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Assessing body mass index stages, individual diabetes and hypertension history effects on the risk of developing hypertension among Ghanaians: A cross-sectional study

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Abstract

Background and Aims: This study aimed to understand the relationship between body mass index (BMI), diabetes and hypertension history, and other risk of hypertension among Ghanaians.

Methods: The BMI data are categorized according to the World Health Organization (WHO) definition. The data were obtained from the WHO Study on global AGEing and adult health (WHO SAGE) Ghana Wave 2. Descriptive statistics were used to summarize the variables, and the association between these variables and hypertension was assessed using the χ^2. Multivariable logistic regression was used to examine the relationship between hypertension and different BMI levels and other variables.

Results: Obesity class II individuals have about a 4-fold higher risk of developing hypertension compared to underweight individuals. Obesity class III, class I, and preobesity individuals have approximately a 3-fold higher risk. Normal weight is associated with increased hypertension risk. Both males and females show a significant increase in hypertension risk across all BMI categories. History of hypertension is linked to a 2.2-fold increased risk. Diabetes history is associated with hypertension when considering other factors. Elevated hypertension risk is observed among married, divorced, and widowed males then never married males. Only widowed females showed an increased risk. Older age significantly increases hypertension risk, particularly in females. Vegetable servings reduce hypertension risk, while fruit servings are associated with an increased risk. Vigorous exercise increases hypertension risk, particularly in females.

Conclusion: Regular check-ups are recommended for married, divorced, and widowed males, focusing on blood pressure (BP) levels. Regular exercise from young age helps lower BP in later years. Individuals with a history of hypertension should follow BP control measures. Encouraging the consumption of the right combination of vegetables and fruits can help lower BP. Female tobacco smoking should be strongly discouraged due to a 54% increased risk of developing hypertension.

KEYWORDS
blood pressure, body mass index, chi-square, diabetes, hypertension, multivariable logistic regression model, WHO SAGE wave 2

1 | INTRODUCTION

Hypertension and cardiovascular disease (CVD) remain significant causes of disability, morbidity, and mortality globally, despite the implementation of health policies and therapeutic advancements.[1,2] Primary and secondary prevention strategies focus on individuals with existing disease or risk factors, while primordial prevention aims to achieve population-level health.[3,4] The World Health Organization (WHO) emphasizes the importance of blood pressure (BP) control due to the high prevalence of CVD worldwide, where 31% of the population is affected, with heart disease and stroke being the most common outcomes.[5]

Similar to numerous African nations, Ghana experiences a relatively high prevalence of hypertension (HTN) at 30.1%.[6] HTN affects one in every four individuals in Ghana, contributing to 4.7% of total hospital admissions and 15.3% of related fatalities.[7] In addition to the imperative of enhancing screening efforts to identify individuals affected by these diseases, it is crucial to identify factors that may potentially trigger the occurrence of these diseases among susceptible individuals. Obesity is recognized as a major risk factor, and WHO considers high BP and obesity as serious concerns. Previous studies have identified various factors contributing to hypertension, including age, gender, smoking, exercise, family history, dietary habits, and body mass index (BMI).[8,9] Obesity rates have been steadily rising globally, including in Europe,[10] and it is a significant risk factor for chronic conditions such as hypertension, dyslipidemia, and type 2 diabetes.[11,12]

Several researchers[3] have undertaken studies to gain a deeper understanding of the correlation between different BMI levels and the evolving risk of hypertension throughout Italy. Dua et al.[13] conducted a cross-sectional study to examine the occurrence of overweight/obesity and hypertension, where the primary objectives were to investigate BP levels and body dimensions. On the other hand, Linderman et al.[14] investigated the heterogeneity in the association between BMI and BP across a wide variety of subgroups, where subgroup analysis was performed and linear regression model used to establish relationship between BMI and BP. Hossain et al.[15] conducted a study to investigate the connections between overweight, obesity, and hypertension, specifically focusing on the relationship between BMI and hypertension in different socioeconomic subgroups using a multiple logistic regression model. Similarly, Tang et al.[15] examined the association between BMI or dyslipidemia and the risk of hypertension and the authors used multiple logistic regression to estimate the impacts of BMI and dyslipidemia on the occurrence of hypertension.

Aheto et al.[16] conducted a study in Ghana to identify crucial risk factors for hypertension, using data from WHO SAGE, where a multilevel regression statistical model was employed and BMI was classified as binary; obese or not obese. Oyekale et al.[17] conducted a study in Ghana to investigate the impact of BMI/arm circumference and other related factors on the risk of hypertension among female of reproductive ages using an instrumental probit regression model, taking into account the potential endogeneity of BMI and arm circumference. Furthermore, Afrifa et al.[18] evaluated the levels of BP and investigated their associations with physical activity (PA) and BMI among urban poor youth in Accra, Ghana, where a multiple linear regression model was used to identify the factors that influenced BP levels. Conversely, Dai et al.[19] investigated the prevalence of hypertension and its associated risk factors among older adults in Ghana, utilizing cross-sectional data from the WHO SAGE, Wave 1, where a logistic regression model was used.

The objective of this study is to enhance our understanding on the association between different stages of BMI, hypertension, and diabetes history versus hypertension risk. The key hypotheses that derive this study are (1) a particular BMI stage can robustly predict hypertension status among Ghanaians, (2) individual hypertension and diabetes history is associated with risk of developing hypertension, and (3) Risk of developing hypertension differ between never married, currently married, cohabiting, divorced, and windowed males and females.

2 | METHODS

This section provides a concise overview of the data, including a brief description. We delve into the outcome variable examined in this study, along with the measurement scales of variables that are considered as potential risk factors associated with the outcome variable. Furthermore, we present the methods employed for modeling the outcome variable. Our model formulation adopts the multivariable logistic regression model,[20,21] allowing us to identify predictors of hypertension and their effects on hypertension risk of occurrence among Ghanaians. We also, investigate the association and influence of an individual diabetes and hypertension history on current hypertension status using the χ^2 test.[22–24]

2.1 | Data and variables definitions

The data used in this study are obtained from the World Health Organization Study on global AGEing and adult health (SAGE) Ghana Wave 2, which was conducted in 2014/2015. These data collection was completed in 2014/2015 and data were released in the public domain in 2020,[25] release of Wave 3 data is still pending (https://

www.who.int/data/data-collection-tools/study-on-global-ageing-and-adult-health/sage-waves). WHO's SAGE is a longitudinal study collecting data on adults aged 50 years and older, plus a smaller comparison sample of adults aged 18–49 years, from nationally representative samples in China, Ghana, India, Mexico, Russian Federation, and South Africa. The data for this study consisted of sample size $n = 4687$ Ghanaians who were at least 18 years old. To analyze the data and identify predictors of hypertension, the logistic regression model was employed. We also used the χ^2 test to investigate association between the binary outcome variable and the categorical variables being studied as potential predictors. The analysis of covariance is used to assess significance difference in systolic and diastolic BP across the different levels BMI as well as individual diabetes and hypertension history on the risk of hypertension.

