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Home Blood Pressure Monitoring and Its Association With Blood Pressure Control Among Hypertensive Patients With High Cardiovascular Risk in China

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Abstract

Objective: Home blood pressure monitoring (HBPM) is viewed as a facilitating factor in the initial diagnosis and long-term management of treated hypertension. However, evidence remains scarce about the effectiveness of HBPM use in the real world. This study aimed to examine the associations of HBPM use with blood pressure (BP) control and medication adherence.

Methods: This prospective cohort study included hypertensive patients with high cardiovascular risk who were aged ≥50 years. At baseline, information about types of BP monitor, frequency of HBPM, perception of anti-hypertensive treatment, and measured office BP were collected. During the 1-year follow-up (visits at 1, 2, 3, 6, and 12 months), information on medication adherence was collected at each visit. The 2 major outcomes were BP control at baseline and medication adherence during the 1-year follow-up. A log-binomial regression model was used to examine the association between frequency of HBPM and outcomes, stratified by the perceptions of anti-hypertensive treatment.

Results: A total of 5,363 hypertensive patients were included in the analysis. The age was (64.6±7.2) years, and 41.2% (2,208) were female. Of the total patients, 85.9% (4,606) had a home BP monitor and 47.8% (2,564) had an incorrect perception of anti-hypertensive treatment. Overall, 24.2% (1,299) of patients monitored their BP daily, 37.6% (2,015) weekly, 17.3% (926) monthly, and 20.9% (1,123) less than monthly. At baseline, the systolic BP and diastolic BP were (146.6±10.8) mmHg and (81.9±10.6) mmHg, respectively, and 28.5% (1,527) of patients had their BP controlled. Regardless of whether the patients had correct or incorrect perceptions of anti-hypertensive treatment, there is no significant association between HBPM frequency and BP control at baseline. During the 1-year follow-up, 23.9% (1,280) of patients had non-adherence to medications at least once. In patients with an incorrect perception of anti-hypertensive treatment, those monitoring BP most frequently (daily) had the highest non-adherence rate (29.9%, 175/585). Compared with those monitoring their BP less than monthly, patients who monitored their BP daily were more likely not to adhere to anti-hypertensive medications (adjusted relative risk = 1.38, 95% confidence interval: 1.11–1.72, $P = 0.004$).

Conclusions: HBPM performance among hypertensive patients in China is, in general, sub-optimal. No association was observed between using HBPM alone and hypertension control, indicating that the effects of HBPM could be conditional. Patients' misconceptions about anti-hypertensive treatment may impair the role of BP monitoring in achieving medication adherence. Fully incorporating the correct perception of hypertension into the management of hypertensive patients is needed.

Keywords: Hypertension; Home blood pressure monitoring; Blood pressure control; Medication adherence

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1. Introduction

Hypertension is a leading modifiable risk factor for cardiovascular disease (CVD) and premature death worldwide.[1,2] Globally, there are an estimated 1.28 billion hypertensive patients aged 30–79, with two-thirds living in low- and middle-income countries (LMICs).[3] China is among the countries bearing the greatest burden from hypertension, with 0.25 billion individuals affected; however, only 15% have their blood pressure (BP) controlled (<140/90 mmHg).[4] A recent review by Chinese experts implied that poor BP control could be attributed to multiple factors, such as disparities in medical resources and an immature health care delivery system for hypertension management, poor patient adherence of hypertension management, a lack of public concern on health promotion, etc.[5] As a promising alternative to office BP and ambulatory BP monitoring,[6] home BP monitoring (HBPM) is expected to contribute to more effective management of patients with hypertension.[7] Previous systematic reviews and meta-analyses showed that HBPM is relatively convenient and more accessible and acceptable to patients, and exhibits comparable reproducibility and capability of predicting outcomes, thereby presenting great potential for increasing long-term treatment adherence and stimulating other lifestyle changes.[8–13]

CLINICAL PERSPECTIVE

WHAT IS NEW?

- Home blood pressure monitoring (HBPM) performance among hypertensive patients in China is, in general, sub-optimal. No significant association was observed between using HBPM alone and hypertension control.
- Misconceptions about anti-hypertensive treatment may impair the role of HBPM in achieving medication adherence. Without correct perceptions, patients who monitored blood pressure daily were more likely to be non-adherent.

WHAT ARE THE CLINICAL IMPLICATIONS?

- The current sub-optimal status of using HBPM as recommended by the guidelines should not be overlooked. Increasing HBPM ownership and fully incorporating correct perceptions of blood pressure into the management of hypertensive patients are needed.
- The effects of HBPM could be conditional, such as whether patients have correct perceptions or whether there are co-interventions. Patients would be truly empowered for effective self-management by integrating the correct perceptions and multifaceted skills in treating hypertension.

