

Role of Telemedicine in Blood Glucose Control among Diabetes Mellitus Patients in Thailand

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Abstract

Diabetes mellitus (DM) is a major health problem that contributes to severe complications and mortality. This study aimed to examine the spatial distribution of DM control across Thailand and to assess the ecological association between telemedicine services and DM control at the provincial level. We conducted an ecological study using publicly available data from the Thailand Health Data Center (HDC) for 2024. We extracted and analyzed data on telemedicine services, obesity prevalence, and DM control using spatial analysis techniques. The unit of analysis was the 77 provinces. We assessed spatial autocorrelation using Global Moran's I and fitted spatial regression models to examine the association between telemedicine services and DM control, adjusting for obesity prevalence. Statistical significance was set at 0.05. Chonburi province had the highest DM control prevalence, while Roi Et province had the lowest. Significant spatial autocorrelation was identified (Global Moran's I = 0.424). The spatial error model demonstrated the lowest Akaike Information Criterion and explained 38% of the variation in DM control. Telemedicine services were significantly associated with higher DM control ($\beta = 0.33$, $p = 0.039$) after adjustment for obesity prevalence. Expanding telemedicine services at the national level, particularly in northeastern Thailand, may improve glycemic control among patients with DM and help prevent severe complications and premature mortality.

Keywords: Blood glucose control, Diabetes mellitus, Spatial regression, Thailand, Telemedicine

Introduction

Diabetes mellitus (DM) is a major global health burden. Middle-aged and elderly populations are most affected, with most residing in Southeast Asia (International Diabetes Federation, 2025). Improved glycemic control can prevent future cardiovascular events such as stroke and myocardial infarction (Leung et al., 2025; Gilani et al., 2024). According to the Health Data Center (HDC), the prevalence of DM in 2025 was 17.29% (Ministry of Public Health, 2024a), while the rate of good glycemic control was 35.68% (Ministry of Public Health, 2024b).

Telemedicine services have emerged and are increasingly utilized in patients with non-communicable diseases, including DM. These services facilitate healthcare delivery through self-monitoring of blood glucose. Telemedicine plays a crucial role in reducing blood glucose levels and HbA1c while promoting patient participation in glycemic control (Lee et al., 2017; Tchero et al., 2019). Despite its potential benefits, the implementation of telemedicine in diabetes care faces several challenges, including limited digital literacy, inadequate access to technology, and concerns regarding privacy and data security (Lee et al., 2017; Tchero et al., 2019). These barriers may affect patient engagement and the effectiveness of diabetes management.

In Thailand, health information systems routinely report glycemic control rates, allowing comparison across administrative areas. However, conventional reporting of provincial rates primarily describes the magnitude of variation across areas and does not determine whether areas with similar outcomes are geographically clustered or whether neighboring areas exhibit related patterns. This distinction is important because geographic variation in

diabetes outcomes may reflect shared contextual factors, including healthcare accessibility, socioeconomic circumstances, digital infrastructure, and the organization and delivery of health services. Consequently, examining the spatial distribution of glycemic control can reveal geographic concentrations of poor or good diabetes outcomes that provincial estimates may obscure.

Spatial analysis is a statistical method that integrates geographic data with mapping techniques for data visualization. It helps identify areas with the highest or lowest disease or health burden, thereby supporting resource allocation and workforce planning (Manda et al., 2020). However, spatial analyses of telemedicine's role in blood glucose monitoring and control remain limited. Therefore, this study aims to investigate the ecological association between provincial telemedicine service coverage and glycemic control rates across Thailand.

Material and Methods

An ecological study was conducted using geographical data from Thailand for the period 1 January to 31 December 2024. Thailand is located in Southeast Asia, with an area of approximately 514,000 km². It shares borders with Myanmar, Laos, and Malaysia. The country is administratively divided into 77 provinces and six regions: central, northeastern, northern, southern, eastern, and western.

