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ORIGINAL RESEARCH

# Trends and Comparisons of Blood Pressure and Fasting Plasma Glucose in Patients with Hypertension, Diabetes, and Comorbidity: 4-Year Follow-Up Data

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**Background:** Patients with both diabetes and hypertension could face more health risks than those with either condition alone, and less attention has been paid to their management outcomes, so this study may be the first to specifically address this problem. We aimed to examine the management outcomes of blood pressure (BP) in hypertensive patients with/without diabetes and fasting plasma glucose (FPG) in diabetic patients with/without hypertension.

**Methods:** Follow-up data were obtained from the National Basic Public Health Service Project in Sanming (2017–2021). A total of 25,795 adults with hypertension only, 4111 adults with diabetes only, and 5729 comorbid adults (namely, hypertensive patients with diabetes) were included. Generalized estimating equations were applied.

**Results:** Systolic blood pressure (SBP) and diastolic blood pressure (DBP) in patients with hypertension only both dropped significantly (Coef. = −0.00088, $P < 0.001$; Coef. = −0.00081, $P < 0.001$). DBP in comorbid patients decreased considerably (Coef. = −0.00033, $P < 0.001$). Pulse pressure in comorbid patients grew rapidly (Coef. = 0.00044, $P < 0.001$). BP control rate in patients with hypertension only increased significantly (OR = 1.00039, $P < 0.001$). FPG control rates in diabetic patients with/without hypertension grew markedly (OR = 1.00013, $P < 0.001$; OR = 1.00020, $P < 0.001$). Comorbid patients had lower baseline SBP and DBP but higher latest SBP than patients with hypertension only (Coef. = −1.18872, $P < 0.001$; Coef. = −1.16049, $P < 0.001$; Coef. = 1.0634, $P < 0.001$). Comorbid patients had lower baseline BP and FPG control rates than those with either condition alone, and differences were greater at the latest follow-up (OR = 0.28086, $P < 0.001$; OR = 0.91012, $P = 0.049$; OR = 0.04020, $P < 0.001$; OR = 0.69465, $P < 0.001$).

**Conclusion:** BP and FPG management outcomes have achieved progress. Comorbid patients have poorer performance than patients with either disease alone in BP levels especially the SBP level and control rates of SBP, DBP, and FPG. Future studies should be conducted using national data and include more confounding factors.

**Keywords:** hypertension, diabetes mellitus, comorbidity, blood pressure, fasting plasma glucose, longitudinal studies

## Background

Hypertension and diabetes mellitus are growing public health concerns in China, contributing to the global pandemic.[1,2] Of importance, the comorbidity of diabetes and hypertension is increasingly becoming an issue. Hypertension mainly occurs in diabetics[3] and, conversely, the incidence of hypertension is twice as high in diabetic patients as in non-diabetics.[4] According to the Chinese epidemiological survey, the detection rate of hypertension in diabetic patients in China is about 49.4%, and the detection rate of diabetes in hypertensive patients is 19.5%.[5,6]

Existing research recognizes the pathophysiological association between hypertension and diabetes,[7,8] demonstrating that elevated BP increases the risk of diabetes,[9–11] while a higher FPG level is an independent risk factor for hypertension.[12,13] Those strong pathophysiological links make hypertensive patients with diabetes have a significantly



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higher risk of target organ damage and cardiovascular death than those with a single condition.[3,9,14,15] Despite the more severe health risk faced by comorbid patients, there has been relatively less discussion about comorbid patients than non-comorbid patients.

Effective management of BP and blood glucose can play a vital role in addressing the issue of reducing adverse cardiovascular outcomes,[7,16,17] which is an important clinical and public health topic.[18] However, the management of hypertension and diabetes in China is problematic[19] and far less effective than in developed countries,[1,20–23] resulting in massive health damage and economic loss.[24] Therefore, this raises many questions regarding the management outcomes of BP and blood glucose in comorbid patients, and whether those patients are less well-controlled than those with either condition alone.

In response to the current serious situation, the Chinese government has made hypertension and diabetes priority targets of the National Basic Public Health Service Project. Extensive research has evaluated this project.[25–27] Up to now, few studies have evaluated the project in terms of analyzing BP and blood glucose levels and changes during follow-up.