Clinical trials have indicated the facilitating roles of HBPM,[8–13] and key hypertension guidelines also recommend incorporating the use of HBPM as part of clinical practice.[14–19] However, despite the promising prospect of HBPM and the increased ownership of HBPM, the effective utilization of HBPM is rather conditional. Two recent reviews on the current development of HBPM indicated that the use of HBPM is particularly subject to human factors that could limit its accuracy and reliability, such as lack of knowledge about hypertension or the proper practice related to HBPM.[20,21] Furthermore, current evidence on the effectiveness of HBPM use in hypertension control and management in the real world remains limited, especially among hypertensive patients at high risk of CVD—for whom identifying and treating risk factors could significantly reduce the risk.[22] Observational research has focused on the ownership of a monitoring device and the frequency of using HBPM,[22–26] whereas studies exploring the relationship between the practice of HBPM and hypertension management are still lacking.

To address these knowledge gaps, we aimed to examine the roles of HBPM in hypertension management among hypertensive patients at high risk of CVD by examining the associations between HBPM use and BP control, and between HBPM use and adherence to anti-hypertensive medication. Findings from the study could help inform better understanding and facilitate the use of HBPM in real-world settings.

2. Methods

2.1. Study design and participants

We established a prospective cohort derived from participants of a randomized controlled trial (the Effects of intensive Systolic blood Pressure lowering treatment in reducing RIsk of vascular evenTs (ESPRIT)).[27] The intervention of the trial was BP-lowering strategies based on different BP targets (office systolic blood pressure (SBP) <120 or <140 mmHg). Participants were provided with 10 types of free first-line anti-hypertensive medications, and other anti-hypertensive drugs could also be used. Physicians were given discretion regarding the medication types and dosages, according to the recommendations of hypertension guidelines. In our study, we collected information about HBPM use and perception of anti-hypertensive treatment, and measured participants' office BP at baseline. During the 1-year follow-up, we collected information on medication adherence at each visit.

From September 2019 to July 2020, participants were enrolled from 102 hospitals and 14 primary medical institutions in 23 provinces across China in the ESPRIT trial. The inclusion criteria of the trial were: (1) aged ≥50 years; (2) having an office SBP of 130–180 mmHg; and (3) with high cardiovascular risk, defined as having at least 1 established CVD (coronary heart disease (CHD), stroke, carotid endarterectomy or carotid stenting, peripheral artery disease with revascularization, abdominal aortic aneurysm ≥5 cm with repair) or at least 2 major cardiovascular risk factors (male ≥60 years old or female ≥65 years old, diabetes mellitus, dyslipidemia, current smoker). The main exclusion criteria of the trial were: (1) known secondary cause of hypertension; (2) proteinuria ≥2+ protein or estimated glomerular filtration rate <45 mL/(min·1.73 m^2); (3) cardiovascular events within 3 months; and (4) a medical condition likely to limit survival to <3 years. Among the eligible population from the trial, we further selected patients who met the following criteria in our analysis: (1) previously diagnosed with hypertension, and (2) randomized to receive a BP-lowering strategy based on guideline-recommended BP target (office SBP <140 mmHg). We excluded those monitoring their BP regularly outside the home (monitoring BP at least once a month but without a BP monitor at home).

The central ethics committee at Fuwai Hospital approved ESPRIT trial in January 2019 (2018-1126). Ethics approvals were obtained at all local sites either by accepting the central ethics approval or by local ethics approval. All the participants provided written informed consent before participation.

2.2. Data collection

We used online questionnaires to collect baseline information regarding demographics and socio-economic status, lifestyle (current smoking, drinking, physical activity), comorbidities (diabetes mellitus, CHD, stroke), anti-hypertensive medication use, physical examination (height, weight, office BP), HBPM use, and perception of anti-hypertensive treatment. HBPM use included the type of BP monitor and frequency (daily, weekly, monthly, less than monthly) of HBPM. If participants reported "under 140/90 mmHg" or "under 130/80 mmHg" as the target for hypertension treatment, this was defined as being aware of the treatment target of hypertension. Participants reporting "correct" to any of the following statements were defined as having misconceptions about anti-hypertensive medications: (1) medications could be discontinued once BP was controlled; (2) medications should not be for long-term use owing to fear of addiction; and (3) medications should only be taken upon symptoms. A correct perception on anti-hypertensive treatment was defined as being aware of the treatment target of hypertension without any aforementioned misconception about anti-hypertensive medications.

After enrollment, participants were followed up at 1, 2, 3, 6, and 12 months. At each follow-up visit, we recorded all anti-hypertensive medications being used and the adherence to prescription. If patients showed non-adherence to a medication, the reason was collected. Patients were asked to bring unused medication to the clinic at each visit, and medication adherence was assessed by self-report combined with pill counts. The latter method was calculated by dividing the number of unused pills by the number of prescribed pills.

