Jurnal
Manajemen Kesehatan Indonesia

Volume 12 Nomor 3 Desember 2024

DETERMINANTS OF DIABETES MELLITUS PREVALENCE IN INDONESIA: A MULTIPLE LINEAR REGRESSION MODEL IN AN ECOLOGICAL ANALYSIS OF ADULTS AGED 15 YEARS AND OLDER

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Article History:
Received: 21/11/2024
Accepted: 30/12/2024
Available Online: 30/12/2024

ABSTRACT

Indonesia faces a double burden of disease, with an increasing prevalence of non-communicable diseases (NCDs), such as diabetes mellitus (DM), alongside communicable diseases. This study investigates the determinants of DM prevalence among individuals aged 15 years and older in Indonesia. An ecological design was employed using secondary data from the 2018 Basic Health Research Report, 2018 Welfare Statistics Report, and the 2019 Provincial in Figures Report, encompassing 514 districts/cities in Indonesia. Data analysis included univariate descriptive statistics, Pearson correlation for bivariate analysis, and multiple linear regression with a backward method to identify significant predictors. The results revealed significant associations between DM prevalence and hypertension ($p < 0.001$), obesity ($p < 0.001$), routine blood sugar testing ($p < 0.001$), good nutrition ($p = 0.016$), the ratio of general hospitals ($p < 0.001$), public health centers ($p < 0.001$), and physicians ($p < 0.001$), as well as the interaction between hospital and physician ratios ($p < 0.001$). The model explained 61.5% of the variance in DM prevalence ($R^2 = 0.615$) and met all multiple linear regression assumptions. Prevalence of hypertension, obesity, and higher ratios of general hospitals and physicians were positively correlated with DM prevalence. At the same time, good nutrition and greater availability of public health centers exhibited protective effects. The positive association of routine blood sugar testing likely reflects increased screening in high-DM areas. These findings highlight the need for targeted public health interventions, emphasizing obesity reduction, nutritional improvements, and equitable healthcare distribution to mitigate DM prevalence in Indonesia.

Keywords: *diabetes mellitus, determinants, healthcare, ecological study, linear regression*

INTRODUCTION

Indonesia is currently grappling with a double burden of disease, characterized by a rising prevalence of non-communicable diseases (NCDs) such as diabetes mellitus (DM) alongside persistent communicable diseases[1]. The World Health Organization (WHO) has identified diabetes as a significant public health concern, particularly in low- and middle-income countries (LMICs) like Indonesia, where healthcare systems often struggle to manage the increasing burden of chronic diseases[2]. The prevalence of diabetes in Indonesia has been steadily increasing, with estimates suggesting that approximately 28.6 million adults (aged 20–79 years) will be living with the condition by 2045[3]. This alarming trend necessitates a comprehensive understanding of the determinants contributing to the rising incidence or prevalence of DM, particularly among individuals aged 15 years and older.

Previous literature has extensively explored various factors influencing diabetes prevalence, including lifestyle choices, socioeconomic status, and healthcare services[4–7]. Studies have highlighted the role of hypertension, obesity, physical inactivity, and dietary habits as critical risk factors for developing diabetes[5,8,9]. Additionally, the availability and accessibility of healthcare services have been shown to impact diabetes management and outcomes significantly[10,11]. However, there remains a paucity of research specifically addressing the determinants of DM in the Indonesian context, particularly at the ecological level, which considers the interplay of various factors across different regions. Research on the prevalence model of DM in Indonesia has also been conducted, but the unit of analysis used was the province, combining data from the Ministry of Health (MoH) and Statistics Indonesia (BPS)[12].

This study seeks to address this gap by analyzing secondary data from national health surveys, welfare statistics, and provincial reports, with districts/cities as the unit of analysis. This selection is made to ensure a more localized and detailed analysis, focusing on districts/cities as the unit of analysis. This approach allows for a deeper understanding of factors influencing DM prevalence at a more granular level compared to broader provincial data, thus providing new insights specific to districts/cities in Indonesia. The focus is on identifying key factors influencing DM prevalence among individuals aged 15 years and older in districts/cities. The research is guided by the hypothesis that demographic, health-related, and healthcare factors significantly contribute to variations in DM prevalence in Indonesia.