Data on the prevalence of DM control and telemedicine services (Ministry of Public Health, 2024b; Ministry of Public Health, 2024c) were publicly available from the Thailand Health Data Center (HDC). The HDC database is updated annually in November. The data were exported to Microsoft Excel (.xlsx) format. We defined DM control as the proportion of patients with diabetes mellitus who achieved good glycemic control. Telemedicine service data were further transformed into telemedicine service density, calculated as the number of telemedicine services per province area (km²). The obesity data (Ministry of Public Health, 2024d) were also included in the analysis, as several studies have demonstrated an association between obesity and blood glucose control (Deng et al., 2025; Bramante et al., 2017; Franz, 2017). Obesity was defined as class I, with a body mass index (BMI) of 25–29.9 kg/m² (Lim et al., 2017).

All data were imported into Quantum GIS (QGIS) version 3.12 for data management and visualization. Spatial autocorrelation was assessed using Global Moran's I and Local Indicators of Spatial Association (LISA). Spatial regression models, including ordinary least squares (OLS), the spatial error model (SEM), and the spatial lag model (SLM), were used to examine the relationship between telemedicine services and the prevalence of DM control. The model with the lowest Akaike Information Criterion (AIC) was considered the best-fitting model.

Results

1. Distribution of DM control, obesity, and density of telemedicine in Thailand

Chonburi Province reported the highest prevalence of DM control. The Eastern, Northern, and Southern regions demonstrated high rates of glycemic control. Conversely, Roi Et Province had the lowest rate. Most provinces in the Northeastern region showed low glycemic control rates, and some provinces in the Southern region also reported low rates (Fig. 1a).

Obesity prevalence was highest in the Bangkok Metropolitan area, while Surin Province reported the lowest prevalence. Four other provinces, which were Narathiwat, Phetchabun, Trat, and Sukhothai, also demonstrated a high prevalence of obesity. Most provinces in the Northeastern region had lower obesity rates (Fig. 1b).

Telemedicine density represented the distribution of health service infrastructure and the capacity to provide services to the provincial population. Yasothon Province showed a high density of telemedicine services. Four other provinces, which were Pathum Thani, Samut Prakan, Nonthaburi, and Ang Thong, also showed high densities. Kanchanaburi Province reported the lowest density. Major provinces in the Northern region and some provinces in the Central region reported low telemedicine service density (Fig. 1c).

2. Spatial autocorrelation

DM control prevalence showed a clustering pattern, with a Global Moran's I of 0.424 (Fig. 2). The Local Indicators of Spatial Association (LISA) analysis showed that low-low (L-L) clusters were mainly concentrated in the northeastern region, indicating areas with low DM control surrounded by neighboring provinces with similarly low values. In contrast, high-high (H-H) clusters were primarily identified in eastern Thailand (Fig. 3).