Additionally, office SBP and diastolic blood pressure (DBP) were measured using a unified and calibrated upper-arm

electronic BP monitor (Omron HBP-1100; Omron Corp, Dalian, China), with the participants in a sitting position and rested for at least 5 min before measurement. Participants' BP was measured 3 times with an interval of 1 min each time. To ensure the accuracy of BP, all values were transmitted to the online questionnaire, and the mean BP was calculated automatically.

Current smoking was defined as smoking at least 1 cigarette per day, drinking as taking alcohol at least weekly, and physical activity as performing any type of exercise at least weekly. Patients with a history of myocardial infarction, or treated with percutaneous coronary intervention or coronary artery bypass graft surgery, or having coronary artery stenosis ≥50%, or having symptoms with objective evidence of myocardial ischemia, were defined as having a history of CHD. Diabetes mellitus or stroke was defined by a history of clinical diagnosis.

2.3. Outcomes

Our study had 2 major outcomes. The first outcome was BP control at baseline. We used office BP when patients were enrolled, which reflected the BP level achieved by routine clinical care in the real world. Controlled hypertension was defined as SBP <140 mmHg and DBP <90 mmHg at 1 visit. We also conducted sensitivity analysis using office BP at 2 consecutive visits before patients were followed, and controlled hypertension was defined as the mean of 2 BP readings <140/90 mmHg in the first analysis, and as 2 BP readings both <140/90 mmHg in the second analysis. The second outcome of the study was medication adherence during the 1-year follow-up. Non-adherence to medications was defined as the proportion of unused pills >20% or self-reported taking medications irregularly due to subjective reasons at any visit during the 1-year follow-up.

2.4. Statistical analysis

Mean ± standard deviation and count (%) were used to describe the distribution of continuous and categorical variables, respectively. We described the baseline characteristics with the patients divided into 4 groups based on different frequencies of HBPM. Continuous variables were tested for mean difference using variance analysis, binary and disordered categorical variables were tested for proportional difference using χ^2 test, and ordinal categorical variables were tested for linear trend using Mantel-Haenszel test.

We examined the association between the frequency of HBPM and outcomes, stratified by the perceptions of anti-hypertensive treatment. We used a log-binomial regression model to examine the association between HBPM frequency and BP control and reported the prevalence ratio (PR) and 95% confidence interval (CI). We also used a log-binomial regression model to examine the association between HBPM frequency and medication adherence and reported the relative risk (RR) and 95% CI. In multivariate analysis, age, sex, marriage, region, education level, annual household income, duration of hypertension history, use of anti-hypertensive medications, baseline SBP, body mass index (BMI), current smoking, drinking, physical activity, diabetes mellitus, CHD, and stroke were adjusted. All analyses were performed using SAS 9.4 (SAS Inc, North Carolina, USA). $P < 0.05$ was deemed statistically significant.

3. Results

There were 5,609 hypertensive patients from the ESPRIT trial who received guideline-recommended BP management. After excluding 246 patients who monitored their BP regularly outside the home, we included 5,363 hypertensive patients in the current analysis, and all of them completed the 1-year follow-up. The age of the study participants was (64.6 ± 7.2) years and 41.2% were female. The duration of hypertension history was (12.7 ± 9.4) years, and 97.5% of patients were treated with anti-hypertensive medications. The most common comorbidities were diabetes mellitus (38.8%), CHD (29.2%), and stroke (26.6%). Among all study participants, 47.8% had incorrect perceptions of anti-hypertensive treatment. In addition, 4,606 (85.9%) patients had a home BP monitor (upper-arm electronic 68.4%, mercury-column 9.5%, and finger or wrist electronic 7.2%). Overall, 24.2% of patients monitored their BP daily, 37.6% weekly, 17.3% monthly, and 20.9% less than monthly. There was a statistically significant difference in the frequency of HBPM by marriage, social-economic status, duration of hypertension history, use of anti-hypertensive medications, lifestyle (current smoking, physical activity), comorbidities (CHD), type of BP monitor, and perception of anti-hypertensive treatment [Table 1].

At baseline, the SBP and DBP were (146.6 ± 10.8) mmHg and (81.9 ± 10.6) mmHg, respectively, and 28.5% (1,527/5,363) had their BP controlled. The baseline BP level by the frequency of HBPM is shown in Figure 1. There were no significant differences in the level of BP among the different monitoring frequencies. The association of HBPM frequency with BP control is shown in Table 2. The rates of BP control in different monitoring frequencies among the total population ranged from 27.4% to 30.8%. Regardless of whether the patients had a correct or incorrect perception of anti-hypertensive treatment, we observed no significant association between HBPM frequency and BP control at baseline, and the results were consistent in the sensitivity analysis [Supplementary Tables 1 and 2, http://links.lww.com/CD9/A64].