METHOD

The research methodology employed in this study was an ecological design, which allowed for the examination of relationships between various determinants and the prevalence of diabetes at the population level. The study utilized secondary data sourced from the 2018 Riskesdas (Basic Health Research), a comprehensive health survey conducted across Indonesia, the 2018 Welfare Statistics Report, and the 2019 Provincial in Figures Report, which reported 2018 data. The unit of analysis used is district/city, including all 514 districts/cities in Indonesia. The data inputted are aggregate data for each district/city. The entered data were checked for correctness and completeness. Data were analyzed using the SPSS application (SPSS Inc., Chicago, IL, USA).

The dependent variable was the prevalence of DM among individuals aged 15 years and older, while the independent variables included various health, lifestyle, socioeconomic, and healthcare factors. Diabetes mellitus prevalence is the aggregate (percentage) of diabetes data among individuals aged 15 years and older from the 2018 Riskesdas, based on a doctor's diagnosis from Riskesdas Kuesioner B06[13]. Univariate analysis using central tendency and dispersion was conducted to describe the research variables.

The Pearson product-moment correlation test was applied to each independent variable with the dependent variable. We use a 5% alpha level for significance. A positive r value indicates that as the value of the independent variable increases, the value of the dependent variable also increases. Conversely, a negative r value suggests that the relationship between the independent and dependent variables is inverse, meaning that as the value of the independent variable increases, the value of the dependent variable decreases, or as the value of the independent variable decreases, the value of the dependent variable increases.

Before multiple linear regression analysis, a collinearity test was performed to identify a strong relationship between two independent variables characterized by a correlation coefficient higher than 0.7[14]. If collinearity was found in these variables, one variable was selected for inclusion in the multiple linear regression model based on the smallest p-value to the dependent variable.

Multiple linear regression modeling using the backward method gradually excluded variables with p-values > 0.05 until the final model included only significant predictors ($p \leq 0.05$). Subsequently, interaction tests were conducted between independent variables with substantial potential for interaction. The final multiple linear regression model was assessed to ensure it met the following assumptions required for the model's proper functioning[15]:

1. Existence Assumption: The dependent variable (Y) for each value of the independent variables (X) must be a random variable with a specific mean and standard deviation. This was checked through descriptive analysis of the residuals, ensuring the mean approached zero and the variance was present.
2. Independence Assumption: Observations of Y must be independent of each other. This was verified using the Durbin-Watson test, where a value between -2 and +2 indicates independence.
3. Linearity Assumption: The relationship between the dependent and independent variables must be linear. This was confirmed by the ANOVA (overall F-test), with a significant result (p-value < alpha).
4. Homoscedasticity Assumption: The variance of Y should be constant for all values of X. This was checked by plotting the residuals and ensuring a random spread around the zero line.
5. Normality Assumption: The residuals should follow a normal distribution, which was verified using the Normal P-P plot of the residuals. If the data points are distributed around the diagonal line and follow its direction,

the regression model satisfies the normality assumption.

RESULTS AND DISCUSSION

This section presents the descriptive statistics, followed by the results of bivariate and multivariate analyses of the key variables examined in this study. Table 1 summarizes the mean, standard deviation (SD), and standard error (SE) for each variable across 514 districts/cities in Indonesia.

Table 1. Descriptive statistics of all variables (N = 514)

	Variables	Mean	SD	SE
1	Diabetes mellitus prevalence (%)	1.79	0.96	0.04
2	ARTI prevalence (%)	4.65	4.50	0.20
3	Pneumonia prevalence (%)	2.02	1.22	0.05
4	Asthma prevalence (%)	2.29	1.18	0.05
5	Hypertension prevalence (%)	8.79	4.27	0.19
6	Underweight prevalence (%)	8.95	3.88	0.17
7	Obesity prevalence (%)	20.50	5.93	0.26
8	Alcohol consumption (last month) (%)	4.81	4.21	0.19
9	Adequate physical activity (%)	66.68	11.54	0.51
10	Preserved food consumption (daily) (%)	4.29	3.40	0.15
11	Sweet beverage consumption (daily) (%)	59.39	12.29	0.54
12	Routine blood sugar testing (%)	1.46	1.27	0.06
13	Soft drink consumption (daily) (%)	2.57	2.03	0.09
14	Secondhand smoke exposure (indoors) (%)	32.74	11.62	0.51
15	Good nutrition prevalence (%)	77.41	6.48	0.29
16	Poverty rate	12.27	7.80	0.34
17	Ratio of general hospitals per 100,000 population	1.11	0.93	0.04
18	Ratio of public health centers per 100,000 population	7.53	7.32	0.32
19	Ratio of physician per 100,000 population	37.80	46.62	2.06