Several attempts have been made to investigate BP and glucose control in patients with hypertension, diabetes, and comorbidity of both diseases.[28,29] To date, current studies have utilized cross-sectional data with small samples and focused more on BP levels and attainment rates, without statistically comparing patients with single and comorbidity. Most studies focus on BP without statistically comparing the control status in patients with single and comorbid diseases. However, few studies compared blood glucose in diabetics with and without hypertension.[29]

The medical reform in Sanming has made remarkable achievements, and the State Council has issued numerous documents to promote Sanming's experience.[30,31] The Sanming government attaches great importance to the National Basic Public Health Service Project, which focuses on hypertension and diabetes, and carries out specific measures, including establishing residents' health records, health education, and regular follow-up visits.[32,33]

In this paper, we established generalized estimating equations to analyze the 4-year follow-up data in Sanming City. We compared blood pressure levels and control rates in hypertensive patients with and without diabetes, and FPG levels and control rates in diabetic patients with and without hypertension. We aim to offer new insights into this study area, emphasize the need to focus on hypertensive patients with diabetes, and evaluate the effectiveness of the National Basic Public Health Service Project.

# Methods

## Data Source

The National Basic Public Health Service Project, led by the National Health and Family Planning Commission, was launched in 2009 to promote the equalization of public health services. Patients with chronic diseases (including hypertension and diabetes) were included in the key management group and should have at least four face-to-face follow-up visits per year, including measurement (BP, FPG, body mass index, etc.) and assessment (disease, lifestyle, medication, etc.).

Data were obtained from the National Basic Public Health Service System and the Integrated Chronic Disease Management System under the project. We analyzed data of patients with hypertension or diabetes who entered the follow-up from January 1, 2017 to June 30, 2021 in Sanming City, Fujian Province, China.

## Study Population

This study included patients based on the following criteria: (a) diagnosed with hypertension or diabetes mellitus; (b) aged 18 years and older; (c) having established a resident health record; (d) entering follow-up of the National Basic Public Health Service Project in Sanming from January 1, 2017 to December 31, 2020; and (e) having more than 1 follow-up visit recorded. Patients with only 1 follow-up record or those aged less than 18 were excluded from this study.

## Dependent Variables

### Disease State

We divided the study population into three groups based on their disease states (whether patients had hypertension/diabetes): hypertensive patients without diabetes, diabetic patients without hypertension, and hypertensive patients with diabetes.

### Follow-Up Period

The follow-up period, measured in days, was set as the moderating variable. Considering the different follow-up dates of patients, the date of each patient's first entry into follow-up was defined as the baseline in this study. The follow-up period is defined as the number of days from baseline for each follow-up.

## Outcome Indicators

### Blood Pressure

BP was measured by medical staff at community-level health facilities using the upper-arm electronic medical BP monitor certified by International Standard Protocols (http://www.dableducational.org, http://www.bhsoc.org/default.stm). Patients were prohibited from smoking, and drinking coffee or tea for 30 minutes before the measurement and rested quietly for at least 5 minutes. When measuring, patients should take a sitting position with feet flat on the floor, relax and keep their bodies still without speaking. Each measurement should be taken at least twice, with an interval of 1~2 minutes, and the average value was recorded.[34]

According to the National Clinical Practice Guidelines on the Management of Hypertension in Primary Health Care in China (2020),[34] hypertensive patients without diabetes should control BP <140/90 mmHg, among which elderly patients aged ≥65 years should control BP <150/90 mmHg; hypertensive patients with diabetes should control BP <130/80 mmHg, among which elderly patients aged ≥65 years should control BP <150/90 mmHg. In this study, this standard was used to calculate the BP control rate = the number of patients who achieve the BP target/number of patients with measured BP * 100%.

Thus, four BP-related indicators were set as dependent variables of interest, including SBP, diastolic blood pressure (DBP), PP, and the BP control rate. Pulse pressure (PP) equals SBP minus DBP.

### Fasting Plasma Glucose

FPG was measured by medical personnel in community-level health institutions, using a portable blood glucose meter that should comply with the national standard (GB/T19634-2005). Patients should be fasting for at least 8 hours before measurements.[35]

According to the National Guidelines for Prevention and Control of Diabetes in Primary Care (2018),[35] the recommended target of fasting plasma glucose is <7.0 mmol/L. The FPG control rate = the number of patients with FPG of <7.0 mmol/L / the number with measured FPG *100%.

Thus, two FPG-related indicators were set as dependent variables of interest, including FPG and the FPG control rate.

## Covariables

Sociodemographic factors include age (continuous, years), gender (male/female), nationality (Han nationality/non-Han nationality), marital status (unmarried/married/divorced/widowed), education (illiterate/primary school/middle school/above high school), and residence (urban living/rural living). Living habits refer to the current situation at each follow-up, including smoking (yes/no), drinking (yes/no), and exercise (yes/no). Physical examination including body mass index (BMI) at each visit.

