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臺灣地區糖尿病健康結果與危險因子解構之地理差異：

一項區域性健康不平等的全面研究

Geographical Disparities in Diabetes Outcomes

and Risk Factors Decomposition in Taiwan:

A Comprehensive Study of Regional Health Disparities

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台灣地區糖尿病健康結果與危險因子解構之地理差異：一項區域性健康不平等的全面研究

論文英文題目：

Geographical Disparities in Diabetes Outcomes and Risk Factors Decomposition in Taiwan: A Comprehensive Study of Regional Health Disparities

本論文係江翊潔君（學號 R10849010）在國立臺灣大學流行病學與預防醫學研究所完成之碩士學位論文，於民國 114 年 5 月 14 日承下列考試委員審查通過及口試及格，特此證明。

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摘要



背景：糖尿病（Diabetes Mellitus, DM）是一種全球盛行的代謝性疾病，對公共衛生構成長期且日益嚴峻的挑戰。糖尿病經常伴隨多種潛在併發症，並對個人與整體社會造成顯著的醫療與經濟負擔。在臺灣，雖然近年（2017–2021 年）糖尿病的發生率與盛行率趨於穩定，且死亡率並未顯著上升，但相關危險因子與糖尿病健康結果（如發生率與死因別死亡率）在各縣市間仍呈現顯著的地理差異，反映出明確的區域性健康不平等現象。

目的：本研究旨在建構完整的疾病歷程架構，包含「危險因子暴露」→「疾病發生」→「醫療照護（診斷與治療）」→「死亡」的進程，並探討其中健康不平等最為顯著、可被解釋與最具介入潛力的環節。本研究更進一步解析臺灣各縣市間糖尿病健康結果及其相關危險因子分布的地理差異，並量化三項主要可修正之危險因子——高身體質量指數（High BMI）、身體活動量不足（Physical Inactivity）與吸菸行為（Smoking）——對糖尿病發生率不平等的貢獻程度。

方法：本研究涵蓋 2017 至 2021 年，並整合臺灣健保資料庫（NHIRD）、國民健康訪問調查（NHIS）、營養健康狀況變遷調查（NAHSIT）與國人死因統計檔，分析糖尿病發生率、死因別死亡率、死亡對發病比（MI ratio）、治療覆蓋率及血糖控制率等指標，並針對三項主要危險因子估算其單獨與聯合之族群可歸因分率（Population Attributable Fraction, PAF）。本研究進一步運用變異係數（Coefficient of Variation, CV）作為地區不平等分析工具，比較縣市別糖尿病發

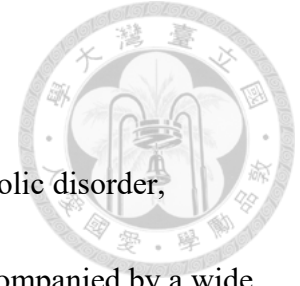


生率的目前情境與使用 PAF 估計移除某危險因子後之縣市別糖尿病發生率反事實情境，兩情境下變異係數之改變，以量化各危險因子對地理空間差異的解釋力。

結果：研究顯示，臺灣各縣市間在糖尿病相關健康指標上存在明顯的區域性差異。東部地區（如花蓮縣、臺東縣）具有較高的糖尿病發生率；花蓮縣與屏東縣之糖尿病死亡率亦居各縣市前列；部分中南部縣市則是在治療覆蓋率及血糖控制成功率方面表現相對落後。在三項主要危險因子當中，高 BMI 之族群可歸因分率最高（男性介於 33.24%至 45.72%；女性介於 17.55%至 42.67%），對糖尿病發生率的整體貢獻最大；相較之下，身體活動量不足（男性介於 14.90%至 17.92%；女性介於 13.80%至 18.83%）與吸菸（男性介於 12.75%至 21.98%；女性介於 0.23%至 2.84%）之貢獻度明顯較低。進一步以目前與反事實情境下變異係數改變量之分析後發現，男性高 BMI 對縣市間糖尿病發生率差異之解釋力最高（3.45%）；女性則以身體活動量不足為最（1.18%）。然而，這三項因子之解釋力皆不足以全面說明地理不平等，顯示尚有其他潛在因素驅動臺灣地區糖尿病發生的不平等分布。整體而言，研究結果突顯出目前既有策略在應對地區性健康不平等方面的侷限，亦顯示需針對具代表性的危險因子採取更差異化的政策。

結論：本研究強調糖尿病防治策略應具備地區化與性別導向特性，並呼籲將肥胖防治納入政策核心，作為減少糖尿病負擔與健康不平等的首要目標。研究亦透過 CV 方法量化並分解不平等來源，提供精準公共衛生於規劃中的資源配置與介入優先順序之實證依據。

Abstract



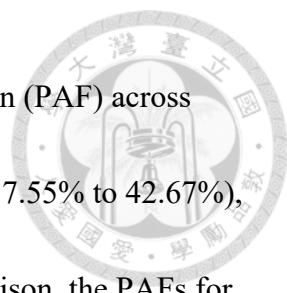
Background: Diabetes Mellitus (DM) is a globally prevalent metabolic disorder, representing a persistent public health challenge. It is frequently accompanied by a wide range of complications and imposes a substantial medical and economic burden on individuals and society. In Taiwan, while the incidence and prevalence of diabetes remained relatively stable during the study period from 2017 to 2021, and the diabetes-specific mortality did not exhibit a significant upward trend, there are still notable geographical disparities persisting across counties in both diabetes-related outcomes as well as in the distribution of associated risk factors. These variations in both outcomes and risk factor distributions reflect pronounced regional health inequalities.

Objectives: This study aims to conceptualize the full disease pathway framework, including “risk exposure” → “disease onset” → “healthcare access (diagnosis and treatment)” → “diabetes-attributable mortality”, seeking to identify the stages where disparities are most pronounced, most attributable, and most amenable to intervention. This study also aims to analyze the geographical disparities in diabetes-related health outcomes and associated risk factor distributions across Taiwan’s counties, and to further quantify and decompose the contributions of three major modifiable risk factors—high body mass index (BMI), physical inactivity, and smoking—to the observed inequalities in diabetes incidence.



Methodology: This study analyzes data from 2017 to 2021, using nationally representative sources: National Health Insurance Research Database (NHIRD), National Health Interview Survey (NHIS), Nutrition and Health Survey in Taiwan (NAHSIT), and Cause of Death Data. Key diabetes-related indicators, including incidence, diabetes-attributable mortality, mortality-to-incidence ratio (MI-Ratio), treatment coverage, and glycemic control, are assessed across regions. Population Attributable Fractions (PAFs) are estimated for high body mass index (BMI), physical inactivity, and smoking, being calculated both individually and jointly, which are also disaggregated by sex and geographic unit. This study further employed the Coefficient of Variation (CV) as a tool to analyze regional inequality by comparing county-level diabetes incidence under the current scenario with a counterfactual scenario in which the population-attributable fraction (PAF) for each risk factor was removed. The change in CV between the two scenarios is used to qualify the explanatory power of individual risk factors on spatial disparities.

Results: The findings reveal persistent geographical inequalities in diabetes-related health indicators across Taiwan. Eastern regions such as 花蓮縣 and 臺東縣 exhibit higher diabetes incidence; 花蓮縣 and 屏東縣 exhibit elevated diabetes-specific mortality; several central and southern counties demonstrate relatively low treatment coverage and suboptimal glycemic control rates. Among the three risk factors, high



BMI demonstrates the highest average population attributable fraction (PAF) across counties (males range from 33.24% to 45.72%; females range from 17.55% to 42.67%), indicating its dominant contribution to diabetes incidence. In comparison, the PAFs for physical inactivity (males range from 14.90% to 17.92%; females range from 13.80% to 18.83%) and for smoking (males range from 12.75% to 21.98%; females range from 0.23% to 2.84%) have lower attribution. Further analysis of the difference in CV between the current and counterfactual scenarios indicates that, for males, high BMI have the strongest explanatory power for inter-county disparities in diabetes incidence (3.45%); among females, physical inactivity accounts for the greatest proportion (1.18%). However, the explanatory power of all the three risk factors remains limited, suggesting the presence of other unmeasured factors potentially driving the unequal geographic distribution of diabetes incidence in Taiwan.

Conclusion: This study underscores the importance of implementing geographically and gender-sensitive diabetes prevention strategies in Taiwan, with an emphasis on obesity reduction as a core public health policy priority to reduce the burden of diabetes. By applying Coefficient of Variation (CV) as decomposition methods to quantify the sources of disparities, the study provides an empirical foundation for precision public health planning, including targeted resource allocation and prioritized interventions.

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Chapter 1 Introduction



1.1 Background

Diabetes mellitus represents one of the most pressing and urgent public health challenges of the 21st century, imposing a substantial and escalating burden globally¹. In Taiwan, it has emerged as one of the leading contributors to both morbidity and premature mortality^{2,5,9}. Despite advancements in medical care and nearly universal healthcare coverage under the National Health Insurance (NHI) system^{3-5,12}, regional health disparities remain a critical concern^{3,4,6,11,14,15}. The burden of diabetes is unevenly distributed across Taiwan, with notable variation in incidence, diagnosis and treatment accessibility, and diabetes-specific mortality across counties^{6,11}. These disparities are not merely epidemiological observations, they are reflections of underlying systemic and structural inequities, with profound implications for health equity^{11,14}.

Geographical disparities describe the variations in individual's exposure to risk factors, access to healthcare, and subsequent health outcomes based on their place of residence, often being discussed in terms of rural or urban settings¹³. In Taiwan, multiple studies have documented such diabetes disparities in three key domains: complication incidence^{3,6,39}, healthcare accessibility^{7,15}, and prognostic outcomes^{3,6,11,14}. While existing studies have successfully mapped county-level differences in diabetes burden^{6,7,14}, few studies adopt an integrated perspective that examines how these factors

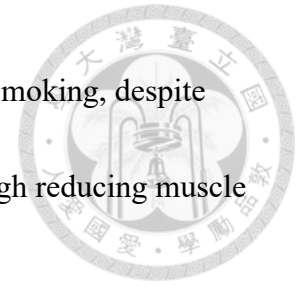
produce such inequalities across the disease continuum. Hence, future investigations should adopt interdisciplinary and multilevel approaches, from risk exposure and care accessibility to clinical outcomes, to effectively narrate Taiwan's diabetes health gap.

In the era of precision public health¹⁶, understanding the geographic heterogeneity of disease burden is essential. Monitoring national averages only is no longer adequate; instead, a full-spectrum analysis exploring the entire disease process is also a must, capturing disparities from upstream risk exposures, through disease incidence, care access, and ultimately to mortality, in order to identify where inequalities are most pronounced and amenable to effective intervention for policymakers and health professionals.

1.2 Diabetes and Its Driving Risk Factors

Diabetes arises from a complex interplay of genetic, behavioral, and environmental determinants^{17-19,29}. While non-modifiable risks exist^{19, 20}, a substantial proportion of diabetes cases can be attributable to modifiable behaviors, including excess body weight^{8,21,38,41}, physical inactivity^{21,22}, and tobacco smoking^{21,23,26,41}. Among these, high body mass index (BMI) consistently ranks as the most influential driver to both local and global burden of diabetes^{21,38}, through promoting insulin resistance and progression to diabetes by inducing systemic inflammation that disrupts β -cell function and reduces insulin sensitivity⁴¹. Physical inactivity exacerbates risk by

impairing insulin sensitivity^{22,24,41} and weight regulation^{25,41}; while smoking, despite being comparatively underemphasized, increases diabetes risk through reducing muscle glucose intake and developing insulin resistance^{27,41}.



These risk factors are not uniformly distributed across populations, and their prevalence varies significantly by demographic and geographic subgroups, which reflects broader disparities in health behaviors, socioeconomic status, and living environments²⁹⁻³³. Following disease onset, disparities can further widen along the care continuum^{28,40}. Disparities in diagnosis rates, treatment coverage, glycemic control, and complication management can shape the long-term health outcomes of individuals with diabetes^{28,39,40}. Ultimately, the endpoint, diabetes-specific mortality, represents the cumulative result of both biological vulnerability and systemic response^{9,34,35}.

Thus, diabetes serves as a critical tracer condition for examining health inequalities: it reflects a progression from preventable risk exposure to avoidable premature death, with each stage offering an opportunity for measurement, intervention, and policy engagement^{36,37}.

1.3 Research Gaps

Although previous studies have explored the prevalence and risk factors of diabetes in Taiwan^{8, 29-33}, and have each illuminated distinct aspects of diabetes-related inequalities in Taiwan^{6,7,14,31,33}, none has adopted a geographically sensitive framework

that integrates the full continuum of the disease process⁴⁰, or has yet integrated these components into a unified analytic structure. Consequently, there still remains an absence of a comprehensive, county-level analysis that traces the continuum from modifiable risk-factor decomposition, through diabetes incidence, treatment uptake, and management quality, all the way to diabetes-specific mortality.

First, prior research often focuses solely on risk factors distribution, or epidemiological outcomes, such as prevalence and incidence, without examining how disparities in upstream risk exposures translate into downstream health outcomes. Second, although a few studies have estimated the population attributable fraction (PAF) of diabetes risk factors in Taiwan^{21,43}, these analyses were conducted exclusively at the national level, without disaggregating results by county or region. This limits the understanding of how the diabetes burden attributable to modifiable risk factors varies across regions. Third, only a limited number of studies have comprehensively assessed how diabetes outcomes vary across Taiwan's subnational units^{6,7,14}. Moreover, even where regional disparities are described, their underlying causes often remain unclear or insufficiently quantified. Traditional research models rarely estimate the relative contribution of each risk factor to regional inequality. Lastly, in terms of diabetes prevention, although the pathway from risk exposure to disease incidence is well recognized⁴¹, there is still limited evidence existing on how much specific factors (high

BMI, physical inactivity, or smoking) explain disparities in diabetes incidence across regions. These research gaps obscure the mechanisms driving unequal diabetes outcomes and constrain the development of targeted, evidence-based public health strategies aimed at diabetes prevention and health equity.

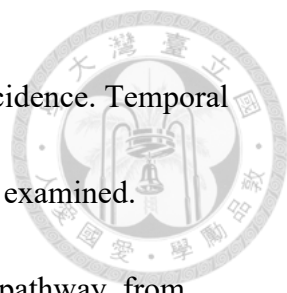


1.4 Study Aims

This study aims to address critical knowledge gaps by mapping health inequalities across the full diabetes continuum within Taiwan's subnational regions through a comprehensive, geographically stratified analysis. Specifically, it seeks to quantify regional disparities in diabetes incidence, treatment coverage, glycemic control, and diabetes-specific mortality from 2017 to 2021. To further approximate the true burden of undiagnosed and untreated diabetes, incidence rates will be adjusted based on treatment coverage.

In addition, in order to decompose the upstream contributions of three major modifiable risk factors (high BMI, physical inactivity, and smoking), this study estimates the population attributable fraction (PAF) of those three risk factors on diabetes incidence, disaggregated by county and sex.

To analyze the sources of inequality, this study employs Coefficient of Variation (CV) as a decomposition metric to quantify the extent to which each risk factor,



individually and jointly, explains geographic variation in diabetes incidence. Temporal trends and sex-specific differences in explanatory power will also be examined. Furthermore, this study evaluates disparities along the entire disease pathway, from upstream risk factor exposure to downstream outcomes, including incidence, treatment uptake, glycemic control, and diabetes-specific mortality, thus highlighting geographical disparities at each disease stage. By integrating risk factor decomposition and spatial inequality metrics, this research aims to identify which factors contribute most significantly to regional disparities in diabetes burden. Ultimately, the findings will inform region-specific, evidence-based public health interventions targeted at reducing diabetes-related health inequalities in Taiwan.

Chapter 2 Methodology



2.1 Data Sources

This study draws on multiple nationally representative data sources from Taiwan to estimate diabetes outcomes and related risk factors across counties and cities. The core analysis focuses on the years 2017 to 2021, during which incidence, mortality, treatment coverage, glycemic control, and population-attributable risk factors were systematically analyzed.

To ensure accurate identification of newly diagnosed diabetes cases, data from 2012 to 2021 are all extracted from the National Health Insurance Research Database (NHIRD), including Ambulatory Care Expenditures by Visits (門急診檔), Inpatient Expenditures by Admissions (住院檔), and Registry for Beneficiaries (承保檔), which provide the individual-level records of diagnosed diabetes cases. Although the main analytical period is 2017 onward, the inclusion of earlier data (2012–2016) is also essential to apply a 5-year lookback window to deal with the lookback bias, which allows for distinguishing true incident cases from prevalent cases already diagnosed prior to 2017. As emphasized in previous research, using an inadequate lookback period may lead to overestimation of incidence due to misclassification of pre-existing cases as new diagnoses⁴⁴.

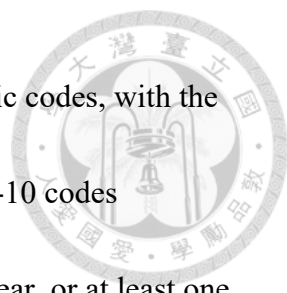


Mortality data are obtained from National Register of Deaths (死因統計檔) maintained by the Ministry of Health and Welfare. As for estimating behavioral risk exposure, this study uses data from the 2017 National Health Interview Survey (NHIS, 國民健康訪問調查). In terms of the blood draw information, treatment and medication records, this study utilizes the data from Nutrition and Health Survey in Taiwan (NAHSIT, 營養健康狀況變遷調查) conducted between 2017 and 2020. Demographic data are calculated by using household registration statistics released by the Department of Household Registration for the years 2011 to 2021. In addition, the Global Burden of Disease (GBD) 2019 estimates from the Institute for Health Metrics and Evaluation (IHME) are used to extract the relative risks (RRs) associated with each behavioral risk factor.

All datasets underwent quality assessments for missingness, logical consistency, and duplicate records prior to analysis.

2.2 Study Population, Inclusion and Exclusion Criteria

This study includes all patients aged over 20 enrolled in Taiwan's National Health Insurance (NHI). Diabetes patients are defined as those who meet diagnostic criteria for diabetes mellitus, including type 1 and type 2 diabetes, and the cases are identified using both ICD-9-CM and ICD-10 codes.



The process of patients' inclusion firstly relies on the diagnostic codes, with the presence of at least two outpatient visits with diabetes ICD-9 or ICD-10 codes (Appendix 1.) in Ambulatory Care Expenditures by Visits within a year, or at least one inpatient admission record in Inpatient Expenditures by Admissions within a single year. Secondly, according to the Lay Description from GBD, patients with uncomplicated diabetes require daily medication, diabetes definition also depends on the medication usage. To identify patients with daily pharmacotherapy, this study links the National Health Insurance Prescription and Treatment Orders Files in Ambulatory Care Expenditures by Visits and Inpatient Expenditures by Admissions, to identify the patients with at least 28 days' supply of anti-diabetic medication in a given year, based on the Taiwan's Diabetes Annual Report (臺灣糖尿病年鑑) definition, to be classified as medication users. Lastly, due to patient age increasing over the observation period, this study computes each individual's age for every analysis year using the date of birth which is recorded in the Registry for Beneficiaries from NHI.

As for the exclusion criteria in this study, gestational diabetes cases in which diabetes codes appeared only during pregnancy, defined as from 270 days before the delivery up to the delivery date or within 90 days before a documented miscarriage, are excluded⁸ (Appendix 2.).



2.3 Measurement of Diabetes Outcomes

2.3.1 Incidence Rate

In epidemiology, incidence rate refers to the occurrence of new cases of a specified disease within a defined population over a specified observation period. In this study, the annual diabetes incidence rate is expressed as the number of new diabetes incident cases during that year divided by the total number of individuals at risk at the mid-year, meaning individuals without a prior diabetes diagnosis at the start of the year. In this study, annual incidence rates of diabetes are calculated for each calendar year from 2017 to 2021, with data from 2012 to 2016 used as a reference and to support case classification. The incidence rate is estimated using the following formula:

$$Incidence\ Rate_t = \frac{N_t}{P_t - C_{t-1}}$$

N_t refers to the number of new diabetes cases diagnosed during year t ; P_t stands for the total number of individuals covered by Taiwan's NHI in the mid-year t ; C_{t-1} denotes the number of prevalent diabetes cases at the end of the previous year ($t-1$).

To enable temporal and international comparisons, the incidence rates in this study are age-standardized by the direct method using the WHO World Standard Population (2000–2025) in 5-year age bands as the following formula:

$$Age\text{-}Standardized\ Incidence\ Rate_t = \frac{\sum_a r_{a,t} w_a}{\sum_a w_a}$$

$r_{a,t}$ is the age-specific incidence rate for age group a in year t , and w_a is the corresponding weight in the standard population.



