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Longitudinal control of blood pressure among a cohort of Ghanaians with hypertension: A multicenter, hospital-based study

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Abstract

There are limited data on factors associated with longitudinal control of blood pressure (BP) among Ghanaians on antihypertensive treatment. We sought to evaluate associations between prospective BP control and 24 putative factors within socio-demographic, biological, and organizational domains. This is a cohort study involving 1867 (65%) adults with hypertension and 1006 (35%) with both hypertension and diabetes mellitus at five public hospitals. Clinic BP was measured every 2 months for 18 months of follow-up. A multivariate logistic regression analysis was fitted via generalized linear mixed models to identify factors associated with clinic BP ≥ 140/90 mm Hg at each clinic visit during follow-up. Mean age of study participants was 58.9 ± 16.6 years and 76.8% were females. Proportions with controlled BP increased from 46.3% at baseline to 59.8% at month 18, $P < .0001$. Eight factors with adjusted OR (95% CI) associated prospectively with uncontrolled BP were male gender: 1.37 (1.09-1.72), secondary education: 1.32 (1.00-1.74), non-adherence to antihypertensive treatment: 1.03 (1.00-1.06), fruit intake: 0.94 (0.89-1.00), duration of hypertension diagnosis: 1.01 (1.00-1.02), hypertension with diabetes mellitus: 2.05

(1.72-2.46), number of antihypertensive medications: 1.63 (1.49-1.79), and estimated glomerular filtration rate (mL/min rise): 0.82 (0.76-0.89). Interventions aimed at addressing modifiable factors associated with poorly controlled BP would be critical in prevention of cardiovascular diseases among Ghanaians.

1 | INTRODUCTION

Hypertension is a leading risk factor responsible for significant morbidity and mortality from cardiovascular diseases (CVDs).[1,2] Although effective treatments are available for the management of hypertension, blood pressure (BP) control is sub-optimal worldwide and the greatest burden of uncontrolled BP is reported in low- and middle-income countries (LMICs) where CVD rates are rapidly rising.[3-5] A multi-national, community-based study has shown that 46.5% of participants were aware they had hypertension and BP control was 32.5% among those being treated. The need for improvement in hypertension control is particularly urgent in LMICs with two-thirds of global burden of hypertension.[6]

The principal factors associated with BP control among those receiving treatment include poor adherence, clinical inertia, and organizational failure.[7-9] The influence of the aforementioned factors on the pervasively high prevalence of uncontrolled hypertension among individuals seeking health care in resource-limited settings have seldom been characterized in prospective studies. It has been suggested that single BP measurements may underestimate associations between BP and cardiovascular events due to the inherent biological variability of BP. Serial measures of BPs over time have been adversely linked with CVD outcomes.[10-12] A plethora of studies conducted in sub-Saharan Africa using cross-sectional designs have consistently reported poor control rates of hypertension with an average of <45% of adult study samples with blood pressure on target.[13-31] There is, however, a paucity of studies on the determinants of poor BP control from prospective cohort studies in sub-Saharan Africa (SSA).

The WHO has estimated that 46% of adults aged 25 years and older in SSA have hypertension with a projected rise in coming decades.[32,33] With awareness rates of <30%, treatment rates of <20%, and control rates of <10%, there is substantial room for improvement in control of hypertension in Africa.[33] Characterizing the factors associated with poor BP control in SSA is an important first step in helping design evidence-based interventions toward mitigating the devastating consequences of uncontrolled BP. Previous studies assessing predictors of BP control in SSA have been cross-sectional and mostly single-center studies.[32,33] These previous studies have not comprehensively evaluated the contributions of organizational factors such as level of healthcare institution, care provider-related factors such as therapeutic inertia and patient-level factors such as socio-demographic and patho-biological variables all of which may differentially contribute to BP control. We sought to characterize the associations between 24 putative factors within socio-demographic, biological, and organizational domains which might contribute to poor BP control in the context of a large prospective cohort of Ghanaians with hypertension recruited into the Ghana Access and Affordability Program (GAAP). The GAAP is a public-private partnership with an overarching objective to improve the management of hypertension and type II diabetes through improved access to medicines and systems strengthening activities. As part of this initiative, a prospective cohort of participants with hypertension was enrolled and followed up for 18 months to assess factors associated with poor control of hypertension in Ghanaian public health institutions.