During the 1-year follow-up, 23.9% (1,280/5,363) of patients had non-adherence to medications at least once, and the main reason was discontinued medication without approval from the physicians as a result of perceived improved conditions, which accounted for 79.7% [Figure 2]. The association of HBPM frequency with 1-year medication adherence is shown in Table 3. In patients with a correct perception of anti-hypertensive treatment, the non-adherence rates of patients with different monitoring frequencies ranged from 21.7% to 27.6%, and there were no significant differences within groups. We observed no association between the frequency of HBPM and 1-year medication adherence in those patients. Among the patients having an incorrect perception of anti-hypertensive treatment, those monitoring their BP most frequently (daily) had the highest non-adherence rate (29.9%). Compared with those monitoring their BP less than once a month, patients who monitored their BP daily were more likely to have non-adherence to anti-hypertensive medications (adjusted RR = 1.38, 95% CI = 1.11–1.72, $P = 0.004$).

4. Discussion

Using a large cohort of hypertensive patients with high CVD risk, we demonstrated that although the majority had a BP monitor at home and monitored their BP at least weekly, only 28.5% had their BP controlled, and BP control was not associated with the frequency of HBPM. This may be partly attributed to the prevalence of incorrect perception of anti-hypertensive treatment, and the increased likelihood of non-adherence to anti-hypertensive medications among those conducting HBPM daily. Our findings highlight the importance of patient education about the correct perception of anti-hypertensive treatment, which indicates an opportunity for improving BP control.

The popularization of HBPM is encouraging. Among all the participants, approximately 80% had a device for HBPM, and 60% conducted HBPM at least weekly, which complies with the guideline recommendation.[28] Among European and Asian countries, the rates of using HBPM varied considerably, ranging from 24.7% to 74.3%.[23–26] Two Chinese studies, which were multi-centered and recruited hypertensive patients from a few

Table 1

Baseline characteristics by the frequency of home blood pressure monitoring in hypertensive patients with high cardiovascular risk.

Characteristic	Total (*n* = 5,363)	Less than monthly (*n* = 1,123)	Monthly (*n* = 926)	Weekly (*n* = 2,015)	Daily (*n* = 1,299)	*F*/χ^2	*P*
Age (year)	64.6 ± 7.2	64.9 ± 7.1	64.5 ± 7.1	64.4 ± 7.2	64.7 ± 7.4	1.36	0.254
Age group (year)						0.40	0.529*
50–59	1,353 (25.2)	265 (23.6)	231 (24.9)	530 (26.3)	327 (25.2)		
60–69	2,707 (50.5)	570 (50.8)	487 (52.6)	1,011 (50.2)	639 (49.2)		
≥70	1,303 (24.3)	288 (25.6)	208 (22.5)	474 (23.5)	333 (25.6)		
Female	2,208 (41.2)	485 (43.2)	374 (40.4)	792 (39.3)	557 (42.9)	6.58	0.087†
In marriage	4,915 (91.6)	1,021 (90.9)	856 (92.4)	1,868 (92.7)	1,170 (90.1)	8.71	0.034†
Urban	3,668 (68.4)	577 (51.4)	626 (67.6)	1,425 (70.7)	1,040 (80.1)	236.61	<0.001†
Educational level						128.86	<0.001*
Primary school or below	1,598 (29.8)	479 (42.7)	282 (30.5)	538 (26.7)	299 (23.0)		
Middle school	1,816 (33.9)	361 (32.1)	314 (33.9)	690 (34.2)	451 (34.7)		
High school or above	1,949 (36.3)	283 (25.2)	330 (35.6)	787 (39.1)	549 (42.3)		
Annual household income (RMB)						109.59	<0.001*
<40,000	3,092 (57.7)	811 (72.2)	545 (58.9)	1,118 (55.5)	618 (47.6)		
40,000–70,000	1,940 (36.2)	260 (23.2)	314 (33.9)	770 (38.2)	596 (45.9)		
>70,000	331 (6.1)	52 (4.6)	67 (7.2)	127 (6.3)	85 (6.5)		
Duration of hypertension history (year)						36.91	<0.001*
<10	2,249 (41.9)	563 (50.1)	373 (40.3)	792 (39.3)	521 (40.1)		
10–19	1,843 (34.4)	361 (32.1)	338 (36.5)	716 (35.5)	428 (32.9)		
≥20	1,271 (23.7)	199 (17.7)	215 (23.2)	507 (25.2)	350 (26.9)		
Use of anti-hypertensive medications						102.30	<0.001*
0	136 (2.5)	54 (4.8)	23 (2.5)	38 (1.9)	21 (1.6)		
1	2,491 (46.4)	600 (53.4)	444 (47.9)	941 (46.7)	506 (39.0)		
2	2,116 (39.5)	386 (34.4)	367 (39.6)	817 (40.5)	546 (42.0)		
≥3	620 (11.6)	83 (7.4)	92 (9.9)	219 (10.9)	226 (17.4)		
Body mass index (kg/m^2)	26.3 ± 3.3	26.1 ± 3.4	26.4 ± 3.3	26.4 ± 3.2	26.2 ± 3.2	1.98	0.115
Lifestyle							
Current smoking	1,695 (31.6)	367 (32.7)	299 (32.3)	674 (33.4)	355 (27.3)	14.96	0.002†
Drinking	697 (13.0)	146 (13.0)	117 (12.6)	289 (14.3)	145 (11.2)	7.20	0.066†
Physical activity	4,126 (63.1)	708 (63.0)	685 (74.0)	1,634 (81.1)	1,099 (84.6)	178.21	<0.001†
Comorbidities							
Diabetes mellitus	2,080 (38.8)	412 (36.7)	362 (39.1)	822 (40.8)	484 (37.3)	6.82	0.078†
Coronary heart disease	1,565 (29.2)	294 (26.2)	257 (27.8)	619 (30.7)	395 (30.4)	9.06	0.029†
Stroke	1,426 (26.6)	322 (28.7)	231 (24.9)	513 (25.5)	360 (27.7)	5.94	0.115†
Type of blood pressure monitor						3,327.87	<0.001†
Upper-arm electronic	3,667 (68.4)	276 (24.6)	683 (73.8)	1,596 (79.2)	1,112 (85.6)		
Mercury-column	509 (9.5)	47 (4.2)	137 (14.8)	244 (12.1)	81 (6.2)		
Finger or wrist electronic	386 (7.2)	32 (2.8)	89 (9.6)	163 (8.1)	102 (7.9)		
Unknown	44 (0.8)	11 (1.0)	17 (1.8)	12 (0.6)	4 (0.3)		
None	757 (14.1)	757 (67.5)	0	0	0		
Had incorrect perception of anti-hypertensive treatment	2,564 (47.8)	625 (55.7)	441 (47.6)	913 (45.3)	585 (45.0)	95.59	<0.001†