2.3.2 Diabetes-Specific Mortality Rate

In epidemiological studies, the cause-specific mortality rate is used to quantify the burden of fatal outcomes attributable to a particular disease. In this study, diabetes-specific mortality is calculated as the following formula:

$$\text{Diabetes-Specific Mortality Rate}_t = \frac{N_t}{P_t}$$

N_t is the number of people who died from diabetes during year t ; P_t stands for the mid-year population covered by Taiwan's NHI.

Age adjustment is also performed using the same WHO standard (year 2000-2025) to make the results comparable under other setting with different age structure.

2.3.3 Mortality-To-Incidence Ratio (MI-Ratio)

MI-Ratio is a summary indicator that reflects the fatality of a specific disease relative to its occurrence and the overall health-system performance. In epidemiological and public health research, MI-Ratio is often used as a proxy for short-term survival and the overall effectiveness of disease detection and treatment strategies. In this study, the annual MI-Ratio for diabetes in year t was calculated as:

$$MI-Ratio_t = \frac{\text{Diabetes-Specific Mortality}_t}{\text{Incidence}_t}$$

A lower MI-Ratio suggests better prognosis and healthcare performance, whereas higher MI-Ratio indicates poorer survival, detection, or treatment gaps in care.

It should be noted that this study's MI-Ratio calculation does not account for time-lagged effects between disease onset and death. Ideally, mortality should be linked to incident cases from prior periods; however, due to the purpose of a general performance reference, the MI-Ratio here is constructed using concurrent-year mortality and incidence as an approximate indicator.

2.4 Risk Factors

This study assesses three key diabetes risk factors—high body mass index (BMI), physical inactivity, and current smoking, and all risk factors data are obtained from the NHIS 2017. For each factor, county- and sex-specific estimates are derived. By standardizing these measurements, this analysis provides a robust, nationally representative profile of key modifiable risk factors for diabetes in Taiwan.

2.4.1 High Body Mass Index (BMI)

BMI is measured by weight (kg) divided by height squared (m^2) in kg/m^2 . In NHIS 2017, treating BMI as a continuous variable, this study utilizes the weighted BMI average, weighted standard deviation, and weighted sample size in each county by male and female in 2017 for calculation.



2.4.2 Physical Inactivity

Physical activity is measured in Metabolic Equivalent of Task (MET) minutes per week, as reported in NHIS. MET is a standardized unit used to quantify the intensity of physical activities, which represents the ratio of the energy expenditure (metabolic rate) during a specific activity to the energy expenditure at rest (resting metabolic rate). To calculate the caloric expenditure (in kilocalories) of a particular activity, the following formula is employed:

$$\text{Energy Expenditure (kcal)} = \text{MET} \times \text{Body Weight (kg)} \times \text{Activity Duration (hours)}$$

NHIS 2017 contains the MET values groups from 0 to 4800. Categories of physical activities include work, commuting (walking or cycling), and leisure-time exercise. Weekly MET for each respondent is calculated by the following formula:

$$MET \text{ minutes/week} = \sum MET \text{ value} \times duration \times frequency$$

This study uses the weighted prevalence and the weighted sample size of physical inactivity by county and sex for estimation.

2.4.3 Smoking

Smoking status (current smoker vs. non-smoker) is self-reported in NHIS 2017. This study uses the weighted prevalence of current smokers and weighted sample sizes for

each county and sex. A key limitation here is the absence of data on smoking cessation history; therefore, smoking status represents point-in-time exposure only, without accounting for cessation or duration.



2.5 Population Attributable Fraction (PAF)

This study uses PAF to quantify the reductional proportion in diabetes incidence that would occur if exposure to a risk factor were reduced to an ideal (counterfactual) level, and sees how can these three risk factors contribute to diabetes incidence in different counties and in male and female across Taiwan.

Hence, this study quantifies the proportion of incident diabetes cases attributable to each risk factor (high BMI, physical inactivity, and smoking) by computing age-, sex-, and county-specific PAFs and then aggregating them to obtain the overall PAF estimates for each county and gender.

Here, if $N_{c,s,a}$ is the number of new diabetes cases in county c , sex s , and age group a , the population-level PAF for county c and sex s is then calculated as the following formula, to get the $PAF_{c,s}$ as the attributable fraction within each age stratum:

$$PAF_{c,s} = \frac{\sum_a (PAF_{c,s,a} \times N_{c,s,a})}{\sum_a N_{c,s,a}}$$

2.5.1 Continuous PAF



For continuous risk factor (BMI), this study assumes a normal distribution of BMI within each county–sex–age stratum, using the weighted mean and standard deviation (SD) from NHIS 2017. The theoretical minimum-risk exposure level (TMREL) is taken from the GBD reference. The continuous PAF is calculated by integrating the GBD relative risk function $RR(x)$ over the observed and counterfactual BMI distributions as the following formula:

$$PAF_{c,s,a} = \frac{\int [f_{c,s,a}(x)RR(x) - f_{c,s,a}(x)RR(TMREL)]dx}{\int f_{c,s,a}(x)RR(x)dx}$$

Here, $f_{c,s,a}(x)$ is the normal density of BMI in stratum (c,s,a) .

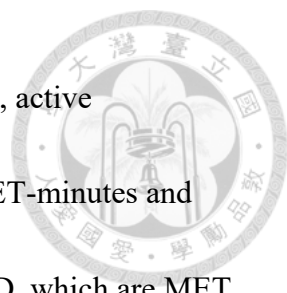
Determinants of PAF include the exposure distribution, relative risk magnitude, and the selection of the counterfactual scenario.

2.5.2 Categorical PAF

For binary or multi-level exposures (physical inactivity, smoking), this study applies the standard categorical formula below:

$$PAF_{c,s,a} = \frac{\sum_i P_{i,c,s,a}(RR_i - 1)}{\sum_i P_{i,c,s,a} RR_i}$$

, where $P_{i,c,s,a}$ stands for the prevalence of the exposure for category i , county c , sex s , and age group a ; RR_i refers to the relative risk under the category i drawn from GBD.



Activity levels, including occupational and household exertion, active commuting, and leisure exercise, are summarized as total weekly MET-minutes and grouped into the same eight standard exposure bands defined by GBD, which are MET =0, 600, 1200, 1800, 2400, 3000, 3600, 4200 MET-min/week. Prevalence ($P_{i,c,s,a}$) of each category i is obtained from NHIS 2017, and the RR_i is the GBD relative risk for MET-minute category i .

Smoking intensity is classified into four categories (0, 10, 20, 30 cigarettes/day), matching GBD groupings. Category-specific prevalence ($P_{i,c,s,a}$) is derived from NHIS 2017 self-reports. This study also uses the standard categorical PAF formula to generate the PAF under each county, sex, and age group, where RR_i is the GBD relative risk for smoking category i .

2.5.3 Overall PAF Estimation

In order to aggregate the stratum-specific PAFs, after computing $PAF_{c,s,a}$ for each stratum and risk factor, this study multiplies each PAF by the corresponding incident count $N_{c,s,a}$, summed across age groups to obtain the attributable cases, and divided by the total incident cases to yield the final PAF estimate for each county and sex.

2.5.4 Joint PAF (High BMI, Physical Inactivity, and Smoking) Estimation

To quantify the combined contribution of the three risk factors selected in this study (high BMI, physical inactivity, and smoking) to the diabetes burden, a joint population attributable fraction (joint PAF) is calculated for each county and sex group.

Assuming independence among the three risk factors, the joint PAF is computed using the following multiplicative formula:

$$PAF_{Joint} = 1 - (1 - PAF_{BMI}) \times (1 - PAF_{Physical\ Inactivity}) \times (1 - PAF_{Smoking})$$

, where each component represents the PAF estimated for the corresponding risk factor and demographic group. This approach prevents double-counting of overlapping effects and provides an integrated estimate of the proportion of diabetes incidence that could potentially be prevented if all three risk factors were eliminated.

2.6 Statistical Decomposition Analysis

This study calculates Coefficient of Variation (CV) from 2017 to 2021 using both observed incidence and treatment-adjusted incidence to quantify the explanatory power of each modifiable factor to geographical disparities, meaning the extent to which individual and combined risk factors contribute to spatial heterogeneity and disparities in diabetes incidence across 20 counties in Taiwan, in order to see how much proportion of the incidence disparity can be explained by removing each factor's effect.

2.6.1 Coefficient of Variation (CV)

Here are the common formulas for CV calculation:

$$CV = \frac{SD}{\hat{y}_i}, \quad SD \text{ (Standard Deviation)} = \sqrt{\frac{1}{n-1} \sum (y_i - \hat{y}_i)^2}$$

To calculate the SD and CV, this study first computes the mean of the incidence rate for each sex and year across all counties as the following formula:

$$\bar{I} = \frac{1}{C} \sum_{c=1}^C I_c$$

, where C equals to 20 (the number of counties in this study), and each county is indexed by c . I_c is the observed incidence rate or treatment-adjusted diabetes incidence rate in county c .

Then, this study evaluates the baseline SD to represent the background disparities of the diabetes incidence rate across the 20 counties in Taiwan without any intervention or exposure of those three risk factors as:

$$SD_{\text{baseline}} = \sqrt{\frac{1}{C-1} \sum (I_c - \bar{I})^2}$$

SD has the same units as the incidence rate and reflects the typical background magnitude of county-level deviation. Also, expressing SD relative to the mean incidence allows comparison across factors and time periods. To facilitate this comparison, this study therefore computes a normalized CV as:

$$CV_{\text{baseline}} = \frac{SD_{\text{baseline}}}{\bar{I}}$$

For each risk factor x , including “High BMI”, “Physical Inactivity”, “Smoking”, and “Joint risk Factors’ Combination”, this study first derives the “risk-factor-adjusted”



incidence in county c , assuming “remove” its effect by computing a counterfactual

incidence in each county as the following formula:

$$I_{x,c} = I_c \times (1 - \text{PAF}_{x,c})$$

, where $\text{PAF}_{x,c}$ is the population attributable fraction for risk factor x in county c .

Then, this study also calculates:

$$\bar{I}_x = \frac{1}{C} \sum_{c=1}^C I_{x,c}, \quad \text{SD}_x = \sqrt{\frac{1}{C-1} \sum (I_{x,c} - \bar{I}_x)^2}$$

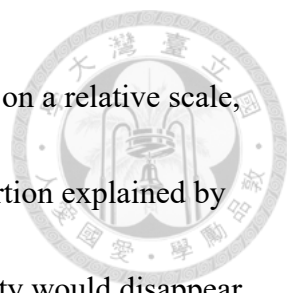
As for the corresponding normalized CV:

$$\text{CV}_x = \frac{\text{SD}_x}{\bar{I}_x}$$

Then, it is now possible to calculate the percentage of between-county inequality in diabetes incidence that can be explained by risk factor x , which is estimated as the relative reduction in normalized CV when adjusting for x :

$$\% \text{ Explained}_x = \frac{\text{CV}_{\text{baseline}} - \text{CV}_x}{\text{CV}_{\text{baseline}}} \times 100\%$$

Here, a higher percentage indicates that there is a greater share of the geographical disparities in diabetes incidence can be attributed to that specific risk factor or their combined effect. This framework makes it possible to quantify how much of the county-level variation in diabetes incidence is attributable to each individual risk factor and their joint effect.



In short, this study uses normalized CV to place that deviation on a relative scale, facilitating comparisons across factors or years; the inequality proportion explained by each risk factor shows how much of the observed spatial heterogeneity would disappear if that factor were uniformly “eliminated” across all counties— thereby highlighting the importance of each factor in shaping regional disparities in diabetes incidence.

2.7 Diabetes Care

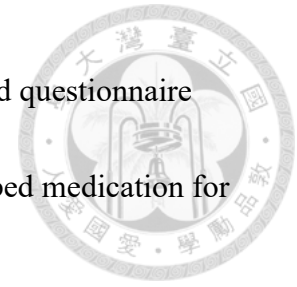
2.7.1 Treatment Coverage

Treatment coverage is defined as the proportion of living diabetes patients who received any kinds of diabetes medication. It can serve as a rough index for a region’s detection power and overall capacity to identify diabetes cases within the population.

To account for undiagnosed diabetes and thus approximate the true (treatment-adjusted) burden of disease beyond those identified in NHI data, this study estimates treatment coverage by using the data from the Nutrition and Health Survey in Taiwan (NAHSIT) from 2017 to 2020. NAHSIT is a nationally representative, cross-sectional survey conducted every four years, which comprises both questionnaire contents and biochemical measurements.

This study analyzes the participants with complete biochemical and questionnaire information. The key biomarker-related variables include: glycated hemoglobin (HbA1c), fasting plasma glucose (FPG), last-meal time, and blood-draw time. The

variable of diabetes medication use is obtained from the self-reported questionnaire (survey code CS0139: “Are you currently taking any doctor-prescribed medication for diabetes?”).



As for the sampling weights, NAHSIT's provided “ewt_iv_for_2017to20” weight for biochemical component is used for all analyses for weighted estimates, enabling national-and county-level generalizability.

In the data cleaning process, this study excludes the participants missing both HbA1c and FPG measurements. The participants who in the questionnaire answered “Don’t know” (code 8888) or “Refused to answer” (code 9999) to the diabetes medication question (survey code CS0139) are also excluded. Lastly, this study doesn’t include the invalid FPG values, which means if the blood-draw time minus the last-meal time is less than 8 hours, the fasting period is not enough for the FPG definition, the FPG values are being excluded. However, these participants still remained eligible based on HbA1c alone.

In the treatment coverage analysis, diabetes patients are defined as individuals meeting any of the following criteria: a fasting plasma glucose (FPG) level ≥ 126 mg/dL, a HbA1c value ≥ 6.5 %, or self-reported current use of diabetes medication. “Treated cases” were among those diabetes patients who reported taking prescribed diabetes medication.

To calculate the treatment coverage for diabetes, showing the proportion of all diabetes patients who were receiving pharmacotherapy, this study uses the formula:

$$\text{Treatment Coverage} = \frac{\text{Number of Diabetes Patients with Self-Reported DM Medication}}{\text{Total Number of Individuals with Diabetes}}$$

2.7.2 Treatment-Adjusted Incidence

To account for disparities in healthcare access and treatment uptake across regions, this study computes treatment-adjusted incidence rates for diabetes by sex and county. This metric aims to estimate the burden of disease that would occur in the absence of treatment, thereby reflecting the underlying risk and the true incidence more directly.

The treatment-adjusted incidence for each group is calculated as:

$$\text{Treatment-Adjusted Incidence}_{c,s,t} = \frac{\text{Observed Incidence}_{c,s,t}}{\text{Treatment Coverage}_{c,s,t}}$$

, where observed incidence c, s, t is the raw incidence rate of diabetes in county c , sex s , and year t ; Treatment Coverage c,s,t is the proportion of individuals with diabetes in the corresponding group who received any form of clinical treatment.

This adjustment allows a more equitable comparison of incidence across regions by standardizing for variation in access to treatment services. In effect, it approximates the "true" incidence burden that might be expected under uniform treatment conditions, which assumes every person with diabetes is diagnosed and detected, enabling a clearer assessment, rather than focusing only on the treated or diagnosed diabetes.

Treatment coverage rates are derived from national survey data and applied at the county-sex-year level. Adjusted incidence values are also used in subsequent inequality decomposition analyses.



2.7.3 Management (Well-Controlled) Rate

In accordance with Taiwan's "888 Plan" for chronic disease management, this study calculates the diabetes management (well-controlled) rate, to assess the effectiveness of diabetes control among those who are receiving medication. The 888 Plan aims to enroll 80 % of patients with hypertension, hyperglycemia, and hyperlipidemia into a care network, and of those, 80 % should receive lifestyle counseling or clinical treatment, so that an 80 % control rate can be achieved.

This study defines the treated cases as all diabetes patients with prescribed anti-diabetic medication, regardless of current glycemic values. The controlled cases are defined as among those treated patients, whose blood glucose measurements met the glycemic targets of FPG $\leq$ 130 mg/dL or HbA1c $\leq$ 7%, or only HbA1c $\leq$ 7% (regardless of FPG values) for a stricter but more reliable indicator of long-term glycemic control, which reflects average blood glucose over the preceding 2–3 months, rather than a single time-point fasting measurement. Hence, the management (well-controlled) rate is then calculated as the following formula:

$$\text{Management Rate} = \frac{\text{Controlled DM Patients}}{\text{DM Patients with DM Medication}} \times 100\%$$

This metric reflects the proportion of individuals under active treatment who have successfully achieved glycemic control, enabling comparison of care effectiveness across different regions in Taiwan.



2.8 Visualization

Spatial patterns of the results are displayed as county-level choropleth maps of Taiwan. All mapping was conducted in R (version 4.5.0) using the `sf`, `tidyverse`, and `ggplot2` packages. By comparing color intensity across counties, regional disparities are made immediately apparent.

This study also uses `ggplot2`, `showtext`, and `ggrepel` packages to create a scatter plot of county-level incidence versus mortality rate, annotated with the Mortality-to-Incidence ratio (MI-Ratio). National mean values for incidence and mortality are included as reference lines, enhancing the interpretability of regional patterns during 2017 to 2021.

In addition, county-level rank plots are generated to visualize changes in diabetes outcomes rankings across years. These longitudinal rank plots are created using `ggplot2` in combination with custom formatting functions, showing year-by-year performance shifts across Taiwan's 22 counties. Data points are annotated with county names and absolute numbers for clearer comparative insights. This visualization supports temporal comparisons, highlighting counties with consistent change of rankings over time.

Chapter 3 Results



3.1 Incidence Rate

Between 2017 and 2021, the age-standardized incidence rates of diabetes in Taiwan remained relatively stable at the national level but exhibited marked spatial disparities across counties and between sexes (Figure 01). Nationally, incidence rates for both males and females fluctuated only modestly year by year. Among males, the average incidence ranged from approximately 0.72% to 0.77%, while among females, it consistently remained lower, between 0.55% and 0.57%. However, these national averages masked substantial geographic variation.

In 2017, 嘉義市 (0.92 %) recorded the highest male incidence rate, and 連江縣 (0.57 %) was the lowest. Among females, 臺東縣 (0.66 %) was the highest, while the lowest were found in 連江縣 (0.38 %) and 臺北市 (0.43 %). By 2021, these regional patterns remained largely unchanged. Among males, the highest incidence rates continued to cluster in 臺東縣 (0.87 %) and 花蓮縣 (0.87 %), while the lowest were again observed in 臺北市 (0.61 %) and 連江縣 (0.63 %). For females, 臺東縣 (0.68 %), 花蓮縣 (0.66 %), and 嘉義縣 (0.62 %) reported the highest incidence, while 臺北市 (0.38 %) showed the lowest (Table 01 – 02, Figure 02). The choropleth maps also reveal that diabetes age-standardized incidence rates are consistently higher among males than females across nearly all regions.



Annual city ranking chart (Figure 03 – 04) further illustrate the regional variation and temporal trends. Overall, eastern and rural counties (especially 臺東縣, 花蓮縣, 嘉義市 and 嘉義縣) emerged as areas with persistently elevated incidence across both sexes. In contrast, urban center such as 臺北市 consistently exhibited lower diabetes incidence. These spatial patterns have remained remarkably stable throughout the study period, indicating a persistent geographic gradient in disease burden. Therefore, the consistently higher incidence in eastern and rural counties, compared to lower rates in metropolitan areas, highlights the importance of addressing regional inequalities in future diabetes control strategies and public health interventions.

3.2 Diabetes-Specific Mortality Rate

Between 2017 and 2021, age-standardized diabetes-specific mortality rates in Taiwan exhibited a modest national decline, yet persistent spatial disparities remained evident across counties and between sexes. Nationally, male mortality rates remained higher than female rates throughout the period. Among males, average mortality hovered around 44 to 50 deaths per 100,000 population, while female mortality ranged from approximately 33 to 38 per 100,000. Despite this overall stability, county-level variation remained substantial (Figure 05).



In 2017, the highest male diabetes mortality rate was observed in 花蓮縣 (52.2 per 100,000), whereas the lowest rates occurred in 金門縣 (15.2 per 100,000) and 臺北市 (22.6 per 100,000). For females in the same year, the highest mortality rates were reported in 新竹市 (46.0 per 100,000) and 屏東縣 (45.7 per 100,000), while the lowest were found in 連江縣 (0.0 per 100,000), 金門縣 (16.5 per 100,000) and 臺北市 (20.8 per 100,000). By 2021, the spatial patterns persisted. The highest male mortality rates was seen in 苗栗縣 (55.9 per 100,000), while 連江縣 (20.5 per 100,000), 金門縣 (21.7 per 100,000), and 臺北市 (27.2 per 100,000) continued to report the lowest rates. Among females, 新竹縣 (42.5 per 100,000), 苗栗縣 (41.2 per 100,000), and 花蓮縣 (40.9 per 100,000) held the highest mortality rates, whereas 連江縣 (7.8 per 100,000) and 臺北市 (20.4 per 100,000) maintained the lowest (Table 03, Figure 06).

