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RESEARCH ARTICLE

HYPERTENSION PREVALENCE AND UNDIAGNOSED CASES IN SUDAN: AN ANALYSIS OF ASSOCIATED RISK FACTORS

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ABSTRACT

PURPOSE

The prevalence of hypertension has escalated globally, affecting approximately 1.39 billion people worldwide out of an estimated global population of 8 billion, with two-thirds residing in low- and middle-income countries. This study aimed to estimate the prevalence of hypertension among adults in Sudan, assess hypertension control, determine the frequency of undiagnosed hypertension, and identify associated risk factors.

METHOD

A cross-sectional facility-based study was conducted at Primary Health Care centers in Karrari Locality, Khartoum State, Sudan, between April 2022 and January 2023, using a multistage sampling method. Two primary methods for data collection are direct interviews and anthropometric measurements. A P-value equal to or less than 0.05 was considered indicative of statistical significance, where the level of confidence was 95%.

FINDINGS

The study involved 385 participants, with 48.6% diagnosed with hypertension, 58.2% having controlled blood pressure, 41.8% uncontrolled, and 6.5% undiagnosed, resulting in a total HTN prevalence of 55.1%. Notably, 44.4% of those with diagnosed HTN were non-smokers, and 37.9% reported never exercising. Central obesity was more prevalent among those diagnosed (63.3%). Increasing age (B = 0.030, p = 0.002) and male sex (B = 0.087, p = 0.029), higher waist circumference (B= 0.132, p= 0.002), were significant risk factors, while exercise frequency (B = -0.172, p = 0.001) and lower salt intake (B = 0.327, p = 0.001) were linked with reduced risk. Overall, the findings highlight a significant burden of HTN and its risk factors in the population studied.

CONCLUSION

This study underlines the high prevalence of hypertension in Khartoum, Sudan, with age, male sex, and central obesity as important risk factors, urging the need for improved measures.

KEYWORDS:

undiagnosed, diagnosed, hypertension, prevalence, control, low- and middle-income countries

INTRODUCTION

Hypertension (HTN) is characterized by elevated blood pressure, defined as a systolic blood pressure (SBP) of 140 mm Hg or more or a diastolic blood pressure (DBP) of 90 mm Hg or more [1]. It is a major chronic condition and represents a significant global public health challenge [2]. In 2019, it was estimated that 1.39 billion individuals in the productive age range of 30 to 79 years had HTN living in low and middle-income countries (LMICs) [3, 4]. The literature has revealed that there is a growing risk of HTN in individuals living in Sub-Saharan Africa. This risk may be caused by a poor health system, lack of physical activity, inadequate nutrition, a growing urbanization rate, and low socioeconomic circumstances [5, 6]. There are two types according to which risk factors for developing HTN can be categorized, which include modifiable and non-modifiable factors. Age, gender, family history, genetic features, and ethnicity are non-modifiable factors, while physical inactivity, smoking, alcohol consumption, high salt intake, dietary choices, and body mass index (BMI) are modifiable factors [7, 8]. These risk factors are also universally known and are termed Classical risk factors (CRFs). Family records of HTN, poor physical activity levels, obesity, high sodium intake, smoking, high alcohol consumption, older age, and male gender are known as CRFs [9]. In contrast, NCRFs may encompass electronic cigarette use, exposure to secondhand smoke, irregular sleep patterns, obstructive sleep apnea, and others.

Undiagnosed hypertension presents a significant concern, as most cases are without symptoms and are often discovered accidentally during routine blood pressure screenings [10]. However, some individuals may exhibit symptoms indicative of end-organ damage, such as stroke-like signs, chest pain, shortness of breath, or acute pulmonary edema [11]. According to 33 surveys, only 27% of people in sub-Saharan Africa knew they had hypertension [12]. For instance, it was reported that 38.2% of the Sudanese population had a prevalence of undiagnosed HTN [13]. South Africa had 49% of the entire HTN [14], and 12.3% in Hawela Tula Sub-City, Hawassa, Southern Ethiopia [15]. Overall, 49.4% of Nubas in North Sudan who were not previously diagnosed with HTN had undiagnosed HTN, according to a trivial population study [16]. National statistics on the prevalence of undetected HTN and the variables that contribute to it in Sudan's general adult citizens are lacking.