## Statistical Analysis

Continuous variables and categorical variables were described using standard deviation (SD) and rate (%) respectively. Statistical tests were performed by *t*-test for two groups of continuous data, by ANOVA for three groups of continuous data, by chi-square test for categorical data, and by rank-sum test for ordered data. The multiple imputations based on chain equations were used to deal with missing values.[36]

The generalized estimating equation (GEE), first proposed by Liang and Zeger in 1986, was applied to analyze unbalanced repeated-measures data.[37] The quasi-information criterion (QIC) was used to select the best-fit working correlation matrix and model.[38] After taking full account of QIC values and our study purpose, the independent working correlation matrix was adopted, and all covariables were included in the adjusted models.

BP-related indicators and FPG-related indicators were set as dependent variables of interest. BP-related indicators were compared between hypertensive patients with/without diabetes, and FPG-related indicators were compared between diabetic patients with/without hypertension. Due to changes in BP and FPG during follow-up, follow-up period×-dependent variables were set as interactions in this study.

GEE was applied to analyze the main effects of disease state (categorical variable, including hypertension only, diabetes only, and comorbidity of hypertension and diabetes) and follow-up period (continuous variable, days) and their interactive effects on dependent variables of interest. First, the disease state and follow-up period were included in crude models. Next, all covariables (age, gender, nationality, residence, education, marital status, body mass index, smoking, drinking, and exercise) were included for full adjustment. In addition, interaction plots were also used to examine whether there are interactions between the disease state and follow-up period. If interaction plots and GEE results show that there is interaction, a simple effect analysis will be performed.

Statistical analyses were performed using STATA 14.0. *P*-value<0.05 and 95% CI were considered statistically different.

# Results

## Demographic Characteristics of the Study Population

Of 35,635 patients included, 25,795 (72.39%) were patients with hypertension only, 4111 (11.54%) were with diabetes only, and 5729 (16.08%) were hypertensive patients with diabetes (Figure 1). In total, 44.98% were males, the mean age at baseline was 63.59 (SD = 10.96) years, and the follow-up period was 1172.53 (SD= 488.82) days (Table 1).

## Main Effects and Interactions

The fully adjusted models showed significant statistical interactions of comorbidity × follow-up period for SBP, DBP, PP, and BP control rate in hypertensive patients with/without diabetes (all *P*-values <0.05) (Table 2). The interaction plots also proved the existence of interactions, illustrating the different slopes of two lines in patients with hypertension and comorbidity, and even the opposite trends were observed in the plots of SBP and PP (Figure 2). That is, comorbidity was significantly associated with SBP, DBP, PP, and BP control rates under the main and interactive effects of disease state and time.

In both the crude and adjusted models, no statistical significance was found in the main effects and interaction term of comorbidity × follow-up period for FPG in diabetic patients with/without hypertension (Tables 3 and S1, and Figure 3A).

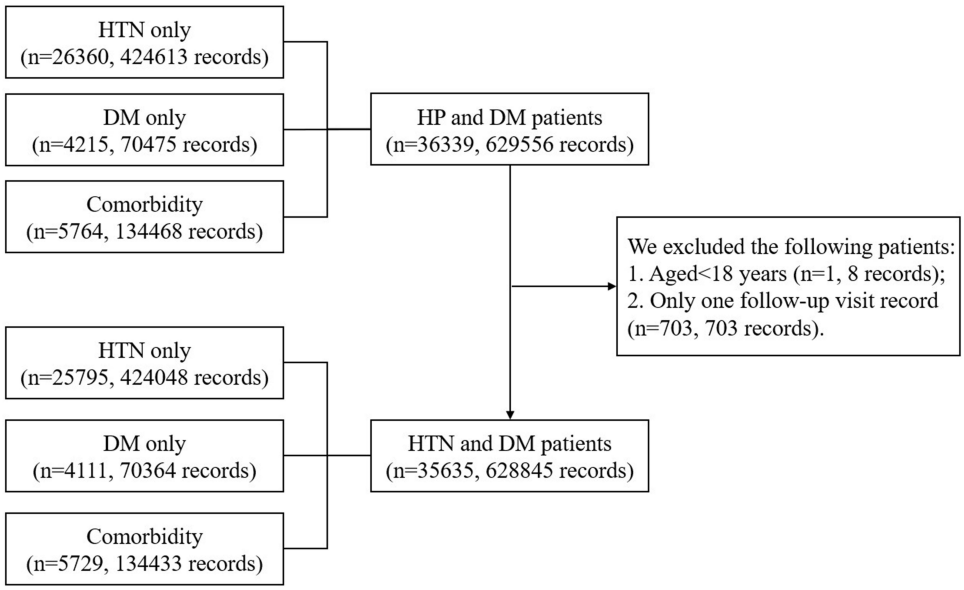


**Figure 1** The selection diagram of study population.
**Abbreviations**: DM, diabetes mellitus; HTN, hypertension; Comorbidity, comorbidity of diabetes and hypertension.