2 | METHODS

2.1 | Study design and participants

This is a prospective cohort study involving adults with hypertension, hypertension with diabetes mellitus and diabetes mellitus at public hospitals in Ghana. Ethical approval was obtained from the Ghana Health Services Ethical Review Committee (GHS-ERC: 12/07/14). This research study was performed in accordance with the relevant regulations. The study protocol is published elsewhere.[34] Briefly, the study was conducted at five hospitals in Ghana with hypertension and diabetes specialty and general clinics. The five study sites included the Agogo Presbyterian Hospital, (APH), Atua Government Hospital, (AGH), Komfo Anokye Teaching Hospital, (KATH), Kings Medical center, (KMC), and the Tamale Teaching Hospital, (TTH).

2.2 | Recruitment of study participants

Participants were eligible if they were 18 years or older with known diagnosis of hypertension and/or type II diabetes presenting for routine care at either a general polyclinic (AGH, KMC, TTH) or a dedicated diabetes or hypertension clinic, (KATH, APH). Participants were excluded if they had hypertensive urgency or emergency or had glycemic complications at initial contact for enrollment. Informed consent was obtained from all consecutively enrolled participants.

2.3 | Evaluation of study participants

Trained Research Assistants interviewed study participants and collected demographic information such as age, gender,

educational attainment, employment status, number of dependents on monthly income and health expenditures. Information on lifestyle behaviors such as alcohol use, cigarette smoking, level of physical activities, frequency and daily quantities of fruits and vegetable consumption and table added salt was also recorded. The duration of hypertension or diabetes diagnosis was noted and compliance with hypertension treatment was assessed using the 14-item version of Hill-Bone compliance to high blood pressure therapy scale.[35] Stroke was self-reported if participant had ever experienced sudden onset of weakness or sensory loss on one side of the body, sudden loss of vision, or sudden loss of speech. Heart failure was self-reported if participant had ever experienced shortness of breath on exertion, on lying down and swelling of both feet. BP measurements were performed following a standardized operating procedure implemented across study sites. Anthropometric assessments performed by study nurses include measurement of weight and height for body mass index (BMI) derivation as well as waist circumference.

2.4 | Laboratory measurements

An International Organization for Standardization (ISO)-certified laboratory was contracted to analyze serum creatinine, lipid profile, and hemoglobin A1C for study participants.

2.5 | Systems strengthening activities at study sites

Study nurses at each site led educational programs on hypertension management by presenting materials on the need for adherence to therapeutic lifestyle and medications aimed at controlling hypertension. Furthermore, treatment guidelines were developed by local experts and used to train physicians on hypertension management. Supply chain systems were also strengthened to enhance availability of antihypertensive medications at hospital pharmacies.[34]

2.6 | Prospective evaluations

Study participants visited study sites every two months to have clinic BP measured for 18 months. At every clinic visit, physician decision to alter antihypertensive medications was recorded. Failure to intensify treatment when BP was uncontrolled was classified as therapeutic inertia and this was assessed post hoc. The Hill-Bone questionnaire was administered six monthly to assess adherence to therapy.

2.7 | Study outcome measures

The main outcome measure was serially measured clinic BP ≥ 140/90 mm Hg during follow-up as a dichotomized variable. Each clinic BP recorded for study participants during follow-up was scored 1 if ≥140/90 mm Hg or scored 0 if <140/90 mm Hg. Secondary outcomes were systolic and diastolic BPs as continuous variables.