Similar to some LMICs, Sudan has a notable gap in the multifaceted management of HTN, encompassing screening awareness, medication, and administration. Because of this, patients and healthcare professionals are burdened with uncontrolled HTN. Moreover, most hypertensive individuals are asymptomatic, and there is a gap in the literature in Sudan that studied the prevalence of undiagnosed HTN.

Therefore, the objective of this study is to investigate hypertension, along with the related risk factors, among adults attending primary health care centers in Karrari Locality, Khartoum state, Sudan. Specifically, the study aims to measure the prevalence of hypertension among adults in this region, evaluate the level of hypertension control, determine the frequency of undiagnosed hypertension, and identify risk factors related to hypertension.

MATERIALS AND METHODS

STUDY DESIGN

To examine the prevalence of hypertension (HTN) and undiagnosed HTN in adult residents who visited primary healthcare centers (PHCs) in Karrari, located in the northern part of Khartoum State, Sudan, a cross-sectional study was carried out

from April 2022 to January 2023. The study was grounded in descriptive epidemiological theory, which is commonly used to quantify disease prevalence, describe population health patterns, and estimate the burden of undiagnosed conditions within defined populations [17]. Accordingly, this design was selected to estimate the prevalence of hypertension, assess the proportion of previously undiagnosed hypertension, and examine associated risk factors among adults attending primary healthcare facilities.

Ethical guidelines were followed in accordance with the Declaration of Helsinki and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies. This research was reviewed and approved by the Khartoum State Ministry of Health, General Directorate of Strategy and Information, Department of Innovation, Development, and Scientific Research, with written approval granted on 12 September 2022. The study was conducted in accordance with the ethical requirements of the approving authority, and no formal approval reference number was issued. Informed consent was obtained from the administrations of the health centers, as well as from all participants prior to inclusion in the study. This process ensured that both institutions and individuals were fully aware of the study's purpose, procedures, and their rights regarding participation, thereby adhering to ethical research standards.

PARTICIPANT AND DATA COLLECTION

Inclusion and Exclusion Criteria

The study involved adults aged 18 years and older. Participants with secondary HTN were excluded to focus on primary HTN prevalence. Pregnant women were also excluded due to the physiological variations linked to pregnancy.

SAMPLING FRAME AND TECHNIQUE

The sampling frame consisted of all adult residents visiting PHC centers in Karrari, with samples drawn through a multistage sampling method.

Stage 1: Selection of PHC Centers

In the Karrari locality, which contains eight healthcare centers, a systematic random sampling method was used to select six centers for the study.

Stage 2: Participant Selection

Participants were chosen using a simple random sampling method from the selected healthcare centers to guarantee unbiased representation. All individuals who met the inclusion criteria were included in the survey.

SAMPLE SIZE CALCULATION

The sample size was computed using the formula $n= N/1+N(e)^2$, where N is the total adult population in Karrari (42,224) and a confidence level of 0.05. This yielded an estimated sample size of 385 participants.

DISTRIBUTION OF PARTICIPANTS

The total sample of 385 participants was distributed proportionally among the selected six PHCs on the basis of their respective population sizes, as shown below in **Table 1**.

TABLE 1: POPULATION AND SAMPLE SIZE DISTRIBUTION ACROSS SELECTED PHCS

PHC Center	Total population	Sample Size Selected
Aboud	15,699	143
Hara 2	4,899	46
Hara 17	7,839	71
Hara 28	4,330	39
Hara 39	5,573	51
Alwihda	3,884	35
Total	**42,224**	**385**

DATA COLLECTION METHODS AND TOOLS

This study employed two primary methods for data collection: direct interviews and anthropometric measurements. A tailored, semi-structured questionnaire on the basis of existing studies (references 9-12) was used during interviews to gather data on sociodemographic factors, risk factors related to HTN, and information on HTN control.

ANTHROPOMETRIC MEASUREMENTS

Height and Body weight were calculated utilizing uniform and calibrated equipment. Body mass index (BMI) was computed using the formula: weight (kg) divided by height (m^2). BMI categories were classified as per the National Institute of Health (NIH) guidelines as follows:

- Underweight: BMI < 18.5 kg/m^2
- Normal: BMI 18.5–24.9 kg/m^2
- Overweight: BMI 25–29.9 kg/m^2
- Obesity: BMI ≥ 30 kg/m^2

Central obesity (CO) was assessed using the waist circumference, which was computed at the narrowest point between the rib cage and the iliac crest. A waist circumference of ≥ 94 cm for men and ≥ 80 cm for women indicated central obesity.