**Table 1** Demographic Characteristics of Patients with Hypertension, Diabetes and Comorbidity at Baseline

| Characteristic | HTN Only (n=25,795) | DM Only (n=4111) | Comorbidity (n=5729) |
|---|---|---|---|
| Age, year, mean ± SD | 64.2 ± 11.1 | 58.8 ± 10.3 | 64.4 ± 9.6 |
| Follow-up period, day, mean ± SD | 1156.3 ± 495.7 | 1075.4 ± 514.0 | 1315.5 ± 403.0 |
| Men, No. (%) | 12,057(46.7) | 1811(44.1) | 2161(37.7) |
| Han nationality, No. (%) | 25,741(99.8) | 4095(99.7) | 5719(99.9) |
| Urban living, No. (%) | 4776(18.5) | 975(23.7) | 1641(28.6) |
| Education, No. (%) | | | |
| Illiterate | 5375(21.3) | 558(13.9) | 1236(22.0) |
| Primary school | 12,215(48.3) | 1868(46.4) | 2674(47.6) |
| Middle school | 7322(29.0) | 1501(37.3) | 1578(28.1) |
| Above high school | 367(1.5) | 101(2.5) | 132(2.4) |
| Marital status, No. (%) | | | |
| Unmarried | 358(1.4) | 67(1.6) | 42(0.8) |
| Married | 21,618(84.6) | 3668(89.7) | 4859(85.3) |
| Divorced | 230(0.9) | 40(1.0) | 36(0.6) |
| Widowed | 3363(13.2) | 315(7.7) | 757(13.3) |
| SBP, mmHg, mean ± SD | 136.9 ± 14.0 | / | 135.9 ± 13.7 |
| DBP, mmHg, mean ± SD | 82.8 ± 9.1 | / | 81.7 ± 8.8 |
| PP, mmHg, mean ± SD | 54.1 ± 11.5 | / | 54.2 ± 11.7 |
| BMI, kg/m2, mean ± SD | 23.6 ± 3.1 | 23.5 ± 3.0 | 24.6 ± 3.3 |
| FPG, mmol/L, mean ± SD | / | 7.7 ± 2.7 | 7.6 ± 2.3 |
| Smoking, No. (%) | 2897(13.8) | 498(14.7) | 464(10.3) |
| Drinking, No. (%) | 1882(9.2) | 240(7.3) | 354(8.0) |
| Exercise, No. (%) | 17,980(69.7) | 2557(69.3) | 3387(68.0) |

**Note**: "HTN only" represents patients with hypertension only, "DM only" represents patients with diabetes only, and "Comorbidity" represents hypertensive patients with diabetes.

**Abbreviations**: DM, diabetes mellitus; HTN, hypertension; Comorbidity, comorbidity of diabetes and hypertension; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; BMI, body mass index; FPG, fasting plasma glucose; SD, standard deviation.

In contrast, we found an interaction between comorbidity and follow-up period in the FPG control rate (*P*-values <0.001) (Table 3). Thus, interaction plots were implemented to examine the interactive relation of disease state and follow-up period, indicating that different slopes appeared between diabetic patients with/without hypertension in the FPG control rate (Figure 3B).

## Simple Effects

Because comorbidity × follow-up interactions for SBP, DBP, PP, BP control rate, and FPG control rate have all reached statistical significance, simple effect analyses were conducted to confirm the effects of disease state and follow-up.

We first analyzed the simple effect of the disease state at baseline and the latest follow-up. Compared with those in hypertensive patients without diabetes, SBP and DBP in comorbid patients were both lower at baseline (Coef. =

**Table 2** Main Effects and Interactions of Disease State and Follow-Up Period on BP-Related Indicators

| Variables | SBP | | DBP | | PP | | BP Control Rate | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | *P*-value | Coef. | *P*-value | Coef. | *P*-value | OR | *P*-value |
| **Crude model** | | | | | | | | |
| Comorbidity (Ref.: HTN only) | 0.7641 | <0.001 | −0.0202 | 0.803 | 0.7896 | <0.001 | 0.1729 | <0.001 |
| Follow-up period | −0.0004 | <0.001 | −0.0012 | <0.001 | 0.0008 | <0.001 | 1.0004 | <0.001 |
| Comorbidity×Follow-up period (Ref.: HTN only×Follow-up period) | 0.0010 | <0.001 | 0.0004 | <0.001 | 0.0006 | <0.001 | 0.9998 | <0.001 |
| **Adjusted model** | | | | | | | | |
| Comorbidity (Ref.: HTN only) | 0.5680 | <0.001 | −0.0872 | 0.256 | 0.6607 | <0.001 | 0.1660 | <0.001 |
| Follow-up period | −0.0009 | <0.001 | −0.0008 | <0.001 | −0.0001 | 0.045 | 1.0003 | <0.001 |
| Comorbidity×Follow-up period (Ref.: HTN only×Follow-up period) | 0.0011 | <0.001 | 0.0004 | <0.001 | 0.0007 | <0.001 | 0.9998 | <0.001 |