Annual city ranking chart (Figure 07 – 08) further illustrate these consistent geographic inequalities. Notably, eastern and rural counties, such as 花蓮縣, 苗栗縣, and 新竹縣, emerged as mortality hotspots for both sexes, while metropolitan regions, especially 臺北市, persistently showed the lowest burden. These findings underscore enduring geographic inequities in diabetes-related mortality, highlighting the need for region-specific public health strategies to reduce the excess burden observed in disadvantaged areas.

3.3 Mortality-To-Incidence Ratio (MI-Ratio) Based on Observed Incidence



From 2017 to 2021, the diabetes mortality-to-incidence ratio (MI-Ratio) across Taiwan's 22 counties and cities exhibited substantial geographic disparities while remaining relatively stable at the national level (Figure 09). The national average MI-Ratio fluctuated slightly, with males ranging from 0.0560 in 2017 to 0.0532 in 2021, and females from 0.0609 in 2017 to 0.0563 in 2021, suggesting persistent patterns in diabetes-related survival and healthcare performance.

Spatial heterogeneity remained prominent throughout the period (Figure 10). Among males in 2017, 雲林縣 (0.0746), 新竹縣 (0.0742), and 花蓮縣 (0.0704) had the highest MI-Ratio. These areas displayed elevated mortality relative to new diabetes diagnoses, suggesting either late diagnosis or poorer post-diagnosis management. In contrast, the counties with the lowest male MI-Ratios in 2017 included 金門縣 (0.0220), 臺北市 (0.0344), and 新北市 (0.0438), indicating better outcomes relative to incidence or possibly earlier detection and intervention. The highest MI-Ratios for males in 2021 was seen in 苗栗縣 (0.0741), whereas the lowest were reported in 金門縣 (0.0289) and 連江縣 (0.0325). For females in 2017, the highest MI-Ratios were observed in 新竹市 (0.0863), 新竹縣 (0.0788), and 基隆市 (0.0787). By 2021, the highest female MI-Ratios were found in 新竹縣 (0.0830), 基隆市 (0.0726), and 苗栗縣

(0.0701). In contrast, the lowest female MI-Ratios during this period were consistently found in 連江縣 (0.0144 in 2021) and 金門縣 (0.0315 in 2017).



The results are also visualized by annual city ranking chart (Figure 11 – 12).

The county-level differences reflect not only potential disparities in healthcare access and quality but may also suggest variations in disease detection, treatment adherence, or population health literacy. Moreover, in each year analyzed, the average female MI-Ratio exceeded that of males, reaffirming the pattern of relatively greater mortality burden among women with diabetes in Taiwan. These findings underscore the importance of regional and sex-specific approaches in diabetes management and support the prioritization of healthcare resources toward counties with persistently elevated MI-Ratios.

3.4 PAF of High BMI

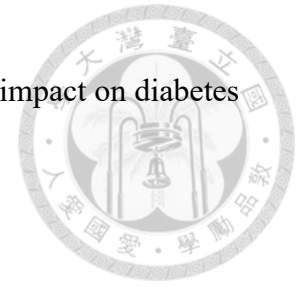
The results demonstrated considerable geographic and sex-specific variation across Taiwan (Figure 13 – 14). Among males, PAFs ranged from 33.2% (南投縣) to 45.7% (臺東縣), indicating that up to nearly half of diabetes incidence can be attributed to high BMI in certain regions. For females, PAFs were generally lower than males', ranging from 17.5% (嘉義市) to 42.7% (苗栗縣). Eastern counties, including 臺東縣 and 花蓮縣, exhibited higher BMI-attributable fractions compared to more urbanized areas such as 臺北市 and 新北市. Overall, males demonstrated higher PAFs than

females in almost all counties, suggesting that overweight and obesity contribute more significantly to diabetes burden among men. The geographic patterns highlighted by the choropleth maps and bar chart underscore the need for region-specific strategies targeting obesity prevention as a means of diabetes control.

3.5 PAF of Physical Inactivity

The results indicated relatively moderate PAFs across all counties, with less variation compared to the PAFs for high BMI (Figure 15 – 16). Among females, PAFs ranged from 13.8% (嘉義市) to 18.8% (苗栗縣), suggesting that approximately 14 to 19% of diabetes cases could be attributed to insufficient physical activity depending on the region. Similarly, among males, PAFs ranged from 14.9% (嘉義市) to 17.9% (花蓮縣). Counties such as 苗栗縣 (female: 18.8%), 花蓮縣 (male: 17.9%), and 嘉義縣 (female: 18.4%) exhibited relatively higher PAFs, while urban centers like 臺北市 (female: 16.3%; male: 17.0%) and 新北市 (female: 18.2%; male: 16.8%) showed slightly lower or moderate values, which also demonstrates a clear gap and disparity between urban and rural areas. Notably, the PAF values for physical inactivity were relatively similar between males and females across most counties, contrasting with the more pronounced sex differences observed for high BMI PAFs. This suggests that the impact of insufficient physical activity on diabetes risk is comparably distributed across genders in Taiwan. The spatial distribution patterns highlight the regions where

promoting and encouraging active lifestyles could yield the greatest impact on diabetes prevention.



3.6 PAF of Smoking

The results revealed stark differences between sexes (Figure 17–18). Among males, smoking accounted for a substantial proportion of diabetes cases, with PAFs ranging from 12.7% in 新竹市 to 22.0% in 臺東縣. Among females, the PAFs were considerably lower, reflecting much lower smoking prevalence among women, ranging from 0.2% in 澎湖縣 to 2.8% in 花蓮縣. Notably, eastern counties such as 花蓮縣 and 臺東縣 exhibited relatively higher female smoking-attributable fractions compared to other regions. The results clearly demonstrate the east–west and urban–rural gradients in smoking-related diabetes burden. Males exhibited markedly higher smoking-attributable PAFs than females across all regions. These findings underscore the significant impact of smoking, particularly among men, on the diabetes burden in Taiwan, and highlight the urgent need for intensified smoking-cessation programs targeted at high-attributable-risk regions and populations.

Lastly, the overall PAF of the three risk factors across Taiwan in 2017 is combinedly visualized by a bar chart (Figure 19).

3.7 Joint PAF of High BMI, Physical Inactivity, and Smoking



The joint PAF estimates for high BMI, physical inactivity, and smoking revealed considerable regional and sex-specific disparities across Taiwan (Figure 20). Among males, joint PAFs ranged from 52.6% in 新竹縣 to 64.7% in 臺東縣, suggesting that more than half of the diabetes cases could be theoretically prevented if all three risk factors were eliminated. For females, joint PAFs were generally lower, ranging from 29.7% in 嘉義市 to 54.4% in 苗栗縣.

Geographically, higher joint PAFs were observed in rural and eastern regions, particularly 臺東縣 and 花蓮縣, for both sexes. In contrast, urbanized areas such as 臺北市 and 新北市 exhibited relatively lower joint PAFs, reflecting different lifestyle and behavioral risk profiles. The substantial joint PAF values emphasize the critical importance of comprehensive, multi-faceted public health strategies targeting obesity reduction, physical activity promotion, and smoking cessation to effectively mitigate the diabetes burden in Taiwan. This result highlights that high BMI contributed the largest share to the total diabetes burden in all the 20 counties in Taiwan.

3.8 Statistical Decomposition Analysis

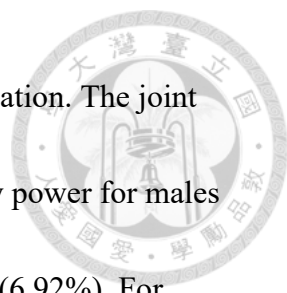
To evaluate the extent to which high BMI, physical inactivity, smoking, and their joint contribution explained geographic inequalities in diabetes incidence, this study employed Coefficient of Variation (CV) metrics across counties. Two types of incidence estimates were being used for comparison: treatment-adjusted incidence and



observed incidence. By comparing the baseline spatial variation with risk factor-adjusted incidence distributions, the percentage of explained inequality was quantified for each factor annually and stratified by sex.

When using observed incidence, among males, most individual and joint models showed negative explanatory values from 2017 to 2020, with high BMI and smoking exhibiting suppression effects. In contrast, 2021 showed a turnaround, with smoking explaining 21.05% and the joint model 15.11% of the spatial inequality. A similar trend was observed for females: negative or near-zero contributions persisted through 2020, but in 2021, BMI (18.60%) and the joint model (15.84%) demonstrated meaningful explanatory capacity. These results suggest that risk factors are more effective in explaining variation when assessed against observed incidence in the general population, particularly in the most recent year of analysis. Together, these findings underscore that these three risk factors collectively lack explanatory power regarding the geographic variation in diabetes incidence (Figure 21 – 22).

The patterns differed markedly when the same models were applied to treatment-adjusted incidence data. High BMI consistently explained the largest share of geographic inequality in diabetes incidence among males, increasing from 3.45% in 2017 to a peak of 8.37% in 2021. Physical inactivity contributed marginally, and the influence of smoking was negative across all years, indicating that adjusting for



smoking either suppressed or did not account for existing spatial variation. The joint model incorporating all three risk factors showed limited explanatory power for males in earlier years (e.g., -0.95% in 2019) but improved notably in 2021 (6.92%). For females, BMI alone had negative or negligible explanatory effects until 2021 (3.18%). Physical inactivity consistently explained a small share of variance (ranging from 0.74% to 1.65%), while smoking had minimal or negative effects. The joint model performed poorly from 2017 to 2020, reaching -5.01% in 2018, but turned positive in 2021 (3.34%), suggesting emerging joint explanatory value (Figure 23 – 24).

3.9 Treatment Coverage

Treatment coverage for diabetes patients across Taiwan's 20 counties and cities during 2017 to 2020 exhibited notable geographic and gender-specific variations. Males generally exhibit lower treatment coverage compared to females across most regions. (Figure 25 – 26) Among males, 基隆市 (82.3%) has the highest treatment coverage included; 新竹市 (39.2%) has the lowest rate. For females, the treatment coverage rates were generally higher than for males. 臺北市 has the highest female treatment coverage (94.4%), and lowest treatment coverage was observed in 桃園市 (40.2%).

The national weighted average treatment coverage generalized from NAHSIT data during 2017 to 2020 is 55.1% for males and 61.1% for females. These findings indicate substantial inter-county disparities in diabetes treatment coverage, with females

achieving higher coverage rates than males. The spatial distribution of treatment coverage points out the need for targeted interventions to improve diabetes diagnosis, highlighting the potential underdiagnosis and untreated burden in diabetes surveillance, particularly in regions with suboptimal coverage rates.

To facilitate intuitive comparisons of treatment coverage across regions and between sexes, this study employs two visualization methods, county-level choropleth maps and bar charts. They are generated to illustrate the spatial distribution of treatment coverage for males and females separately. These visualizations provide a clearer depiction of geographic disparities and enable easier interpretation of inter-county variations in diabetes treatment coverage.

To account for uncertainties inherent in survey-based estimations, 95% confidence intervals (CIs) for treatment coverage rates were calculated based on the complex survey design and sampling weights of the NAHSIT dataset. These intervals provide an indication of statistical precision and reflect the degree of uncertainty due to sampling variability. Including CIs allows a more robust interpretation of inter-county comparisons, as overlapping intervals suggest non-significant differences, while non-overlapping intervals point to potentially meaningful disparities in treatment coverage. These intervals are reported alongside point estimates in all relevant figures, enabling

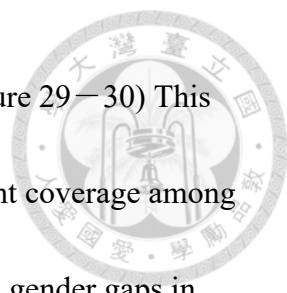
clearer evaluation of regional variations under the context of survey sampling uncertainty.



3.10 Treatment-Adjusted Incidence

To more accurately reflect the true burden of new-onset diabetes, this study adjusted the observed incidence rates by treatment coverage, accounting for potential undiagnosed or untreated cases. The treatment-adjusted incidence is calculated by dividing each county's crude incidence rate by the corresponding treatment coverage for the same year, sex, and location. This adjustment corrects for potential underreporting in the claims data and provides a better approximation of the true incidence, especially in populations with low healthcare utilization or access barriers (Figure 27).

The treatment coverage data from 2017 to 2020 are applied to estimate treatment-adjusted incidence for the period 2017 to 2021, under the assumption that treatment patterns remained stable between 2020 and 2021. County-level treatment-adjusted incidence rates are then computed for all 20 administrative regions by sex and year (Figure 28). The treatment-adjusted incidence in 臺東縣 and 花蓮縣 remained consistently higher than in metropolitan areas like 臺北市 and 新北市. This adjustment also amplified the magnitude of disparity, emphasizing the need to consider access to care and detection in diabetes surveillance and control strategies. Moreover, the gender disparity remained apparent: males consistently exhibited higher treatment-adjusted



incidence rates than females across all years and most counties. (Figure 29–30) This pattern likely reflects both higher crude incidence and lower treatment coverage among males, underscoring the importance of targeted interventions to close gender gaps in diabetes management and detection. Together, these treatment-adjusted figures offer a more realistic representation of diabetes burden and suggest that observed geographic disparities are, in part, driven by variation in healthcare access and utilization—factors essential for shaping effective, equitable public health policies.

3.11 MI-Ratio Based on Treatment-Adjusted Incidence

To further assess diabetes-related disease burden beyond raw incidence or mortality, this study also calculates the Mortality-to-Incidence (MI) Ratio using treatment-adjusted incidence data (Figure 31). The MI-Ratio offers an approximation of case fatality or relative disease severity by comparing mortality to adjusted incidence estimates. Across the years 2017 to 2021, MI-Ratios revealed consistent sex and spatial disparities in diabetes outcomes (Figure 32). Nationally, males exhibited higher MI-Ratios compared to females throughout the period, suggesting a greater relative burden or potentially more severe progression of diabetes-related complications. Temporal patterns showed only modest fluctuations in MI-Ratios (Figure 33–34), indicating relative stability in treatment outcomes or fatality risk over time. However, substantial geographic variation remained evident.



In 2017, among males, the highest MI-Ratios was observed in 新竹縣 (0.0565), while the lowest occurred in 臺北市 (0.0213). For females in 2017, the highest MI-Ratios were in 新竹市 (0.0746), 花蓮縣 (0.0585), and 雲林縣 (0.0573), whereas the lowest were in 桃園市 (0.0245), 澎湖縣 (0.0268), and 臺東縣 (0.0302). By 2021, male MI-Ratios peaked in 基隆市 (0.0572), 苗栗縣 (0.0565), and 新竹縣 (0.0503), and were lowest in 臺東縣 (0.0151), 澎湖縣 (0.0221), and 嘉義市 (0.0249). Female MI-Ratios in 2021 were highest in 臺中市 (0.0531), 臺北市 (0.0502), and 雲林縣 (0.0482), and lowest in 臺東縣 (0.0242), 桃園市 (0.0262), and 澎湖縣 (0.0280).

These county-level differences reflect not only potential disparities in healthcare access and quality but also suggest variations in disease detection, treatment adherence, or population health literacy. Moreover, in each year analyzed, the average female MI-Ratio exceeded that of males, reaffirming the pattern of relatively greater mortality burden among women with diabetes in Taiwan. These findings reinforce earlier observations of spatial health inequality and emphasize the need for equitable, region- and sex-specific improvements in diabetes management and public health interventions.

3.12 Management (Well-Controlled) Rate

The results revealed substantial regional and sex-specific disparities in glycemic control. Under the FPG-or-HbA1c definition, the national average management rate was 71.7% for males and 64.5% for females. By contrast, using the stricter HbA1c-only

definition, the national averages dropped to 61.2% for males and 54.3% for females.

Spatial variation is clearly evident, especially among males. Under the FPG-or-HbA1c standard (Figure 35), for males, the highest management rates were observed in 臺北市 (90.8%), 基隆市 (88.5%), and 臺中市 (84.4%), whereas the lowest were in 澎湖縣 (37.7%) and 新北市 (44.9%). Among females, the highest rates were in 新北市 (81.4%), 基隆市 (80.3%), and 新竹市 (79.1%), while the lowest were in 澎湖縣 (30.5%) and 臺東縣 (42.2%). On the other hand, when applying the HbA1c-only standard, a more pronounced decline in control rates is observed across all regions (Figure 36). For males, high control rates remain in 基隆市 (85.4 %) and 臺中市 (81.7 %), while the lowest rates are found in 南投縣 (32.3 %) and 新北市 (34.3 %). For females, again 基隆市 (74.9 %) and 臺北市 (65.9 %) maintained relatively higher control, whereas 澎湖縣 (30.5 %) and 雲林縣 (32.1 %) showed the lowest levels.

The spatial distribution of management rates, notably, metropolitan areas generally exhibit better glycemic control than rural and outlying counties (Figure 37). These findings emphasize the importance of region-specific strategies to enhance long-term diabetes management, particularly targeting areas with suboptimal control.

95% confidence intervals are also included in all relevant figures, representing as error bars alongside the point estimates to reflect the statistical uncertainty of the management rate estimates.

Chapter 4 Discussion



4.1 Main Findings

This study systematically examined the regional disparities in full disease continuum across Taiwan, from risk factor exposure to disease incidence, treatment coverage, glycemic management, and eventual diabetes-specific mortality. The findings revealed persistently striking geographic inequalities in all stages of the diabetes cascade, particularly between rural and urban areas, and between sexes. For example, 苗栗縣 and 臺東縣 had the overall highest PAF of the three risk factors; 花蓮縣 consistently showed higher diabetes incidence and elevated diabetes-specific mortality rates. In contrast, metropolitan areas like 臺北市 and 新北市 exhibited more favorable outcomes throughout the continuum.

Among all examined risk factors, as evidenced by PAF estimates, high BMI emerged as the strongest individual risk contributor to diabetes incidence. When multiple risk factors were jointly considered, their combined PAF was up to 60% in some counties, particularly among males, indicating that a significant portion of the diabetes burden may be prevented through targeted behavioral interventions. As for the explanatory power in reducing CV to incidence rates, although the explanatory power of BMI is also the highest (ranging from 3% to 3.5% in males from 2017 to 2020, based on treatment-adjusted incidence), it is still not strong enough to explain the disparities.

4.2 Comparisons with Existing Literature



The findings from this study are largely consistent with previous research on diabetes epidemiology in Taiwan⁶. Prior literature has long documented regional disparities in chronic disease outcomes, particularly linked to socioeconomic status and healthcare access gradients^{6,7,14,15}. Consistent with these literatures, this study confirms the existence of geographic disparities in diabetes outcomes within Taiwan, especially the contrast between metropolitan and rural areas. However, this study identifies a notable and somewhat counterintuitive deviation from existing evidence that the diabetes-specific mortality rates were relatively lower in some eastern counties during the study period, including 宜蘭縣 and 臺東縣. This pattern, which has not been highlighted in previous studies, challenges our previous knowledge that rural or less urbanized regions uniformly experience worse health outcomes. The discovery suggests that factors beyond healthcare access, such as unmeasured community-level influences, may contribute to these regional mortality patterns.

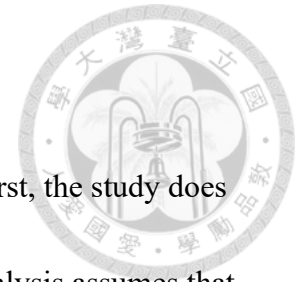
In addition to documenting outcome disparities, this study advances the field by decomposing upstream risk factors to elucidate the underlying drivers of the observed geographic differences. The high burden attributable to BMI aligns with findings from the Global Burden of Disease (GBD) project, where overweight and obesity

consistently rank among the leading risk factors for diabetes worldwide⁴⁵. Our estimation that BMI alone accounts for over 40% of diabetes incidence in some counties for males is in line with global patterns reported by GBD. Moreover, the decomposition approach focusing on changes in CV represents a methodological innovation, offering a new analytical tool for chronic disease onset. strengthens the interpretation of geographical disparities of diabetes epidemiology.

4.3 Strengths

This study is distinguished by several methodological strengths. First, it holds comprehensive data integration of multiple national datasets (NHIRD, NHIS, NAHSIT, and the Death Registry), allowing for robust, multi-level analysis of diabetes outcomes and their risk factors across all counties and sexes in Taiwan. Second, it conducts decomposition analysis by linking 2017 risk factor data to 2021 incidence outcomes and applying CV decomposition, providing novel insights into the temporal dynamics of chronic disease emergence and the spatial distribution of preventable risks. Third, this study uses an innovative treatment-adjusted metrics. The construction of treatment-adjusted incidence enables a more equitable comparison of disease burden across regions with varying detection capacity, overcoming limitations of raw claims-based metrics. Lastly, this study carries out sex- and county-level disaggregation. The dual focus on geography and gender provides a nuanced understanding of health disparities.