Note: ARTI: Acute Respiratory Tract Infection; SD: Standard Deviation; SE: Standard Error

The health factors show that the average prevalence of diabetes mellitus is 1.79% (SD = 0.96), hypertension is 8.79% (SD = 4.27), and obesity is 20.50% (SD = 5.93). Other health conditions, such as ARTI, pneumonia, and asthma, have average prevalences of 4.65% (SD = 4.50), 2.02% (SD = 1.22), and 2.29% (SD = 1.18), respectively. The average prevalence of underweight is 8.95% (SD = 3.88), and routine blood sugar testing is conducted in an average of 1.46% (SD = 1.27) of the population.

In terms of lifestyle factors, alcohol consumption in the last month has an average of 4.81% (SD = 4.21), and 66.68% of the population engages in adequate physical activity (SD = 11.54). Preserved food consumption has an average of 4.29% (SD = 3.40), while sweet beverage consumption is reported at an average of 59.39% (SD = 12.29). Soft drink consumption averages 2.57% (SD = 2.03), and 32.74% of the population is exposed to secondhand smoke indoors (SD = 11.62). Socioeconomically, the average poverty rate is 12.27% (SD = 7.80), and 77.41% of the population is reported to have good nutrition (SD = 6.48). Healthcare indicators show that the average ratio of general hospitals per 100,000 population is 1.11 (SD = 0.93), while the average ratio of public health centers is 7.53 (SD = 7.32), and the ratio of physicians is 37.80 per 100,000 population (SD = 46.62).

Table 2. Correlations between all variables (*N* = 514)

		1	2	3	4	5	6	7	8	9
1	Diabetes mellitus prevalence	1.000								
2	ARTI prevalence	-0.152#	1.000							
3	Pneumonia prevalence	-0.114#	0.367#	1.000						
4	Asthma prevalence	0.358#	0.069	-0.011	1.000					
5	hypertention prevalence	0.413#	-0.080	-0.129#	0.336#	1.000				
6	Underweight prevalence	-0.153#	-0.071	-0.242#	0.055	-0.068	1.000			
7	Obesity prevalence	0.606#	-0.061	0.126#	0.316#	0.360#	-0.461#	1.000		
8	Alcohol consumption (last month)	-0.136#	0.026	-0.123#	-0.048	0.023	0.178#	-0.137#	1.000	
9	Adequate physical activity	-0.092*	0.011	-0.219#	-0.103*	0.030	0.140#	-0.266#	0.073	1.000
10	Preserved food consumption (daily)	0.121#	0.131#	0.270#	0.204#	0.016	-0.094*	0.207#	-0.128#	-0.241#
11	Sweet beverage consumption (daily)	0.204#	-0.098*	-0.106*	0.130#	0.320#	0.065	0.173#	-0.201#	0.102*
12	Routine blood sugar testing	0.697#	-0.160#	-0.166#	0.373#	0.304#	-0.113*	0.550#	-0.169#	-0.173#
13	Soft drink consumption (daily)	-0.118#	0.174#	0.329#	0.101*	-0.030	-0.117#	0.062	0.082	-0.125#
14	Secondhand smoke exposure (indoors)	-0.057	-0.166#	-0.234#	0.102*	0.105*	0.129#	-0.013	-0.088*	0.137#
15	Good nutrition prevalence	0.224#	-0.020	-0.100*	0.111*	0.250#	-0.280#	0.334#	-0.266#	0.010
16	Poverty rate	-0.417#	0.418#	0.334#	-0.276#	-0.407#	0.076	-0.359#	0.227#	0.102*
17	Ratio of general hospitals per 100,000 population	0.364#	-0.004	-0.035	0.202#	0.097*	-0.186#	0.321#	0.098*	-0.163#
18	Ratio of public health centers per 100,000 population	-0.204#	0.256#	0.265#	-0.082	-0.133#	-0.153#	-0.013	0.231#	-0.157#

		1	2	3	4	5	6	7	8	9
19	Ratio of physician per 100,000 population	0.480$^{\#}$	-0.068	-0.061	0.232$^{\#}$	0.175$^{\#}$	-0.118$^{\#}$	0.335$^{\#}$	-0.025	-0.087*

Note: #) p value < 0.01; *) p-value < 0.05; variable number 1:Diabetes mellitus prevalence; 2:ARTI (Acute Respiratory Tract Infection) prevalence; 3:Pneumonia prevalence; 4:Asthma prevalence; 5:hypertension prevalence; 6:Underweight prevalence; 7:Obesity prevalence; 8:Alcohol consumption (last month); 9:Adequate physical activity.