2.8 | Statistical analysis

We investigated 24 potential factors for associations with poor BP control based on literature search, our understanding of the epidemiology of BP control and empirical evidence from our data. For baseline characteristics, means were compared using the Student's *t* test and proportions were compared using the chi-squared test or Fisher's exact test. A multivariate logistic regression analysis was fitted via generalized linear mixed models (GLMM) with a random intercept (to account for the repeated nature of the data and clustering by hospitals) to identify factors independently associated with the risk of clinic BP reading of ≥140/90 mm Hg. Independent variables evaluated included the following *socio-demographic factors*: age, gender, educational attainment, marital status, monthly income, employment status, dependents on household income and location of residence; *lifestyle/behavioral factors*: cigarette smoking, current alcohol use, physical activity, table added salt, fruit and vegetable intake, antihypertensive therapy adherence; *patho-biologic factors:* duration of hypertension diagnosis, co-morbid diabetes, number of antihypertensive medications, estimated glomerular filtration rate, waist circumference and diagnoses of stroke or cardiac failure; and finally *health system factors:* level of healthcare institution and availability of all prescribed antihypertensives on NHIS. The scores on Hill-Bone compliance to high blood pressure therapy scale assessed every 6 months were averaged. We constructed sequential models first to assess independent socio-demographic variables followed by patho-biologic and behavioral variables associated with primary and secondary outcome measures. In all analyses, two-tailed *P*-values <.05 were considered statistically significant. Secondary analysis considering SBP and DBP as continuous outcomes was also performed using linear mixed modeling to account for within-subject correlation of SBP and DBP and missing at random. Model diagnosis and fit were assessed using residual plots analysis. Statistical analysis was performed using SAS 9.4.

3 | RESULTS

3.1 | Demographic, lifestyle, and clinical characteristics of cohort at enrollment

Between July 1, 2015 and April 30, 2016, we enrolled 1867 (65%) participants with hypertension (HTN) and 1006 (35%) with both hypertension and diabetes (HTN + DM). Follow-up ended on July 31, 2017. There were significant differences in demographic characteristics between the HTN and HTN + DM groups as shown in Table 1. The mean ± SD duration of hypertension diagnosis among

the HTN + DM group of 9.1 ± 7.2 years was significantly longer than 7.2 ± 7.2 years among the HTN group, $P < .0001$. The HTN group were on an average of 2.2 ± 0.9 antihypertensive medications compared with 1.8 ± 0.9 among the DM + HTN group, $P < .0001$ with angiotensin-converting enzyme inhibitors and angiotensin receptor blockers being used more commonly among DM + HTN group than HTN group while calcium channel blockers and beta blockers were more commonly prescribed among HTN group compared with DM + HTN group. Among the HTN group, 57.1% reported having all medications for disease control covered by the national health insurance and 47.9% in the DM + HTN group. Monthly expenditures on medications were higher in the DM + HTN group than in the HTN group (Table 1).

3.2 | Blood pressure control during follow-up

During follow-up, there was a mean ± SD of 6.5 ± 3.0 BP recordings per participant. Out of 9 total study visits: 1084 (41.2%) attended all visits, 428 (16.3%) attended eight visits, 302 (11.5%) 7 visits, 217 (8.2%) attended 6 visits, 155 (5.9%) had 5 visits, and 447 (17.0%) attended 4 or less visits. Differences in baseline demographic characteristics of those who completed all study visits and those who missed some visits are shown in Table S1. The unadjusted mean ± SD systolic BP at enrollment of 143.5 ± 21.9 mm Hg significantly declined to 139.2 ± 22.7 mm Hg at month 6, 137.1 ± 21.9 mm Hg at month 12, and 136.6 ± 22.0 mm Hg at month 18. Adjusted mean ± SD reductions in SBP were −3.81 ± 0.52 mm Hg at month 6, −5.21 ± 0.55 mm Hg at month 12 and −5.53 ± 0.59 mm Hg at month 18. Similarly, DBP declined from 83.0 ± 18.3 mm Hg at month 0, to 80.7 ± 13.9 mm Hg at month 6, 79.5 ± 12.7 mm Hg at month 12 and 79.5 ± 12.6 mm Hg at month 18. Adjusted mean ± SD reductions in DBP were −1.74 ± 0.32 mm Hg at month 6, −2.59 ± 0.33 mm Hg at month 12 and −2.63 ± 0.35 mm Hg at month 18.