4.4 Limitations and Further Work



Despite its strengths, this study still has several limitations. First, the study does not account for population migration or residential mobility. The analysis assumes that individuals remained in the same county throughout the study period. Population mobility may introduce misclassification in geographic attribution of both incidence and risk factors. Second, this study does not incorporate secondhand smoke exposure. While smoking is included as a key risk factor, secondhand smoke exposure, a significant diabetes risk particularly among women, is not measured due to data limitations. Third, MI-Ratio has temporal ambiguity. The MI-Ratio calculations are based on same-year incidence and mortality, which may not accurately reflect the true case fatality due to lag time between diagnosis and death. This limitation suggests the MI-Ratio should be interpreted just as a proxy for system performance rather than exact survival outcome. Additionally, self-reported behavior measures may cause research bias. Physical activity, smoking status, and taking diabetes medication are based on self-reports in NHIS, subject to recall and social desirability bias. Lastly, there may be other potential confounding factors behind the research. Furthermore, this study does not adjust for other potential contributors to diabetes, such as dietary intake, stress, environmental exposures, or genetic predisposition.



Additionally, this study does not apply age-standardized PAFs in the final stage of calculating the changes in the CV, instead relying solely on county-level PAF estimates. The absence of age standardization may attenuate the explanatory power of risk factors for diabetes incidence inequalities. This is because the distribution of PAFs and diabetes incidence rates across age groups exhibits opposing trends: higher PAFs are observed among younger populations, where incidence rates are lower; lower PAFs are found among older populations, where incidence rates are higher. As a result, the lack of age adjustment could dilute the true contribution of risk factors to spatial disparities in incidence. Incorporating age-standardized PAFs into decomposition analyses represents an important direction for future research aimed at improving the precision and validity of inequality assessments.

Lastly, the Gini Index and Lorenz Curve⁴⁶ are also widely used and representative tools for quantifying inequality. Gini Index provides a standardized metric ranging from 0 to 1, capturing the degree of concentration across a distribution; on the other hand, Lorenz Curve visually represents the cumulative distribution of diabetes incidence or health resource allocation across counties. These methods are commonly applied in health economics and epidemiology to assess the equity of health outcomes and resource distribution. Future research may consider integrating the Gini Index and Lorenz Curve as complementary tools to further examine and compare geographical

health inequalities under different measurement frameworks, thereby enhancing the assessment of policy intervention impacts.



4.5 Public Health Implications

The findings carry important implications for public health planning and diabetes control policy in Taiwan. First, this study provides region-specific intervention prioritization. Counties with persistently high incidence and mortality require tailored, multi-level interventions to reduce structural barriers to care. Second, this study targets the most impactful risk factor. Given that BMI contributes the most to incidence, obesity prevention should be prioritized, particularly in rural male populations. Policy measures might include improved nutrition labeling, sugar taxation, and subsidized physical activity programs. Third, this study suggests to reform treatment coverage infrastructure. Disparities in treatment coverage and glycemic management are important contributors to mortality inequality. Expanding primary care infrastructure and incentivizing chronic disease management programs are necessary steps. Fourth, this study uses the changes of CV for policy monitoring. The CV-based approach provides a quantifiable method for tracking changes in spatial inequality over time. Policymakers could adopt this metric to monitor progress toward equitable diabetes control at the regional level.

4.6 Conclusion



This study provides a comprehensive assessment of geographic disparities in diabetes outcomes across Taiwan by integrating national datasets and applying both epidemiological and statistical methods. By tracing the full disease continuum from risk factor exposure to mortality, it reveals pronounced regional and sex-based inequalities, particularly in rural counties. High BMI is identified as the most influential modifiable risk factor, while CV analysis underscores the explanatory power of risk exposure to disease onset. Crucially, disparities in treatment coverage and glycemic control, are also predictive of mortality inequality. These findings highlight the need for region- and gender-sensitive public health strategies that go beyond national averages to target structural gaps in prevention, detection, and chronic disease management.

Chapter 6 Tables

Table 01: Age-Standardized Diabetes Incidence Rate by Sex Across Taiwan from 2017 to 2021

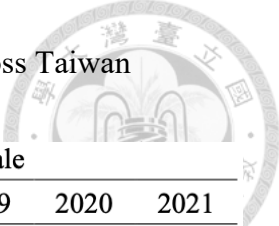


	Male					Female				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
南投縣	0.6398	0.6649	0.6926	0.6691	0.7470	0.5901	0.5695	0.5839	0.5738	0.5634
嘉義市	0.9215	0.9060	0.8948	0.8857	0.7454	0.6325	0.6354	0.6740	0.6234	0.4839
嘉義縣	0.6244	0.6435	0.6237	0.6409	0.7549	0.5545	0.5164	0.5479	0.4999	0.6178
基隆市	0.8048	0.8378	0.8018	0.8052	0.7669	0.5794	0.6365	0.6127	0.6007	0.5460
宜蘭縣	0.7113	0.7371	0.7784	0.7915	0.8034	0.5969	0.6595	0.6766	0.6670	0.6156
屏東縣	0.7258	0.7375	0.7457	0.7699	0.7815	0.5830	0.5561	0.5571	0.5710	0.6062
彰化縣	0.6808	0.6966	0.7418	0.7500	0.7109	0.5612	0.5412	0.6316	0.6100	0.5535
新北市	0.7839	0.7710	0.7699	0.7603	0.7176	0.5609	0.5410	0.5343	0.5077	0.5011
新竹市	0.7825	0.7947	0.7904	0.8839	0.7252	0.5333	0.5635	0.5419	0.5829	0.5448
新竹縣	0.6815	0.6726	0.7343	0.6973	0.6771	0.5397	0.5091	0.5410	0.5486	0.5124
桃園市	0.7552	0.8203	0.8079	0.8391	0.7419	0.5567	0.5778	0.5870	0.5800	0.5491
澎湖縣	0.7538	0.7585	0.7961	0.7672	0.8005	0.5745	0.5511	0.5798	0.4801	0.5836
臺中市	0.7975	0.8245	0.8530	0.8708	0.7648	0.5897	0.5915	0.6123	0.5946	0.5453
臺北市	0.6575	0.6845	0.6823	0.6652	0.6129	0.4310	0.4456	0.4286	0.4187	0.3842
臺南市	0.7695	0.7840	0.7901	0.8241	0.7353	0.5859	0.5991	0.5881	0.6311	0.5641
臺東縣	0.7378	0.7342	0.7125	0.6995	0.8716	0.6614	0.6055	0.6054	0.6102	0.677
花蓮縣	0.7419	0.7312	0.8062	0.8505	0.8659	0.5684	0.6037	0.6276	0.6908	0.6628
苗栗縣	0.6744	0.6620	0.6898	0.7044	0.7541	0.5762	0.5277	0.5707	0.6030	0.5875
連江縣	0.5732	0.8023	0.8652	0.8965	0.6312	0.3841	0.4102	0.4196	0.4675	0.5375
金門縣	0.6930	0.6576	0.7735	0.6946	0.7499	0.5241	0.4672	0.5070	0.4495	0.5329
雲林縣	0.6378	0.6134	0.6432	0.6289	0.7361	0.5123	0.5264	0.5512	0.5256	0.5684
高雄市	0.7520	0.7516	0.7698	0.7986	0.7539	0.5384	0.5458	0.5561	0.5431	0.5484

Table 02: Age-Standardized Diabetes Incidence Rate by Sex Across Taiwan from 2012 to 2016

	Male					Female				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
南投縣	5.0904	0.9014	0.7615	0.6877	0.6696	5.2944	0.8075	0.6545	0.6037	0.5447
嘉義市	8.0985	1.5362	1.1572	1.1164	1.0224	6.8516	1.1241	0.8777	0.7933	0.7417
嘉義縣	5.2842	0.8867	0.7429	0.6946	0.6242	5.3078	0.7980	0.6356	0.6033	0.5377
基隆市	7.0258	1.2418	1.1085	0.9369	0.8320	6.7219	1.0368	0.8556	0.7099	0.6933
宜蘭縣	5.6750	1.0223	0.8510	0.7741	0.7295	5.9505	0.8644	0.7233	0.6573	0.6198
屏東縣	5.8140	1.0101	0.8340	0.7823	0.7206	5.755	0.7980	0.6879	0.6169	0.5783
彰化縣	5.7541	0.9102	0.7724	0.7007	0.6622	5.6487	0.7590	0.6456	0.5982	0.5363
新北市	6.4257	1.1182	0.8991	0.8200	0.7669	5.8792	0.8489	0.7015	0.6209	0.5562
新竹市	6.1397	1.0108	0.8727	0.905	0.8753	5.6152	0.7612	0.6734	0.6751	0.5720
新竹縣	5.1374	0.9042	0.7649	0.7474	0.7211	5.2101	0.7491	0.644	0.6096	0.5720
桃園市	6.2711	1.1437	0.9334	0.8854	0.7829	6.0305	0.8997	0.7268	0.6346	0.5841
澎湖縣	7.5829	1.1783	0.9143	0.8302	0.7880	7.334	0.8754	0.7608	0.5931	0.5936
臺中市	6.6485	1.1757	0.9824	0.8842	0.8190	6.3106	0.9266	0.7683	0.6655	0.6061
臺北市	6.1814	1.0122	0.8291	0.7563	0.6829	4.7586	0.7140	0.5527	0.5107	0.4540
臺南市	6.4420	1.0856	0.8821	0.7929	0.7779	5.8262	0.8472	0.6805	0.601	0.5772
臺東縣	5.6208	1.2314	1.0243	0.8590	0.7813	5.9305	1.0698	0.9714	0.8276	0.6395
花蓮縣	6.5173	1.0903	0.9362	0.8544	0.8655	6.7777	0.9592	0.7863	0.718	0.7323
苗栗縣	5.1273	0.8725	0.7526	0.6778	0.6646	5.3054	0.7694	0.6323	0.5745	0.5633
連江縣	6.5430	0.8894	0.8745	0.8629	0.5940	4.2508	0.5409	0.5685	0.6707	0.6725
金門縣	5.3416	0.8594	0.7528	0.6943	0.6470	4.6202	0.6611	0.5808	0.516	0.4664
雲林縣	5.4883	0.8836	0.7730	0.6930	0.6219	5.3566	0.7420	0.6389	0.5891	0.5287
高雄市	6.6631	1.0974	0.8614	0.8146	0.7991	5.8289	0.8381	0.6567	0.5985	0.5800

Table 03: Age-Standardized Diabetes-Specific Mortality by Sex Across Taiwan from 2017 to 2021



	Male					Female				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
連江縣	27.770	12.817	4.160	20.609	20.496	0	1.546	7.783	27.896	7.7504
金門縣	15.230	21.563	22.145	23.674	21.651	16.492	16.865	25.048	15.303	20.828
宜蘭縣	31.535	28.425	26.160	29.537	30.935	25.806	23.751	20.392	26.904	23.778
新竹縣	50.542	50.786	46.795	43.863	44.631	42.518	43.464	34.236	36.409	42.527
苗栗縣	40.889	40.060	48.993	47.054	55.853	38.824	36.738	35.733	40.215	41.182
彰化縣	42.457	34.569	31.699	33.432	34.752	39.864	31.657	30.478	25.95	29.249
南投縣	44.369	41.330	36.677	35.730	39.602	41.088	37.083	32.828	30.053	35.186
雲林縣	47.610	47.840	42.506	45.625	52.584	39.143	33.426	34.592	31.724	36.579
嘉義縣	41.223	40.300	37.063	36.640	43.854	35.345	31.024	32.559	28.951	33.636
屏東縣	48.601	45.835	50.215	53.217	50.373	45.716	39.150	39.939	39.556	39.504
臺東縣	43.367	37.602	43.349	34.035	29.305	28.554	23.674	36.899	24.446	23.371
花蓮縣	52.195	50.660	55.528	41.715	49.396	43.451	45.773	38.434	35.201	40.875
澎湖縣	36.269	26.118	26.390	31.062	35.060	28.865	29.621	31.973	25.411	30.723
基隆市	35.664	34.923	38.373	49.105	53.323	45.611	35.955	33.094	35.344	39.636
新竹市	49.561	26.916	40.499	37.646	35.494	46.029	32.822	29.442	27.365	24.881
嘉義市	41.140	39.043	31.106	38.986	34.836	36.233	31.288	28.210	32.608	27.03
臺北市	22.604	21.875	21.715	21.519	27.170	20.756	18.218	16.549	17.054	20.429
高雄市	49.145	43.767	44.116	46.700	49.240	39.641	36.857	35.726	34.133	36.545
新北市	34.304	31.630	30.791	31.284	39.817	29.849	25.837	24.496	26.583	30.905
臺中市	45.972	38.336	44.358	42.536	44.575	38.585	38.374	39.143	33.684	36.835
臺南市	49.619	48.679	42.570	42.938	43.239	38.471	36.987	34.122	31.845	32.324
桃園市	36.613	38.381	34.927	35.337	39.826	33.950	32.121	31.002	32.103	35.77

Chapter 7 Figures



Figure 01: Taiwan Age-Standardized Observed Diabetes Incidence Rate by Sex from 2017 to 2021 (%)

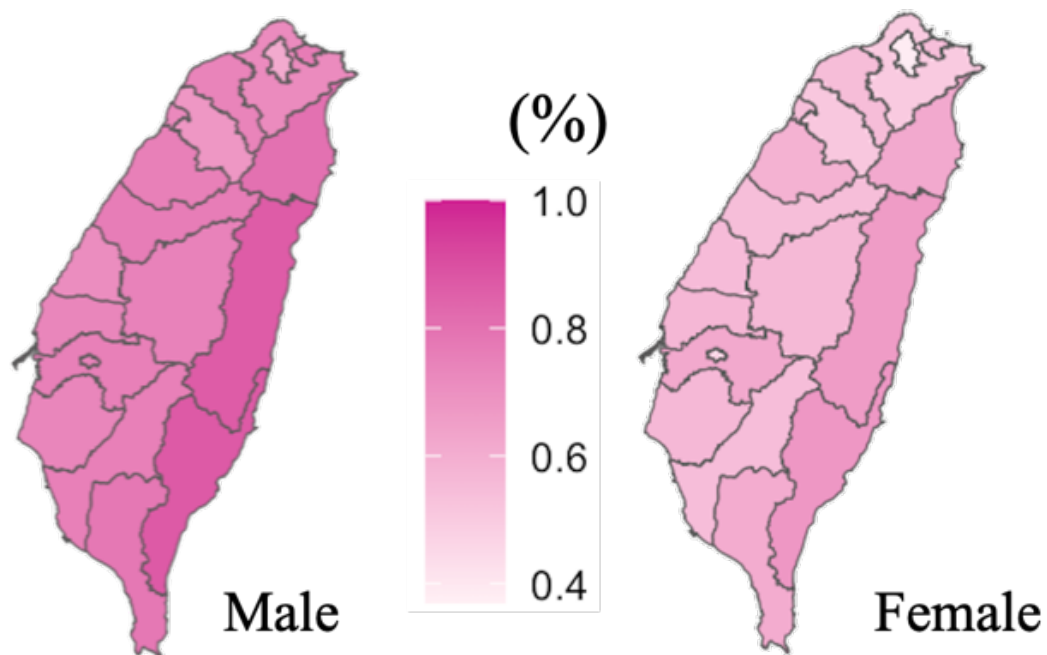


Figure 02: Age-Standardized Observed Diabetes Incidence Rate by Sex Across Taiwan in 2021 (%)

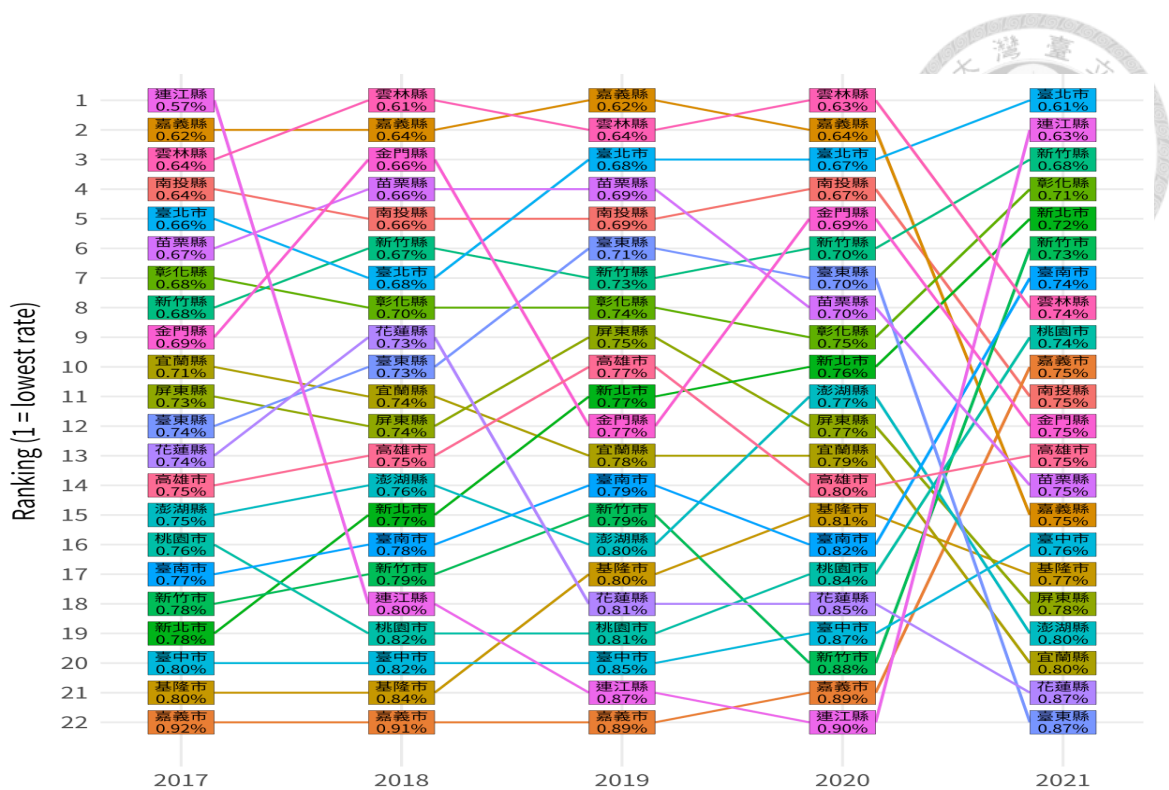


Figure 03: Age-Standardized Observed Diabetes Incidence Rate Ranking in Male

Across Taiwan from 2017 to 2021

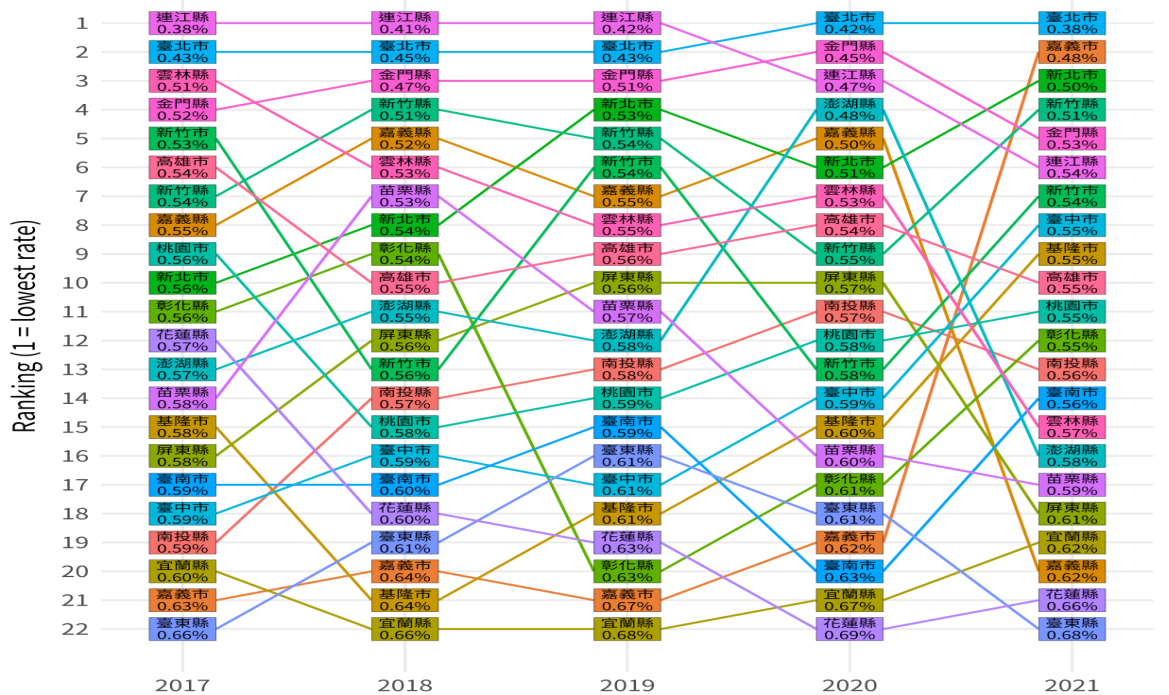


Figure 04: Age-Standardized Observed Diabetes Incidence Rate Ranking in Female

Across Taiwan from 2017 to 2021

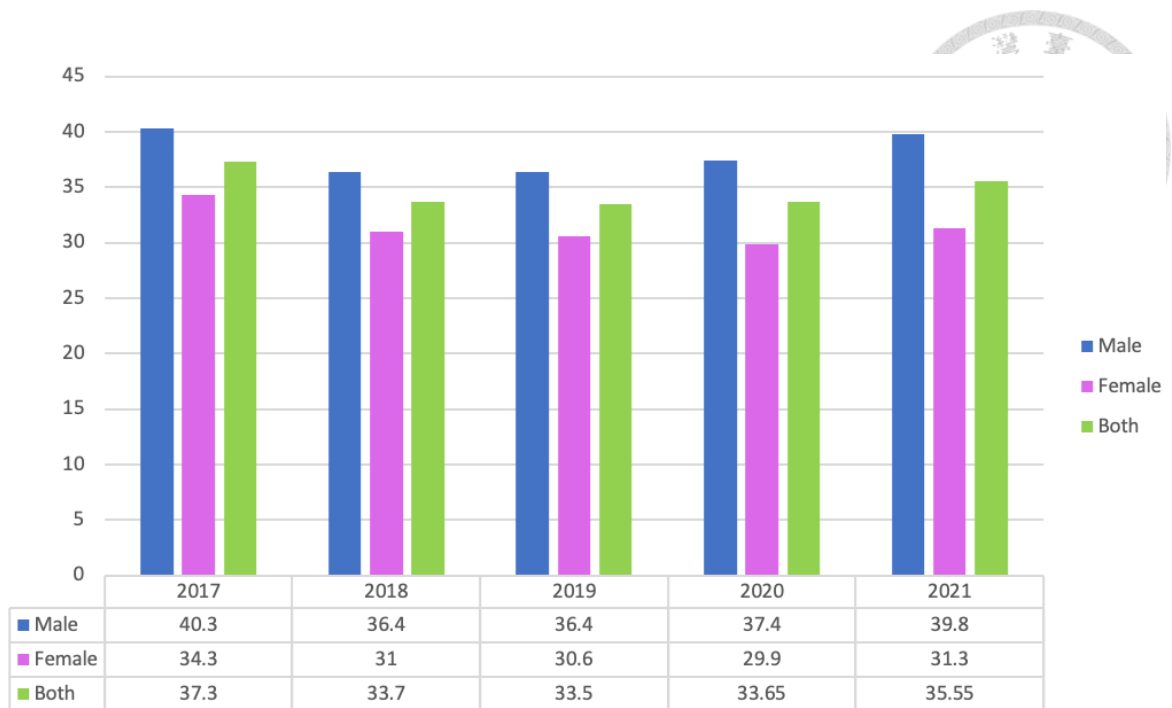


Figure 05: Taiwan Age-Standardized Diabetes-Specific Mortality Rate by Sex from 2017 to 2021 (per 100,000)