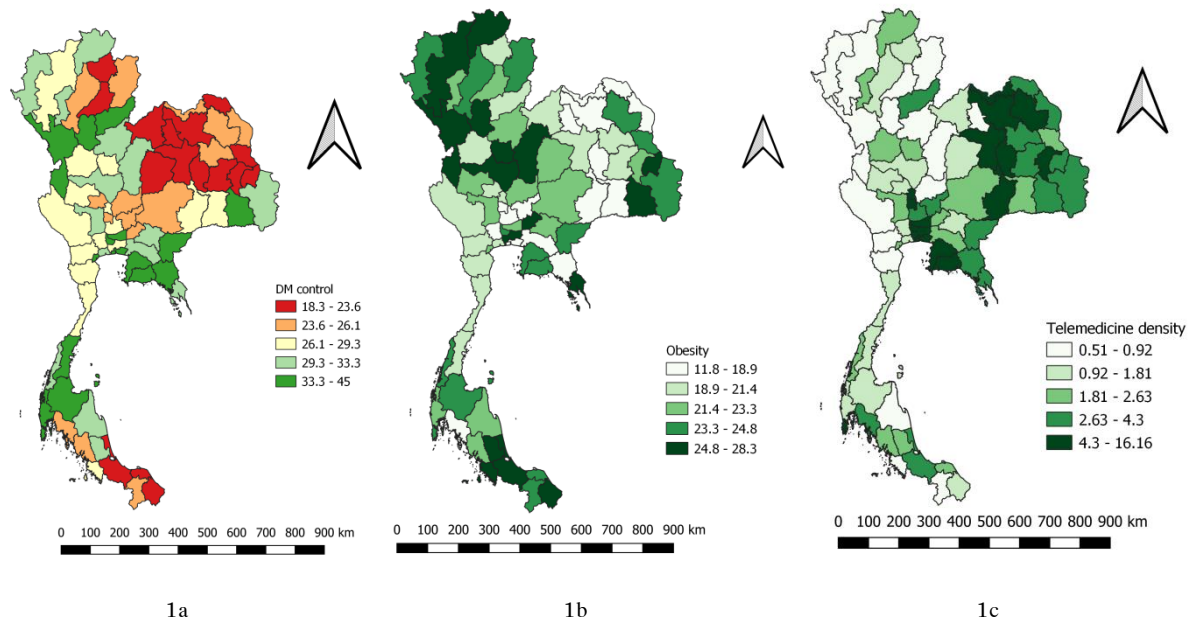


Figure 1 Variables distribution 1a) Prevalence of DM control 1b) Prevalence of obesity 1c) Telemedicine density

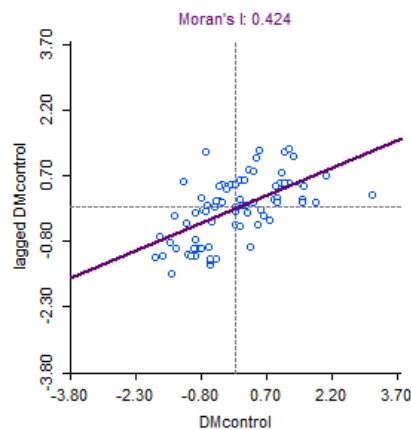


Figure 2 Moran's I of prevalence of DM control

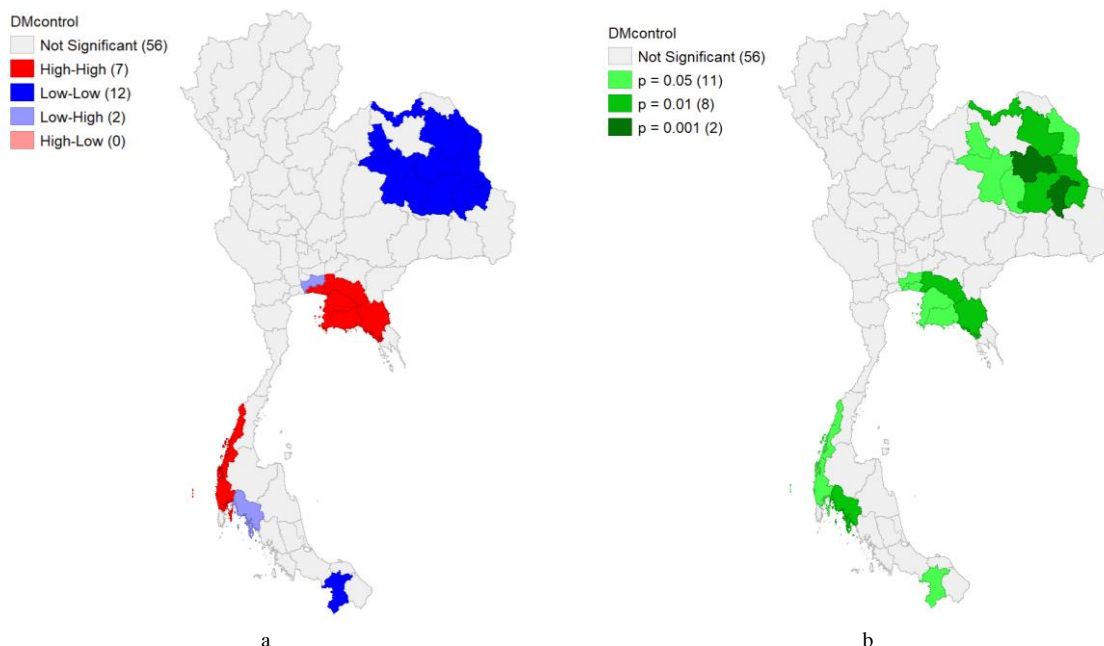


Figure 3 Local indicator of spatial association (LISA) a. cluster map b. significance map