Overall, the proportion of study participants with target BP <140/90 mm Hg increased from baseline value of 46.3% to 54.5% at month 6, 58.6% at month 12 and 59.8% at month 18, $P < .0001$. Proportion of participants with optimal BP <120/80 mm Hg increased to 17.6% at month 6, 20.0% at month 12 and 21.0% at month 18 compared with baseline of 12.5% while those with stage II hypertension of 160/100 mm Hg declined from 22.7% at baseline to 17.7% at month 6, 14.1% at month 12 and 14.3% at month 18. Mean SBP and DBP at baseline and during follow-up declined for both those with hypertension only and hypertension plus diabetes as were the proportions with blood pressure readings at cut-offs of optimal, adequate, stages 1 and 2 for both groups as shown in Figure S1A-D.

3.3 | Adherence to treatment and failure to intensify antihypertensive treatment during follow-up

Adherence to hypertension therapy assessed using the Hill Bone antihypertensive adherence scale improved significantly from a score of 18.2 ± 4.0 at baseline (n = 2,783) to 16.8 ± 3.1 at month 6 (n = 2,329), 16.4 ± 2.8 at month 12 (n = 2,092), and 16.4 ± 2.8 (n = 1,570) at month 18, (lowest score of 14 indicates excellent adherence, highest score 56 indicate poor adherence). Physicians documented decisions whether or not they altered antihypertensive medication in the face of uncontrolled BP during clinic visit, as an indicator of therapeutic inertia. Among participants with uncontrolled BP, physicians changed antihypertensive medications at rates that varied between 8.6% and 19.8% of clinic visits with therapeutic inertia worsening over the course of 18 months (Shown in Figure S2A).

3.4 | Determinants of blood pressure control

Factors associated with poor BP control were assessed among a prospective cohort of 2632 participants with at least one BP measurement after baseline visit. Eight factors with adjusted OR (95% CI) independently associated with uncontrolled BP were male gender: 1.37 (1.09-1.72), secondary education: 1.32 (1.00-1.74), non-adherence to antihypertensive treatment: 1.03 (1.00-1.06), fruit intake: 0.94 (0.89-1.00), duration of hypertension diagnosis: 1.01 (1.00-1.02), hypertension with diabetes mellitus: 2.05 (1.72-2.46), number of antihypertensive medications prescribed: 1.63 (1.49-1.79) and increasing estimated glomerular filtration rate (each mL/min increase): 0.82 (0.76-0.89), Table 2. Furthermore, we identified 8 factors namely increasing age, male gender, primary level education, duration of hypertension, comorbid diabetes, increasing number of antihypertensive medications, eGFR, and heart failure were associated with systolic BP as a continuous variable while eight factors were associated with poor diastolic BP control, Table 2. We also assessed BP control per participant over the course of follow-up defined as number of clinic visits with BP ≥140/90 mm Hg divided by number of clinic visits during follow-up. Only 287 (10.9%) patients had BP controlled at all clinic visits (Figure S2B).

4 | DISCUSSION

We have identified 8 independent factors associated with poor control of prospectively measured BP among Ghanaians seeking health care at public hospitals. These include male gender and educational status (demographic factors), poor adherence to treatment and regularity of fruit intake (lifestyle/behavioral factors) and four patho-biologic factors namely, longer duration of hypertension, comorbid diabetes, higher number of antihypertensive medications and renal impairment. Several previous studies assessing factors associated with poor BP control have been based on BP measures obtained in a cross-sectional fashion and may be subject to the biases due to the inherent variability of blood pressure. For instance, we found receiving health care at a tertiary level, longer duration of hypertension, poor adherence to therapy, reported difficulties in obtaining antihypertensive medications and increasing number of antihypertensive medications to be the five factors associated with poor BP control in the same cohort

TABLE 1 Comparison of baseline demographic and clinical characteristics of study participants according to disease status