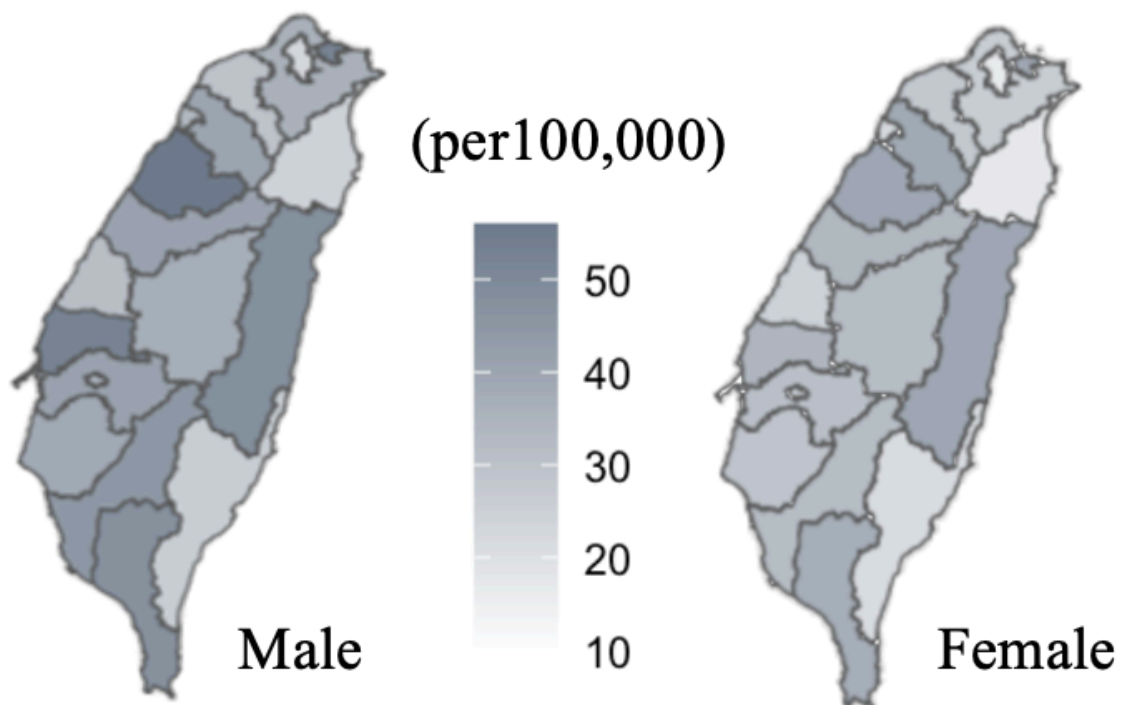


Figure 06: Age-Standardized Diabetes-Specific Mortality Rate by Sex Across Taiwan in 2021 (per 100,000)

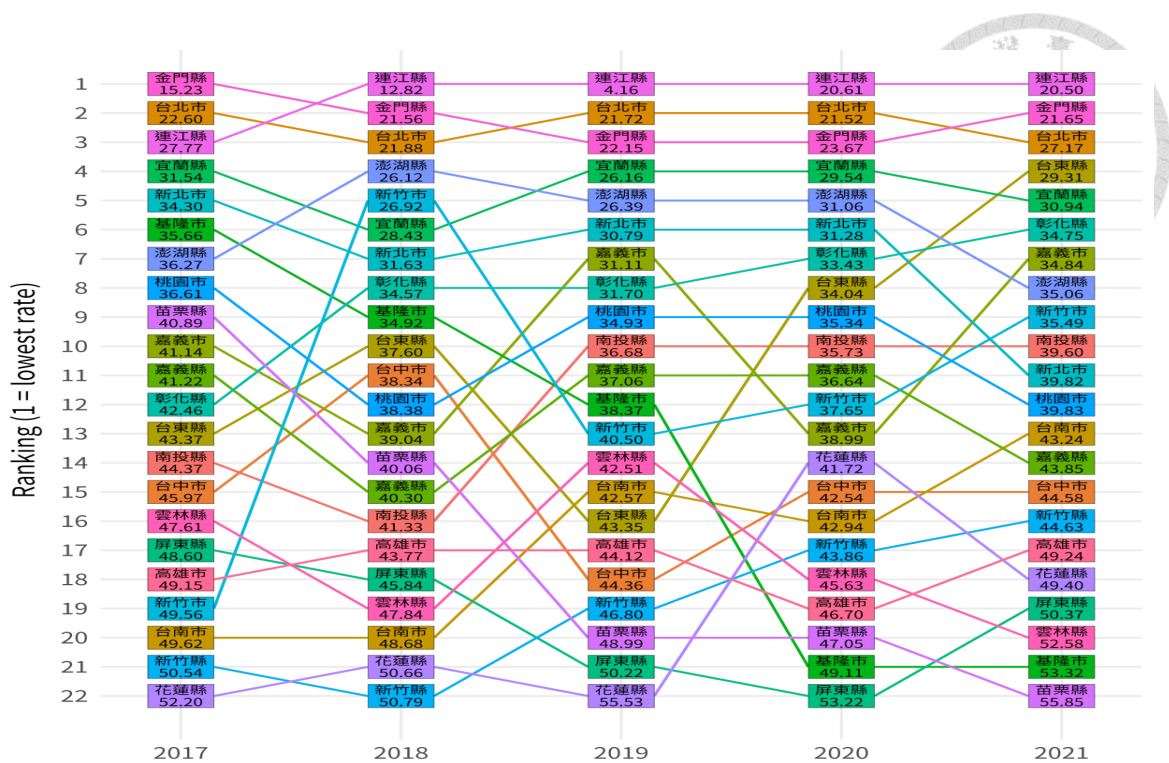


Figure 07: Age-Standardized Diabetes-Specific Mortality Rate Ranking in Male Across Taiwan from 2017 to 2021 (per 100,000)

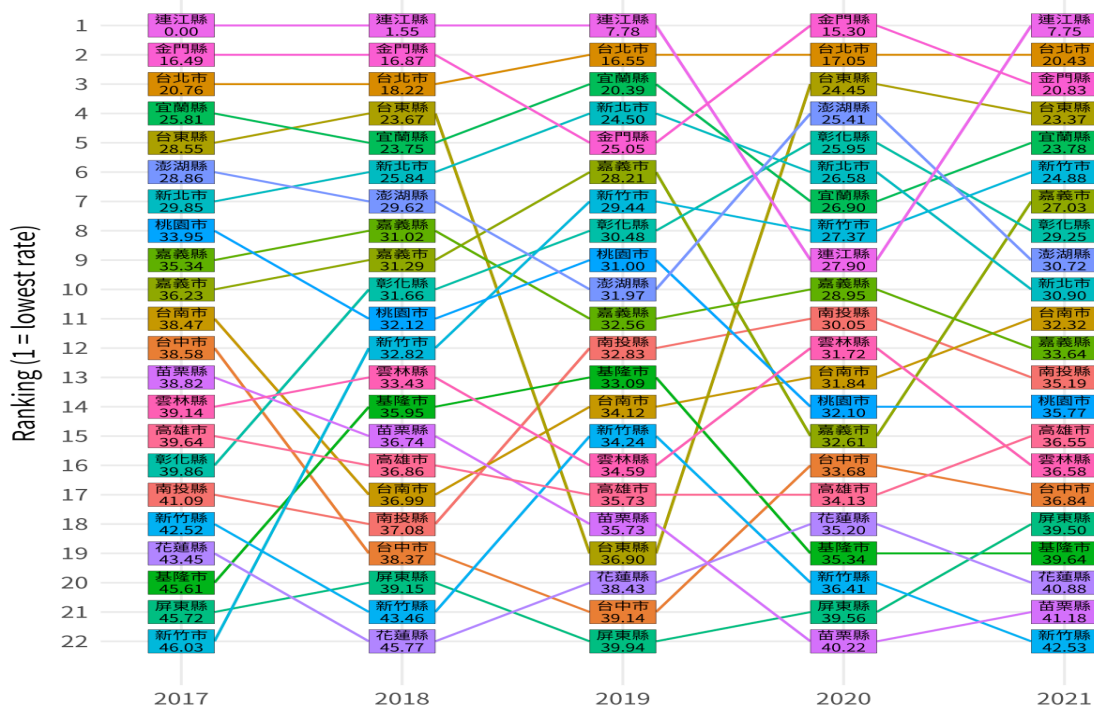


Figure 08: Age-Standardized Diabetes-Specific Mortality Rate Ranking in Female Across Taiwan from 2017 to 2021 (per 100,000)

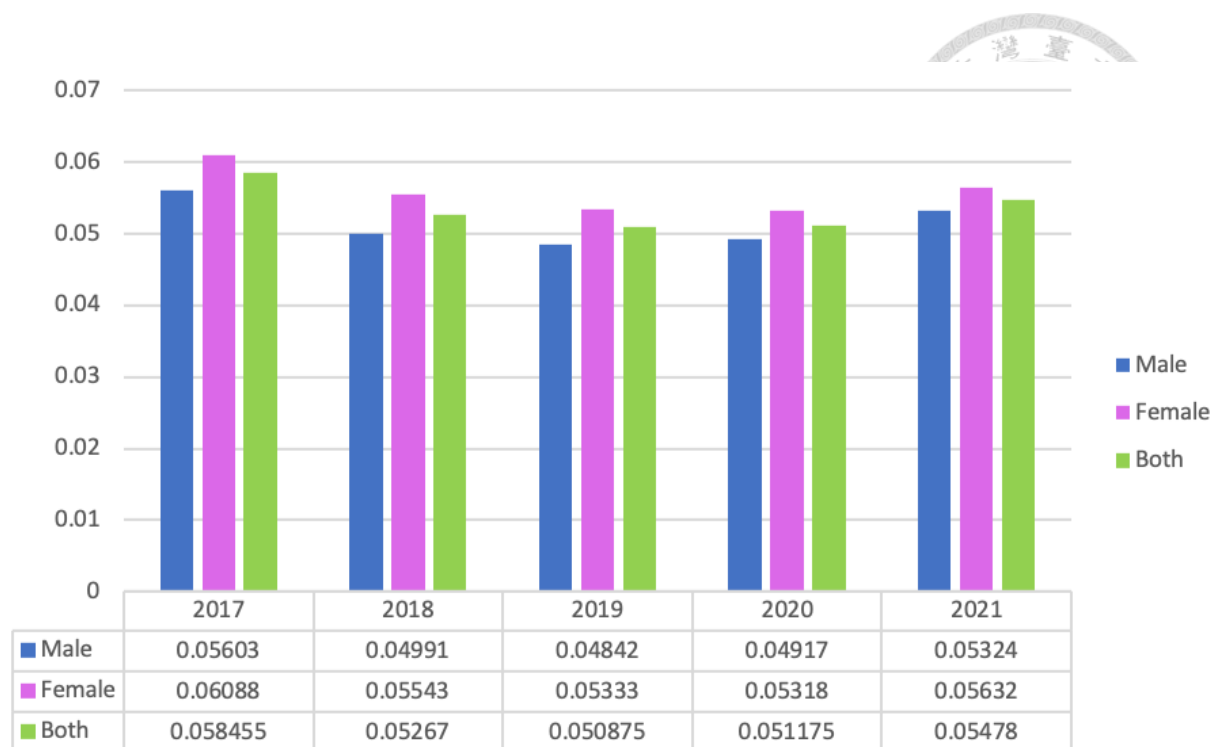


Figure 09: Taiwan Age-Standardized Diabetes MI-Ratio (Based on Observed Incidence)

by Sex from 2017 to 2021

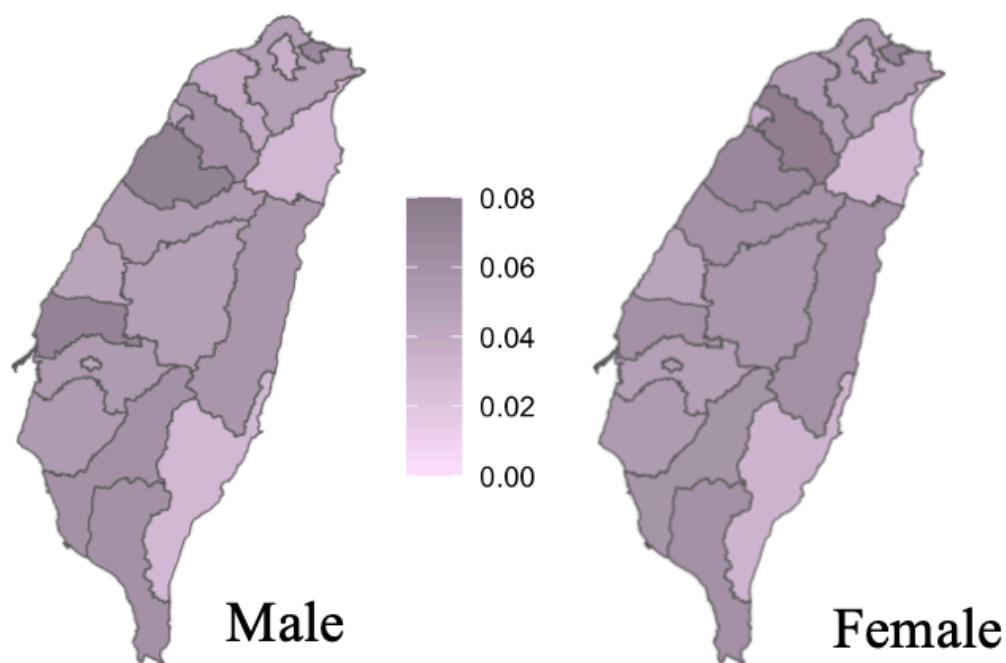


Figure 10: Age-Standardized Diabetes MI-Ratio (Based on Observed Incidence) by Sex

Across Taiwan in 2021

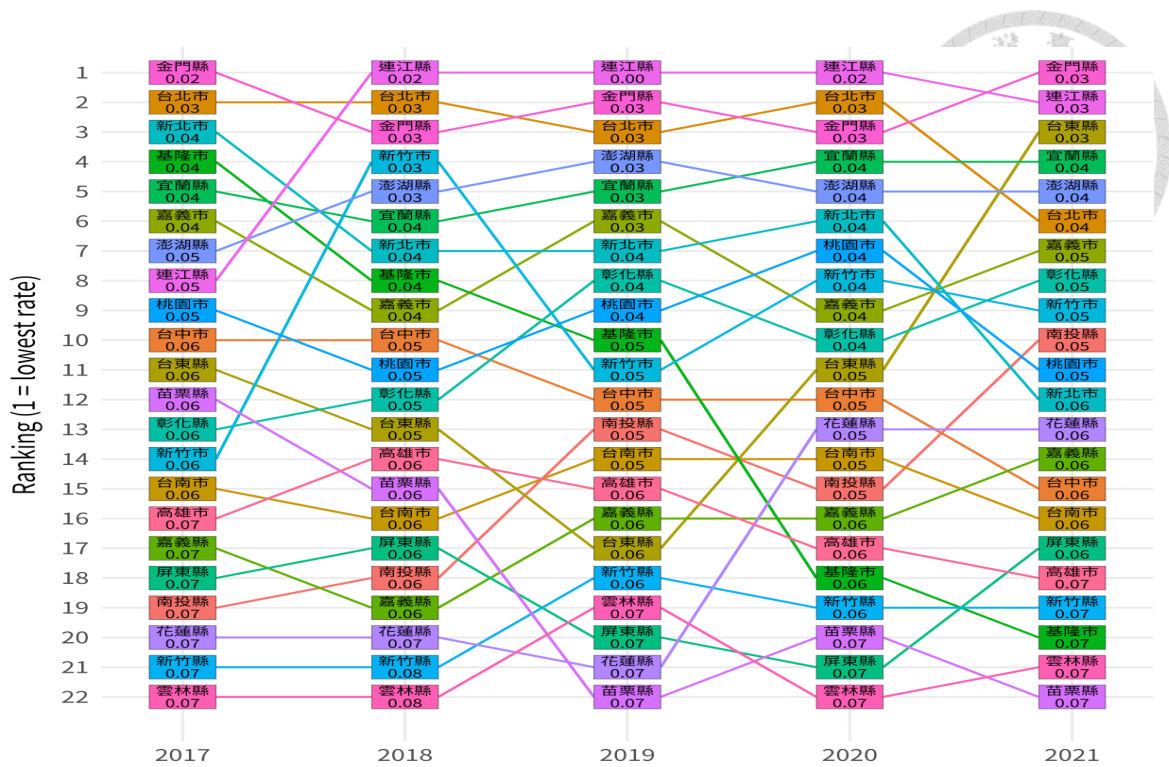


Figure 11: Age-Standardized Diabetes MI-Ratio (Based on Observed Incidence)