2. Bivariate analysis

A clustering pattern emerged between obesity prevalence and DM control, although spatial autocorrelation was weak (Global Moran's $I = -0.023$). Telemedicine service and the prevalence of DM control showed a negative spatial autocorrelation pattern (Global Moran's $I = -0.098$) (Fig. 4). The LISA analysis of obesity and DM control prevalence revealed low-low (L-L) clusters in the provinces of Nong Khai, Nakhon Phanom, Nong Bua Lamphu, Khon Kaen, Maha Sarakham, Kalasin, and Roi Et. High-low (H-L) clusters indicating lower DM control prevalence surrounded by areas with higher obesity prevalence were identified in Sakon Nakhon, Mukdahan, Yasothon, and Amnat Charoen provinces. Most provinces in the northeastern region demonstrated a high-low (H-L) pattern for telemedicine services and DM control, indicating higher telemedicine service levels in neighboring provinces but lower DM control prevalence. Only Mukdahan and Nong Bua Lamphu provinces showed a low-low (L-L) pattern. High-high (H-H) clusters, representing areas characterized by high telemedicine service levels and a high prevalence of DM control in neighboring areas, were observed in Chonburi, Rayong, Samut Prakan, and the Bangkok Metropolitan Area (Fig. 5).

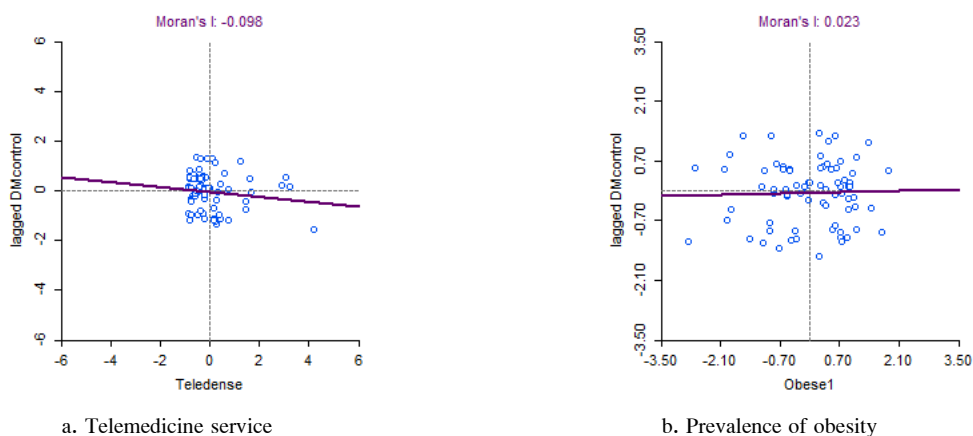


Figure 4 Bivariate Moran's I between a. Telemedicine service and b. Prevalence of obesity and prevalence of DM control