2.1.1 | Outcome variable

The outcome variable used in this study is the dichotomous hypertension variable. To determine hypertension status of a subject in this study, we used the systolic and diastolic BP measurements. These measurements were recorded repeatedly, for each subject, three times (with 1 min between each measurement) at the same visit. As a common practice among medical practitioners, we used the mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) to classify study subjects as hypertensive or not. Hypertension, as defined by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High BP (JNC7), is characterized by a SBP of 140 mmHg or higher and a DBP of 90 mmHg or higher.[26] These values are widely accepted as diagnostic criteria for hypertension in various reports and guidelines.[26–28] The condition of hypertension occurs when the force of blood against the arterial walls surpasses the normal BP levels.[29] SBP represents the pressure exerted on the arteries during heartbeats, while DBP represents the pressure during resting phases. Alternative guidelines suggest that hypertension should be defined as BP consistently exceeding 130/80 mmHg. The World Health Organization (WHO)[30] defines hypertension (high BP) as when the pressure within the blood vessels reaches or exceeds 140/90 mmHg.[29,31] In this study, we classified subjects as hypertensive if SBP is ≥140 and SBP ≥ 90.[21] The hypertension variable (HTN) takes the values of 1 if SBP is ≥140 and DBP ≥ 90 and 0 otherwise.

2.1.2 | Potential risk factors

This study considers several risk factors as potential risk factors of hypertension. Nevertheless, in-depth analysis and conclusions will solely rely on the noteworthy risk factors derived from the final or most accurate model. For the BMI variable (BMI), the data contain measurement on height in cm and weight in kg measurements which we have used to calculate the BMI by dividing the weight in kilograms by height in meters squared. Based on the BMI estimates and according to the BMI cutoffs recommended by the WHO,[32] we classify subject weight as underweight, normal, preobesity, and obesity if BMI ranges from <18, 18.5–24.9, 25–29.9, >30 kg/m^2, respectively. We classified obesity into class I (30–34.00 kg/m^2), class II (35–39.99 kg/m^2), and class III (>40 kg/m^2). This study investigates for BMI category that is likely to predict hypertension among Ghanaians. The BMI variable takes the values of 0, 1, 2, 3, or 4 if BMI is classified as normal, overweight, obesity class I, class II, or class III, respectively.

Other variables investigated as potential predictors of hypertension among Ghanaians are individual's diabetes and hypertension history. The diabetes history variable (DM) takes the values of 1 if study participant has ever been diagnosed with diabetes (high blood sugar) or 0 if never. The hypertension history variable (HTNhis) takes the values of 1 if study participant has ever been diagnosed with hypertension (high BP) or 0 if never.

Ages of the study participants were collected quantitatively. In this study, we categorized age into older and young age using the United Nations definition that an older person is a person who is over 60 years of age.[33] So the age variable (takes values of 1 if age is 60 years and above and 0 if age is less than 60 years), gender (takes value of 1 if male or 0 if female), marital status (ms) (takes the value of 0 if never married, 1 if currently married, 2 if cohabiting, 3 if divorced, or 4 if widowed), ever been to school (sch) (1 if yes or 0 if no), ever smoked tobacco (smok) (1 if yes or 0 if no), ever consumed alcohol (alcho) (1 if yes or 0 if no), work involves vigorous exercise (vigex) (1 if yes or 0 if no), ever diagnosed with angina (ang) (1 if yes or 0 if no), ever diagnosed with asthma (asthm) (1 if yes or 0 if no), chronic lung disease (cld) (1 if ever been diagnosed with chronic lung disease [emphysema, bronchitis, COPD]), injuries (inj) (1 if ever involved in road traffic accident or 0 if no), trusted person (trst) (1 if participant has someone he/she can trust or confine in or 0 if no), fruits servings (frtsv) (1 if fruits servings is at least two cups per day or 0 if fruits servings is less than two cup served per day), and vegetable servings (vegsv) (one if vegetable servings is at least two cups per day or zero if fruits servings is less than two cup served per day). Descriptive statistics of these variables including the outcome variable are shown in Tables 1 and 2.

2.2 | Statistical methods

The outcome variable (hypertension) is binary and hence we model the relationship between the outcome variable and the risk factors using the multivariable logistic regression model.[16,17] The logistic regression model is used to model binary outcome variables where the log odds of the outcomes are modeled as a linear combination of the risk factors.

Let $y_i = (y_1, y_2, \ldots, y_n)$ denotes an n-dimensional vector of the binary hypertension variable for the i^{th} subject. The outcome variable y_i is recorded for each subject $i, i = 1, \ldots, n$. In this study, all measurements were observed, there is no missing values.[34–36] This

TABLE 1 Descriptive statistics of variables used in this study ($n = 4687$ subjects).

Risk factor	*n* (%)
Hypertension (HTN)	
Yes (1: systolic blood pressure [SBP] ≥ 140/ diastolic blood pressure [DBP] ≥ 90)	1536 (32.77)
No (0: SBP < 140/DBP < 90)	3151 (67.23)
Ever been diagnosed with chronic lung disease (cld)?	
Yes (coded 1)	26 (0.55)
No (coded 0)	4,661 (99.45)
Ever been diagnosed with asthma (asthm)?	
Yes (coded 1)	158 (3.37)
No (coded 0)	4529 (96.63)
Ever been diagnosed with hypertension (HTNhis)?	
Yes (coded 1)	549 (11.71)
No (coded 0)	4138 (88.29)
Ever been diagnosed with diabetes (DM)?	
Yes (coded 1)	163 (3.48)
No (coded 0)	4524 (96.52)
Ever had injuries from car accident (inj)?	
Yes (coded 1)	78 (1.66)
No (coded 0)	4609 (98.34)
Ever been diagnosed with angina (ang)?	
Yes (coded 1)	139 (2.97)
No (coded 0)	4548 (97.03)
Gender (gender)	
Male (coded 1)	2482 (52.95)
Female (coded 0)	2205 (47.05)
Marital status (ms)	
Never married (coded 0)	134 (2.86)
Currently married (coded 1)	2760 (58.89)
Cohabiting (coded 2)	59 (1.26)
Divorced (coded 3)	616 (13.14)
Widowed (coded 4)	1118 (23.85)
Ever been to school?	
Yes (coded 1)	2325 (49.61)
No (coded 0)	2362 (50.39)
Age group (age)	
Yes (coded 1: >60 years)	2167 (46.23)
No (coded 0: ≤60 years)	2520 (53.77)
Have you ever smoked tobacco (smok)?	
Yes (coded 1)	1149 (24.51)
No (coded 0)	3538 (75.49)

TABLE 2 Descriptive statistics of variables used in this study ($n = 4687$ subjects) cont....