BLOOD PRESSURE MEASUREMENT

Blood pressure (BP) was measured using a calibrated portable mercury sphygmomanometer, with the right cuff size for each individual. Measurements were collected in a sitting position, with the arm at the level of the heart, following 15 minutes of rest. The average of three BP readings was recorded for each individual. These readings were classified according to the Joint National Committee (JNC) 8 guidelines [18].

- Normal Blood Pressure: Defined as systolic BP < 120 mmHg and diastolic < 80 mmHg.
- Prehypertensive: Defined as systolic BP 120–139 mmHg and diastolic BP 80–89 mmHg.
- Stage 1 Hypertension: Defined as systolic BP ≥ 140 mmHg or diastolic BP ≥ 90 mmHg.
- Stage 2 Hypertension: -For adults aged < 60 years: Target BP <140/90 mmHg.

-For adults aged ≥ 60 years: Target BP < 150/90 mmHg.

-For patients with diabetes or chronic kidney disease: Target BP < 140/90 mmHg, regardless of age.

SAMPLE SIZE CALCULATION

The size of the sample was measured with the help of the formula, the same as used in previous literature, by supposing a 30% prevalence of risk factors like high salt and sugar intake. Using a 95% confidence interval and a margin of error of 5%, and 385 was the size of the sample of participants was determined.

STATISTICAL ANALYSIS

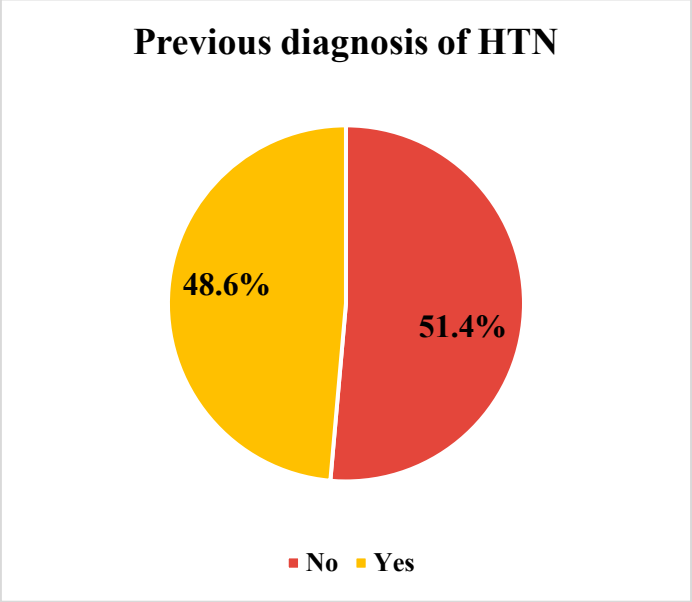
Data entry and statistical analysis were conducted by a researcher using the Statistical Package for Social Sciences IBM-SPSS software for Windows version 27.0 (SPSS Inc., Chicago, IL). Continuous data were expressed as the mean ± standard deviation (SD) after confirming the normality of the distribution. Logistic regression was employed to study the risk factors linked with elevated BP (HTN, whether known or unknown). A P-value of 0.05 or less was considered indicative of statistical significance, with a confidence level set at 95%.

RESULTS

PREVALENCE OF HYPERTENSION DIAGNOSIS

The results of this study showed that 187 participants (48.6%) were previously diagnosed with HTN out of the total 385 participants as depicted in Figure 1. This reveals that before this investigation, about half of the population studied had been diagnosed with HTN.

FIGURE 1: PREVALENCE OF HTN DIAGNOSIS (N=385)



HYPERTENSION CONTROL AND PREVALENCE OF UNDIAGNOSED CASES

Table 2 presents data on HTN among adults without previous HTN diagnosis and the control of those with diagnosed HTN according to the JNC-8 guidelines. The prevalence of HTN diagnosis was 48.8%. Among participants with a previous HTN diagnosis, 58.2% had controlled BP (102 for systolic and 116 for diastolic). In comparison, 41.8% were categorized as uncontrolled (85 for systolic and 71 for diastolic), showing the need for better management in the uncontrolled group. Among those with no previous diagnosis of HTN, 81.9% (312 for systolic and 318 for diastolic) had normal BP. In comparison, 11.6% (47 for systolic and 42 for diastolic) were classified as prehypertensive, and 6.5% (26 for systolic and 25 for diastolic) had undiagnosed or unknown HTN, showing the need for improved testing measures.