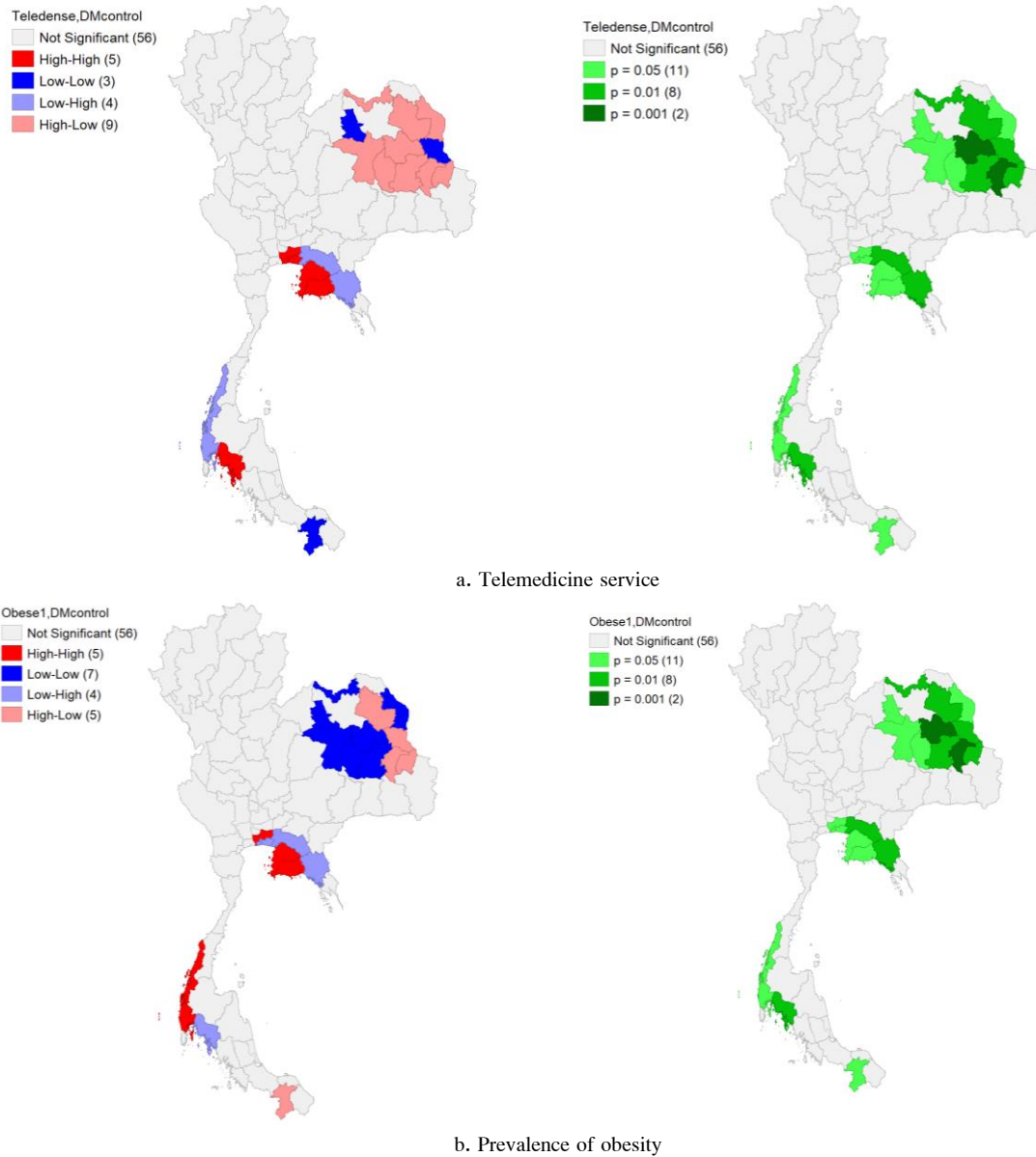


Figure 5 Local indicators of spatial association (LISA) between a. Telemedicine service b. Prevalence of obesity and prevalence of DM control

3. Spatial regression

The OLS model showed that obesity prevalence and telemedicine service were associated with increases in DM control prevalence of 0.3% and 0.17%, respectively; however, these associations were not statistically significant. The SLM indicated that telemedicine service increased the prevalence of DM control by 0.26% ($p = 0.09$) after adjustment for obesity prevalence. The SEM demonstrated the lowest AIC and explained 38% of the variation. This model also showed that telemedicine service significantly increased the prevalence of DM control by 0.33% (Table 1).