Characteristic	Hypertension (HPT) N = 1867	Hypertension and diabetes mellitus N = 1006	*P*-value
Age, mean ± SD	58.0 ± 13.0	60.0 ± 10.8	<.0001
Female, n (%)	1434 (76.9)	778 (77.4)	.77
Location of residence			
Urban	635 (34.1)	564 (56.1)	<.0001
Semi-urban	384 (20.6)	247 (24.6)	
Rural	843 (45.3)	195 (19.4)	
Highest educational status			
No formal education	743 (39.8)	361 (36.0)	.19
Primary level	294 (15.7)	172 (17.1)	
Secondary level	627 (33.6)	347 (34.6)	
Tertiary level or more	203 (10.9)	124 (12.4)	
Monthly household income			
>1000 Ghana cedis (GHc)	127 (9.2)	87 (12.6)	.0004
500-1000 GHc	153 (11.1)	109 (15.8)	
300-500 GHc	203 (14.8)	111 (16.1)	
210-300 GHc	120 (8.7)	57 (8.3)	
<210 GHc	773 (56.2)	325 (47.2)	
Level of health institution			
Tertiary referral level	765 (41.0)	781 (77.6)	.0001
Secondary/district level	936 (50.1)	217 (21.6)	
Primary level	166 (8.9)	8 (0.8)	
Vascular risk factors			
Duration of hypertension, (y)	7.2 ± 7.2	9.1 ± 7.2	<.0001
Duration of diabetes mellitus, mean ± SD (y)	NA	9.8 ± 7.2	NA
Systolic blood pressure at enrollment (mm Hg), mean ± SD	142.5 ± 21.3	145.3 ± 22.7	.001
Diastolic blood pressure at enrollment (mm Hg), mean ± SD	83.2 ± 13.1	81.8 ± 12.5	.005
Medical co-morbidities			
Previous stroke diagnosis	84 (4.5)	70 (7.0)	.005
Previous heart failure diagnosis	121 (6.5)	51(5.1)	.13
Lifestyle/Behavioral factors			
Current alcohol use	160 (8.6)	60 (6.0)	.01
Current cigarette smoking	9 (0.48)	5 (0.50)	.96
Previous cigarette smoking	111 (5.9)	86 (8.5)	.008
Fruit consumption			
Daily intake of fruits in a week, mean ± SD	2.54 ± 2.01	2.61 ± 2.01	.41
Fruit servings per day, mean ± SD	1.64 ± 1.68	1.69 ± 1.33	.42
Vegetable consumption			
Daily intake of vegetables in a week, mean ± SD	5.00 ± 2.20	4.86 ± 2.11	.10
Vegetable servings per day, mean ± SD	2.19 ± 1.60	2.28 ± 1.50	.15
Added salt at table			
Never	1491 (79.9)	866 (86.1)	<.0001
Rarely	157 (8.4)	42 (4.2)	
Occasionally	117 (6.3)	54 (5.3)	
Very often	101 (5.4)	44 (4.4)	

(Continues)

TABLE 1 (Continued)

Characteristic	Hypertension (HPT) N = 1867	Hypertension and diabetes mellitus N = 1006	*P*-value
Regular physical activity			
Participants engaged in physical activities daily	1,092 (58.5)	640 (61.5)	.008
Duration of time spent on physical activities in minutes, mean ± SD	18.2 ± 23.0	20.5 ± 23.9	.01
>60 min	141 (7.6)	88 (8.7)	.07
20-59 min	723 (38.7)	422 (41.9)	
<20 min	1,003 (53.7)	496 (49.3)	
Anthropometric indicators			
Waist circumference, mean ± SD	95.0 ± 13.2	98.2 ± 12.6	<.0001
Waist circumference elevated, n (%)	1,075 (57.9)	704 (70.1)	<.0001
Body mass index, mean ± SD	26.9 ± 5.9	26.7 ± 5.2	.42
Health expenditure indicators			
Monthly expenditure on medicines, mean ± SD (cedis)	34.1 ± 46.7	67.1 ± 81.9	<.0001
Travel cost to hospital, mean ± SD (cedis)	7.2 ± 12.7	9.2 ± 20.2	.001
Dependents on monthly household income, mean ± SD (cedis)	5.7 ± 4.3	5.5 ± 4.1	.14
Health insurance coverage for all medications, n (%)	1059 (57.1)	481 (47.9)	<.0001
Laboratory Indicators			
eGFR, mean ± SD	76.6 ± 15.4	74.4 ± 18.4	.003
Proportion with dyslipidemia, n (%)	220 (82.7)	212 (80.0)	.42
Antihypertensive Medications, mean ± SD	2.2 ± 0.9	1.8 ± 0.9	<.0001
Classes of Antihypertensive Medications			
Angiotensin-converting enzyme-inhibitor	770 (41.2)	471 (46.8)	.004
Angiotensin receptor blocker	427 (22.9)	363 (36.1)	<.0001
Beta blockers	218 (11.7)	55 (5.5)	<.0001
Calcium channel blocker	1,570 (84.1)	592 (58.8)	<.0001
Diuretics	732 (39.2)	159 (15.8)	<.0001
Methyldopa	282 (15.1)	163 (16.2)	.44
Hydralazine	22 (1.2)	21 (2.1)	.06