Risk factor	*n* (%)
Body mass index (BMI) category	
Underweight (coded 0: <18 kg/m^2)	531 (11.33)
Obesity class III (coded 1: >40 kg/m^2)	67 (1.43)
Obesity class II (coded 2: 35–39.99 kg/m^2)	138 (2.94)
Obesity class I (coded 3: 30–34.00 kg/m^2)	271 (5.78)
Preobesity (coded 4: 25–29.9 kg/m^2)	916 (19.54)
Normal (coded 5: 18.5–24.9 kg/m^2)	2764 (58.97)
Have you ever consumed alcohol (alcho)?	
Yes (coded 1)	2733 (58.31)
No (coded 0)	1954 (41.69)
Have someone you can trust (trst)?	
Yes (coded 1)	3691 (78.75)
No (coded 0)	996 (21.25)
Your work involves vigorous exercise (vigex)?	
Yes (coded 1)	2219 (47.34)
No (coded 0)	2468 (52.66)
Number of times Vegetables served per day (vegsv)	
≥2 cups (coded 1)	1028 (21.93)
<2 cups (coded 0)	3659 (78.07)
Number of times fruits served per day (frtsv)	
≥2 cups (coded 1)	1267 (27.03)
<2 cups (coded 0)	3420 (72.97)

study focuses on how the risk of hypertension is affected by the $\mathbf{X}_i$, an $n \times p$ design matrix of risk factor for the ith subject. The general form of the logistic regression model $\sqrt{38 \mid 39}$ can be written as

$$\begin{aligned}\text{logit}\left(E\left(y_i = \pi_i = 1 \mid X_i\right)\right) &= \log\left(\frac{\pi_i}{1-\pi_i}\right) \\ &= \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi},\end{aligned} \tag{1}$$

where β is a $p \times 1$ vector of the fixed effects; which represents the effects of the risk factors on the hypertension, π_i is the probability of having hypertension. From model (1), our potential logistic mixed model to be fitted can be written as

$$\begin{aligned}\log\left(\frac{\pi_i}{1-\pi_i}\right) = {} & \beta_0 + \beta_1 \times \text{cld}_i + \beta_2 \times \text{asthm}_i + \beta_3 \times \text{HTNhis}_i \\ & + \beta_4 \times \text{DM}_i + \beta_5 \times \text{inj}_i + \beta_6 \times \text{ang}_i \\ & + \beta_7 \times \text{gender}_i + \beta_8 \times \text{age}_i + \beta_9 \times \text{ms}_i \\ & + \beta_{10} \times \text{sch}_i + \beta_{11} \times \text{smok}_i + \beta_{12} \times \text{alcho}_i \\ & + \beta_{13} \times \text{vigex}_i + \beta_{14} \times \text{vegsv}_i + \beta_{15} \times \text{frtsv}_i \\ & + \beta_{16} \times \text{trst}_i + \text{b}_{0i} + \epsilon_i.\end{aligned} \tag{2}$$

First, we assessed statistical significance of the association between the outcome (HTN) and the covariates using STATA version 14. In STAT, we used the command "tab binary outcome variable binary covariate, chi row" to produced results that displayed percentages along with numerator and denominator used in deriving them as well as the χ^2 and p-values. For example, in this study the outcome variable is HTN and consider a covariate asthma, then the command to produce the χ^2 results would be "tab HTN asthm, chi row" and so on. The logistic regression model (2) was fitted using R version 3.3.1, using the glm function with the command *glm(outcome variable ~ covariate 1 + covariate 2 + … + covariate p, data = data name, family = binomial(link = "logit"). All statistical test were conducted under the hypothesis of significance difference (two-sided test).*

3 | ANALYSIS AND RESULTS

This section presents descriptive statistics of the variables in the data and then performed bivariate analysis of hypertension and each of the categorical risk factors using the χ^2 test[18–20] of association. In this study, we used the logistic model[16,17] to estimate the likelihood of BMI (bmi), diabetes (DM), and hypertension (HTNhis) history in predicting current hypertension (HTN) after adjusting for other risk factors.

3.1 | Descriptive statistics

Tables 1 and 2 show that out of the total number of 4687 Ghanaians in the study, 1536 (32.77%) are classified as hypertension and 3151 (67.23%) no hypertension. The percentage distributions showed that only 26 (0.55%) of the study subjects have ever been diagnosed with chronic lung disease and 4661 (99.45%) has never been diagnosed with chronic lung disease. About 158 (3.37%) subjects have ever been diagnosed with asthma and 549 (11.71%) have hypertension history.

Study subjects with history of diabetes are 164 (3.48%) and 78 (1.66%) of the subjects have ever had injuries through car accident. 139 (2.97%) of the study subjects have ever been diagnosed with angina and out of the sample of 4687, 2482 (52.95%) are males and 2205 (47.05%) are females. High proportion, 2760 (58.89%), of the study participants are currently married, followed by 1118 (23.85%), 616 (13.14%), 134 (2.86%), and 59 (1.26%) are widowed, divorced, never married, and cohabiting respectively. The proportion 2362 (50.39%) of those who have never been to school is approximately equal the proportion, 2325 (49.61%), of those who have ever been to school. We observed that small proportion, 1149 (24.51%), of the study subjects ever smokes tobacco compared with a higher proportion 3538 (75.49%) of those who never smoke tobacco. Majority, 2733 (58.31%), of the study subjects ever consume alcohol and 2219 (47.34%) of the study participants work involves vigorous exercise. Two thousand hundred and sixty-seven (46.23%) of the study participants are 60 years old and those are 60 years old and below represents 2520 (53.77%). High proportion of the study subjects have normal BMI followed by preobesity, underweight, class I, class II and then class III. High proportion 3691 (78.75%) of the study subject responded that they have someone they can truest and can confined in. The statistics also showed that low proportion, 1028 (21.93%), of the study participants have vegetables servings at least two cups per day. Those who have fruits serving at least two cups per day is lower, 1267 (27.03%), then those who have less than two cups per day.