Table 1 Spatial regression between telemedicine service, obesity, and prevalence of DM control (n = 77)

Factor	OLS (SE)	p-value	SLM (SE)	p-value	SEM (SE)	p-value
Prevalence of obesity	0.301 (4.077)	0.09	0.298 (0.141)	0.035	0.304 (0.135)	0.025
Telemedicine service	0.175 (0.177)	0.382	0.269 (0.159)	0.091	0.331 (0.160)	0.039
Constant	91.819 (4.427)	<0.001	5.257 (4.116)	0.201	20.780	<0.001
ρ	-		0.093	-		
λ	-		-		0.578	
Fisher statistic (F-stat)	1.604		-		-	
R ²	0.041		0.364		0.386	
Log-likelihood	-236.032		-224.511		-223.509	
AIC	478.063		457.022		453.019	

SE=standard error; ρ = spatial autoregressive parameter; λ =spatial error coefficient; R²=coefficient of determination; AIC=Akaike's information criterion

Discussion

Most provinces in the Northeastern region of Thailand showed low prevalence of diabetes mellitus (DM) control. Previous studies conducted in this region have identified several barriers to glycemic control among the Northeastern population. Inappropriate dietary habits, particularly the consumption of highly seasoned foods, have been reported as a major barrier to blood glucose control (Numsang et al., 2023). In addition, poor knowledge regarding DM (Phuwilert et al., 2024), as well as high BMI and obesity, were associated with poor glycemic control among people living in the Northeastern region (Sakboonyarat et al., 2021).

A high prevalence of obesity has been reported in both the Northern and Southern regions of Thailand. A study in Chiang Rai Province identified several factors associated with obesity and found that inadequate health information on appropriate physical activity and low levels of social support were significant contributors (Ayanan et al., 2021).

A low density of telemedicine services was observed in the Northern region. The region's mountainous terrain creates geographical barriers to internet connectivity and telemedicine implementation. A previous meta-analysis reported that unreliable internet connectivity was a major factor limiting the effectiveness and accessibility of telemedicine services (Arora et al., 2024).

Telemedicine services increased the prevalence of DM control by 0.33%, with statistical significance in the spatial error model (SEM). This model also explained 38% of the variation and had the lowest Akaike Information Criterion (AIC). Previous meta-analyses of randomized controlled trials reported that telemedicine significantly reduced blood glucose levels among patients in telemedicine groups (Lee et al., 2017). Another meta-analysis also reported that telemedicine utilization significantly reduced HbA1c levels among patients with DM (Tchero et al., 2019).

Various technologies can be integrated into telemedicine services. A previous interventional study incorporated a real-time blood glucose monitoring database into telemedicine, recording individual patient glucose levels and

generating alerts for hypoglycemic events. This system also provided patient counseling via a mobile application. The intervention significantly reduced both blood glucose and HbA1c levels (Di Molfetta et al., 2022; Han et al., 2023).

Telemedicine can also be delivered through mobile health (mHealth) platforms. Previous Indonesian literature combined mHealth services with self-management theory to improve glycemic control among patients with DM. This approach significantly reduced blood glucose levels compared with the control group (Ramlan & Polytechnic, 2023).

During the coronavirus disease 2019 (COVID-19) pandemic, telemedicine played an important role in maintaining glycemic control among patients with DM (Tangwanaprai et al., 2023). It enabled healthcare providers to continue delivering care and support. A study in India reported that using a Diabetes Telemanagement System (DIMS) improved blood glucose control and reduced average direct medical costs per patient (Kesavadev et al., 2015).

The reviewed studies in Thailand consistently demonstrate the effectiveness of telehealth-based interventions in improving self-management and clinical outcomes among patients with chronic diseases, particularly DM. Various forms of digital healthcare delivery, including tele-nursing, telepharmacy, and mobile telehealth applications, were implemented to support patient education, self-care, medication management, and continuous follow-up. The tele-nursing intervention significantly enhanced health-promoting behaviors among individuals with uncontrolled diabetes by providing remote guidance, monitoring, and self-management support. Participants who received tele-nursing services showed greater improvements in diabetes-related health behaviors compared with those receiving routine care (Sriprasert et al., 2023). Similarly, telepharmacy services improved diabetes management through remote pharmacist consultations and medication counseling. Patients receiving telepharmacy support showed improved medication knowledge, higher treatment adherence, enhanced medication-use problem-solving skills, and significantly better glycemic control, as reflected by reductions in fasting blood glucose and HbA1c levels (Fakhongyoo, 2024). In addition, a telehealth self-management program delivered through a mobile application and educational materials improved self-care behaviors among patients with type 2 diabetes mellitus and dyslipidemia. Beyond behavioral improvements, the intervention produced positive clinical outcomes, including reductions in blood glucose levels, HbA1c, total cholesterol, and triglycerides (Tanapibunphol, 2024).