Data are presented as mean ± standard deviation or *n* (%).

*Mantel-Haenszel test for linear trend; †χ^2 test for proportional difference.

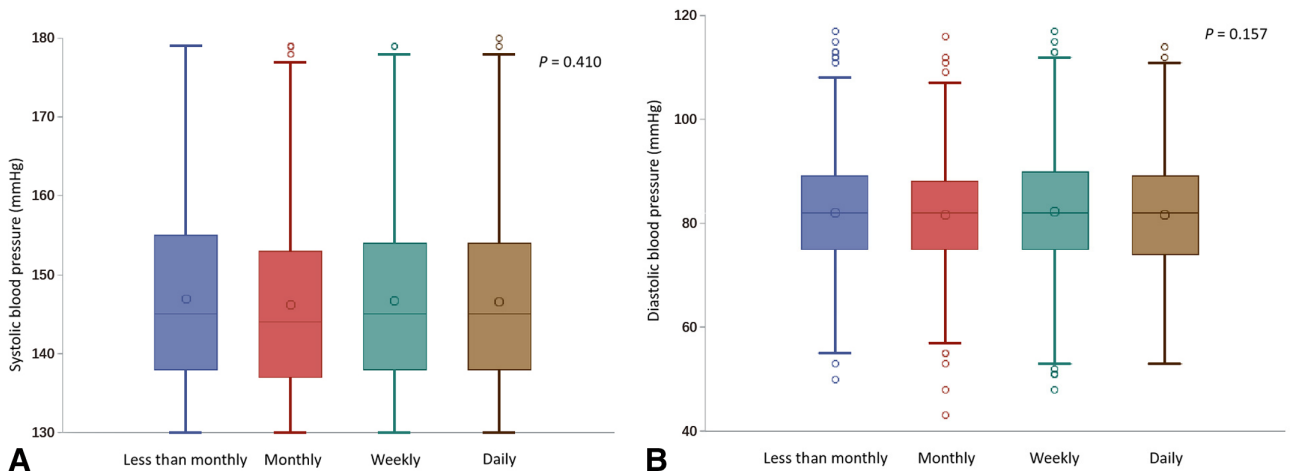

Figure 1: Baseline blood pressure level by frequency of home blood pressure monitoring in hypertensive patients with high cardiovascular risk. (A) Systolic blood pressure. (B) Diastolic blood pressure. *P*: Comparison of the office systolic and diastolic blood pressures at baseline in different frequencies of home blood pressure monitoring by variance analysis.