Continued table 2:

		10	11	12	13	14	15	16	17	18
10	Preserved food consumption (daily)	1.000								
11	Sweet beverage consumption (daily)	0.122$^{\#}$	1.000							
12	Routine blood sugar testing	0.114$^{\#}$	0.182$^{\#}$	1.000						
13	Soft drink consumption (daily)	0.425$^{\#}$	0.127$^{\#}$	-0.150$^{\#}$	1.000					
14	Secondhand smoke exposure (indoors)	-0.051	0.191$^{\#}$	-0.089*	-0.002	1.000				
15	Good nutrition prevalence	-0.031	0.103*	0.299$^{\#}$	-0.120$^{\#}$	0.041	1.000			
16	Poverty rate	-0.073	-0.278$^{\#}$	-0.428$^{\#}$	0.150$^{\#}$	-0.145$^{\#}$	-0.292$^{\#}$	1.000		
17	Ratio of general hospitals per 100,000 population	0.100*	0.022	0.409$^{\#}$	0.036	-0.170$^{\#}$	0.079	-0.088*	1.000	
18	Ratio of public health centers per 100,000 population	0.034	-0.049	-0.203$^{\#}$	0.363$^{\#}$	-0.072	-0.193$^{\#}$	0.411$^{\#}$	0.205$^{\#}$	1.000
19	Ratio of physician per 100,000 population	0.017	0.089*	0.582$^{\#}$	-0.093*	-0.154$^{\#}$	0.120$^{\#}$	-0.183$^{\#}$	0.515$^{\#}$	0.030

Note: #) p value < 0.01; *) p-value < 0.05; variable number 10: Preserved food consumption (daily); 11: Sweet beverage consumption (daily); 12: Routine blood sugar testing; 13: Soft drink consumption (daily); 14: Secondhand smoke exposure (indoors); 15: Good nutrition prevalence; 16: Poverty rate; 17: Ratio of general hospitals per 100,000 population; 18: Ratio of public health centers per 100,000 population; 19: Ratio of physician per 100,000 population.

Table 2 presents the correlations between all variables. Significant positive correlations with DM prevalence were observed for hypertension prevalence (r = 0.413), obesity prevalence (r = 0.606), routine blood sugar testing (r = 0.697), good nutrition prevalence (r = 0.224), the ratio of general hospitals (r = 0.364), and the ratio of physicians (r = 0.480). Conversely, significant negative correlations were identified between DM prevalence and ARTI prevalence (r = -0.152), pneumonia prevalence (r = -0.114), underweight prevalence (r = -0.153), alcohol consumption (r = -0.136), poverty rate (r = -0.417), sweet beverage consumption (r = -0.204), preserved food consumption (r = -0.121), and adequate physical activity (r = -0.092). Secondhand smoke exposure (indoors) exhibited no significant correlation with DM prevalence. It is important to note that none of the correlation coefficients between the independent variables exceeded 0.7, indicating the absence of collinearity concerns. Consequently, all variables were included in the subsequent multiple linear regression analysis.

Table 3 shows that all multiple linear regression assumptions, including existence, independence, linearity, homoscedasticity, and normality, are fulfilled.