**Note**: Comorbidity and Follow-up period are main effects, and Comorbidity×Follow-up period is interactive effect.
**Abbreviations**: Coef., coefficient; OR, odds ratio.

−1.18872, *P*-value <0.001; Coef. =−1.16049, *P*-value <0.001), while SBP was higher in comorbid patients at the latest follow-up (Coef. = 1.06344, *P*-value <0.001) (Table 4). There was no significant difference in PP between hypertensive patients with/without diabetes at baseline, but at the most recent follow-up, PP was higher in comorbid patients than that in hypertensive patients without diabetes (Coef. =0.85284, *P*-value <0.001) (Table 4). Patients with comorbidity were less likely to achieve BP and FPG control goals than those with either hypertension and diabetes alone at baseline (OR = 0.28086, *P*-value <0.001; OR = 0.91012, *P*-value = 0.049) (Tables 4 and 5). Besides, the differences were even greater at the latest follow-up (OR = 0.04020, *P*-value <0.001; OR = 0.69465, *P*-value <0.001) (Tables 4 and 5).

Tables 4 and 5 also showed the different simple effects of the follow-up period in patients with different disease states. SBP dropped in hypertensive patients without diabetes (Coef. = −0.00088, *P*-value <0.001), while no significant change was observed in comorbid patients. DBP decreased during following up in hypertensive patients with/without diabetes (Coef. = −0.00081, *P*-value <0.001; Coef. = 0.00033, *P*-value <0.001). PP climbed over the follow-up period in comorbid patients (Coef. = 0.00044, *P*-value <0.001), whereas it did not change significantly in patients with hypertension only. The BP control rate in patients with hypertension only increased over time (OR = 1.00039, *P*-value <0.001), while no significant change was observed in comorbid patients. The FPG control rate in diabetic patients with/without hypertension increased during follow-up (OR = 1.00020, *P*-value <0.001; OR = 1.00013, *P*-value <0.001), and the rate of comorbid patients was growing faster than those with hypertension alone.

## Discussion

To the best of our knowledge, this is the first study to compare BP levels and control rates in hypertensive patients with/without diabetes and FPG levels and control rates in diabetics with/without hypertension, using 4-year large-scale follow-up data from the National Basic Public Health Service Project. We found significant interactions between SBP / DBP / PP / BP control rate / FPG control rate and follow-up period. By contrast, there was no interaction between FPG and the follow-up period. Our results highlighted that considerable progress has been made regarding BP and FPG management outcomes in the project. Besides, patients with comorbidity showed significantly poorer performance than patients with either disease alone.

Our results suggested that primary care providers have made great achievements in the management outcomes of BP and FPG. Prior studies have noted the significance of chronic disease management under the National Basic Public Health Services Program, demonstrating that follow-up visits serve to achieve continuous disease management outcomes and avoid disease progression.[25] However, most studies on this topic have used cross-sectional data with