Telemedicine services have also been recommended for patients with hypertension. These services enable remote blood pressure monitoring and support medical advice to improve adherence to antihypertensive treatment. Home-based telemedicine interventions have been shown to improve blood pressure control and reduce cardiovascular disease risk (Bernocchi et al., 2014; Omboni & Ferrari, 2015; Pellegrini et al., 2020).

This study demonstrated a modest effect of telemedicine density on DM control. Despite the well-demonstrated benefits of telemedicine, several digital barriers may constrain its effectiveness and widespread adoption. These barriers include inadequate access to digital devices, unreliable internet connectivity, limited digital literacy, and insufficient technical skills among patients, particularly older adults and those residing in rural or underserved areas. In addition, concerns regarding data privacy, cybersecurity, and the reliability of telecommunication platforms may undermine users' confidence in telehealth services. Healthcare providers may also face challenges with system integration, technical support, and the extra time required to adapt to digital workflows. Consequently, although telemedicine offers substantial opportunities to enhance healthcare accessibility and improve chronic disease

management, addressing these digital barriers is essential to ensure equitable access, promote user acceptance, and support the long-term sustainability of telehealth interventions.

Strength and limitations

This study sought to quantify the effect of telemedicine services and the prevalence of DM control using spatial analysis. However, this study used aggregated provincial-level indicators from the HDC database. The telemedicine and obesity indicators were obtained from aggregated provincial-level databases and were not restricted to individuals included in the DM control indicator. Therefore, interpret the observed associations as ecological, population-level associations rather than individual-level relationships.

The HDC database does not provide the actual proportion of the population receiving telemedicine services at the provincial level. Therefore, we used telemedicine service density as a proxy for healthcare system capacity. This measure may not fully reflect actual telemedicine utilization or accessibility and may introduce measurement error. The HDC provides separate prevalence estimates for obesity class I (BMI 25–29.9 kg/m²) and obesity class II (BMI ≥30 kg/m²). However, we identified an error in the class II obesity prevalence data. Furthermore, because obesity class I may represent an earlier stage of obesity and was considered more relevant to examining its relationship with DM control, it was included in the analysis, whereas obesity class II was excluded. Consequently, interpret the findings with caution, as the analysis may not fully capture the potential association between more severe obesity and DM control.

Conclusion and Suggestion

A lower prevalence of DM control remains predominantly observed in the northeastern region of Thailand, largely driven by geographic barriers and unequal distribution of healthcare services. Although telemedicine services have clearly improved glycemic control, persistent systemic inequities limit their impact. To address this gap, a decentralized implementation model is required to replace the traditional home-to-hospital approach to care delivery.

Therefore, telemedicine services should be strengthened across the northeastern region by transforming sub-district health promoting hospitals into local telemedicine hubs. Rather than relying solely on patients' personal digital devices, strengthening the digital infrastructure of these local facilities would enable stable, secure provider-to-provider consultations. This structural transformation could effectively extend tertiary-level specialists into remote communities, thereby promoting equitable access to healthcare for underserved populations.

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Author Contributions

Prajak Nonsiri: Conceptualization, Data collection, Manuscript preparation

Worrayot Darasawang: Methodology and data analysis

Conflict of interests

All authors declare that they have no conflict of interest

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Declaration of Generative AI and AI-assisted Technologies

During the preparation of this manuscript, the authors used ChatGPT to check and improve the language and used Google Gemini to create a graphical abstract. After using it, the authors thoroughly reviewed and edited the content and accept full responsibility for the final version of the publication.

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