Table 3. Summary of the Assumptions of Multiple Linear Regression

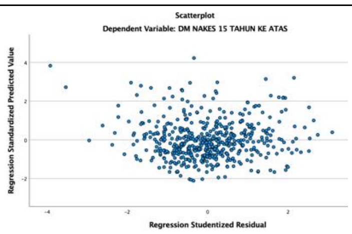
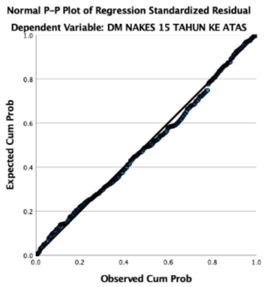
Assumptions	Test Method	Value/Result	Explanation
Existence assumption	The mean approaches zero and the variance (standard deviation) is present	Mean: <0.00001 standard deviation: 0.593	Existence assumption fulfilled
Independence assumption	Durbin-Watson in the final model, with a value between -2 and +2	1.629	Independence assumption fulfilled
Linearity assumption	ANOVA (overall F-test) with a significant result (p value<=0.05)	P value<0.001	Linearity assumption fulfilled
Homoscedasticity assumption	Plotting the residuals and ensuring a random spread around the zero line		Homoscedasticity assumption fulfilled
Normality assumption	Normal P-P plot of the residuals distributed around the diagonal line and follow its direction		Normality assumption fulfilled

Table 4. Final Model of Multiple Linear Regression

Model	Unstandardized Coefficients		Standardized Coefficients	P-value	R^2
	B	Standard Error	Beta		
(Constant)	0.768	0.335		0.022	0,615
Hypertension prevalence	0.036	0.007	0.158	<0.001	
Obesity prevalence	0.045	0.006	0.279	<0.001	
Routine blood sugar testing	0.299	0.031	0.399	<0.001	
Good nutrition prevalence	-0.011	0.004	-0.073	0.016	
Ratio of general hospitals per 100,000 population	0.170	0.044	0.166	<0.001	

Ratio of public health centers per 100,000 population	-0.018	0.004	-0.137	<0.001
Ratio of physician per 100,000 population	0.007	0.002	0.331	<0.001
Interaction between ratio of general hospitals and physician per 100,000 population	-0.002	0.001	-0.303	0.001

Table 4 presents the final model of multiple linear regression analyzing the determinants of diabetes mellitus (DM) prevalence among individuals aged 15 years and older in Indonesia. The model includes both unstandardized and standardized coefficients for each variable, along with their standard errors (SE) and significance values (p-value). Notably, hypertension emerged as a critical factor positively correlated with DM prevalence ($B = 0.036$, $p < 0.001$), suggesting that areas with a higher prevalence of hypertension also experience a higher prevalence of diabetes[12,16,17]. This relationship aligns with existing literature that highlights the interconnectedness of these two chronic conditions, often referred to as comorbidities[18–20]. Hypertension and diabetes are closely linked conditions that significantly increase the risk of cardiovascular complications. In type 2 diabetes, the body becomes resistant to insulin, which can harm blood vessels and lead to narrowing and salt retention, raising blood pressure[21]. High blood sugar levels (hyperglycemia) further damage blood vessels by reducing the production of nitric oxide, a substance that helps relax and widen blood vessels[21]. Additionally, both conditions overstimulate the nervous system and create harmful molecules called free radicals, which worsen blood pressure issues.

Obesity was also found to be positively associated with DM prevalence ($B = 0.045$, $p < 0.001$). This study is in line with research by Boles et al., where obesity plays a significant role in causing prediabetes and diabetes[22]. Therefore, individuals who have developed prediabetes need to change their dietary behavior with a focus on healthy eating. Furthermore, routine blood sugar testing was positively correlated with diabetes prevalence ($B = 0.299$; $p < 0.001$), which may reflect a higher diabetes prevalence in certain regions may be due to increased awareness and diagnosis, leading to the identification of previously undetected cases, which contributes to the higher prevalence as more individuals are diagnosed and receive treatment[23]. Indonesia is ranked among the top three countries globally, with an estimated 14.3 million individuals living with undiagnosed diabetes in 2021[3]. This finding suggests that increased screening efforts could lead to earlier detection and management of diabetes, ultimately improving health outcomes.

Conversely, good nutritional status demonstrated a protective effect against diabetes prevalence ($B = -0.011$, $p = 0.016$). This is in line with the research by Lago-Sampedro et al., which indicates that populations with better nutrition are less likely to experience high rates of diabetes[24]. In addition, adopting healthier dietary patterns could help reduce the unsustainably high rates of obesity, cardiovascular disease, and diabetes mellitus[25]. The health and well-being of both current and future generations depend on good nutrition as a fundamental pillar of health. Public health initiatives aimed at improving nutritional education and access to healthy food options are crucial in addressing diabetes in Indonesia.

