NCD strategies.[24,25] While implementation faces challenges (funding, decentralization), opportunities exist to leverage technology (e.g., telemedicine) and public-private partnerships, engaging local communities to ensure cultural relevance and uptake.[26–28]

Longitudinal studies are required to establish the causality between comorbidities and DM mortality to overcome the limitations of a cross-sectional design. Individual level data can mitigate ecological fallacies and provide accurate estimates. Qualitative research exploring the cultural and social determinants of health behaviors in provinces such as North Sulawesi could further inform intervention design. Additionally, evaluating existing DM programs, such as community-based initiatives or electronic health records in rural clinics, can guide policies. Investigating the interactions between DM and comorbid conditions is also critical, given their impact on mortality.

The findings of the present study should be interpreted in light of several limitations. First, because this analysis was based on aggregated provincial estimates from a single year, the observed associations were ecological in nature and should not be interpreted as evidence of temporal or causal relationships. Second, both the age-standardized DM mortality rates and SEVs were derived from GBD-modeled estimates rather than direct measurements. Although the GBD framework synthesizes multiple data sources using standardized statistical methods, these estimates remain subject to model-based uncertainty, which may be greater in provinces with sparse or lower-quality primary data. Consequently, between-province differences and the resulting correlation estimates should be interpreted cautiously. Additionally, the use of provincial-level data—rather than district-level data—may mask meaningful within-province heterogeneity. Further studies using longitudinal, geographically detailed, and primary data sources are needed to clarify temporal patterns, validate modeled associations, and characterize local variation.

In conclusion, the results of this analysis shows that diverse diabetes comorbidity profiles across

heterogeneous Indonesian provinces necessitate region-specific strategies. Urban areas require lifestyle interventions, while rural regions require infrastructure, and unique regions offer opportunities for research. These findings advocate tailored policymaking for DM comorbidities on a global scale rather than a generic approach.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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