3.2 | Bivariate analysis of current hypertension (HTN) versus risk factors

In this section, we performed bivariate analysis between the binary current hypertension variable (HTN) and versus categorical variables. In this analysis, we used the Chi-Square test of association to test for significance of association between the two variables (binary response vs. categorical risk factors). The results of the bivariate analysis are presented in shown in Table 3. The results indicate that these variables are significantly associated with the hypertension. Alternatively, an individual hypertension status is significantly associated with whether such individual has ever been diagnosed with hypertension, diabetes, consumed alcohol, and had injuries due to car accident. The Chi-Square results also indicate that an individual hypertension status is significantly associated with gender, marital status, age group, and BMI category defined by WHO.[32]

3.3 | Logistic regression model

In this section, we identify BMI category(ies) that is/are more likely to predict hypertension status among Ghanaians. We also investigate the risk of hypertension among Ghanaians who have hypertension and diabetes history and are expose to other risk factors. We achieve this using the logistic regression model.[16,17] The logistic regression model takes the form described in Equation (2). We present univariate and multivariable results from the logistic regression model in Table 4.

The results indicate that all BMI stages/categories are associated with an increased risk of hypertension, as shown by both the unadjusted odds ratio (UnOR) and adjusted odds ratio (AOR). Specifically, when considering both UnOR and AOR estimates, we observed that Ghanaians classified as obesity class II are approximately four times more likely to develop hypertension. This means that obesity class II strongly predicts hypertension status, with a 300% increased risk. On the other hand, Ghanaians with a BMI classified as normal have only a 49% chance of developing hypertension. Obesity class III, class I, and pre-obesity also increase the risk of hypertension by approximately 3-fold.

Subgroup analysis of males versus females are shown in Table 5. It can be observed that obesity class III is associated with 8.3-fold increase in the risk of hypertension and approximately 4-fold increase

TABLE 3 Bivariate analysis of hypertension and potential risk factors.

Risk factor	Hypertension		*p*-Value
	HTN (0: systolic blood pressure [SBP] < 140/diastolic blood pressure [DBP] < 90)	HTN (1: systolic blood pressure [SBP] ≥ 140/diastolic blood pressure [DBP] ≥ 90)	
Ever been diagnosed with hypertension (HTNhis)?			
Yes (1)	253 (8.03)	296 (19.27)	<0.001
No (0)	2898 (91.97)	1240 (80.73)	
Ever been diagnosed with diabetes (DM)			
Yes (1)	87 (2.76)	76 (4.95)	<0.001
No (0)	3064 (97.24)	1460 (95.05)	
Ever has injury through car accident (inj)?			
Yes (1)	62 (1.97)	16 (1.04)	0.020
No (0)	3089 (98.03)	1520 (98.96)	
Gender (gender)?			
Male (1)	1724 (54.71)	758 (49.35)	<0.001
Female (0)	1427 (45.29)	778 (50.65)	
Marital status (ms)?			
Never married (0)	107 (3.40)	27 (1.76)	<0.001
Currently married (1)	1935 (61.41)	825 (53.71)	
Cohabiting (2)	50 (1.59)	9 (0.59)	
Divorce (3)	405 (12.85)	211 (13.74)	
Widowed (4)	654 (20.76)	464 (30.21)	
Age group (age)?			
>60 (1)	1353 (42.94)	814 (52.99)	<0.001
≤60 (0)	1798 (57.06)	722 (47.01)	
Ever consumed alcohol (alcho)?			
Yes (1)	1873 (59.44)	860 (55.99)	<0.024
No (0)	1278 (40.56)	676 (44.01)	
Number of times fruits served per day (frtsv)?			
≥2 (1)	794 (25.20)	473 (30.79)	<0.001
<2(0)	2357 (74.80)	1063 (69.21)	
BMI category (BMI)			
Underweight (coded 0: <18 kg/m^2)	414 (13.14)	117 (7.62)	<0.001
Obesity class III (coded 1: >40 kg/m^2)	39 (1.24)	28 (1.82)	
Obesity class II (coded 2: 35–39.99 kg/m^2)	68 (2.16)	70 (4.56)	
Obesity class I (coded 3: 30–34.00 kg/m^2)	149 (4.73)	122 (7.94)	
Preobesity (coded 4: 25–29.9 kg/m^2)	536 (17.01)	380 (24.74)	
Normal (coded 5: 18.5–24.9 kg/m^2)	1945 (61.73)	819 (53.32)	

for obesity class II and I among males. Even pre-obesity and normal weight, respectively, results in 3.1- and 1.8-fold increase in the risk of developing hypertension among the males. Among the females' group, obesity class III does not significantly predict hypertension despite increase risk. Obesity class II is associated with approximately 4-fold increase in the risk of hypertension, similar to the elevated risk observed among the males. Among the females, obesity class I, pre-obesity and normal weight are respectively associated with 2.9-, 2.7-,

TABLE 4 Unadjusted and adjusted odds ratio from the logistic regression model.