Ranking in Male Across Taiwan from 2017 to 2021

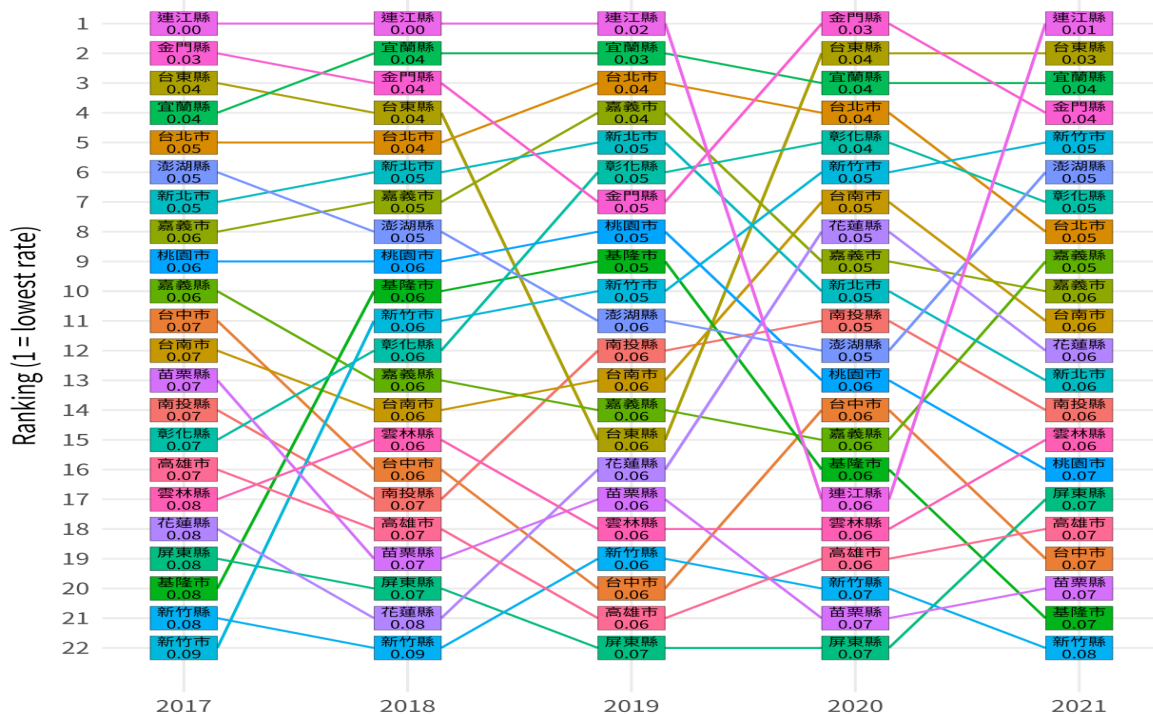


Figure 12: Age-Standardized Diabetes MI-Ratio (Based on Observed Incidence)

Ranking in Female Across Taiwan from 2017 to 2021

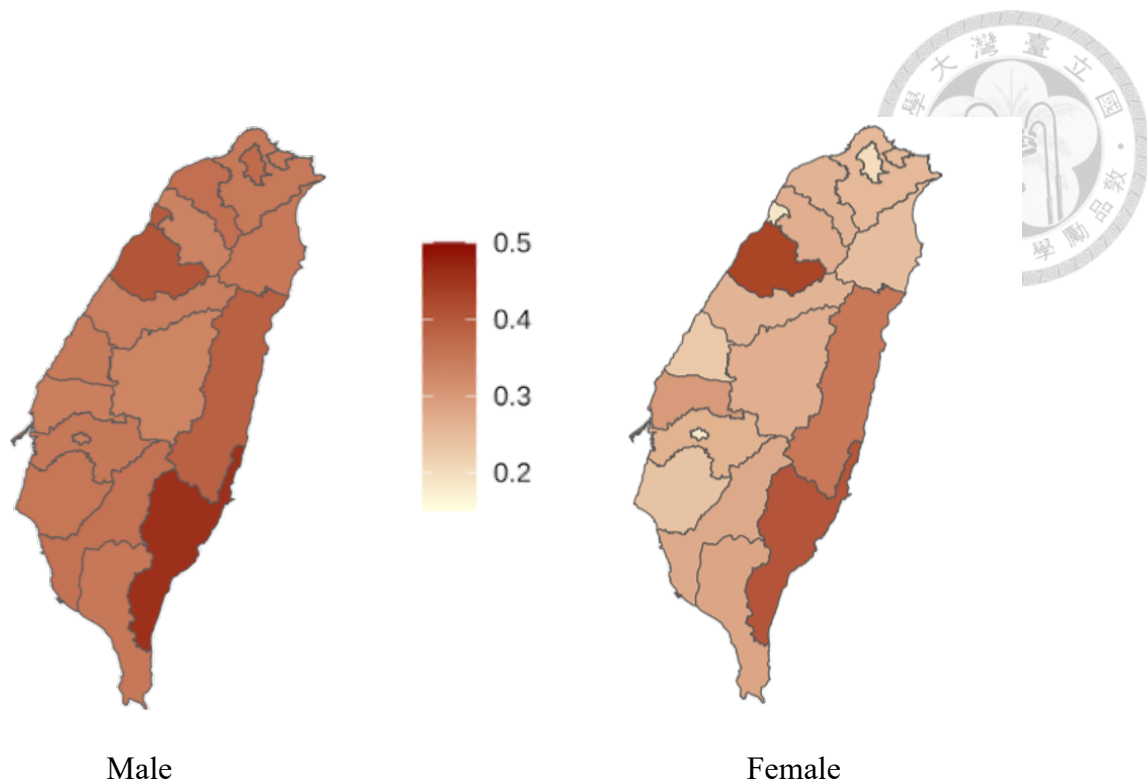


Figure 13: BMI PAF by Sex Across Taiwan by Sex during 2017 to 2020

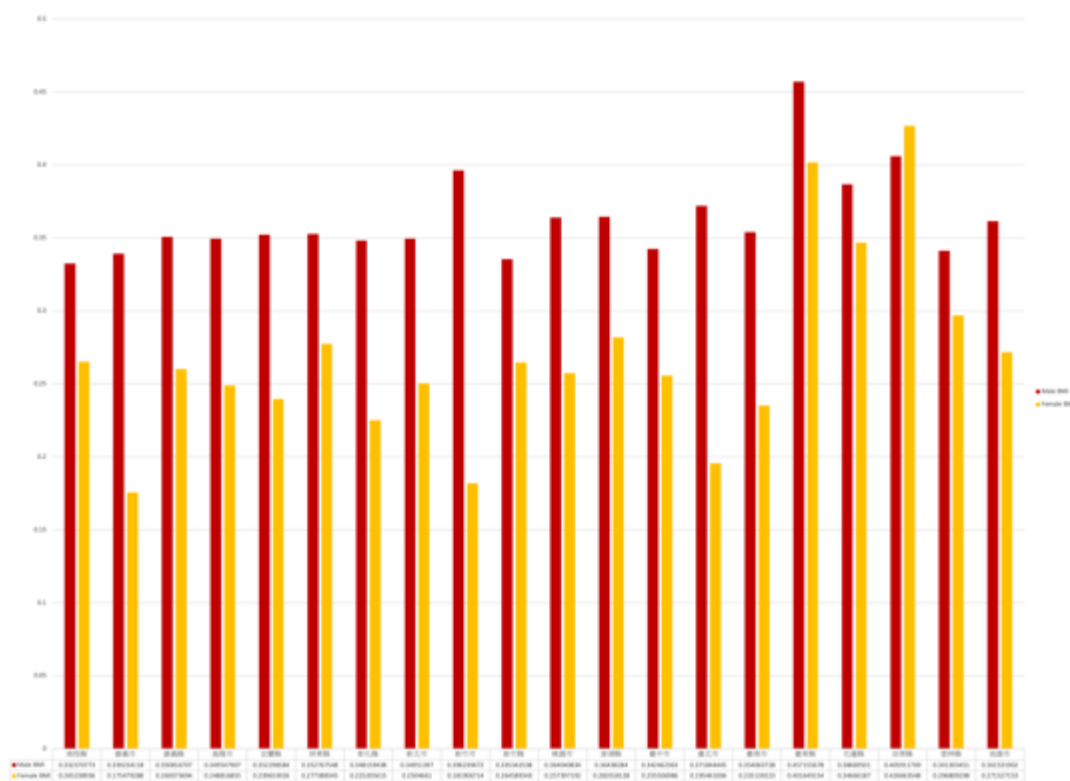


Figure 14: BMI PAF Across Taiwan by Sex during 2017 to 2020

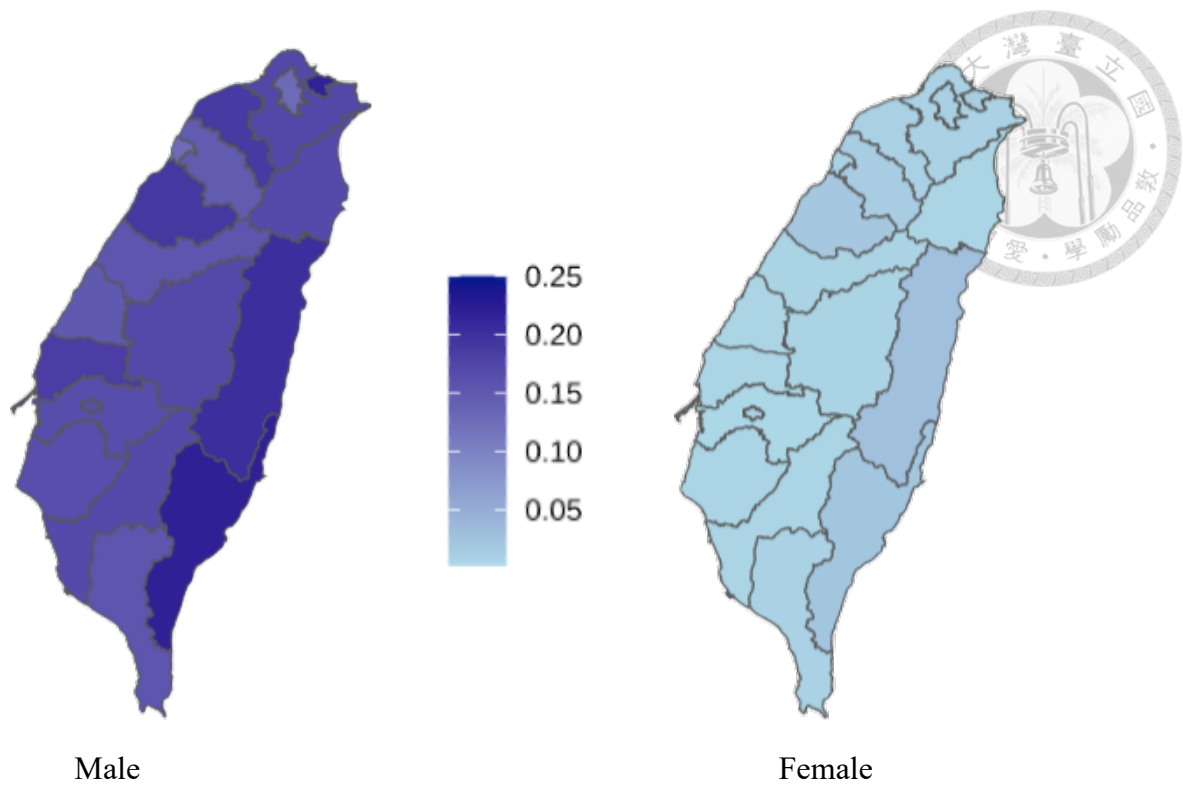


Figure 17: Smoking PAF by Sex Across Taiwan during 2017 to 2020

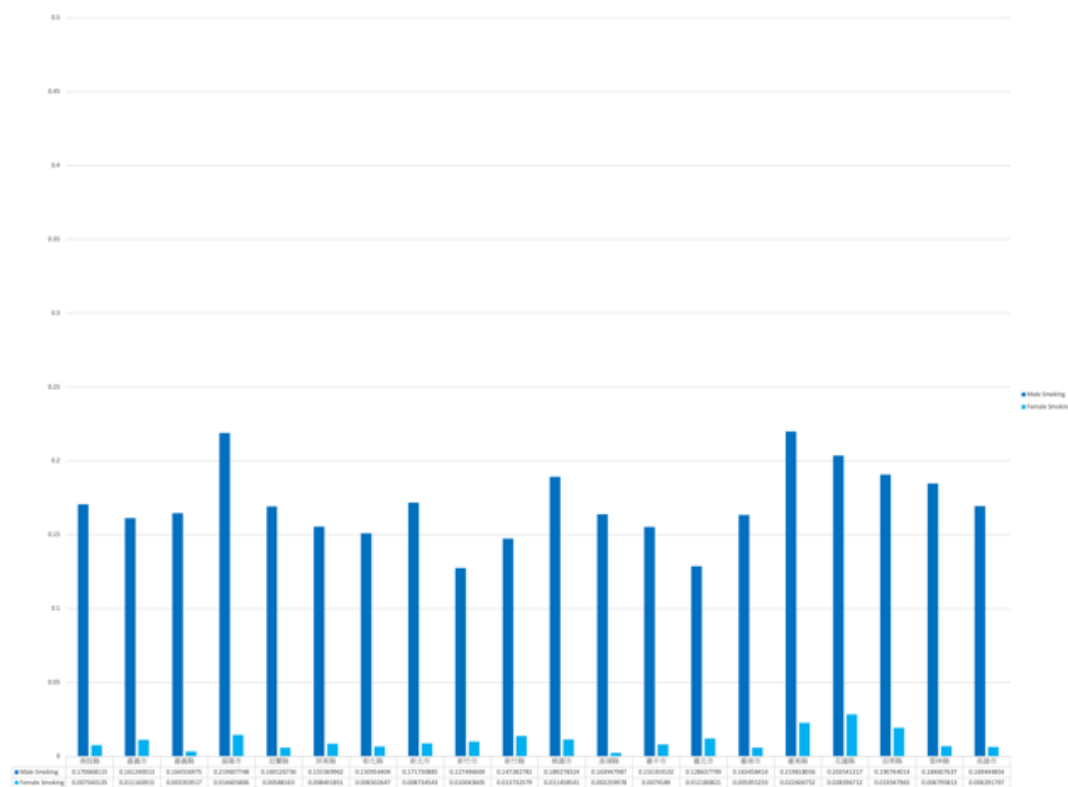


Figure 18: Smoking PAF by Sex Across Taiwan during 2017 to 2020

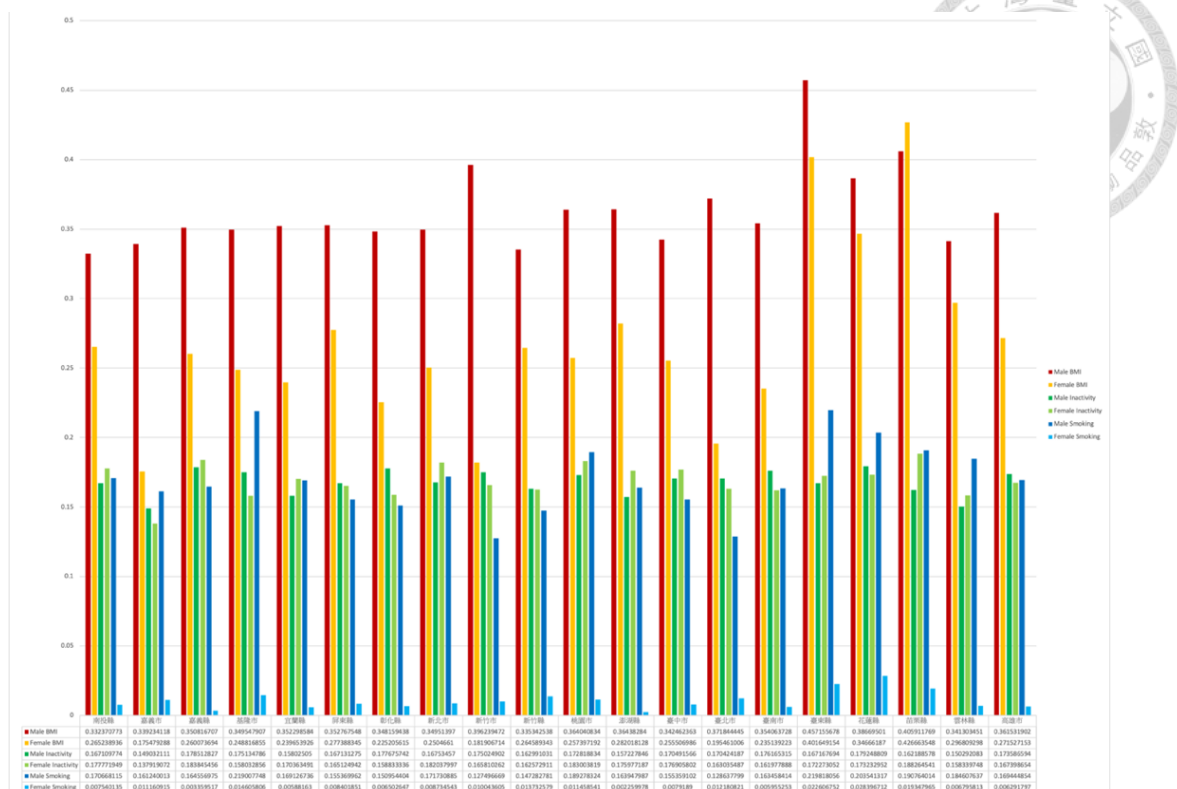


Figure 19: Overall PAF by Sex Across Taiwan during 2017 to 2020

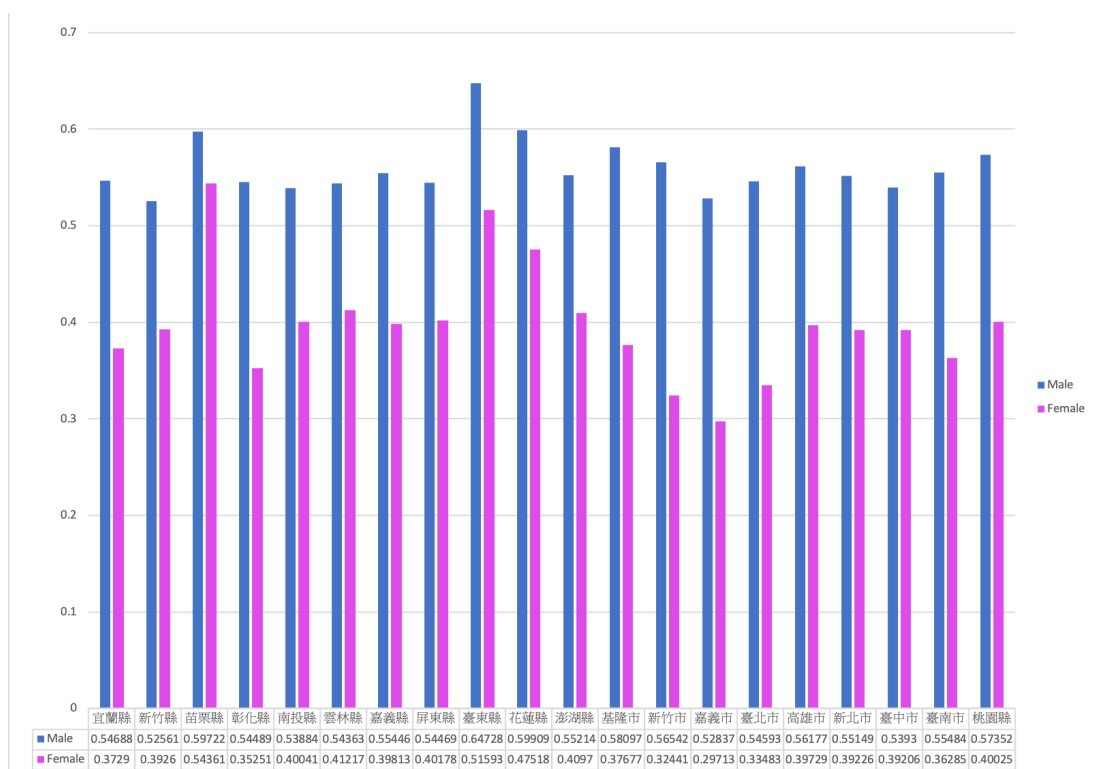


Figure 20: Joint PAF of High BMI, Physical Inactivity, and Smoking by Sex Across Taiwan during 2017 to 2020

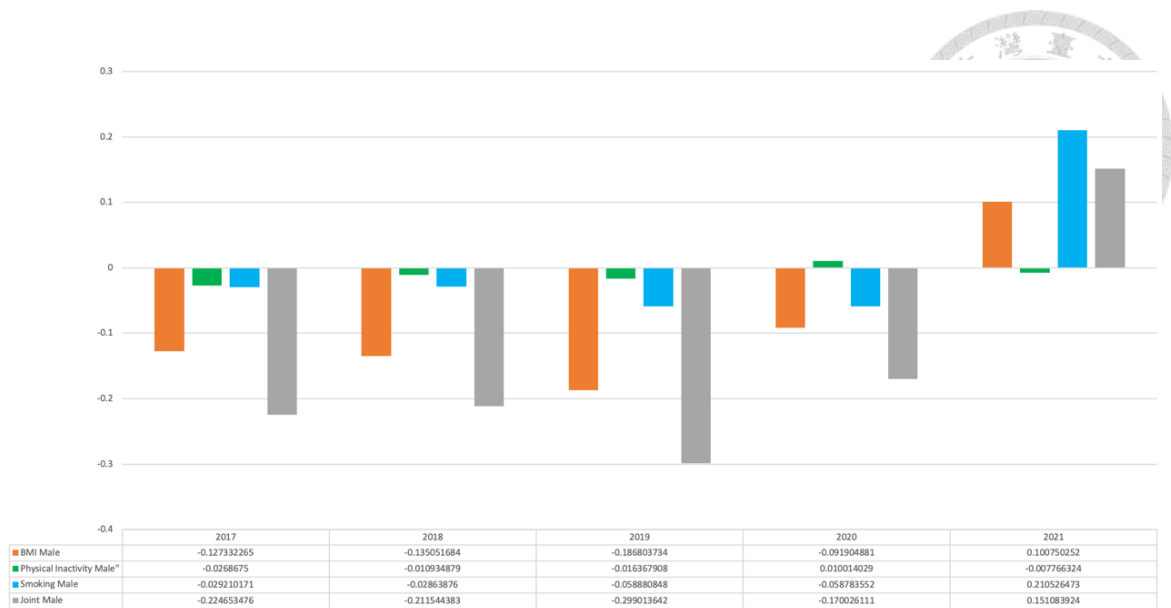


Figure 21: Taiwan Diabetes Disparities Explanatory Power in Male from 2017 to 2021