Table 2

The association of home blood pressure monitoring frequency with blood pressure control at baseline in hypertensive patients with high cardiovascular risk.

		Unadjusted		Adjusted*	
Frequency	**Controlled, *n* (%)**	**PR (95% CI)**	***P***	**PR (95% CI)**	***P***
Total patients					
Less than monthly ($n = 1,123$)	326 (29.0)	Reference		Reference	
Monthly ($n = 926$)	285 (30.8)	1.06 (0.93–1.21)	0.389	1.05 (0.91–1.21)	0.529
Weekly ($n = 2,015$)	553 (27.4)	0.95 (0.84–1.06)	0.342	0.92 (0.80–1.04)	0.188
Daily ($n = 1,299$)	363 (27.9)	0.96 (0.85–1.09)	0.555	0.90 (0.76–1.05)	0.125
Patients with correct perception of anti-hypertensive treatment					
Less than monthly ($n = 498$)	152 (30.5)	Reference		Reference	
Monthly ($n = 485$)	162 (33.4)	1.09 (0.91–1.31)	0.333	1.08 (0.88–1.31)	0.468
Weekly ($n = 1,102$)	296 (26.9)	0.88 (0.75–1.04)	0.128	0.85 (0.71–1.04)	0.083
Daily ($n = 714$)	193 (27.0)	0.89 (0.74–1.06)	0.184	0.82 (0.68–1.02)	0.063
Patients with incorrect perception of anti-hypertensive treatment					
Less than monthly ($n = 625$)	174 (27.8)	Reference		Reference	
Monthly ($n = 441$)	123 (27.9)	1.00 (0.82–1.22)	0.985	0.98 (0.79–1.22)	0.863
Weekly ($n = 913$)	257 (28.2)	1.01 (0.86–1.19)	0.895	0.98 (0.82–1.19)	0.870
Daily ($n = 585$)	170 (29.1)	1.04 (0.87–1.25)	0.638	0.94 (0.76–1.16)	0.554

*Multivariate analysis, adjusted for age, sex, marriage, region, education level, annual household income, duration of hypertension history, use of anti-hypertensive medications, body mass index, current smoking, drinking, physical activity, diabetes mellitus, coronary heart disease, and stroke. CI: Confidence interval; PR: Prevalence ratio.

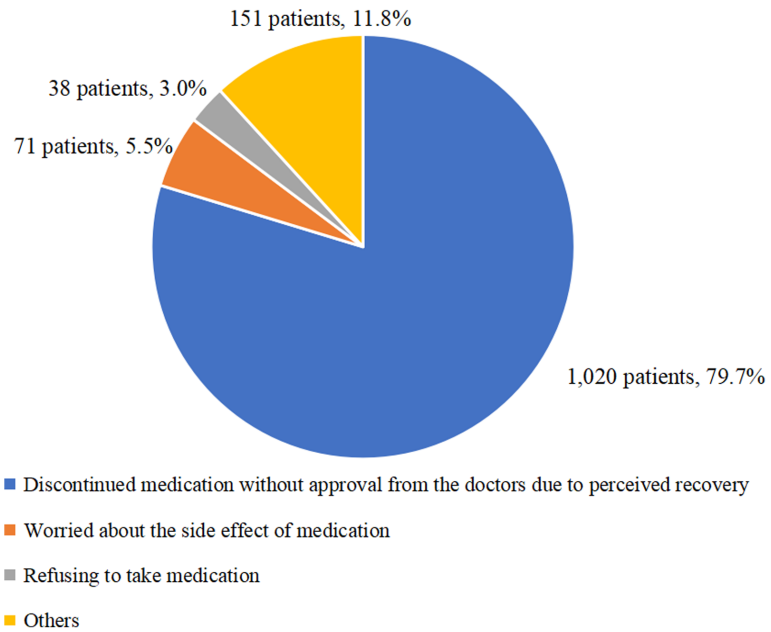

Figure 2: Subjective reasons for medication non-adherence in hypertensive patients with high cardiovascular risk during the 1-year follow-up.

developed provinces or cities, showed that 28% of the hypertensive patients from these communities conducted HBPM at least once a week,[29] and 54% were observed among outpatients.[30] Many participants in our study were from large and mid-sized cities, which could represent the majority of hypertensive patients with high CVD risk in urban settings. The affordable price and simple procedure have facilitated the rapidly increasing use of HBPM.