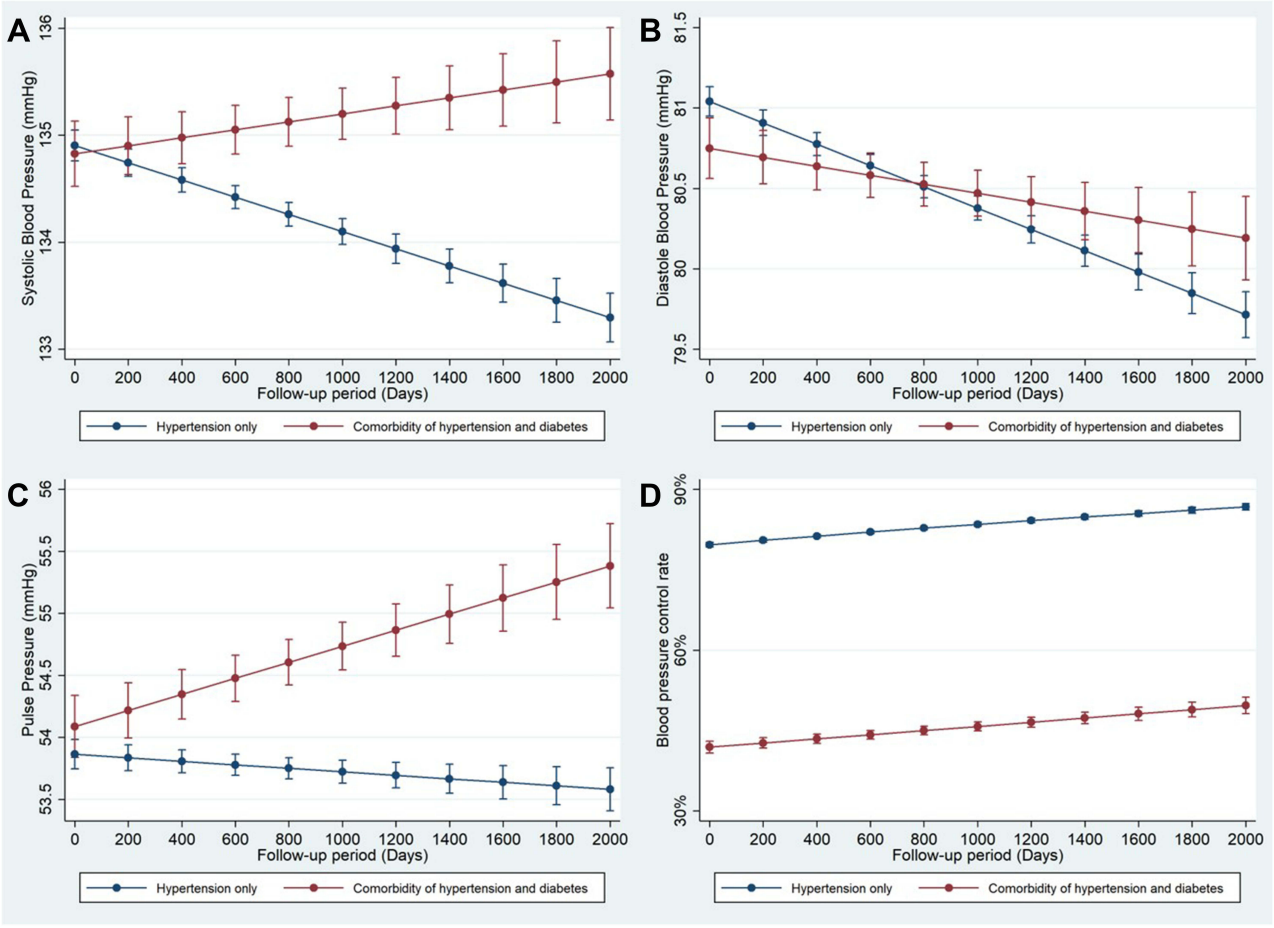


**Figure 2** Interaction plots of blood pressure-related indicators of hypertensive patients with/without diabetes. SBP (**A**), DBP (**B**), PP (**C**), and BP control rate (**D**). Interaction plots are dependent variables estimated by generalized estimating equations after adjusting for all covariables and interaction (disease state×follow-up period).

small sample sizes, without evaluating long-term follow-up changes in BP and FPG.[25,26,39,40] Meanwhile, the findings further confirmed the differences in trends and rates of change in management outcomes between patients with different disease states. Our findings highlight the significant improvement in the FPG control rate in diabetic patients

**Table 3** Main Effects and Interactions of Disease State and Follow-Up Period on FPG-Related Indicators

| Variables | FPG | | FPG Control Rate | |
|---|---|---|---|---|
| | Coef. | *P*-value | OR | *P*-value |
| **Crude model** | | | | |
| Comorbidity (Ref.: DM only) | 0.00139 | 0.965 | 0.78806 | <0.001 |
| Follow-up period | −0.00002 | 0.471 | 1.00013 | <0.001 |
| Comorbidity×Follow-up period (Ref.: DM only×Follow-up period) | −0.00001 | 0.892 | 1.00008 | 0.027 |
| **Adjusted model** | | | | |
| Comorbidity (Ref.: DM only) | −0.01234 | 0.706 | 0.81673 | <0.001 |
| Follow-up period | −0.00001 | 0.854 | 1.00013 | <0.001 |
| Comorbidity×Follow-up period (Ref.: DM only×Follow-up period) | −0.00001 | 0.843 | 1.00008 | 0.02 |