(Based on Observed Incidence Rate)

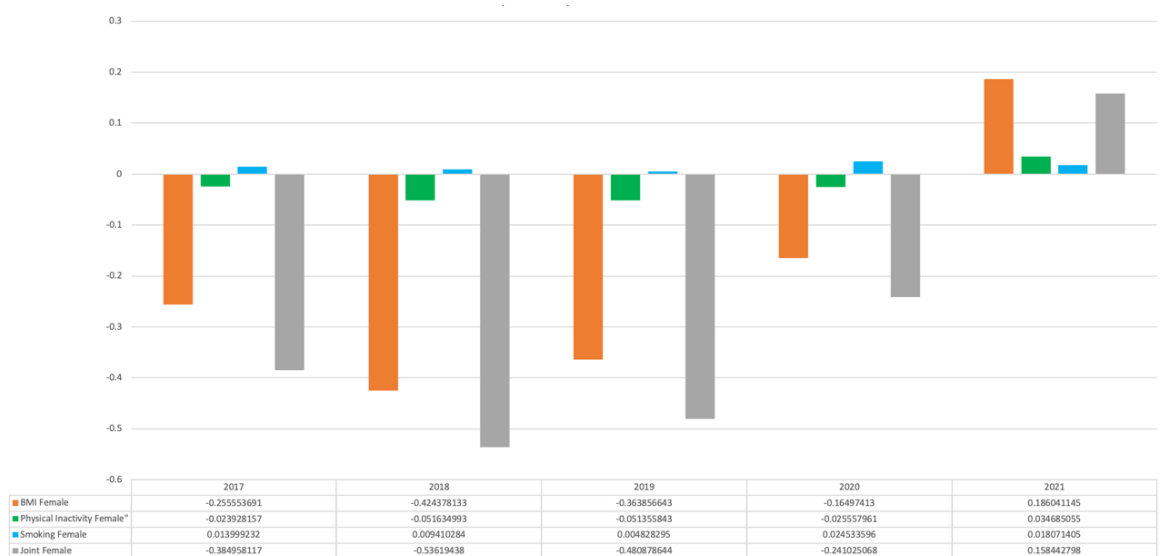


Figure 22: Taiwan Diabetes Disparities Explanatory Power in Female from 2017 to

2021 (Based on Observed Incidence Rate)

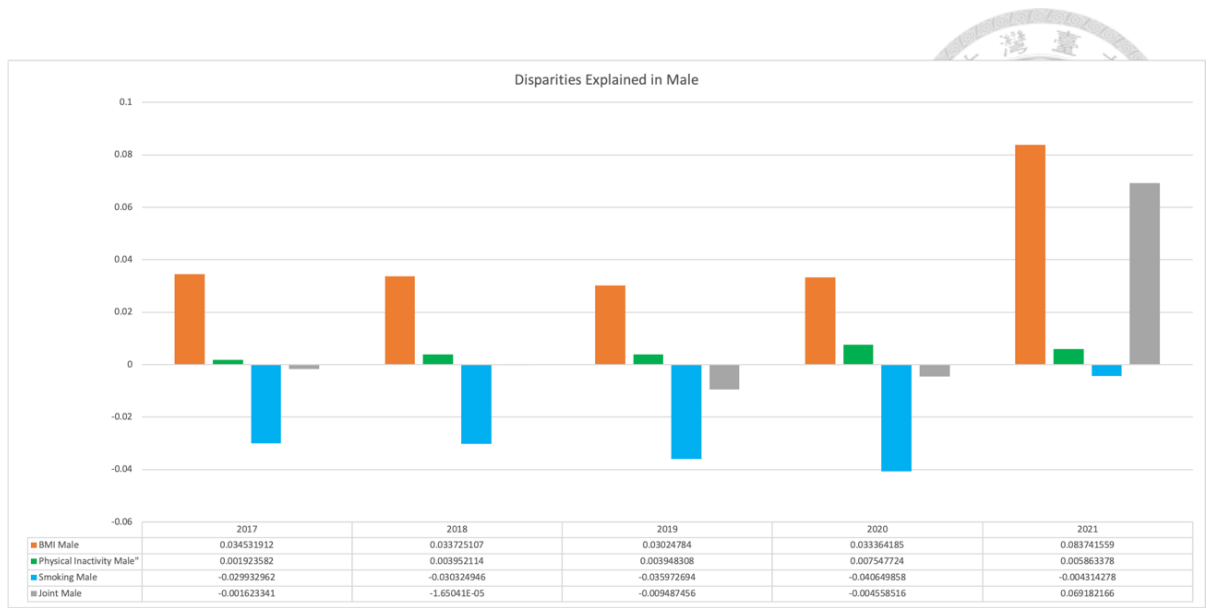


Figure 23: Taiwan Diabetes Disparities Explanatory Power in Male from 2017 to 2021
(Based on Treatment-Adjusted Incidence Rate)



Figure 24: Taiwan Diabetes Disparities Explanatory Power in Female from 2017 to 2021 (Based on Treatment-Adjusted Incidence Rate)

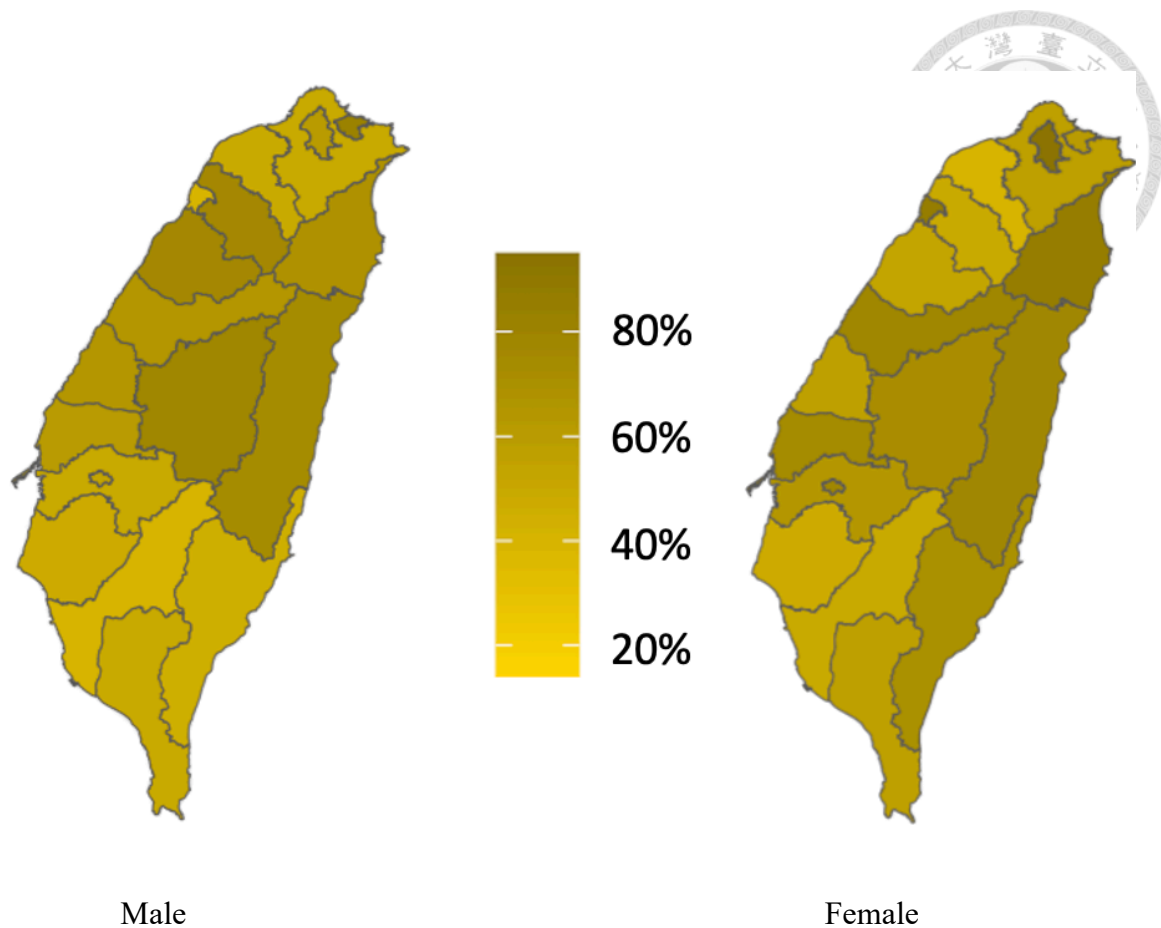


Figure 25: Diabetes Treatment Coverage by Sex Across Taiwan during 2017 to 2020

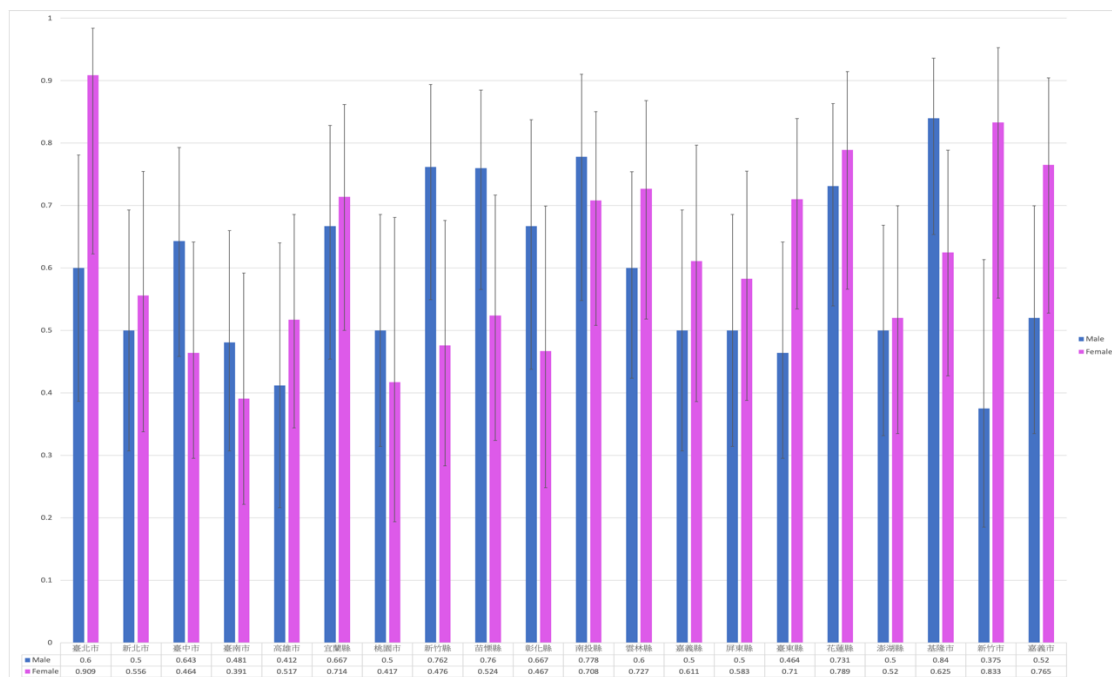


Figure 26: Diabetes Treatment Coverage Across Taiwan by Sex during 2017 to 2020

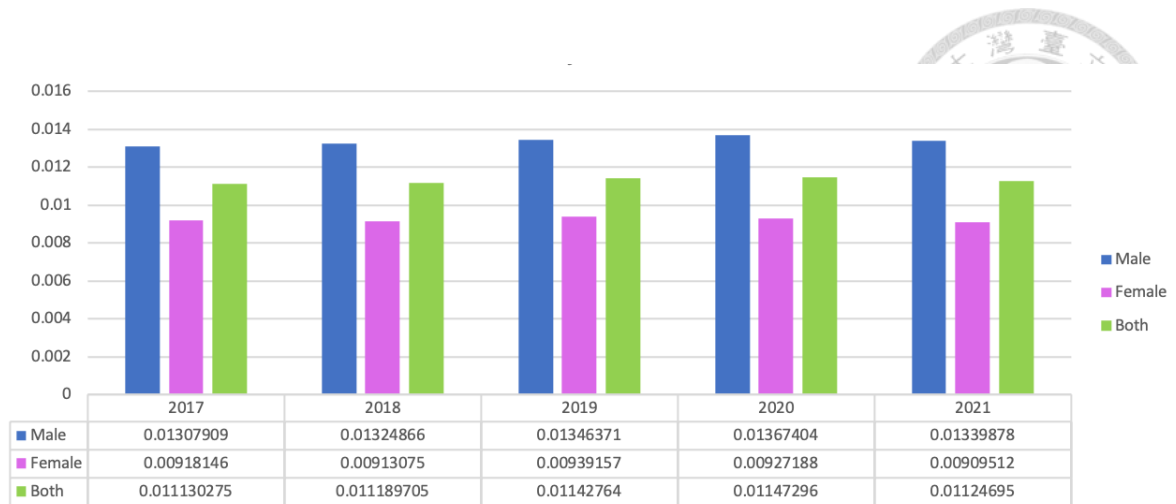


Figure 27: Taiwan Age-Standardized Treatment-Adjusted Diabetes Incidence Rate from 2017 to 2021

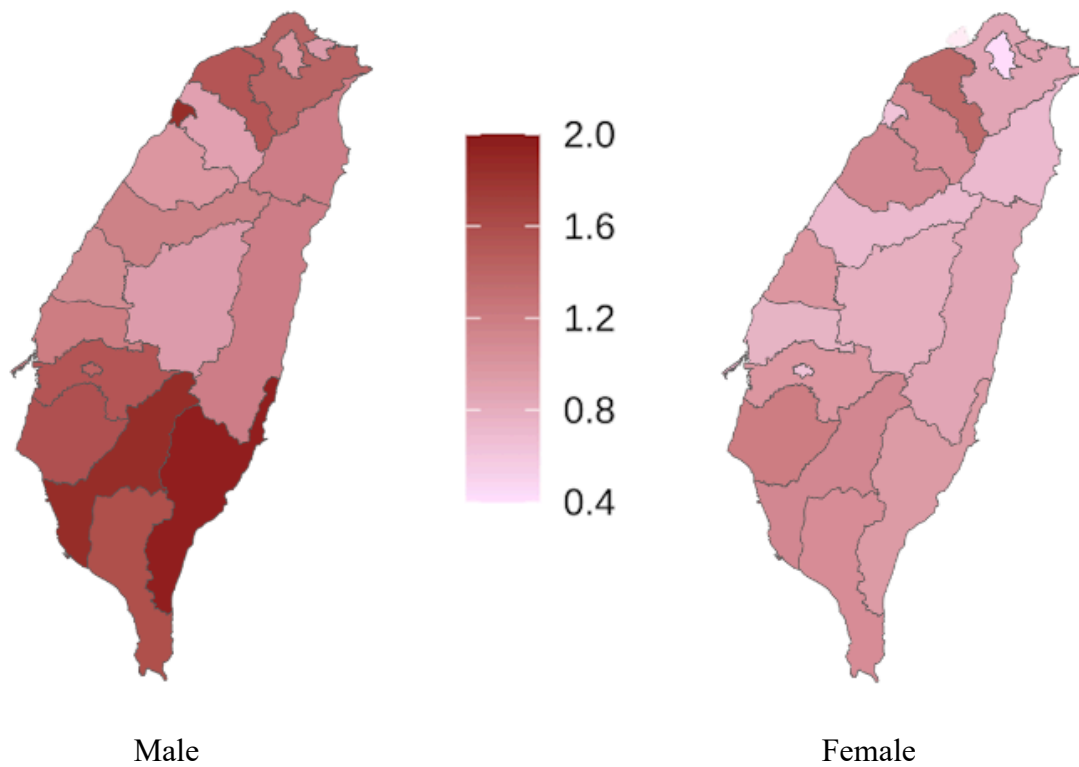


Figure 28: Age-Standardized Treatment-Adjusted Diabetes Incidence Rate by Sex

Across Taiwan in 2021 (%)

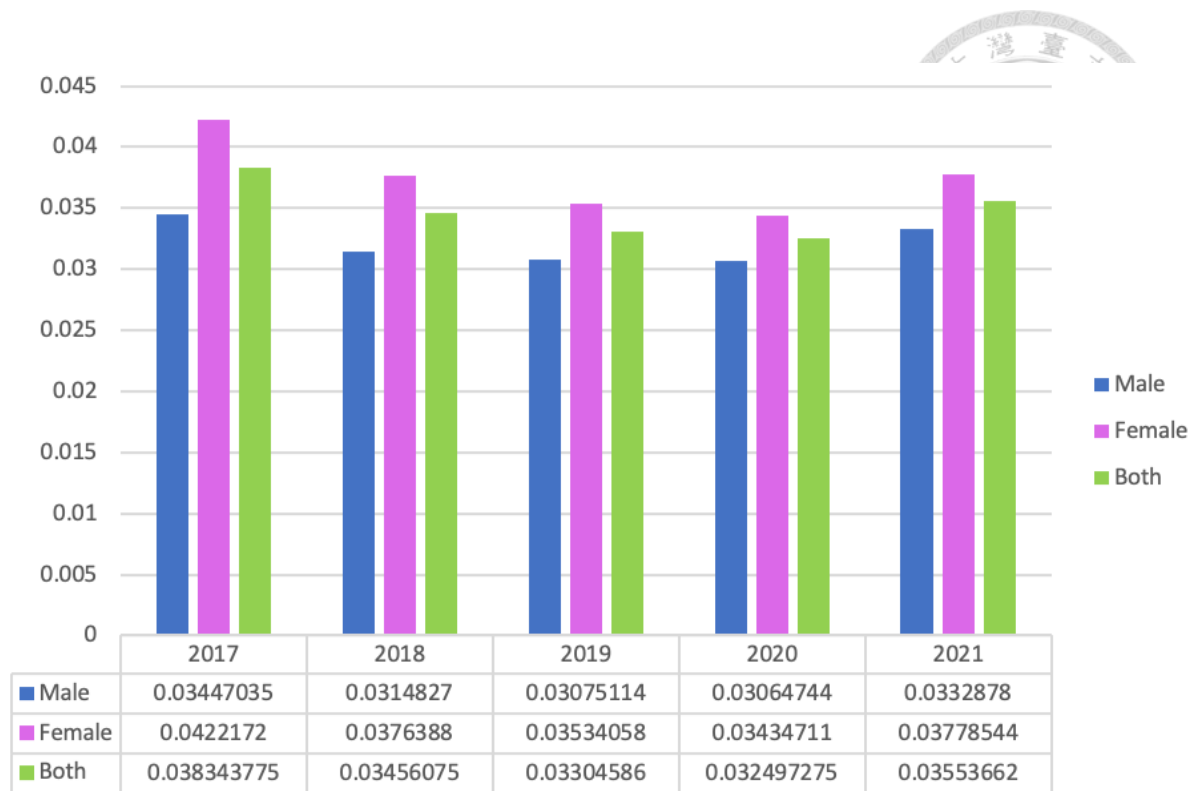


Figure 31: Taiwan Age-Standardized Diabetes MI-Ratio (Based on Treatment-Adjusted Incidence) from 2017 to 2021