Our study indicated a sub-optimal state of hypertension control and no observed association between the use of HBPM and BP control. The low BP control rate found in this study was aligned with the results of recent studies that had shown sub-optimal BP control among LMICs in general (10.8%),[31] as well as in China in particular (10%–15%).[32] The low BP control rate could potentially be due to various reasons associated with health care, including poor access to multiple drugs and consequent underuse, treatment inadequacy,[32,33] and poor patient adherence.[33] However, the findings do not mean a failed prospect of HBPM in its promising role in hypertension management; they rather suggest a more systematic way in which we should perceive and approach hypertension and its management. A previous meta-analysis showed that self-monitoring alone is not associated with better BP control, but that it could lead to significant BP reductions when combined with co-interventions, such as medication titration, education, or lifestyle counseling. Furthermore, the effectiveness of self-monitoring increased with the intensity of the co-interventions. The meta-analysis also indicated that self-monitoring appeared more effective in those with fewer BP medications at baseline or those with higher BP (but not >170 mmHg), suggesting that HBPM might have more significant effects in certain groups of people.[34] In this study, the effect of HBPM under evaluation was without any co-intervention, and heterogeneities in terms of medication use and BP levels at baseline also existed in the study population. This could, to some extent, explain why

Table 3

The association of home blood pressure monitoring frequency with 1-year medication adherence in hypertensive patients with high cardiovascular risk.

		Unadjusted		Adjusted*	
Frequency	**Non-adherence, *n* (%)**	**RR (95% CI)**	***P***	**RR (95% CI)**	***P***
Total patients					
Less than monthly ($n = 1,123$)	242 (21.5)	Reference		Reference	
Monthly ($n = 926$)	198 (21.4)	0.99 (0.84–1.17)	0.927	0.95 (0.79–1.14)	0.550
Weekly ($n = 2,015$)	468 (23.2)	1.08 (0.94–1.24)	0.284	1.04 (0.90–1.22)	0.575
Daily ($n = 1,299$)	372 (28.6)	1.33 (1.15–1.53)	<0.001	1.29 (1.10–1.52)	0.002
Patients with correct perception of anti-hypertensive treatment					
Less than monthly ($n = 498$)	108 (21.7)	Reference		Reference	
Monthly ($n = 485$)	110 (22.7)	1.05 (0.83–1.32)	0.708	1.05 (0.81–1.37)	0.692
Weekly ($n = 1,102$)	258 (23.4)	1.08 (0.89–1.32)	0.449	1.09 (0.87–1.36)	0.465
Daily ($n = 714$)	197 (27.6)	1.27 (1.04–1.56)	0.021	1.24 (0.97–1.58)	0.080
Patients with incorrect perception of anti-hypertensive treatment					
Less than monthly ($n = 625$)	134 (21.4)	Reference		Reference	
Monthly ($n = 441$)	88 (20.0)	0.93 (0.73–1.18)	0.557	0.83 (0.64–1.08)	0.173
Weekly ($n = 913$)	210 (23.0)	1.07 (0.89–1.30)	0.472	1.00 (0.81–1.24)	0.996
Daily ($n = 585$)	175 (29.9)	1.39 (1.15–1.70)	<0.001	1.38 (1.11–1.72)	0.004

*Multivariate analysis, adjusted for age, sex, marriage, region, education level, annual household income, duration of hypertension history, use of anti-hypertensive medications, baseline systolic blood pressure, body mass index, current smoking, drinking, physical activity, diabetes mellitus, coronary heart disease, and stroke. CI: Confidence interval; RR: Relative risk.

we did not observe any significant associations between HBPM and BP control. In addition, consistent surveillance of BP levels enabled by HBPM is different from actively participating in hypertension management with HBPM; the latter requires more self-management skills, such as obtaining correct perception and knowledge, lifestyle modification, medication adherence, etc,[34,35] which could substantially influence BP control.

A negative role of misconception about hypertension was observed in the performance of HBPM, especially regarding medication adherence. Previous studies indicated that a good knowledge of hypertension could predict good medication adherence.[36] Compared with high-income countries, the lack of access to information and lower education level more significantly affect misconception of disease and treatment in LMICs, which further impairs disease management.[37] In our findings, regular HBPM could not guarantee a good adherence to medication if the knowledge about hypertension was incorrect, especially among those monitoring their BP daily, most of whom made their own decision to discontinue medication owing to the perceived improved conditions. These patients seem to exhibit heightened diligence in managing their hypertension through increased monitoring frequency; however, their misconceptions about the BP-lowering target and medication, which resulted in such patients stopping their medication if they thought their symptom was improved or their monitoring suggested a seemingly controlled BP, means these patients had a higher risk of making decisions without approval from their physicians about reducing or stopping medications. This is the key reason explaining the observed medication non-adherence in our study. The other reasons, such as worries about medication side effects, also reflect patients' insufficient knowledge about hypertension management. This indicates that correct perceptions and good knowledge play a more decisive role than behavior in achieving effective hypertension management.

Among the patients with correct perceptions on hypertension, our study did not observe any effects of HBPM in improving medication adherence. Previous systematic reviews suggested that more significant effects of HBPM are usually identified when combined with other interventions in the trials, such as adherence reminders, patient education, or telemedicine.[8–10,31] In our study, HBPM was not an intervention by design, and no other aforementioned facilitators were included. Therefore, the role of HBPM in improving medication adherence could be relatively limited, which suggests that in a real-world setting, the performance of HBPM could be strengthened through combined strategies for facilitating its function. In addition, the duration of follow-up may impact the observation of HBPM effects, as these effects could be short-term. A previous study looking at supportive measures (including HBPM) on medication adherence observed a fading effect of the measures with time, with the highest difference between the intervention and control groups soon after the study initiation.[38] Observational data focusing on the changing effect of HBPM on medication adherence is sparse, and further studies are needed to explore the potential trajectories and influencing factors.

Considering the study cohort was established amid the coronavirus disease 2019 (COVID-19) period, the outbreak of the pandemic may have influenced the utilization of healthcare services among some patients. However, the COVID-19 pandemic should not have affected the outcomes of this study. For the analysis of BP control, we used the baseline data of the ESPRIT trial. Before the COVID-19 outbreak, we had already enrolled more than two-thirds of the total participants. Subsequently, enrollment was suspended except at several unaffected sites. Our sites were all outside Hubei Province, and only limited patients were infected in the cities of our sites during the 2020 wave of COVID-19. We restarted the enrollment in April 2020 and finished it in July 2020, when there were no patients infected by COVID-19 in China. In terms of the non-adherence to medications, this study was not affected by objective reasons, such as a lack of anti-hypertensive drugs.

Our observations on the performance of HBPM could provide implications for facilitating improved use of HBPM in real-world settings. As HBPM could empower patients in realizing patient-centered hypertension management and contribute to proactive intervention for reducing the clinical and economic burden of CVD,[21] the current sub-optimal status of using HBPM as recommended by the guidelines should not be overlooked. Increasing ownership and fully incorporating the knowledge of HBPM into clinical practice are needed. In addition, patient education on the basics of hypertension should be prioritized before the patients take charge of managing the disease, given the importance of correct perception about hypertension management as well as the necessary skills. Moreover, as human factors play a pivotal role in influencing the performance of HBPM, further studies are needed to comprehensively examine the associated human factors that could facilitate more effective use of HBPM.

5. Limitations

The findings in this study should be interpreted with consideration of the following limitations. First, the study population comprised patients who participated in ESPRIT trial; such a population may care more about health than those not in this trial. Second, we only included patients with high risk for CVD who were aged ≥50 years; therefore, the findings may not be applicable to younger populations or those with lower CVD risk. Third, this study only collected information related to the measuring frequency to evaluate whether HBPM was conducted regularly, and did not gather the time and ways of taking the measurement. Therefore, it is not possible to evaluate whether HBPM was performed in the correct fashion. Further research would be needed to detail the related practice of HBPM in hypertension management. Fourth, the medication non-adherence was observed in a trial that had already required a regular follow-up. Thus, medication adherence in the real world could be even worse. Fifth, although we adjusted potential confounders in the multivariable model, remnant bias may exist owing to the nature of observational study. The analysis was predominantly based on self-reported data of using HBPM and medication adherence, and potential recall bias or social desirability would exist, which could be a confounder to consider when interpreting the results. To minimize the bias regarding medication adherence, we took measures such as asking the patients to bring unused medication at each visit and assessing medication adherence based on self-report combined with pill counts. Sixth, the role of healthcare professionals in patient education about hypertension and its management is crucial for realizing effective practice.[39–42] However, in this study, we did not collect sufficient information to further elaborate on this point.

6. Conclusions

The performance of HBPM among patients with hypertension in China is, in general, sub-optimal. No significant association was observed between HBPM use and hypertension control in this study, indicating that the effects of HBPM could be conditional, such as whether there are co-interventions or more precise subgroup analysis. This study highlights that patients' misconceptions about anti-hypertensive treatment may pose challenges to the function of BP monitoring in achieving medication adherence. Raising awareness of and fully incorporating the correct perceptions of BP into the management of hypertensive patients is essential. Patients could be truly empowered for effective self-management by integrating the correct perceptions and multifaceted skills in treating hypertension.

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Author contributions

Jing Li and Jiaying Li designed the research; Jiaying Li and Aoxi Tian searched the literature and drafted the manuscript; and Jiaying Li and Jinzhuo Ge performed the statistical analysis. Jiamin Liu, Yue Peng, Xiaoming Su reviewed and revised the manuscript. All the authors made critical revisions to the manuscript for important intellectual content. Jing Li, Jiaying Li, Jiamin Liu, and Jinzhuo Ge had full access to the data in this study. Jing Li and Jiaying Li took responsibility for data integrity and data analysis accuracy. All authors read and approved the final manuscript.

Conflicts of interest

None.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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