using only enrollment BP measures.[36] By using approximately seven BP measurements per participant with 18 months of follow-up, we have been able to characterize factors which may possibly be consistent predictors of poor hypertension control among patients under routine care settings and could be potential targets for remediation.

In addition to more frequent clinic visits during the study period for BP monitoring, participants also received educational sessions on hypertension as part of systems strengthening activities for the study. This may have accounted for the modest improvements in BP control during follow-up. Nearly, 46% of all hypertensive patients had controlled BP at enrollment[36] with salutary increment of up to 60% at month 18. Of note, adherence to antihypertensive treatment improved significantly during follow-up. In spite of these positive trends, there is still considerable room for improvement. Only 11% of study participants had BP under control at all clinic visits and a substantial majority had gradations of uncontrolled BP during follow-up. A notable observation was that between 30% and 45% of hypertensive patients presenting regularly to hospitals for routine follow-up had uncontrolled BPs, yet therapeutic modifications by physicians were very infrequent in this sub-group of patients. The contribution of therapeutic inertia to poor control of hypertension among Ghanaians is quite substantial and estimated to be between 80.2% and 91.4% of clinic visits. This observation is higher than 75% reported in previous studies conducted in Spain and China.[37-39] Clinical inertia and under-treatment of high-risk hypertensive patients has been associated with physician beliefs such as awaiting for full drug effect, patients almost near target, poor compliance, fear of side effects, poor BP measurement techniques or white-coat hypertension and lack of awareness of treatment guidelines occasionally.[40]

Although the high burden of undiagnosed and untreated hypertension in SSA remains a major challenge, treating patients with known hypertension to therapeutic goals represents an additional level of challenge in the fight against hypertension. The challenge of poorly controlled hypertension can be addressed by designing evidence-based interventions that are culturally attuned and

TABLE 2 Determinants of blood pressure control in a prospective Ghanaian cohort (Full models)