	Unadjusted odds ratio (OR)				Adjusted OR			
Parameter	**OR**	**SE**	**95% confidence interval (CI)**	***p*-Value**	**OR**	**SE**	**95% CI**	***p*-Value**
Ever been diagnosed with hypertension (HTNhis)?								
No (Ref)	-	-	-	-	-	-	-	
Yes	2.73	0.252	(2.283–3.275)	<0.001	2.19	0.217	(1.806–2.660)	<0.001
Ever been diagnosed with diabetes (DM)?								
No (Ref)	-	-	-	-	-	-	-	
Yes	1.83	0.294	(1.339–2.510)	<0.001	1.22	0.210	(0.871–1.709)	0.248
Ever had injury through road accident (inj)?								
No (Ref)	-	-	-	-	-	-	-	
Yes	0.52	0.148	(0.302–0.912)	0.022	0.53	0.156	(0.300–0.945)	0.031
Gender								
Female (Ref)	-	-	-	-	-	-	-	
Male	0.80	0.050	(0.714–0.911)	<0.001	1.12	0.089	(0.960–1.311)	0.149
Marital status (ms)								
Never (Ref)	-	-	-	-	-	-	-	
Currently married	1.69	0.371	(1.099–2.597)	0.017	1.42	0.319	(0.917–2.206)	0.115
Divorce	2.07	0.478	(1.312–3.250)	0.002	1.70	0.404	(1.069–2.712)	0.025
Widowed	2.81	0.629	(1.813–4.359)	<0.001	2.26	0.527	(1.432–3.570)	<0.001
Age group (age)								
≤60 (Ref)	-	-	-	-	-	-	-	
>60	1.49	0.094	(1.325–1.694)	<0.001	1.48	0.104	(1.288–1.696)	<0.001
Ever consumed alcohol (alcho)?								
No (Ref)	-	-	-	-	-	-	-	
Yes	0.87	0.055	(0.767–0.982)	0.025	0.94	0.063	(0.821–1.069)	0.331
Number of fruits served per day?								
<2 cups (Ref)	-	-	-	-	-	-	-	
≥2 cups	1.32	0.091	(1.154–1.512)	<0.001	1.36	0.103	(1.1670–1.574)	<0.001
Body mass index category (BMI)								
Underweight (coded 0: <18 km/m^2) (Ref)	-	-	-	-	-	-	-	
Obesity class III (coded 1: >40 kg/m^2)	2.54	0.683	(1.500–4.303)	<0.001	2.69	0.748	(1.556–4.638)	<0.001
Obesity class II (coded 2: 35–39.99 kg/m^2)	3.64	0.728	(2.462–5.389)	<0.001	3.81	0.803	(2.520–5.759)	<0.001
Obesity class I (coded 3: 30–34.00 kg/m^2)	2.90	0.466	(2.114–3.971)	<0.001	3.17	0.537	(2.276–4.421)	<0.001
Preobesity (coded 4: 25–29.9 kg/m^2)	2.51	0.312	(1.966–3.201)	<0.001	2.76	0.360	(2.137–3.563)	<0.001
Normal (coded 5: 18.5–24.9 kg/m^2)	1.49	0.167	(1.195–1.858)	<0.001	1.63	0.189	(1.299–2.046)	<0.001
Work involves vigorous exercise?								
No (Ref)	-	-	-	-	-	-	-	
Yes	-	-	-	-	1.26	0.087	(1.101–1.44)	<0.001
Number of vegetables served per day								
<2 (Ref)	-	-	-	-	-	-	-	
≥2	-	-	-	-	0.79	0.066	(0.667–0.926)	0.004

TABLE 5 Subgroup (male and female) analysis odds ratio from the logistic regression model.

Parameter	Male				Female			
	Odds ratio (OR)	SE	95% confidence interval (CI)	*p*-Value	OR	SE	95% CI	*p*-Value
Ever been diagnosed with hypertension (HTNhis)?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	2.66	0.414	(1.957–3.607)	<0.001	2.27	0.296	(1.757–2.930)	<0.001
Marital status (ms)								
Never married (Ref)	-	-	-	-	-	-	-	-
Currently married	2.49	0.916	(1.213–5.124)	0.013	0.89	0.266	(0.497–1.600)	0.702
Cohabiting	-	-	-	-	0.17	0.136	(0.036–0.812)	0.026
Divorce	3.80	1.509	(1.742–8.274)	<0.001	0.94	0.289	(0.518–1.721)	0.851
Widowed	4.16	1.704	(1.864–9.284)	<0.001	1.31	0.390	(0.727–2.345)	0.372
Age group (age)								
≤60 (Ref)	-	-	-	-	-	-	-	-
>60	1.335	0.126	(1.109–1.607)	0.002	1.53	0.169	(1.236–1.903)	<0.001
Number of cups of fruits served per day?								
<2 cups (Ref)	-	-	-	-	-	-	-	-
≥2 cups	1.462	0.148	(1.199–1.785)	<0.001	1.32	0.148	(1.058–1.642)	<0.014
Body mass index category (BMI)								
Underweight (coded 0: <18 km/m^2) (Ref)	-	-	-	-	-	-	-	-
Obesity class III (coded 1: >40 kg/m^2)	8.28	3.786	(3.382–20.290)	<0.001	1.45	0.549	(0.689–3.046)	0.329
Obesity class II (coded 2: 35–39.99 kg/m^2)	4.05	1.564	(1.903–8.633)	<0.001	3.93	1.035	(2.344–6.582)	<0.001
Obesity class I (coded 3: 30–34.00 kg/m^2)	4.50	1.233	(2.626–7.696)	<0.001	2.87	0.642	(1.850–4.446)	<0.001
Preobesity (coded 4: 25–29.9 kg/m^2)	3.09	0.593	(2.125–4.504)	<0.001	2.72	0.498	(1.902–3.895)	<0.001
Normal (coded 5: 18.5–24.9 kg/m^2)	1.82	0.307	(1.305–2.532)	<0.001	1.60	0.263	(1.162–2.211)	0.004
Work involves vigorous exercise?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	-	-	-	-	1.41	0.142	(1.158–1.719)	<0.001
Ever had injury through car accident?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	-	-	-	-	0.40	0.174	(0.170–0.939)	0.037
Ever been to school?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	-	-	-	-	0.80	0.087	(0.649–0.993)	0.043
Ever smoke tobacco?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	-	-	-	-	1.54	0.264	(1.104–2.159)	0.011
Number of cups of vegetables served per day?								
No (Ref)	-	-	-	-	-	-	-	-
Yes	-	-	-	-	0.73	0.088	(0.577–0.926)	0.010

and 1.6-fold increase in the risk of hypertension. The risks of developing hypertension associated with pre-obesity and normal weight are similar among males and females. Significant elevated risk is observed across all the stages of BMI with the exception of obesity class III for females' group.

The unadjusted odds ratio (UnOR) for an individual's history of hypertension reveals that having a hypertension history is associated with a 3-fold increase in the risk of hypertension compared to those without a history of hypertension. After adjusting for other risk factors, the adjusted odd ratio (AOR) indicates that individuals with a history of hypertension still face a 2-fold increase in the risk of developing hypertension. The subgroup analysis revealed that there is approximately 3-fold increase in the risk of hypertension among males and approximately 2-fold increase among females. The risk is more elevated among males compared with females.

Ghanaians with a history of diabetes have a 1.83-fold higher risk of developing hypertension compared to those without diabetes. However, when other risk factors are taken into account, an individual's history of diabetes does not significantly predict their hypertension status, despite a 1.2-fold increase in the risk of hypertension. History of diabetes is not associated with hypertension in both males and females.

Both the UnOR and AOR results suggest a significant decrease in the risk of developing hypertension among individuals who have experienced car accident injuries. The subgroupd analysis revealed that injury is not a significant predictor of hypertension among males but have shown to significantly reduce risk of hypertension by 60% among females.

Additionally, a significant reduction in the risk of hypertension is observed among males compared to females. However, after considering other risk factors for hypertension, this reduction in risk becomes statistically insignificant.

In our observations, we found that currently married Ghanaians have a 1.69-fold increased risk of developing hypertension, while divorced individuals have a 2.07-fold increased risk, and widowed individuals have a 2.81-fold increased risk. Specifically, the risk of developing hypertension is approximately three times higher among widowed individuals. However, after accounting for other risk factors, the AOR for currently married individuals is no longer statistically significant, despite a 1.42-fold increased risk. On the other hand, the AORs for divorced and widowed individuals indicate an approximate 2-fold increased risk of developing hypertension. The subgroup analysis in Table 5 showed that there is approximately 4-fold increase in the risk developing hypertension among male who are windowed and divorced. Windowed females have insignificantly 1.3-fold increase in the risk of developing hypertension and approximately 6% reduced risk among divorced females. The results also revealed that males who are currently married has 2.5-fold increase in the risk of developing hypertension but insignificant reduced risk among currently married females. females who are cohabiting has a significant reduced risk of hypertension relative to those who have never married. The results indicate that currently married, divorced and windowed males have elevated risk of developing hypertension relative to males who have never married. On the other hand, currently married, cohabiting, and divorced females have reduced risk of developing hypertension relative to never married female with the exception of windowed females who have 30% insignificant increase in the risk of developing hypertension.

Being in the older age group (60 years and above) is linked to a 1.5-fold increased risk of developing hypertension. After accounting for other risk factors, the risk of hypertension is still elevated, with a 1.47-fold increase. Using the subgroup analysis, we discovered that older females have elevated risk of developing hypertension compared with males, representing approximately 53% and 34% increased risk of hypertension in females and males respectively.

Alcohol consumption is linked to a reduction of approximately 13% in the risk of developing hypertension. This association becomes statistically insignificant, with a 6% reduction, after accounting for other risk factors. Alcohol was not statistically significant in the subgroup analysis.

Both the UnOR and AOR estimates indicate a 1.32- and 1.36-fold increased risk of developing hypertension among participants who reported consuming at least 2 cups of fruits servings per day, respectively. Fruits serving increases the risk hypertension in both males and females.

Vigorous exercise and vegetables servings per day were not significant predictors of hypertension under the univariate model. However, these variables become significant after adjusting for other risk factors. The AORs indicate that there is 26% increased risk of hypertension among those whose work involves vigorous exercise and 21% reduced risk of developing hypertension among those whose have at least 2 cups of vegetables servings per day. There is no significant association between developing hypertension and those whose work involves vigorous exercise. However, vigorous exercise among females is significantly associated with 1.4-fold increase risk of hypertension. Vegetable servings on the other hand reduces risk of developing hypertension by approximately 27% among the females. However, this is not statistically significant among the males group.

Ever been to school and ever smoke tobacco where not statistically significant in the general population of study participants. However, the subgroup analysis, in Table 5, reported a 20% reduced risk of developing hypertension among females who has ever been to school and approximately 54% increased risk of hypertension among females who has ever smoke tobacco.

As highlighted in various studies,[21,37–39] SBP plays a crucial role in determining high BP (hypertension). Exploratory analyses of the SBP is presented in Figure 1, which displays box-and-whisker plots representing the mean SBP and DBP across different BMI stages. Notably, the median values of mean SBP and DBP for individuals classified as obesity class II are above 140 (as indicated by the horizontal brown line) and 90 (as indicated by the horizontal blue line), respectively. In contrast, the median values for the other BMI stages are below 140, except for obesity class I, where the median value is slightly above 140. Among the 1945 participants classified as

having a normal BMI, the median SBP value is significantly lower than 140, indicating a lower risk of hypertension as indicated by the results in Table 4. The elevated SBP values observed in obesity class II and III contribute to an increased risk of high BP (hypertension) (see Table 4). These findings suggest that maintaining a lower SBP is protective against the development of hypertension.

The mean profiles of SBP and DBP across different BMI categories, measured at 1-min intervals, are depicted in Figure 2. It is evident that the mean profiles for obesity class II and class I (both SBP and DBP) consistently exceed 140 (represented by the horizontal blue-dash line) and 90 (represented by the horizontal blue-dash line), respectively, throughout the measurement periods.

This indicates a high risk of developing hypertension associated with these BMI categories, as already established in Table 4. In the case of preobesity, all DBP values surpass 90, but most of the SBP values remain below 140. Consequently, the relative risk of hypertension is lower when compared to obesity class II and class I. Similarly, obesity class III demonstrates DBP values mostly above 90, but nearly all SBP values remain below 140, indicating a comparatively lower risk of hypertension compared to obesity class

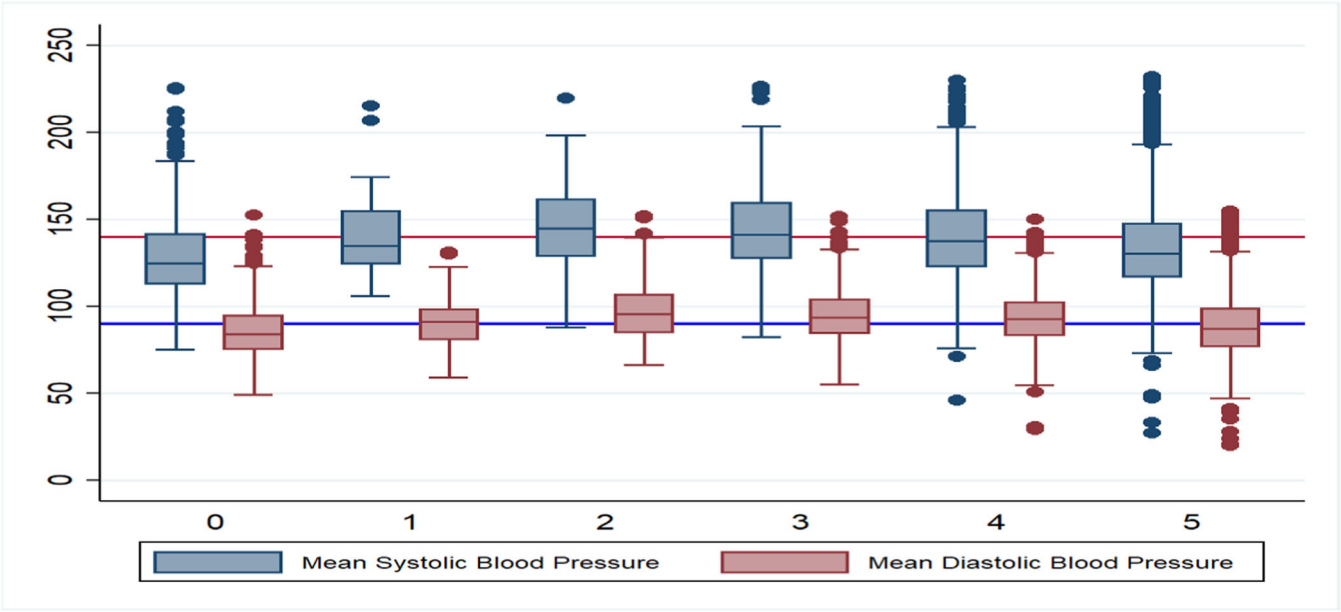

FIGURE 1 Box-and-whisker plots of mean systolic blood pressure (SBP), ash box-and-whisker plots and diastolic blood pressure (DBP), brown box-and-whisker plots, by the different stages of body mass index (BMI): 0 for underweight; BMI < 18 kg/m^2, 1 for obesity class III; BMI > 40 kg/m^2, 2 for obesity class II; BMI: 35–39.99 kg/m^2, 3 for obesity class I; BMI: 30–34 kg/m^2, 4 for preobesity; BMI: 25–29.9, and 5 for normal weight; BMI: 18.5–24.9 kg/m^2. The horizontal axis indicates both SBP and DBP levels.

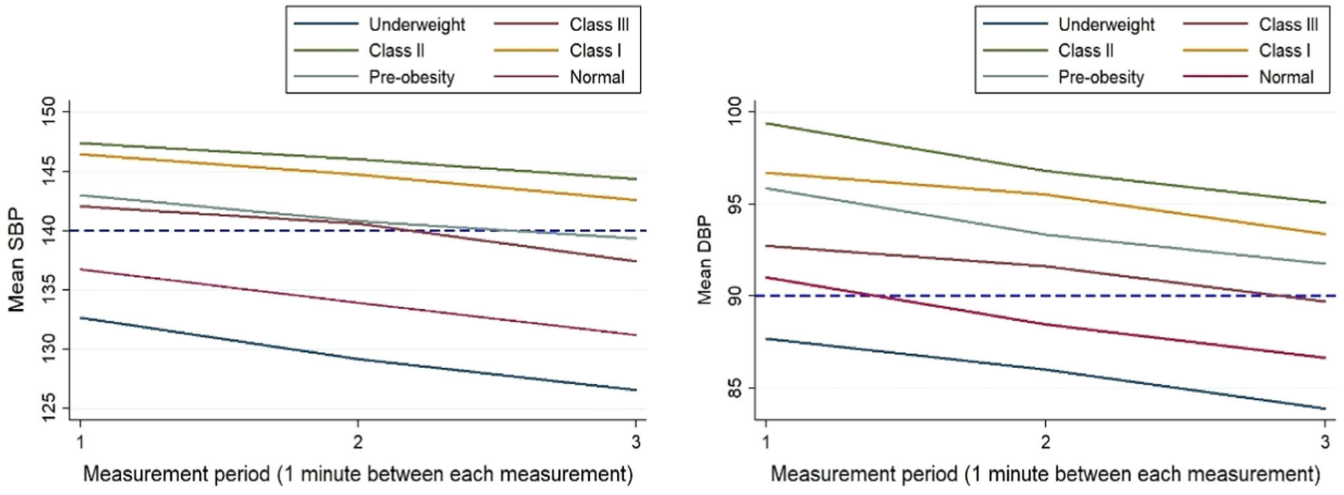

FIGURE 2 Mean systolic blood pressure (SBP) for three measurement periods (with 1 min between each measurement) by the different stages of body mass index.

II and class I. Individuals classified as having a normal BMI exhibit mean SBP values below 140, indicating an estimated lower risk of hypertension within this group.

4 | DISCUSSION

In this paper, we focused on determining the specific stage of BMI that strongly predicts the occurrence of hypertension among Ghanaians. Additionally, we took into account other potential risk factors of hypertension and examined the likelihood of developing hypertension among Ghanaians who had previously been diagnosed with hypertension and diabetes. Throughout our analysis, we considered various factors to identify significant predictors of hypertension using the logistic regression model to established the relationship between hypertension and potential risk factors.

The findings of this study demonstrate a consistent association between all stages/categories of BMI and a heightened risk of hypertension. Specifically, Ghanaians classified as obesity class II exhibit approximately four times greater likelihood of developing hypertension. Similarly, obesity class III, class I, and pre-obesity contribute to an approximately 3-fold increase in the risk of hypertension. The findings presented are consistent with previous research studies,[8,40] which highlight the relationship between obesity, as measured by BMI, and the risk of hypertension. Some authors have expressed concerns about the ability of BMI to accurately predict the risk of hypertension and CVD.[41,42] However, our study, along with the research conducted by Landi et al.,[3] demonstrated that BMI can effectively predict hypertension. BMI among males and females' groups is associated with an increased risk of developing hypertension.

According to our findings, individuals with a history of hypertension have increase in the risk of developing hypertension. This finding aligns with the WHOs' recognition, as stated in their report (WHO, 2022), that having a family history of hypertension is a nonmodifiable risk factor for developing hypertension as well as. Ranasinghe et al.[43] study that demonstrated a significantly higher prevalence of hypertension among individuals with a family history compared to those without.

Additionally, our study revealed a noteworthy reduction in the risk of developing hypertension among individuals who have previously experienced car accident injuries, contrary to a study conducted by Howard et al.[44] which demonstrated a significant increase in the risk of hypertension and injury severity score. Several authors[45] have discussed the increased risk of hypertension associated with head injury and traumatic brain injury.[46] These conditions can result in damage to the parts of the brain that control BP. In addition to the direct impact on BP-regulating brain regions, the stress experienced due to an accident alone can significantly elevate the victim's BP, potentially leading to hypertension or even death. In our study, we observed a significantly reduced risk of hypertension because the injury variable considered does not represent a current injury but rather reflects an injury that the individual had experienced at some point in their lifetime.

We observed that the risk of developing hypertension was significantly higher among currently married, divorced, widowed individuals compared with never married individuals. This finding agrees with finding by various authors.[47] Never married females have increased risk of developing hypertension compared with currently married, divorced, and cohabiting females except windowed females who have increased risk of developing hypertension compared never married females. Our findings are consistent with Ramezankhani et al.[48] study results that never married males are at a higher risk of hypertension compared to married males.

An increased risk of developing hypertension was observed among Ghanaians who are above 60 years of age compared to those who are 60 years and below, a finding which agrees with finding from various studies.[5,49–51] For instance, Gurven et al.[52] observed that age-related increases in BP have been documented in nearly all populations, except among hunter-gatherers, farmers, and pastoralists. We found that those who has ever consumed alcohol are associated reduction in the risk of hypertension. In the present study, the decreased risk of hypertension observed among individuals who have consumed alcohol in the past may indicate a reduction in alcohol intake among those individuals since high dose of alcohol leads to a decrease in BP for up to 12 h following consumption but beyond 13 h, there is an increase in BP[53] conducted a study which demonstrated that consuming. An increased risk of hypertension is observed among individuals whose work involves vigorous exercise. While one might expect exercise to consistently lower BP, the actual impact depends on factors such as the intensity, frequency, and duration of the exercise.[54,55]

Consuming at least two cups of fruits per day is associated with an increased risk of hypertension, a finding which contradicts findings from various authors in the literature[56] and consuming at least two servings of vegetables per day has been linked to a reduced risk of developing hypertension. The consumption of fruits and vegetables has been found to significantly reduce the risk of hypertension, however, the association between hypertension and fruits and vegetables consumption is largely dependent on fruits and vegetables type.[57] Subgroup analysis reported a significant reduced risk of developing hypertension among females who has ever been to school. Our study's findings are contrary to Iddrisu et al.[21] results but consistent with the majority of recent research examining the impact of education on BP and hypertension. Our results and many others revealed that education plays a role in BP and hypertension, with higher education levels generally associated with lower BP and reduced cardiovascular risk.

We discovered significant increased risk of hypertension among females who has ever smoke tobacco. This finding agrees with studies conducted by various authors.[21,58,59] For instance, Li et al.[58] study revealed that former smokers have increased risk of developing hypertension when compared with nonsmokers. Also, in a study conducted by Millett et al.,[59] it was found that smoking, diabetes, and high BP increase the risk of heart attack in both men and women. However, the study also revealed that women experience an additional or excess risk compared to men. Several factors, including

diabetes, BP, and cigarette smoking, may contribute to a higher risk of hypertension among women compared to men. For instance, a study conducted by Millett et al.[59] revealed that female smokers had an approximately 3.5 times higher risk of heart attack compared to nonsmoking females, whereas male smokers had a 2.2 times higher risk. Additionally, when comparing individuals with high BP, women had higher risk of experiencing a heart attack compared to men.[59] Similarly, Iddrisu et al.[21] reported that high BP is more commonly associated with females than males. Moreover, women with Type I diabetes were found to have an almost three times higher risk of heart attack, while women with Type II diabetes had higher risk compared to their male counterparts.[59] These factors, along with other relevant factors, contribute to the higher risk of hypertension observed among women.

5 | CONCLUSIONS

Obesity class II is likely to be a robust predictor of hypertension status among Ghanaians and all participants categorized as obesity class II were found to have hypertension. This means being classified as obesity class I in Ghana is more likely to be classified as having hypertension. BMI can effectively predict hypertension. It should be noted that although BMI does not directly reflect fat distribution in the body (as argued by various authors), it indirectly captures a certain amount of fat due to its reliance on an individual's weight, which includes the weight of fat. Having a family history of hypertension significantly increased the risk of developing hypertension and is high among males compared with females with history of hypertension. It is important to note that fresh injuries are often associated with higher BP levels but low BP is observed after a few hours. Windows should be given psychological or social, economic support as part of BP control measures. It is important for BP control authorities to emphasize the importance of regular exercise during both young and old age as part of their public health campaigns. For reduction in hypertension risk to be achieved, the right proportion and type or vegetables and fruits consumption must be considered. This study further confirms systolic BP as a key determinant of high BP or hypertension.

Based on the findings of this study, there are several policy implications that can be drawn. Recognize that Obesity Class II can serve as a strong indicator of hypertension risk among Ghanaians. Therefore, healthcare policies should prioritize early identification and intervention for individuals in this obesity category. Acknowledge that BMI can be a valuable tool for predicting hypertension risk, even though it does not directly account for fat distribution and then encourage healthcare providers to routinely calculate and monitor BMI as part of hypertension risk assessments. Promote awareness about the heightened risk of hypertension associated with a family history of the condition, particularly among males and also implement targeted screening and education programs for individuals with a family history of hypertension. Provide healthcare guidelines and recommendations for managing BP levels in the context of fresh injuries and ensure that individuals are informed about the temporary increase in BP following injuries, which typically normalizes after a few hours. Recognize the importance of providing psychological and social support to widows as part of broader BP control measures. Addressing the emotional and economic needs of widowed individuals can contribute to better BP management. Advocate for dietary interventions that focus on the right proportion and type of vegetable and fruit consumption. These policy implications can guide healthcare authorities and policymakers in developing strategies and interventions to effectively address and reduce hypertension prevalence among the Ghanaian population. One limitation of this study is that most of the variables collected are historical and hence limits one's ability to assess their impact on the outcome at the time in which study was conducted or when data were collected.

AUTHOR CONTRIBUTIONS

Abdul-Karim Iddrisu: Conceptualization; data curation; formal analysis; methodology; software; supervision; validation; visualization; writing—original draft; writing—review and editing. **Mohammed Adam**: Methodology; software; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Supporting data for this manuscript results are available at [https://www.who.int/data/data-collection-tools/study-on-global-ageing-and-adult-health/sage-waves] upon request from "@World Health Organization (WHO) study on Global AGEing and Adult Health (SAGE)." The authors have no right to release the data to a third party. All authors have read and approved the final version of the manuscript (Abdul-Karim Iddrisu) had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

The lead author Abdul-Karim Iddrisu affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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