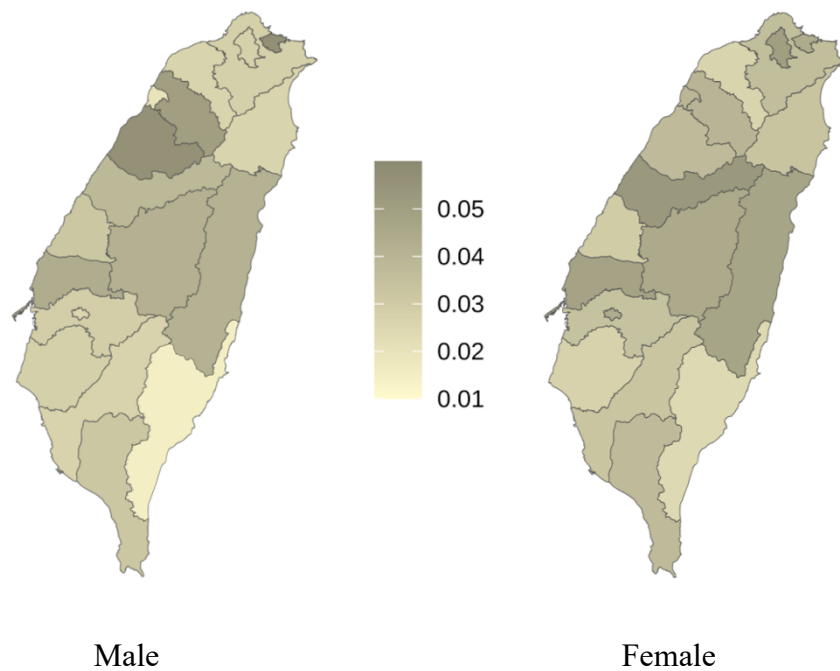


Figure 32: Age-Standardized Diabetes MI-Ratio (Based on Treatment-Adjusted Incidence) by Sex Across Taiwan in 2021 (%)

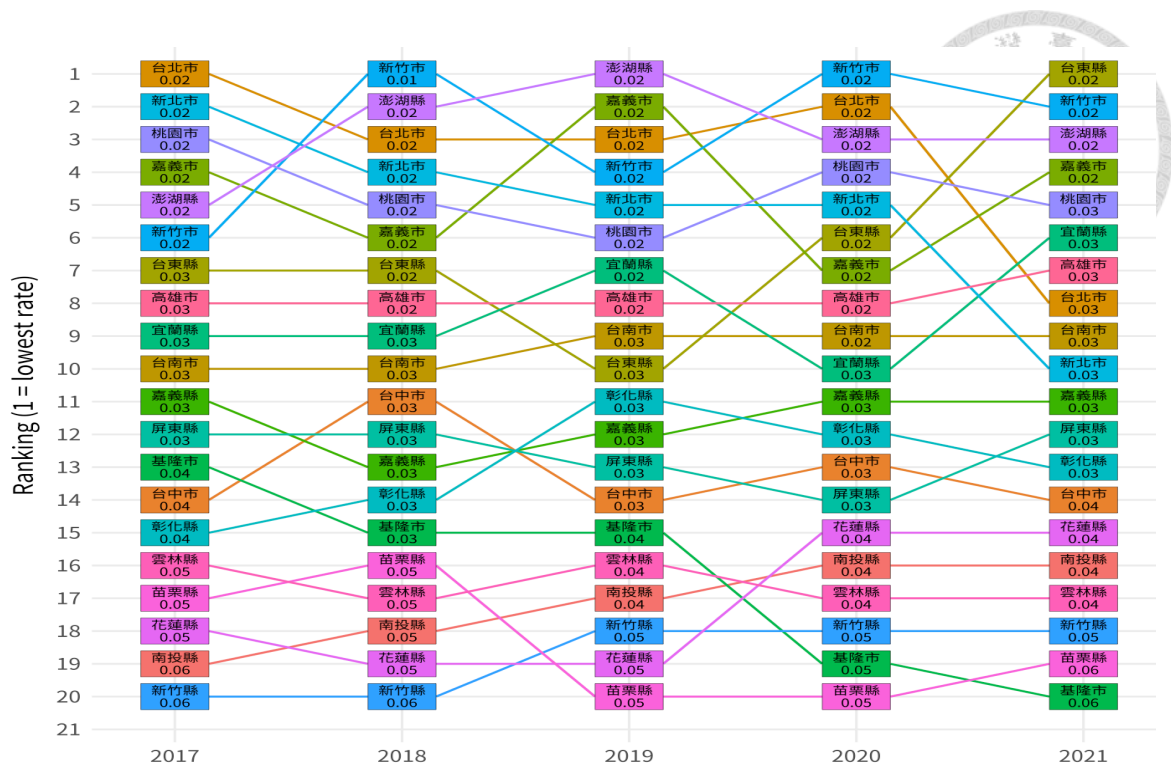


Figure 33: Age-Standardized Diabetes MI-Ratio (Based on Treatment-Adjusted Incidence) Ranking in Male Across Taiwan from 2017 to 2021

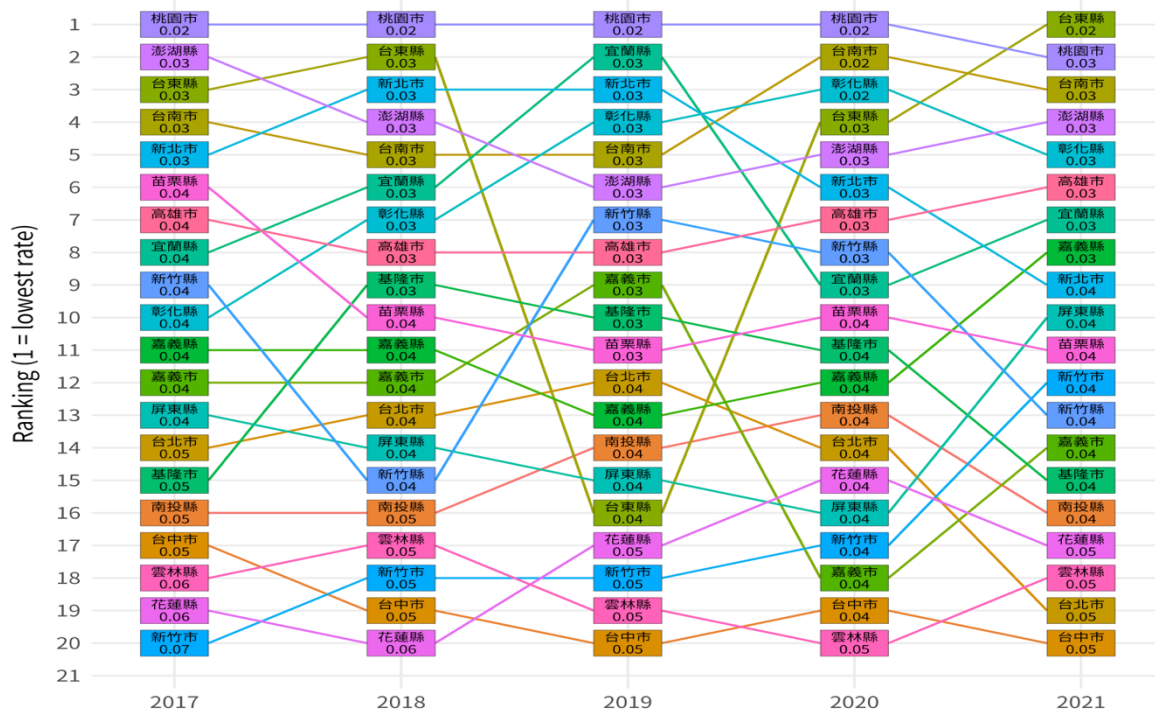


Figure 34: Age-Standardized Diabetes MI-Ratio (Based on Treatment-Adjusted Incidence) Ranking in Female Across Taiwan from 2017 to 2021

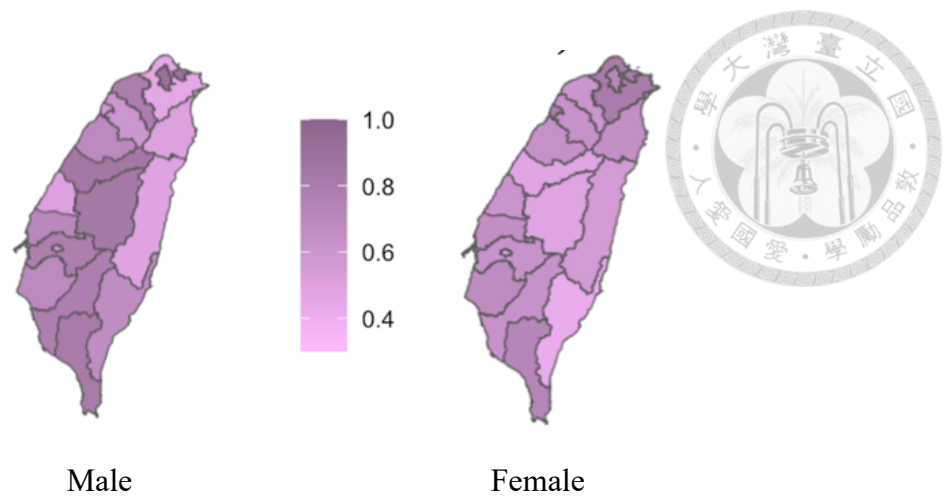


Figure 35: Diabetes Management Rate (HbA1c or FPG Well-Controlled) by Sex Across Taiwan during 2017 to 2020

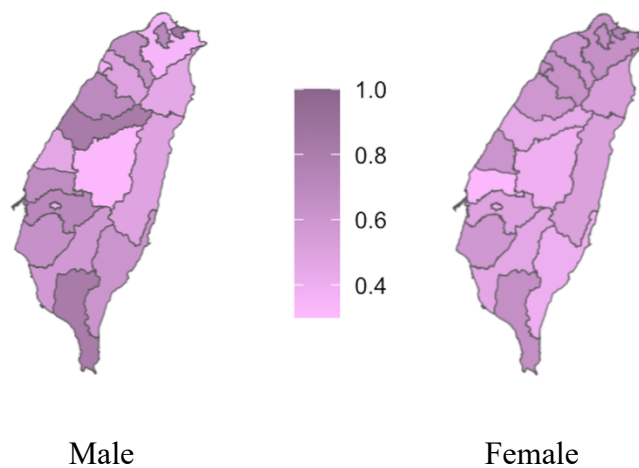


Figure 36: Diabetes Management Rate (HbA1c Well-Controlled) by Sex Across Taiwan during 2017 to 2020

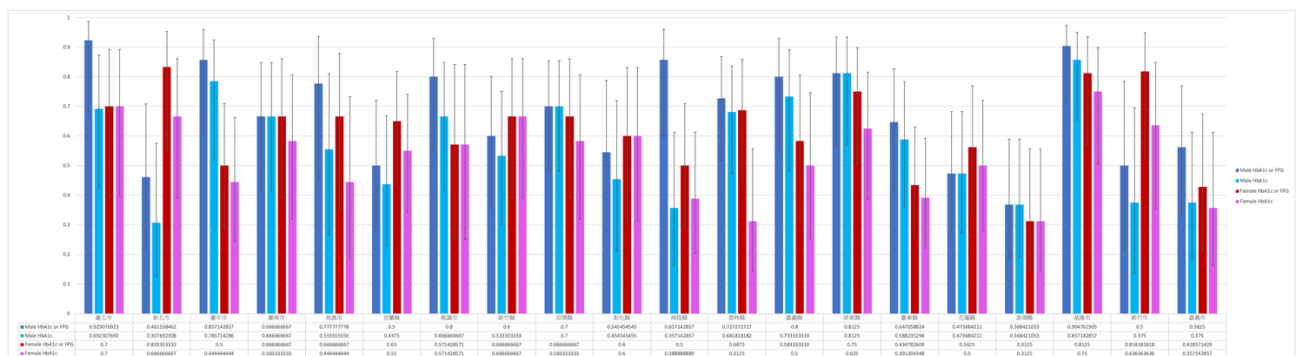


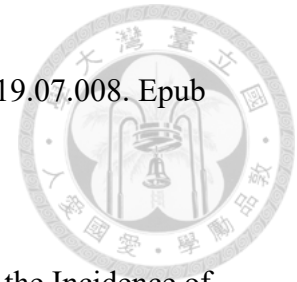
Figure 37: Diabetes Management Rate Across Taiwan during 2017 to 2020

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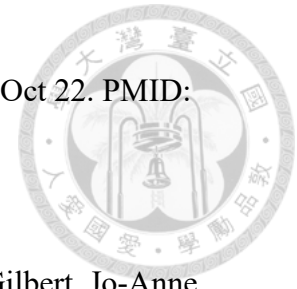


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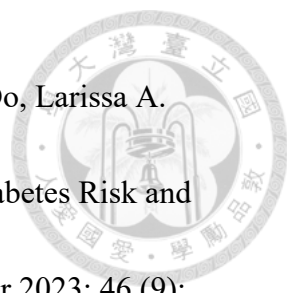
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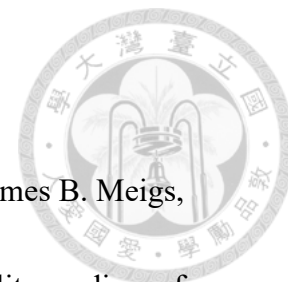
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Appendices

Appendix 1. Diabetes Inclusion:

Presence of at least two outpatient visits with diabetes ICD-9 or ICD-10 codes in
Ambulatory Care Expenditures by Visits within a year. (ICD-9: 250, 250.0, 250.00,
250.01, 250.02, 250.03, 250.09, 250.1, 250.10, 250.11, 250.12, 250.13, 250.19, 250.2,
250.20, 250.21, 250.22, 250.23, 250.29, 250.3, 250.30, 250.31, 250.32, 250.33, 250.39,
250.5, 250.50, 250.51, 250.52, 250.53, 250.59, 250.6, 250.60, 250.61, 250.62, 250.63,
250.69, 250.7, 250.70, 250.71, 250.72, 250.73, 250.79, 250.8, 250.80, 250.81, 250.82,
250.83, 250.89, 250.9, 250.90, 250.91, 250.92, 250.93, 250.99; ICD-10: E08.0, E08.1,
E08.3, E08.4, E08.5, E08.6, E08.8, E08.9, E10.0, E10.1, E10.3, E10.4, E10.5, E10.6,
E10.7, E10.8, E10.9, E11.0, E11.1, E11.3, E11.4, E11.5, E11.6, E11.7, E11.8, E11.9,
E12.0, E12.1, E12.3, E12.4, E12.5, E12.6, E12.7, E12.8, E12.9, E13.0, E13.1, E13.3,
E13.4, E13.5, E13.6, E13.7, E13.8, E13.9, E14.0, E14.1, E14.3, E14.4, E14.5, E14.6,
E14.7, E14.8, E14.9)



Appendix 2. Diabetes Exclusion:

Gestational diabetes cases in which diabetes codes appeared only during pregnancy, defined as from 270 days before the delivery up to the delivery date (ICD-9-CM: 640–677) or within 90 days before a documented miscarriage (ICD-9-CM: 632, 634–638, 656.4), are excluded.

Appendix 3. Relative Risk (RR) Table by GBD (Provided by IHME):

Appendix Table 7a. Relative risks used by age and sex for each outcome for all risk factors except for ambient air pollution, alcohol, smoking, and non-optimal temperature																			
Risk - Outcome	Category / Units	Morbidity / Mortality	Sex																
				20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65-69 years	70-74 years	75-79 years	80-84 years	85-89 years	90-94 years	95+ years
High body-mass index in adults																			
Diabetes mellitus type 2 - 5 kg/m2	Both	Both	Both	3.547 (2.514 to 5.219)	3.547 (2.514 to 5.219)	3.453 (2.516 to 4.681)	3.549 (2.583 to 5.913)	3.16 (2.497 to 3.699)	2.864 (2.453 to 3.312)	2.624 (2.224 to 3.038)	2.417 (2.089 to 2.779)	2.215 (1.868 to 2.686)	2.046 (1.724 to 2.379)	1.896 (1.597 to 2.228)	1.74 (1.446 to 2.074)	1.61 (1.287 to 1.758)	1.461 (1.207 to 1.758)	1.461 (1.207 to 1.758)	1.461 (1.207 to 1.758)

Appendix Table 7a. Relative risks used by age and sex for each outcome for all risk factors except for ambient air pollution, alcohol, smoking, and non-optimal temperature														
Risk - Outcome	Category / Units	Morbidity / Mortality	Sex											
				25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65-69 years	70-74 years	75-79 years
Low physical activity														
Diabetes mellitus type 2 - 0 METs		Both	Both	1.519 (1.519 to 1.519)	1.519 (1.519 to 1.519)	1.519 (1.519 to 1.519)	1.447 (1.447 to 1.447)	1.323 (1.323 to 1.323)	1.213 (1.213 to 1.213)	1.109 (1.109 to 1.109)	1.0 (1.0 to 1.0)	0.900 (0.900 to 0.900)	0.804 (0.804 to 0.804)	0.696 (0.696 to 0.696)
Diabetes mellitus type 2 - 1200 METs		Both	Both	1.460 (1.418 to 1.508)	1.460 (1.418 to 1.508)	1.460 (1.418 to 1.508)	1.390 (1.350 to 1.435)	1.271 (1.235 to 1.313)	1.165 (1.132 to 1.204)	1.066 (1.035 to 1.101)	0.961 (0.933 to 0.992)	0.864 (0.840 to 0.893)	0.772 (0.750 to 0.798)	0.669 (0.650 to 0.691)
Diabetes mellitus type 2 - 1800 METs		Both	Both	1.400 (1.317 to 1.496)	1.400 (1.317 to 1.496)	1.400 (1.317 to 1.496)	1.333 (1.254 to 1.424)	1.218 (1.146 to 1.302)	1.117 (1.051 to 1.194)	1.022 (0.961 to 1.092)	0.921 (0.867 to 0.985)	0.829 (0.780 to 0.886)	0.741 (0.697 to 0.792)	0.641 (0.603 to 0.685)
Diabetes mellitus type 2 - 2400 METs		Both	Both	1.340 (1.216 to 1.484)	1.340 (1.216 to 1.484)	1.340 (1.216 to 1.484)	1.276 (1.157 to 1.413)	1.166 (1.058 to 1.292)	1.070 (0.970 to 1.185)	0.978 (0.887 to 1.084)	0.882 (0.800 to 0.977)	0.793 (0.720 to 0.879)	0.709 (0.643 to 0.785)	0.614 (0.557 to 0.680)
Diabetes mellitus type 2 - 3000 METs		Both	Both	1.267 (1.175 to 1.373)	1.267 (1.175 to 1.373)	1.267 (1.175 to 1.373)	1.206 (1.118 to 1.307)	1.103 (1.025 to 1.196)	1.011 (0.938 to 1.096)	0.925 (0.858 to 1.003)	0.834 (0.773 to 0.904)	0.750 (0.696 to 0.813)	0.670 (0.622 to 0.727)	0.580 (0.538 to 0.629)
Diabetes mellitus type 2 - 3600 METs		Both	Both	1.194 (1.117 to 1.278)	1.194 (1.117 to 1.278)	1.194 (1.117 to 1.278)	1.136 (1.064 to 1.217)	1.039 (0.973 to 1.112)	0.953 (0.892 to 1.020)	0.871 (0.816 to 0.933)	0.786 (0.735 to 0.841)	0.707 (0.662 to 0.757)	0.632 (0.591 to 0.676)	0.547 (0.512 to 0.585)
Diabetes mellitus type 2 - 4200 METs		Both	Both	1.120 (1.039 to 1.206)	1.120 (1.039 to 1.206)	1.120 (1.039 to 1.206)	1.067 (0.989 to 1.148)	0.975 (0.905 to 1.050)	0.894 (0.830 to 0.963)	0.818 (0.759 to 0.880)	0.737 (0.684 to 0.794)	0.664 (0.615 to 0.714)	0.593 (0.550 to 0.638)	0.513 (0.476 to 0.552)
Diabetes mellitus type 2 - 600 METs		Both	Both	1.490 (1.469 to 1.514)	1.490 (1.469 to 1.514)	1.490 (1.469 to 1.514)	1.418 (1.388 to 1.441)	1.297 (1.279 to 1.318)	1.189 (1.173 to 1.208)	1.087 (1.072 to 1.105)	0.980 (0.967 to 0.996)	0.882 (0.870 to 0.896)	0.788 (0.777 to 0.801)	0.682 (0.673 to 0.693)

Appendix Table 7d. Relative risks used by age and sex for each outcome for smoking globally																	
Risk - Outcome	Category / Units	Morbidity / Mortality	Sex														
				30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years	65-69 years	70-74 years	75-79 years	80-84 years	85-89 years	90-94 years	95+ years
Smoking																	
Diabetes mellitus	0 Cigarettes Per Day	Both	Female	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)
				1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)
Diabetes mellitus	0 Cigarettes Per Day	Both	Male	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)	1.00 (1.00 to 1.00)
Diabetes mellitus	10 Cigarettes Per Day	Both	Female	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)
				1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)
Diabetes mellitus	10 Cigarettes Per Day	Both	Male	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)	1.43 (1.21 to 1.67)
Diabetes mellitus	20 Cigarettes Per Day	Both	Female	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)
				1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)
Diabetes mellitus	20 Cigarettes Per Day	Both	Male	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)	1.64 (1.32 to 1.96)
Diabetes mellitus	30 Cigarettes Per Day	Both	Female	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)
				1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)
Diabetes mellitus	30 Cigarettes Per Day	Both	Male	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)	1.78 (1.36 to 2.21)

Appendix 4. Incidence vs Mortality:

