




Factors Associated with Treatment Adherence in People with Both Hypertension and Pre-Diabetes: A Cross-Sectional Study in a Semi-Rural Community in Thailand

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Purpose: Hypertension (HTN) combined with prediabetes (pre-DM) has become an important public health concern worldwide. Patients need to adhere to both pharmacological and non-pharmacological treatments in order to regulate both blood pressure and blood glucose levels and reduce the risk of serious complications. This study examined factors associated with treatment adherence in people with both HTN and pre-DM.

Methods: A cross-sectional study was conducted between January and March 2025. A sample of 275 people with both HTN and pre-DM was recruited from 11 subdistrict health-promoting hospitals (HPHs) in Sai Noi, a semi-rural district in Nonthaburi Province, Thailand. Data were collected using structured questionnaires. Multiple regression analysis was used to examine factors associated with treatment adherence.

Results: It was revealed that female sex, knowledge about HTN and pre-DM/T2DM, social support, patient-provider relationship, convenience of traveling to health services, and convenience in using these services were significantly positively correlated with adherence to treatment. Meanwhile, experience of medication side effects, smoking, and alcohol consumption were negatively correlated with it. The multiple regression model was statistically significant in predicting treatment adherence ($F = 11.36$ (5, 269), $p < 0.001$) and included overall support from family ($B = 2.23$, $p < 0.001$), smoking ($B = -132.61$, $p < 0.001$), experience of medication side effects ($B = -89.51$, $p = 0.004$), knowledge of pre-DM/T2DM ($B = 14.67$, $p = 0.013$), and patient-provider relationship ($B = 2.23$, $p = 0.033$) as significant factors.

Conclusion: Disease-related knowledge, support from family, and patient-provider relationship positively influence treatment adherence of people with both HTN and pre-DM, while side effects of medication and smoking negatively influence it. These findings provide valuable insights for health officials that could inform future intervention and management strategies for this dual-risk population.

Keywords: treatment adherence, knowledge, social support, patient-provider relationship, side effects, smoking, pre-DM

Introduction

Prediabetes (pre-DM), also known as impaired glucose tolerance, has become an important public health concern. According to the International Diabetes Federation (IDF), the worldwide prevalence of pre-DM rose from 318 million (6.7%) in 2015¹ to 541 million (10.6%) in 2021,² while the prevalence in low-and middle-income countries (LMICs) was higher at 13.1%.³ A clinical review reported that pre-DM significantly increases the likelihood of developing type 2 diabetes mellitus (T2DM) with progression rates of 10% annually,⁴ and a meta-analysis of 103 prospective cohort studies reported up to 50% progression within 5 years.⁵ In addition, a large prospective cohort study of adults ≥ 18 years in the US showed that the prevalence of pre-DM combined with hypertension (HTN) was 14.7% (5,011/34,047).⁶ Evidence



from several prospective cohort studies has also indicated that combined pre-DM/T2DM and HTN, known as “dual risk,” is linked to an increased risk of cardiovascular disease (CVD).^{7–9} A prospective cohort study in China (N=4,193) also reported that CVD risk was significantly elevated in patients with pre-DM plus HTN and T2DM plus HTN compared with that in a reference group.⁷ Moreover, compared with HTN alone, combined pre-DM and HTN was significantly associated with all-cause and cardiovascular mortality, with higher hazard ratios.^{6,9} Against this background, HTN and T2DM are known as leading modifiable risk factors for CVD and death.^{10–13}

In the context of dual-risk patients with HTN and pre-DM, adherence to treatment is a crucial determinant of the extent to which both blood pressure and blood glucose levels are regulated. Adherence to treatment can reduce the risk of serious health complications^{14–16} and lower healthcare expenditures.¹⁷ According to the World Health Organization (WHO), adherence is defined as “The extent to which a person’s behavior – taking medication, following a diet, executing lifestyle changes – follows medical advice.” Adherence has also been defined as “The extent to which patient behavior corresponds with recommendations from a healthcare provider” (p.136).¹⁴ However, poor adherence to long-term treatment of chronic diseases is a striking problem worldwide, making adherence improvement a priority of the public health agenda. The most common barrier to treatment adherence is the lack of perceived immediate benefit, particularly in people with asymptomatic or chronic conditions.¹⁴ A systematic review of 10 studies from 6 countries (N = 3,218) on adherence to antihypertensive medication reported that the rate of adherence ranged widely from 8.9% to 96.8%.¹⁸ Another systematic review of 27 studies from 12 countries (N = 463,711) on adherence to T2DM medication reported adherence rates of 38.5% to 93.1%.¹⁹ In addition to pharmacological treatment, non-pharmacological treatment involving lifestyle modifications/long-term behavioral changes is essential for people with HTN²⁰ and pre-DM,¹⁷ particularly those with both.

The clinical guidelines for the management of individuals with pre-DM by the American Diabetes Association Professional Practice Committee²¹ recommend combining metformin therapy with lifestyle modifications to manage pre-DM and delay or prevent its progression to T2DM, particularly for high-risk individuals. However, pharmacological uptake was limited, particularly in LMICs with resource-constrained health systems.²¹ Similarly, pharmacological interventions for this group remain limited in Thailand. The Thai clinical practice guidelines for diabetes primarily emphasize lifestyle modification for individuals with pre-DM.²² The use of T2DM medications for individuals with pre-DM is considered on a case-by-case basis at the physician’s discretion.²² For individuals with both HTN and pre-DM attending a non-communicable disease (NCD) clinic at the subdistrict health-promoting hospitals (HPHs), the prescribed pharmacological treatment generally focuses on controlling blood pressure, but not blood sugar, while the management of pre-DM focuses on non-pharmacological behavioral modification.²² Therefore, patients are required to adhere to treatment emphasizing lifestyle modifications/long-term behavioral changes, including a healthy diet, regular physical activity, appropriate weight management, stress management, and avoidance of risk behaviors (such as smoking and alcohol consumption). Good treatment adherence to these recommendations can help regulate blood pressure²³ and blood glucose levels,²⁴ thereby reducing the risk of developing associated complications.

In Thailand, the sixth National Health Examination Survey of individuals aged 15 years or older reported that the prevalence of HTN, T2DM, and pre-DM was 25.4%, 9.5%, and 10.7%, respectively.²⁵ According to the Thai Health Data Center of Nonthaburi, a province neighboring Bangkok, the incidence of HTN per 100,000 population there increased from 806.45 in 2022 to 937.74 in 2023 and to 1,033.93 in 2024, while the corresponding figures for T2DM were 423.64, 461.00, and 517.89. A report based on health screenings also revealed an increase in pre-DM rates in Nonthaburi Province, from 3.95% (5,123/129,417) in 2023 to 6.87% (6,202/90,204) in 2024. Notably, Sai Noi District, the north-westernmost semi-rural district of Nonthaburi, reported the highest rate of pre-DM cases in the province, with an increase in pre-DM from 8.74% (1,285/14,699) in 2023 to 10.14% (1,254/12,396) in 2024.²⁶

Although Sai Noi is located near Bangkok, many of its residents have a lifestyle that more closely resembles that of rural populations rather than urban ones, and much of the community is directly involved in agriculture (eg, farming and fruit gardening) Despite urbanization having developed more slowly in Sai Noi than in other districts in Nonthaburi, the area of its farmland, predominantly in the form of smallholdings, has decreased by one-third over the last two decades. Recently, Sai Noi has also experienced a demographic transition, with the proportion of older people increasing from 18% to 23% between 2022 and 2025.²⁶ These changes, along with the associated aging of the agricultural workforce,

could have led people to change their occupations and lifestyles in ways that may increase the prevalence of age-associated chronic conditions such as HTN, T2DM as well as pre-DM. Similar changes have been reported in other rural areas in LMICs.²⁷

To the best of our knowledge, no study has focused on treatment adherence (medication and lifestyle) among people with both HTN and pre-DM in Thailand, particularly at subdistrict HPHs. This study was thus conducted to examine factors associated with treatment adherence in people with both HTN and pre-DM at the subdistrict HPHs in Sai Noi District, Nonthaburi. The findings should be beneficial for health officials in providing a better understanding of treatment adherence and its related factors in people with both HTN and pre-DM.

In accordance with the WHO's adherence model,¹⁴ treatment adherence is defined as the extent to which a patient's behavior, including taking medication and implementing recommended lifestyle modifications such as a healthy diet and physical activity, corresponds with mutually agreed recommendations from a healthcare provider. This definition complies with a patient-centered perspective that emphasizes collaborative decision-making and mutual agreement rather than passive compliance. Within this framework, patients are viewed as active participants in caring for their health, particularly in the long-term management of chronic conditions.¹⁴

Guided by the WHO's adherence model,¹⁴ this study categorized variables into five domains: patient-related, disease-related, treatment-related, healthcare provider-related, and healthcare system-related factors. Although social and economic factors are identified as a separate dimension in the WHO's adherence model, this study operationalized individual-level social and economic characteristics (eg., education, income, and social support) under patient-related factors.²⁸ Conceptualizing treatment adherence as a dependent behavioral variable enables the examination of multiple factors that potentially influence it. In this study, treatment adherence covers both pharmacological treatment and non-pharmacological interventions, including behavioral and lifestyle modifications.

Materials and Methods

Study Design and Settings

A cross-sectional study was conducted between January 2025 and March 2025 at 11 subdistrict HPHs in Sai Noi District, Nonthaburi Province, Thailand. Sai Noi is one of the six districts of Nonthaburi Province bordering Bangkok. In Thailand, the district health system is an integrated network providing decentralized primary care at subdistrict HPHs close to people's homes and coordinated secondary and tertiary care with the district hospitals and the provincial hospital.²⁹ In Sai Noi, there are 11 subdistrict HPHs serving 76,440 people. In addition to primary care, an extended NCD clinic is scheduled at each HPH at least once a month. Patients with NCDs (eg, diabetes, hypertension, hyperlipidemia) have scheduled follow-up visits with a doctor every 1 to 3 months, depending on their medical condition. People with both HTN and pre-DM undergo annual blood chemistry monitoring, which includes a test of fasting blood sugar (HbA1c testing is provided only for people with T2DM undergo annual blood chemistry monitoring).

Study Sample

A convenience sample of 275 people with both HTN and pre-DM attending the NCD clinic at 11 subdistrict HPHs in Sai Noi District was recruited to participate in this study. The inclusion criteria were as follows: (1) aged 35 years or older, (2) a diagnosis of HTN and being prescribed antihypertensive medication for more than 3 months, (3) blood sugar level (FBS/DTX) of 100–125 mg/dL, (4) able to communicate in Thai, and (5) willingness to participate in this study. Patients were excluded if their Mini-Cog score was ≤ 3 .³⁰

For sample size estimation, a power analysis for linear multiple regression was conducted using G*power (version 3.1.9.7). A fixed model with R^2 deviation from zero was specified, with an alpha level of 0.05, statistical power of 0.90, a medium effect size ($f^2=0.15$) as defined by Cohen,³¹ and 30 predictors. The minimum required sample size was 226. This was increased to 272 to account for an anticipated 20% of incomplete or missing data. Thus, 25 participants were recruited from each HPH (25×11 HPHs = 275).

Instruments

The structured questionnaires used in this study included measures of Background characteristics, Treatment adherence, Knowledge about hypertension and pre-diabetes/diabetes (HTN and pre-DM/T2DM), Social support, Disease-related information, Treatment-related information, Healthcare provider-related information, Patient-provider relationship, and Healthcare system-related information. Content validity of the questionnaires was determined by three experts (two faculty members specializing in adult nursing and nutrition, and an advanced practice nurse specializing in diabetic care). The scale content validity index (S-CVI) of these instruments ranged from 0.91 to 1, indicating good content validity, with high item relevance and good coverage of the construct domain. Prior to data collection, a pilot study was conducted among 30 participants to test the internal consistency reliability of the questionnaires.

Dependent Variable

Treatment Adherence

Treatment adherence refers to behaviors related to medication taking, diet, exercise, and daily activity, risk factor avoidance, stress management, and medication and follow-up visits. It was measured by the Adherence to Hypertensive Treatment Scale. Higher total scores indicate greater adherence to treatment. This scale was developed by Meekusol et al³² and adapted by Taengsakha et al³³ to measure treatment adherence among Thai patients at a semi-rural district hospital in Thailand.³³ In this study, the modified scale comprised 24 items relevant to people with both HTN and pre-DM. This scale encompassed both pharmacological and non-pharmacological aspects, including diet (6 items), exercise and daily activity (5 items), risk factor avoidance (4 items), stress management (3 items), and medication and follow-up visits (6 items). Examples of the items include, “I choose to cook or eat food cooked by boiling, blanching, or steaming, instead of frying with oil,” “Each workout I do takes at least 30 minutes,” and “I keep doctor’s appointments.” Participants were asked to respond to each item on a visual analog scale (VAS) from 0 (“never”) to 100 (“always”). The overall Cronbach’s for this scale was 0.75, representing acceptable internal consistency.

Independent Variables

Participants’ Background Characteristics

Participants’ background characteristics included sex, age, healthcare coverage scheme, healthcare costs, education level, income, smoking, and alcohol consumption.

Knowledge About HTN and Pre-DM/T2DM

The HTN and pre-DM/T2DM knowledge scale was developed by the researchers based on a literature review.^{33–35} It comprises 23 items, measuring knowledge across two subscales: HTN (15 items) and pre-DM/T2DM (8 items). The participants responded to each item in the form of “yes,” “no,” or “don’t know.” Each correct answer earns 1 point. We calculated the scores by summing the item response scores of each subscale; a higher total score reflected more knowledge about HTN and pre-DM/T2DM. The Kuder–Richardson 20 (KR-20) that of the subscale measuring knowledge about HTN was 0.83, and that of knowledge about pre-DM/T2DM was 0.77, representing acceptable reliability.

Social Support

The Social Support Scale was developed by Wongyai et al³⁵ and later modified by Taengsakha et al³³. This scale has been used among people with diabetes³⁵ and hypertension³² in Thailand. The scale separately measures social support from two distinct sources: family members and healthcare providers. In each of these cases, four subscales are used: emotional (6 items), appraisal (5 items), informational (7 items), and instrumental support (6 items). Participants respond to each item on the scale using a five-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*). An example of the social support items is, “When you feel tired of taking medicine every day, do you have someone to encourage you?” We calculated the overall scores for each source by summing the individual item response scores. A higher total score corresponds to a higher level of social support. Cronbach’s for the overall Social Support Scale was 0.96, indicating adequate internal reliability.

Disease–Related Information

Disease–related information collected from medical records included blood pressure, blood sugar, comorbidities, duration of HTN, and duration of pre-DM.

Treatment–Related Information

Treatment–related information, including the number of medication types and the total number of pills per day, was collected from medical records. The experience of medication side effects associated with antihypertensive medications was reported by the participants.

Healthcare Provider–Related Factors

Characteristics of providers included the type of physician (Family medicine versus general practitioner) as well as the patient–provider relationship.

The patient–provider relationship was measured using a VAS developed by Wongyai et al³⁵ This evaluated the patient’s perceptions of the quality of their relationship with their healthcare provider.

Participants were asked to rate their perceived relationship on a 100 mm horizontal line. The scale ranged from 0 (“very poor”) to 100 (“very good”).

Healthcare System–Related Factors

This study employed a questionnaire on health service accessibility developed by Wongyai et al,³⁵ which was used in previous studies^{33,35} It includes fill-in-the-blank questions on distance, travel time, and the cost of travel to the health service setting, waiting time for services, and the frequency of follow-up appointments.

The Convenience Access Scale consists of two items that assess participants’ convenience in accessing health services using a VAS: “How convenient is it for you to travel for health services?” and “How convenient is it for you to use the health services?” Participants were asked to rate their perceived convenience on a 100 mm horizontal VAS, marking the point that best represented their assessment of convenience. The scale ranged from 0 (“not at all convenient”) to 100 (“very convenient”).

Data Collection

Following ethical approval, permission to conduct the study was obtained from the Public Health Office of Nonthaburi Province. The researcher coordinated with the directors and in-charge nurses at NCD clinics at the 11 subdistrict HPHs in Sai Noi District to schedule recruitment. Patients with HTN who were registered at these subdistrict HPHs were screened for eligibility by the in-charge nurse. Eligible patients attending the clinics during the data collection period were approached through convenience sampling by the researcher or trained research assistant (RA) and informed about the study. Those who provided written informed consent completed a structured questionnaire independently. For participants with limited literacy, the researcher or RA read the questions aloud to them. Data collection was conducted in a quiet area to ensure confidentiality and minimize interruptions. It took place at each site within 3–4 days. A total of 298 eligible individuals were initially approached. Of these, ten were inconvenient to participate in, and eight were excluded due to Mini Cog screening score ≤ 3 . An additional five patients were unable to complete the questionnaire. As a result, 275 participants successfully completed the study, yielding an overall response rate of 92.3%.

To ensure consistency in data collection, the RA was trained, and a practice session was conducted prior to the study. Guidance on standardized procedures was also provided for administering the questionnaire and for assisting participants with limited literacy to minimize bias. Data collection began after the RA demonstrated consistent and accurate administration, and the principal researcher continuously monitored the process to ensure adherence to the study protocol.

Ethical Considerations

Prior to data collection, this study was approved by the Ethics Committee of the Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand (COA No. MURA2024/806). Participation in the study was voluntary and confidential. The participants were also informed that they could withdraw from the study at any time without any

adverse effect on the care they receive. All participants provided written informed consent prior to participating in this study.

Data Analysis

Descriptive statistics were used to analyze participant-, disease-, treatment-, healthcare provider-, and healthcare system-related factors. Data were tested to determine whether they met the assumption of normality. Pearson's product-moment correlation, Spearman's product-moment correlation, or point-biserial correlation was used to test the relationship between the dependent variable and each independent variable as appropriate. To control for confounding factors, stepwise multiple linear regression was used to identify factors associated with treatment adherence, based on predefined criteria for entering ($p < 0.05$) and removing ($p > 0.10$) variables. Multicollinearity among predictors was assessed using variance inflation factors (VIFs) and tolerance statistics to ensure that each predictor contributed independently to the regression model. In this study, VIF values near 1 and tolerance values near 1 indicate minimal multicollinearity, suggesting that the predictor has little linear association with other independent variables and that coefficient estimates are not substantially inflated. All statistical analyses were performed using IBM SPSS version 31.³⁶

Reporting Guidelines

This study was reported in accordance with the STROBE guidelines. The checklist items were integrated throughout the manuscript, and the completed checklist is provided as [supplementary material](#).

Results

Background Characteristics, Knowledge, and Social Support

Most of the participants were 60 years or older ($n = 191$, 69.5%) and were female ($n = 180$, 65.5%), had a primary school education or lower ($n = 230$, 83.6%), and had a monthly income of 5,000 baht (~US\$150) or less ($n = 192$, 69.8%) (Table 1).

Table 2 shows that most participants had moderate overall knowledge scores of HTN and pre-DM/T2DM. When analyzing medical conditions in more detail, it was observed that participants possessed moderate knowledge of HTN, including its causes, symptoms, complications, and management. For pre-DM/T2DM, participants also demonstrated

Table 1 Background Characteristics of Participants ($n = 275$)

Characteristics	Frequency	Percent
Sex		
Male	95	34.5
Female	180	65.5
Age (years), range = 35–88, Mean = 64, SD = 9.26		
< 60 years	84	30.5
≥ 60 years	191	69.5
Educational level		
Primary education or lower	230	83.6
Secondary education or higher	45	16.4
Monthly income (baht), range = 0–40,000, Mean = 4,739.6, SD = 5,975.96		
≤ 5,000 baht	192	69.8
> 5,000 baht	83	30.2

(Continued)

Table 1 (Continued).

Characteristics	Frequency	Percent
Healthcare coverage scheme		
Universal Coverage Scheme (UCS)	250	90.9
Other Scheme	25	9.1
Healthcare cost (baht), range 0–500, Mean = 10, SD = 55.03		
No	265	96.4
Yes	10	3.6
Comorbidities		
No	59	21.5
Yes	216	78.5
Smoking		
No	241	87.6
Yes	34	12.4
Drinking alcohol		
No	231	84.0
Yes	44	16.0
Duration of HTN (months), range 3–384, Mean = 105.8, SD = 68.92		
≤ 60 months	93	33.8
61 – 119 months	72	26.2
≥ 120 months	110	40.0
Duration of pre-DM (months), range = 1–144 months, Mean = 15.7, SD = 17.97		
< 12 months	99	36.0
12 – 35 months	136	49.4
> 36 months	40	14.6
SBP (mmHg) range 97–171, Mean = 136.2, SD = 12.52		
≤ 150	241	87.6
> 150	34	12.4
DBP (mmHg) range 50–98, Mean = 76.2, SD = 9.12		
≤ 90	259	94.2
> 90	16	5.8
Fasting blood sugar level (mg/dl), range = 100–125, Mean = 108.0, SD = 6.75		

Abbreviations: HTN, Hypertension; pre-DM, Pre-diabetes; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.

Table 2 Knowledge of HTN and Pre-DM/T2DM and Social Support by Source (n = 275)

Knowledge	Possible Range	Min-Max	Means \pm SD
Knowledge of HTN	0-15	0-15	10.9 \pm 3.48
- Cause and symptoms of HTN	0-11	0-11	8.2 \pm 2.87
- Management of HTN	0-4	0-4	2.7 \pm 0.92
Knowledge of pre-DM/T2DM	0-8	0-8	5.3 \pm 2.10
- Cause and symptoms of pre-DM/T2DM	0-5	0-5	3.0 \pm 1.31
- Management of pre-DM/T2DM	0-3	0-3	2.3 \pm 0.96
Overall knowledge	0-23	0-23	16.3 \pm 5.10
Social support from family			
Emotional support	6-30	6-30	24.6 \pm 5.25
Appraisal support	5-25	5-25	20.4 \pm 4.74
Informational support	7-35	7-35	27.6 \pm 6.67
Instrumental support	6-30	6-30	23.5 \pm 5.16
Overall social support	24-120	26-120	96.3 \pm 19.39
Social support from healthcare providers			
Emotional support	6-30	6-30	25.5 \pm 4.45
Appraisal support	5-25	5-25	21.2 \pm 3.99
Informational support	7 – 35	11 – 35	30.5 \pm 4.41
Instrumental support	6 – 30	10 – 30	24.3 \pm 4.91
Overall social support	24 – 120	51 – 120	101.6 \pm 14.82

Abbreviations: HTN, Hypertension; pre-DM, Pre-diabetes; T2DM, Type 2 diabetes mellitus.

a moderate understanding of symptoms and complications; however, their specific knowledge of causes of the disease was only fair.

The participants had good overall social support scores across informational, emotional, and appraisal support. However, instrumental support was found to be moderate. Considering the sources of support, it was found that participants received more support from healthcare providers (mean = 101.6, SD = 14.82) than from family members (mean = 96.3, SD = 19.39), particularly in terms of informational and instrumental support (Table 2).

Treatment, Provider, and Service Settings

Regarding prescribed treatments, most participants had three types of medications or fewer (n = 214, 77.8%). The majority had also experienced some side effects from their medications (n = 219, 79.6%), such as polyuria, dizziness, fatigue, cough, and peripheral edema.

Most participants had family medicine physicians as their primary providers (n = 165, 60%). Additionally, most participants reported that they had a good patient-provider relationship (n = 243, 88.4%). Most participants attended health service settings within 5 km (n = 250, 90.9%), with the trip typically taking less than 10 min (n = 175, 63.6%). Their waiting time for health services was mostly 60 min or less (n = 176, 64.0%). Most felt that their attendance of (n = 255, 92.7%) and use of health services were convenient (n = 247, 89.8%) (Table 3).

Most participants had a moderate self-reported level of overall treatment adherence (mean = 1604.1, SD = 216.99). When considering each aspect of treatment adherence, it was found that adherence to medication and follow-up appointments (mean = 482.1, SD = 76.28), risk factor avoidance (mean = 279.5, SD = 75.66), and stress management (mean = 204.5, SD = 78.09) were at moderate levels. Meanwhile, adherence to recommendations about diet (mean =

Table 3 Treatment-Related Variables, Healthcare Provider-Related Variables and Accessibility to Healthcare Service (n = 275)

Variables	Frequency	Percent
Types of medications, range = 1–6, Mean = 2.7, SD = 1.08		
≤ 3	214	77.8
> 3	61	22.2
Number of pills taken per day, range = 1–10, Mean = 3.2, SD = 1.56		
≤ 3	168	61.1
> 3	107	38.9
Experience of medication side effect (s)		
No	56	20.4
Yes	219	79.6
Type of Physician		
General practitioner	110	40.0
Family medicine physicians	165	60.0
Patient-provider relationship (score), range = 22–100, Mean = 89.3, SD = 11.61		
< 80	32	11.6
≥ 80	243	88.4
Distance to health service setting (km), range = 0.1–30 km, Mean = 2.9, SD = 2.87		
≤ 5 km	250	90.9
> 5 km	25	9.1
Travel time to health service setting (minutes), range = 1–30, Mean = 12.2, SD = 7.62		
≤ 10 minutes	175	63.6
> 10 minutes	100	36.4
Transportation costs (baht), range = 0–100, Mean = 8.2, SD = 19.55		
No	223	81.1
Yes	52	18.9
Convenience in traveling for health services (score), range = 27–100, Mean = 90.1, SD = 11.02		
< 80 score	20	7.3
≥ 80 score	255	92.7
Convenience in using health service (score), range = 0–100, Mean = 89.0, SD = 12.89		
< 80 score	28	10.2
≥ 80 score	247	89.8
Waiting time for health service (minutes), range = 5–240, Mean = 73.7, SD = 53.77		
≤ 60 minutes	176	64.0
> 60 minutes	99	36.0

(Continued)

Table 3 (Continued).

Variables	Frequency	Percent
Frequency of follow-up appointments (months), range = 1–3, Mean = 2.2, SD = 0.70		
1 months	44	16.0
2 months	123	44.7
3 months	108	39.3

362.2, SD = 74.76) and adherence to exercise and daily activity (mean = 275.7, SD = 103.72) were at fair levels (Table 4).

Factors Related to Treatment Adherence

For background characteristics, it was revealed that sex had a significant relationship with treatment adherence ($r_{pb} = 0.183$, $p = 0.002$). Specifically, females exhibited higher adherence than males. Smoking and alcohol consumption had significant negative relationships with treatment adherence ($r_{pb} = -0.213$, $p < 0.001$; $r_{pb} = -0.166$, $p = 0.006$, respectively). Educational level, healthcare coverage scheme, and healthcare cost were not significantly related to treatment adherence ($p > 0.05$).

Knowledge about HTN, pre-DM/T2DM had significant positive relationships with treatment adherence ($r_s = 0.142$, $p = 0.018$; $r_s = 0.179$, $p = 0.003$, respectively). Overall, social support from family and healthcare personnel was significantly related to treatment adherence ($r_s = 0.240$, $p < 0.001$; $r_s = 0.159$, $p = 0.008$, respectively). None of the disease-related characteristics was significantly associated with treatment adherence ($p > 0.05$) (Table 5).

For medication-related factors, only one factor, “experience of medication side effects,” was found to have a significantly negative relationship with treatment adherence ($r_{pb} = -0.188$, $p = 0.002$). For provider-related factors, it was found that only the patient-provider relationship had a significant positive relationship with treatment adherence ($r_s = 0.227$, $p < 0.001$). For factors related to clinical settings, it was found that convenience of traveling to health services and convenience in using the services were significantly positively related to treatment adherence ($r_s = 0.230$, $p < 0.001$; $r_s = 0.174$, $p = 0.004$, respectively) (Table 5).

Multiple Regression Model Predicting Treatment Adherence

A multiple linear regression model comprising five variables was found to be statistically significant in predicting treatment adherence among people with both HTN and pre-DM ($F_{(5,269)} = 11.36$, $p < 0.001$; $R^2 = 0.174$). The model indicated that social support from family ($B = 2.23$, $p < 0.001$), smoking ($B = -132.61$, $p < 0.001$), experience of medication side effects ($B = -89.51$, $p = 0.004$), knowledge of pre-DM/T2DM ($B = 14.67$, $p = 0.013$), and patient-provider relationship ($B = 2.23$, $p = 0.033$) were factors significantly influencing treatment adherence (Table 6).

Table 4 Participants' Treatment Adherence (n = 275)

Treatment adherence	Possible Range	Min-Max	Means ± SD
Diet	0-600	152-582	362.2 ± 74.76
Exercise and daily activity	0-500	14-500	275.7 ± 103.72
Risk factor avoidance	0-400	23-400	279.5 ± 75.66
Stress management	0-300	0-300	204.5 ± 78.09
Medication and follow-up visits	0-600	204-600	482.1 ± 76.28
Overall	0-2400	987-2245	1604.1 ± 216.99

Table 5 Correlations of Patients' Factors, Disease Characteristics Factors, Medication Factors, Provider Factors, and Clinical Setting Factors with Treatment Adherence (n = 275)

Variables	Means \pm SD	Correlation Coefficient	p-value
Sex	-	0.183 ^{pb}	0.002*
Age	64.0 \pm 9.2	0.095 ^p	0.118
Educational level	-	0.004 ^s	0.943
Income (bath/month)	4,739.6 \pm 5,975.9	0.066 ^s	0.273
Healthcare coverage scheme	-	-0.061 ^s	0.310
Healthcare cost	10.0 \pm 55.0	0.061 ^{pb}	0.316
Comorbidities (yes/no)	-	-0.038 ^{pb}	0.533
Smoking	-	-0.213 ^{pb}	<0.001*
Drinking alcohol	-	-0.166 ^{pb}	0.006*
Knowledge of HTN	10.9 \pm 3.4	0.142 ^s	0.018*
Knowledge of pre-DM/T2DM	5.3 \pm 2.1	0.179 ^s	0.003*
Overall support from family	96.3 \pm 19.3	0.240 ^s	<0.001*
Overall social support from healthcare personnel	101.6 \pm 14.8	0.159 ^s	0.008*
Duration of HTN (months)	105.8 \pm 68.9	0.077 ^s	0.206
Duration of pre-DM (months)	15.7 \pm 17.9	-0.059 ^s	0.327
FBS	108.0 \pm 6.7	-0.077 ^s	0.205
SBP (controlled vs uncontrolled)	-	-0.026 ^s	0.664
DBP (controlled vs uncontrolled)	-	0.100 ^s	0.098
Number of medications (type)	2.7 \pm 1.0	-0.014 ^s	0.819
Number of pills taken per day	3.2 \pm 1.5	-0.048 ^s	0.428
Experience medication side effect (s) (yes/no)	-	-0.188 ^{pb}	0.002*
Physician provider (Fam med/ GP)	-	0.020 ^{pb}	0.737
Patient-provider relationship (score)	89.3 \pm 11.6	0.227 ^s	<0.001*
Distance to health service setting (km)	2.9 \pm 2.8	-0.075 ^s	0.217
Travel time to health service setting (minutes)	12.2 \pm 7.6	0.005 ^s	0.938
Convenience in traveling (score)	90.1 \pm 11.0	0.230 ^s	<0.001*
Waiting time for health service (minutes)	73.7 \pm 53.7	0.040 ^s	0.511
Convenience in using health service (score)	89.0 \pm 12.8	0.174 ^s	0.004*
Frequency of follow-up appointments (months)	2.2 \pm 0.7	-0.037 ^s	0.547
Transportation costs (baht)	8.2 \pm 19.5	-0.053 ^s	0.384

Note: p, Pearson's Product-Moment Correlation; s, Spearman's Product-Moment Correlation; pb, Point-Biserial Correlation; and *, p < 0.05.