Determinants	Adjusted OR (95%CI) BP control (≥140/90 mm Hg)	Coefficient (95% CI) Mean systolic BP	Coefficient (95% CI) Mean diastolic BP
Socio-demographic			
Age	1.03 (0.95-1.12)	**0.81 (0.10-1.52)**	**−2.62 (−3.04 to −2.19)**
Male gender	**1.37 (1.09-1.72)**	**3.80 (1.83-5.77)**	0.42 (−0.75 to 1.59)
Education			
Tertiary	1.03 (0.79-1.33)	1.44 (−0.84 to 3.72)	1.26 (−0.10 to 2.61)
Secondary	**1.32 (1.00-1.74)**	0.68 (−1.91 to 3.27)	1.07 (−0.47 to 2.61)
Primary	1.06 (0.79-1.42)	**3.03 (0.61-5.46)**	**2.05 (0.61-3.49)**
None	1.00	0.00	0.00
Marital status			
Married	1.07 (0.85-1.35)	0.61 (−1.43 to 2.66)	0.68 (−0.53 to 1.89)
Divorced	1.02 (0.83 - 1.25)	0.42 (−1.37 to 2.20)	0.21 (−0.85 to 1.27)
Widow	0.67 (0.41-1.09)	−3.07 (−7.37 to 1.23)	−1.10 (−3.65 to 1.46)
Single	1.00	0.00	0.00
Income (per each 100 GHc rise)	1.02 (0.94-1.12)	0.73 (−0.04 to 1.51)	−0.12 (−0.59 to 0.34)
Unemployed	0.88 (0.73-1.06)	−0.97 (−2.59 to 0.65)	−0.90 (−1.86 to 0.06)
Dependents on household income	0.99 (0.97-1.01)	−0.08 (−0.26 to 0.10)	−0.06 (−0.16 to 0.05)
Location of residence			
Urban	1.15 (0.89-1.49)	0.86 (−1.16 to 2.89)	0.44 (−0.76 to 1.65)
Semi-urban	1.12 (0.88-1.41)	0.41 (−1.84 to 2.65)	1.17 (−0.16 to 2.50)
Rural	1.00	0.00	0.00
Lifestyle/Behavioral			
Any cigarette use	1.19 (0.28-5.14)	−0.15(−13.00 to 12.70)	−1.83 (−9.49 to 5.83)
Current alcohol use	0.86 (0.65-1.13)	−1.52 (−3.92 to 0.89)	0.54 (−0.89 to 1.97)
Physical activity	0.95 (0.81-1.12)	−0.64 (−2.02 to 0.75)	0.16 (−0.66 to 0.99)
Fruit intake (servings/d)	**0.94 (0.89-1.00)**	−0.41 (−0.91 to 0.09)	−0.24 (−0.54 to 0.05)
Vegetable intake (servings/d)	0.97 (0.91-1.03)	−0.15 (−0.66 to 0.37)	−0.10 (−0.41 to 0.21)
Salt intake	1.03 (0.82-1.30)	−0.05 (−2.06 to 1.97)	−0.48 (−1.68 to 0.72)
Adherence to Hypertension treatment	**1.03 (1.00-1.06)**	0.18 (−0.08 to 0.44)	**0.23 (0.08-0.39)**
Patho-biologic factors			
Duration of hypertension	**1.01 (1.00-1.02)**	**0.14 (0.03-0.24)**	0.05 (−0.01 to 0.11)
Hypertension with DM	**2.05 (1.72-2.46)**	**6.83 (5.26-8.39)**	**1.16 (0.23-2.09)**
Number of antihypertensives	**1.63 (1.49-1.79)**	**4.88 (4.07-5.68)**	**1.62 (1.14-2.09)**
Estimated GFR (mL/min rise)	**0.82 (0.76-0.89)**	**−2.02 (−2.65 to −1.38)**	**−0.50 (−0.88 to −0.12)**
Waist circumference	0.97 (0.91-1.03)	−0.49 (−1.00 to 0.03)	**0.82 (0.52-1.13)**
Heart failure	0.76 (0.56-1.04)	**−3.13 (−5.79 to −0.47)**	0.70 (−0.88 to 2.28)
Stroke	1.03 (0.74-1.43)	0.58 (−2.31 to 3.47)	1.01 (−0.71 to 2.72)
Organizational			
Antihypertensives covered by National Insurance	1.07 (0.92-1.25)	−0.25 (−1.60 to 1.09)	0.24 (−0.56 to 1.04)
Level of Health Institution			
Tertiary level	1.38 (0.85-2.23)	5.07 (0.70-9.44)	**−3.43 (−6.03 to −0.83)**
Secondary/district level	1.50 (0.90-2.48)	5.04 (0.89-9.18)	**−4.36 (−6.82 to −1.89)**
Primary	1.00	0.00	0.00

Bold indicate variables which attained significant independent associations with dependent variables.

sensitive to the local settings where patients are receiving care based on factors identified in the local population. For instance, patient-level factors associated with poor BP control such as male gender and educational level require further studies to unravel the unique contributors to poor control in these specific demographic sub-groups so interventions could be targeted to improve their BP control. We observed significant improvements in adherence to antihypertensive treatment during follow-up for the entire cohort for which we speculate could have due to the regular education given to patients at each visit. However, the fact that adherence scores measured every 6 months were better among those with BP on target than those not on target suggests that individual level rather than group educational intervention for the poorly adherent might improve adherence further. There is sufficient evidence of beneficial associations between high adherence to antihypertensive treatment and reduced risk of cardiovascular events.[41,42] Furthermore, the Dietary Approaches to Stopping Hypertension (DASH) diet has emphasized the importance of increasing fruit and vegetable intake while reducing the consumption of red meat.[43] In our cohort, a unit increase in fruit serving per week was associated with improved BP control over follow-up with an adjusted OR of 0.94 (95% CI: 0.89-1.00) and that for vegetable intake was 0.97 (0.91-1.03). Indeed, increased long-term fruit but not vegetable consumption was found to reduce the risk of developing hypertension from an analysis of 3 large prospective US cohorts.[44] A recent study has reported on a protective association between green leafy vegetable consumption and stroke occurrence among Ghanaians and Nigerians.[45,46]

The findings from our study have important public health ramifications. The WHO has identified hypertension in Africa as an epidemic and in 2015, the World Heart Federation set a key target of achieving a 25% relative reduction in the prevalence of raised blood pressure globally via enhanced awareness, detection, and control.[47] However, geopolitical, health-system, healthcare professional, and patient-related factors that hamper hypertension control require carefully crafted solutions to achieve these laudable goals. Universal health coverage across Africa to support patients with hypertension is a major challenge. In this vein, the widespread availability of national health insurance coverage policy for hypertension care in Ghana is a significant step forward and may have been contributory to the measure of success in controlling BP at public hospitals. Hence in our analyses, insurance coverage, health expenditures, household income, and other socio-economic indicators were not independent predictors of BP control. Having insurance coverage has been shown in the United States to be associated with improved BP control among hypertensive patients.[48] Furthermore, health system factors such as the level of health institution were not independent predictors of poor BP control, perhaps due to clustering effect of having standard study procedures across sites. Health professional level factors, in particular, therapeutic inertia is a major challenge and could be addressed by the implementation of clinical guidelines as only 16 (26%) of 62 African countries have clinical practice guidelines on hypertension.[31] Certainly, the paucity of physicians across SSA means that task shifting strategies such as the deployment of Community Health Nurses would be instrumental in overcoming some of the system-level barriers to hypertension management due critical shortage of skilled personnel.[49,50]

4.1 | Strengths and limitations

This is one of the few studies emanating from SSA to identify the determinants of poor BP control in a prospective cohort of hypertensive patients. There are some limitations worth mentioning. Although we observed significant improvements in clinic BP control over the course of follow-up, many participants found the two monthly visits difficult to comply with leading to attrition in follow-up. Hence, the improved outcomes might reflect healthy survivorship bias, however, our statistical approach accounted for the missing data. Many of the independent variables such as fruit intake and income levels were assessed only at baseline but could have changed during follow-up. The dynamics of such time-dependent variables could influence prospective BP control but these were not assessed in the present study.

5 | CONCLUSION

Modest improvements in BPs measured prospectively were observed in this Ghanaian cohort due probably to more frequent clinic visits, and patient education. Our study, conducted in a resource-limited setting has uncovered potential targets such as therapeutic inertia and specific demographic subgroups for which interventions aimed at improving BP control further may be directed.

CONFLICT OF INTEREST

The authors have the following competing interests: Funding for this study was provided by MSD, Pfizer, Sanofi (each a Participant company) and Bill and Melinda Gates Foundation (collectively, the funders) through the New Venture Fund (NVF). FSS, LMM, GB, DA, JPR, DOA, LA, JS received honoraria from NVF for participation in the present study. There are no patents, products in development or marketed products to declare.

AUTHOR CONTRIBUTIONS

Fred Stephen Sarfo, Linda M. Mobula, Gilbert Burnham, and David Ofori-Adjei involved in conceptualization. Daniel Ansong involved in data curation. Mulugeta Gebregziabher and Fred Stephen Sarfo involved in formal analysis. Fred Stephen Sarfo and Osei Sarfo-Kantanka involved in investigation. Fred Stephen Sarfo, Daniel Ansong, and Jacob Plange-Rhule involved in methodology. Lynda Arthur and Jasper Sablah involved in project administration. David Ofori-Adjei, Gilbert Burnham, Jacob Plange-Rhule, Daniel Ansong, and Edith Gavor involved in supervision. Fred Stephen Sarfo involved in writing-original draft. Linda M. Mobula, David Ofori-Adjei, and Jacob Plange-Rhule involved in writing-review and editing.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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