**Note**: Comorbidity and Follow-up period are main effects, and Comorbidity×Follow-up period is interactive effect.

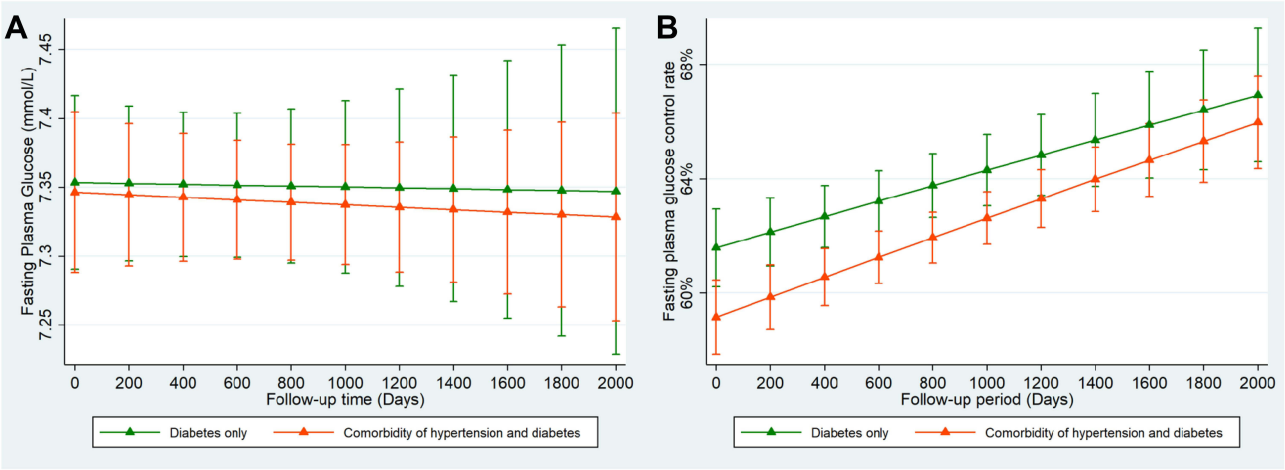


**Figure 3** Interaction plots of fasting plasma glucose-related indicators of diabetic patients with/without hypertension. The FPG (**A**), and FPG control rate (**B**). Interaction plots are dependent variables estimated by generalized estimating equations after adjusting for all covariables and interaction (disease state×follow-up period).

but also point out the unsatisfactory BP control rate in comorbid patients, which can provide a reference for the long-term development of FPG and BP under this program and further explore the deeper reasons for poor control, such as self-management ability and economic burden of patients.[41,42]

No significant decrease in FPG levels was observed during the follow-up regardless of whether diabetic patients had comorbid hypertension, which might be explained by fluctuations in FPG that make it difficult to control at a stable low level and the large rise in FPG in the non-compliant records. Similar problems were reported in previous studies. Pan et al[25] identified problems with diabetes management in the National Basic Public Health Service Project, including low participation among residents and insufficient awareness of the dangers of diabetes. The results of He et al[43] were consistent with this study, showing that there was no significant change in FPG in 300 diabetic patients with/without hypertension before and after 4-year community-based management.

Patients with comorbid hypertension and diabetes tend to have lower FPG control rates than patients with diabetes alone at baseline, and the difference between the two groups became progressively larger during follow-up, emphasizing that FPG management outcomes of comorbid patients need to be taken seriously. So far, however, there has been little discussion about the FPG control rate in comorbid patients. Bi et al[44] found that 5.13% of hypertensive patients with diabetes achieved the FPG control goal in Inner Mongolia, which was much lower than the control rate in this study. This

**Table 4** Simple Effects of Disease State and Follow-Up Period on BP-Related Indicators

| Variables | SBP | | DBP | | PP | | BP Control Rate | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | *P*-value | Coef. | *P*-value | Coef. | *P*-value | OR | *P*-value |
| **Disease state (at baseline)** | | | | | | | | |
| Comorbidity (Ref.: HTN only) | −1.18872 | <0.001 | −1.16049 | <0.001 | −0.01622 | 0.924 | 0.28086 | <0.001 |
| **Disease state (at the latest follow-up)** | | | | | | | | |
| Comorbidity (Ref.: HTN only) | 1.06344 | <0.001 | 0.19783 | 0.061 | 0.85284 | <0.001 | 0.0402 | <0.001 |
| **Follow-up period** | | | | | | | | |
| HTN only | −0.00088 | <0.001 | −0.00081 | <0.001 | −0.00007 | 0.22 | 1.00039 | <0.001 |
| Comorbidity | 0.00012 | 0.365 | −0.00033 | <0.001 | 0.00044 | <0.001 | 1.00003 | 0.147 |