Table 6 Multiple Regression Analysis Predicting Treatment Adherence (n = 275)

Characteristics	B	SE	Beta	t	p-value	95% CI for B	Tolerance	VIF
Constant	1199.63	113.37		10.58	< 0.001	[976.43, 1422.82]		
Social support from family	2.23	0.65	0.20	3.43	< 0.001	[0.95, 3.50]	0.91	1.10
Smoking	-132.61	36.69	-0.20	-3.62	< 0.001	[-204.84, -60.38]	0.99	1.01
Experience of medication side effects	-89.51	30.41	-0.17	-2.95	0.004	[-149.38, -29.64]	0.96	1.04
Knowledge of pre-DM/T2DM	14.67	5.90	0.14	2.49	0.013	[3.07, 26.28]	0.94	1.07
Patient-provider relationship	2.23	1.04	0.12	2.15	0.033	[0.18, 4.28]	1.00	1.01

Discussion

In this study, the participants were 275 patients with both HTN and pre-DM recruited from 11 HPHs in Sai Noi, a semi-rural district of Nonthaburi Province, Thailand.

From bivariate analysis, this study revealed that female sex, knowledge about HTN and pre-DM/T2DM, social support, patient-provider relationship, convenience of traveling to health services, and convenience in using attending such services were significantly positively correlated with adherence to treatment. Conversely, experience of medication side effects, smoking, and drinking alcohol were negatively correlated with treatment adherence. The factors influencing treatment adherence can be categorized into five domains based on the WHO's adherence framework.¹⁴

The study findings can be explained based on the Health Belief Model in that individuals who perceive greater benefits and fewer barriers to health-related behaviors are more likely to engage in them (Rosenstock, 1974).³⁷ In this study, knowledge of HTN and pre-DM/T2DM likely enhanced perceived susceptibility and potential future severity of their health conditions, thereby enhancing treatment adherence. In addition to knowledge, social support and a positive patient-provider relationship may act as cues to action, promoting adherence to treatment. In contrast, the experience of medication side effects is perceived as significantly discouraging treatment adherence.

In terms of patient-related factors, our finding of better adherence among females is consistent with previous studies in France, Malaysia, and China.^{38–42} Females tend to seek healthcare and receive healthcare services, including health behavior modifications, more regularly than males.^{43–47} Meanwhile, smoking and drinking alcohol can be viewed as competing risk behaviors and are significantly and negatively related to treatment adherence, indicating that smokers and drinkers were more likely to fail to adhere to treatment than non-smokers or those who do not consume alcohol.^{48,49} Individuals engaging in these behaviors may have lower perceived risk and greater perceived barriers to treatment adherence.^{48,49}

Better knowledge about HTN and pre-DM/T2DM increases perceived susceptibility and severity, thereby enhancing treatment adherence. Individuals who understand their diseases are more likely to exhibit better treatment adherence.^{50,51} Despite two-thirds of the participants having HTN for more than five years and nearly half having pre-DM for one to three years, they have only a moderate level of knowledge about their conditions. This may be because hypertension is often a silent condition, despite being emphasized during routine care and prioritized in treatment with antihypertensive medications. In contrast, when health education is insufficiently addressed to both HTN and pre-DM, patients may have limited awareness of their dual risk and the importance of managing both conditions. A lack of knowledge and understanding of their own health conditions may result in poor adherence to treatment, particularly lifestyle modifications (eg, diet and exercise), and an increased likelihood of developing various complications in the future.^{12,52}

We also found that social support from both sources (family members and healthcare providers) had a significantly positive correlation with treatment adherence. This is in line with previous studies in LMICs.^{32,53,54} Thai family culture remains highly influential, emphasizing extended families living together, where members support each other in various aspects of life, including finances, childcare, and eldercare.⁵⁵ Healthcare providers also play an important role in promoting adherence to treatment, as they can be a valuable source of social support by providing health information and guidance regarding treatment.^{56,57} Similar to other Asian patients,⁵⁸ Thai patients often perceived the physician as

the authoritative source of knowledge and management of their illnesses.⁵⁹ However, overall support by family is relatively essential in managing diet, medications, and daily activities.⁵⁹ Our study found that family support had a stronger positive relationship than support from healthcare providers, reflecting the family's role in caring for patients mentally and emotionally, monitoring treatment adherence behaviors, and helping with daily activities.^{58,60–62}

The existence of a good relationship between patient and provider was also found to have a statistically significant positive relationship with treatment adherence in this study. Overall, the patients in this study had good relationships with healthcare providers. The people in the semi-rural area mostly had UCS and used primary care services at their local subdistrict HPHs, and the healthcare team also regularly provides home visits to the elderly and people with disabilities and runs health-promoting activities in the community. These programs may foster familiarity and facilitate trust between patients and providers.^{52,63} Such trust can make patients more open to discussions with healthcare providers, which in turn improves treatment adherence.⁶⁴ Indeed, several previous studies also reported that strong patient–provider relationships are positively related to treatment adherence.^{32,58,65,66}

Regarding treatment-related factors, the experience of medication side effects after taking antihypertensive medications was significantly negatively related to treatment adherence. This is consistent with previous studies,^{67,68} which reported that a history of allergic reactions to drugs or the occurrence of side effects reduces adherence to medication regimens. The most commonly reported side effects of antihypertensive medications are frequent urination and dry cough, which affect daily life and cause physical discomfort.