Healthcare access indicators also played a significant role in determining diabetes prevalence. The ratio of general hospitals was positively correlated with DM prevalence ($B = 0.170$, $p < 0.001$), suggesting that areas with more hospitals may experience higher rates of diabetes. Areas with a higher number of hospitals may experience higher diabetes rates due to several factors. First, better access to healthcare services facilitates easier diagnosis and reporting of diabetes, which can lead to higher recorded prevalence rates. For instance, a study published in Diabetes Care discusses how improving the quality of diabetes care[26], including enhancing access to healthcare services, can lead to better detection and management of diabetes, thereby contributing to higher recorded prevalence rates. Second, regions with more hospitals are often more urbanized, and urbanization has been associated with unhealthy lifestyles, such as physical inactivity and poor diet, which increase the risk of diabetes. Additionally, a systematic review in Population Health Metrics highlighted that urbanization is linked to higher diabetes prevalence[27].

Conversely, the ratio of public health centers showed a negative correlation with diabetes prevalence ($B = -0.01$, $p < 0.001$), indicating that greater access to primary healthcare services may help mitigate the prevalence of diabetes. This occurs because as the ratio of public health centers increases, more people can be served by Puskesmas staff. Puskesmas employees are able to reach a larger portion of the population, especially in promotive efforts and education, where they can act as educators, consultants, and collaborators in providing diabetes mellitus-related services in a given area[28].

Additionally, the ratio of physicians was positively associated with DM prevalence ($B = 0.007$, $p < 0.001$), suggesting that regions with a higher number of physicians may also report higher diabetes rates. This could indicate increased diagnosis rates and better reporting of diabetes, similar to the ratio of general hospitals. Interestingly, the interaction between hospital and physician ratios was negatively correlated with diabetes prevalence ($B = -0.002$, $p < 0.001$), suggesting that a balanced distribution of healthcare resources may be essential for effective diabetes management[11,29].

Based on the results of multiple linear regression, the equation of the DM prevalence among individuals aged 15 years and older in Indonesia is obtained as follows:

$$\begin{aligned} \textit{Diabetes Mellitus Prevalence} &= 0.768 + 0.036 * (X1) + 0.045 * (X2) + 0.299 * (X3) - \\ &\quad 0.011 * (X4) + 0.170 * (X5) - 0.018 * (X6) + \\ &\quad 0.007 * (X7) - 0.002 * (X5 * X7) \end{aligned}$$

Where:

X1 = Hypertension prevalence

X2 = Obesity prevalence

X3 = Routine blood sugar testing

X4 = Good nutrition prevalence

X5 = Ratio of general hospitals per 100,000 population
X6 = Ratio of public health centers per 100,000 population
X7 = Ratio of physicians per 100,000 population

The final regression model explained 61.5% of the variation in diabetes prevalence ($R^2 = 0.615$), indicating a strong relationship between the identified determinants and diabetes prevalence in Indonesia. The findings underscore the multifaceted nature of diabetes prevalence, highlighting the need for comprehensive public health strategies that address both individual and systemic factors contributing to diabetes prevalence.

CONCLUSIONS

This study has identified several key determinants of diabetes mellitus prevalence among individuals aged 15 years and older in Indonesia. The positive correlations between hypertension, obesity, and healthcare facility availability with diabetes prevalence underscore the urgent need for public health interventions aimed at addressing these risk factors. Conversely, good nutrition and the ratio of public health centres demonstrated a protective effect, highlighting the importance of promoting healthy eating habits and strengthening primary healthcare services.

The implications of these findings extend beyond theoretical understanding, emphasizing the necessity for targeted interventions that promote healthy lifestyles, improve nutritional access, and enhance healthcare delivery systems to combat the rising prevalence of diabetes in Indonesia effectively.

The findings of this research contribute to the existing body of knowledge on diabetes determinants in Indonesia and provide valuable insights for policymakers and healthcare professionals. Future research should focus on longitudinal studies to explore the causal relationships between these determinants and diabetes prevalence, as well as the effectiveness of targeted interventions in reducing diabetes rates.

ACKNOWLEDGEMENT

The authors would like to acknowledge the contributions of the Indonesian Ministry of Health and the various health institutions that provided access to the secondary data utilized in this study. Special thanks are extended to the research team for their dedication and commitment to this project.

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