**Note**: Disease state (HTN only, Comorbidity) and Follow-up period are simple effects.

**Table 5** Simple Effects of Disease State and Follow-Up Period on FPG-Related Indicators

| Variables | FPG Control Rate | |
|---|---|---|
| | OR | *P*-value |
| **Disease state (at baseline)** | | |
| Comorbidity (Ref.: DM only) | 0.91012 | 0.049 |
| **Disease state (at the latest follow-up)** | | |
| Comorbidity (Ref.: DM only) | 0.69465 | <0.001 |
| **Follow-up period** | | |
| DM only | 1.00013 | <0.001 |
| Comorbidity | 1.00020 | <0.001 |

**Note**: Disease state (DM only, Comorbidity) and Follow-up period are simple effects, where Comorbidity is the effect value relative to DM only (reference group).

discrepancy could be attributed to the fact that the patients in this study had better adherence to medication and life interventions due to follow-up, the baseline FPG of the patients was lower in this study, the stricter FPG control goal of Bi's study, and regional and demographic differences. Thus, this study offers some important insights into the problem of revealing comorbid patients from long-term follow-up data.

The management outcomes of BP levels in comorbid patients, especially SBP, are of greater concern than in patients with hypertension only. In this study, SBP and DBP were significantly lower in comorbid patients than in patients with hypertension only at baseline, and there was no difference in the PP level between them. However, at the latest follow-up, SBP and PP were significantly higher in comorbid patients than in patients with hypertension only. These findings raise the possibility that the control of BP levels in comorbid patients was much worse than that in patients with hypertension only during the follow-up period. It seems possible that these results are because comorbid patients need to take more drugs and tend to have poorer medication nonadherence.[45]

In addition to BP levels, patients with comorbidity of hypertension and diabetes had much lower BP control rates than patients with hypertension alone at both baseline and latest follow-up. The large disparity may partly be explained by the different BP control goals in the guidelines cited in this study, but it also suggests that despite the stricter goals in the guidelines for comorbid patients, the actual management outcomes were still not promising. This study supports evidence from current studies.[46,47] This study has further strengthened the confidence in the research results on this topic, with data type and research method that have not been emphasized in previous studies.

The strong pathophysiological link between hypertension and diabetes, which are mutually reinforcing, may explain the higher BP and FPG levels in comorbid patients than in those with either disease alone.[7] On the one hand, increased BP is positively associated with the incidence of diabetes.[9–11,48] Inversely, higher FPG is also correlated with higher BP[9,49] and is an independent risk factor for developing hypertension.[12,13]

Indeed, the management of comorbid patients is more difficult than that of patients with only one disease, in terms of higher out-of-pocket costs,[41,50] higher demands on health care,[51] higher likelihood of delayed treatment, the inadequate capacity and time for health care delivery.[52] Studies have demonstrated that the coexistence of diabetes and hypertension had a statistically significant negative impact on medication adherence, with comorbid patients having the lowest medication adherence among hypertensive and diabetic populations.[45] Hence, comorbidity of hypertension and diabetes could be a major consideration, if not the only one, causing poorer management outcomes of BP and FPG in comorbid patients.

Our study has several limitations. First, we did not analyze current levels and control rates of BP and FPG, because follow-up dates were not completely consistent for each patient. Second, we used FPG rather than glycated hemoglobin, which is related to the fact that FPG is more commonly used in follow-up due to limitations in China, whereas evidence

also showed that FPG may be a more important indicator than glycated hemoglobin in the development of hypertension.[12] Third, the follow-up data were obtained in Sanming, which does not reflect the overall situation in China. Fourth, due to data limitations, this study failed to analyze the impact of primary disease, complications, and hypertension severity on outcome indicators.

## Conclusions

This study is based on 4-year large-scale follow-up data from the National Basic Public Health Service Project in Sanming City. One of the findings to emerge from this study is that progress has been made regarding BP and FPG management outcomes in the National Basic Public Health Service Project, but no significant decrease in FPG level was observed. Before this study, there was little discussion of evidence comparing BP in hypertensive patients with/without diabetes and FPG in diabetic patients with/without hypertension. Thus, this study appears to be the first study to demonstrate that patients with comorbidity of hypertension and diabetes showed significantly poorer performance than patients with either disease alone in BP level especially SBP level controlling, BP control rate, and FPG control rate.

## Data Sharing Statement

The datasets generated in this study are not available.

## Ethics Statement

This study was approved by the Biomedical Ethics Committee of Wuhan University (IRB 2022007).

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## Author Contributions

All authors contributed to data analysis, drafting or revising the article, have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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## Disclosure

The authors report no conflicts of interest in this work.

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