With regard to healthcare system-related factors, our study showed that the healthcare scheme and healthcare costs were not significantly related to treatment adherence. This may be because the vast majority of the participants (96%) receive free healthcare services at the subdistrict HPHs through the different health insurance schemes.⁶⁹ Convenience of traveling to health services and convenience in using the services were significantly positively related to treatment adherence, which is consistent with previous studies.^{33,35,70,71} It is assumed that the participants in this study felt that it was convenient to attend the service setting and use the services due to their subdistrict HPH's proximity to their residence or in a community with easy access.^{64,71}

As treatment adherence is influenced by a complex interplay of personal, clinical, and contextual factors; thus, any single factor is unlikely to demonstrate strong relationships when examined independently. When controlling for confounding factors, knowledge about pre-DM/T2DM, social support from the family, patient–provider relationship, smoking, and the experience of medication side effects were significantly predictive of treatment adherence among people with both HTN and pre-DM. These findings provide valuable insights for health officials by highlighting the factors influencing adherence to treatment among individuals with both HTN and pre-DM. They could also inform future intervention and management strategies for this dual-risk population. When a patient has fasting glucose between 100 and 125 mg/dL, a pre-DM alert should be generated, necessitating management based on the National practice guidelines. This could help to ensure that more emphasis is placed on pre-DM as a disease state, rather than a silent precursor.^{17,72}

The provision of information about HTN together with pre-DM/T2DM increases patients' knowledge and understanding of their conditions, their perceived susceptibility, and the severity of the dual risk to which they are exposed. This can, in turn, enhance adherence to medications and recommendations to follow a healthy lifestyle, such as via improved diet, more physical activities, and support for smoking cessation.^{73–76} This supports the assertion that Thailand's Universal Healthcare Coverage should cover the integration of self-management education for people with chronic diseases.

As family support is essential for promoting treatment adherence, this study suggests that family-based interventions, particularly those targeting dietary management, physical activity, and medication adherence, with a specific emphasis on older adults who may rely more heavily on family support. Community-based peer or family support groups integrated within primary care networks, as well as telehealth strategies for patient education⁷⁷ could be considered as additional interventions to enhance self-management and medication adherence. These interventions may be particularly beneficial in rural and semi-rural communities in Thailand and other LMICs⁵⁴ with comparable healthcare and resource contexts. Furthermore, enhancing the quality of patient–provider relationships is essential, ultimately promoting more effective and sustained treatment adherence. This can be achieved through building trust, ensuring continuity of care by the same care

team, and involving patients in treatment decisions tailored to their individual contexts,⁵² which may vary across social and health system settings.

Strengths and Limitations

To the best of our knowledge, this study is the first to examine treatment adherence among individuals living with both HTN and pre-DM, particularly at subdistrict health facilities in a semi-rural district of Thailand. Nevertheless, several limitations of this work should be acknowledged. First, the use of convenience sampling may have introduced selection bias. This study may be subject to healthy volunteer bias, as individuals attending the NCD clinic who agreed to participate may have been more health-conscious or motivated to follow treatment recommendations and engage in health-related behaviors than those who declined participation. Specifically, those with higher treatment adherence are more likely to have agreed to participate in this study. In addition, the participants who attended the HPHs' NCD clinic would be more likely to have higher adherence than those who did not. Second, some participants may have over-reported their adherence to the treatment due to social desirability bias. Third, the sample was relatively homogeneous—predominantly female, older, and with lower income and education levels—which may limit the generalizability of the findings to other populations. Last, its cross-sectional design hinders the establishment of causal relationships between variables.

Conclusions

This study revealed that female sex, knowledge about HTN and pre-DM/T2DM, social support, good patient-provider relationship, convenience of traveling to healthcare services, and convenience in using these services were significantly positively correlated with adherence to treatment in semi-rural Thai patients with pre-DM and HTN. Meanwhile, the experience of medication side effects, smoking, and consumption of alcohol were negatively correlated with treatment adherence. Controlling for confounders, knowledge of pre-DM/T2DM, social support from family, good patient-provider relationship, smoking, and the experience of medication side effects were statistically significant in predicting treatment adherence among people with both HTN and pre-DM. These findings provide valuable insights for health officials by enhancing understanding of treatment adherence among individuals with both HTN and pre-DM and should inform future intervention and management strategies for this dual-risk population in the primary care settings. Future research should include longitudinal studies, intervention studies, and studies in diverse populations.

Data Sharing Statement

Data supporting this study are available from the corresponding author.

Ethics Approval and Informed Consent

This study was approved by the Committee on Human Rights Related to Research Involving Human Subjects, the Faculty of Medicine Ramathibodi Hospital, Mahidol University.

All participants were informed about the purposes, procedures, and preservation of confidentiality and anonymity in this study, as well as the potential risks and benefits. This study was conducted in accordance with the tenets of the Declaration of Helsinki.

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Disclosure

The authors declare that they have no conflicts of interest.

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