TABLE 2: HYPERTENSION CONTROL AND PREVALENCE OF UNKNOWN HYPERTENSION (N=385)

Prevalence	SBP	DBP	%
BP control among participants with previous HTN diagnosis			
Controlled	102 (54.5)	116 (62.0)	58.2
Uncontrolled	85 (45.5)	71 (38.0)	41.8
BP among adults with no previous HTN diagnosis			
Normal BP	312 (81.1)	318 (82.6)	81.9
Prehypertension	47 (12.2)	42 (11.0)	11.6
Undiagnosed/unknown HTN	26 (6.7)	25 (6.4)	6.5

DEMOGRAPHIC CHARACTERISTICS

Table 3 presents the distribution of demographic data among participants with and without a previous HTN diagnosis, totaling 385 individuals. This demographic distribution provides knowledge about the prevalence of HTN in different gender and marital status classifications within the study sample size. Overall, the total number of participants with diagnosed HTN was 187, while 198 had no previous diagnosis. In terms of sex, the study included 120 females and 265 males. 60.1% of those with diagnosed HTN were male, while 77.3% of those without a previous diagnosis were also males.

The age of participants varied from 24 to 73, with a mean age of 44 years (standard deviation ±8 years). Regarding marital status, all the participants with prior HTN diagnoses were either married or widowed. Among married participants, 87.2% were diagnosed with HTN, and 12.8% of participants with diagnosed HTN were widowed. In contrast, none of the participants with diagnosed HTN were single, whereas 18.6% of those without a previous HTN diagnosis were single. Among married participants, 78.3% of those without a diagnosis prior were married, and 3.1% were widowed.

TABLE 3: DISTRIBUTION OF DEMOGRAPHIC DATA AMONG PARTICIPANTS WITH AND WITHOUT PREVIOUS HTN DIAGNOSIS (N=385)

Variable	Diagnosed HTN		No previous HTN diagnosis		Total
	F	%	F	%	
Sex					
Female	75	39.9	45	22.7	120
Male	112	60.1	153	77.3	265
Age (years)					
24 – 73, mean ± standard deviation = 44 ± 8 years					385
Marital status					
Single	0	0	37	18.6	37
Married	163	87.2	155	78.3	318
Widowed	24	12.8	6	3.1	30
TOTAL	**187**	**100.0**	**198**	**100.0**	**385**

DISTRIBUTION OF RISK FACTORS IN PARTICIPANTS BY HYPERTENSION DIAGNOSIS

Table 4 presents the allocation of risk factors among participants with and without a previous HTN diagnosis. Regarding the family history of HTN, 9.2% of participants with diagnosed HTN reported no family history, compared to 27.2% of those without a previous diagnosis. Most participants had a first-degree family history (68.9% with diagnosed HTN vs. 65.7% without), while 21.9% of those with diagnosed HTN had a second-degree family history, compared to 7.1% of those without. Regarding smoking status, 44.4% of participants with diagnosed HTN were not smokers, while 51.2% of those without a previous diagnosis were non-smokers. Current smokers made up 29.9% of the diagnosed group and 7.5% of the non-diagnosed group.

Regarding exercise frequency, 37.9% of participants with diagnosed HTN reported never exercising, compared to 62.1% of those without. A higher percentage of participants with diagnosed HTN exercised 1-3 times a week (41.2%) compared to the non-diagnosed group (18.6%). Regarding fatty food consumption, 75.4% of participants with diagnosed HTN reported eating fatty foods sometimes, while 49% of those without a previous diagnosis reported the same. Salt consumption showed that 55.7% of participants with diagnosed HTN consumed ≤2,300 mg per day, compared to 66.2% of those without. Regarding BMI, 18.6% of those with diagnosed HTN were underweight, while 13% of those without were underweight. Normal weight was reported by 38% of those with diagnosed HTN and 55.4% of those without. Obesity was present in 15.1% of participants with diagnosed HTN and 4.1% of those without.

Lastly, central obesity was more prevalent in participants with diagnosed HTN (63.3%) compared to 51.1% of those without a diagnosis. Overall, the data indicates significant differences in risk factors between the two groups.

TABLE 4: DISTRIBUTION OF RISK FACTORS AMONG PARTICIPANTS WITH AND WITHOUT PREVIOUS HTN DIAGNOSIS (N=385)

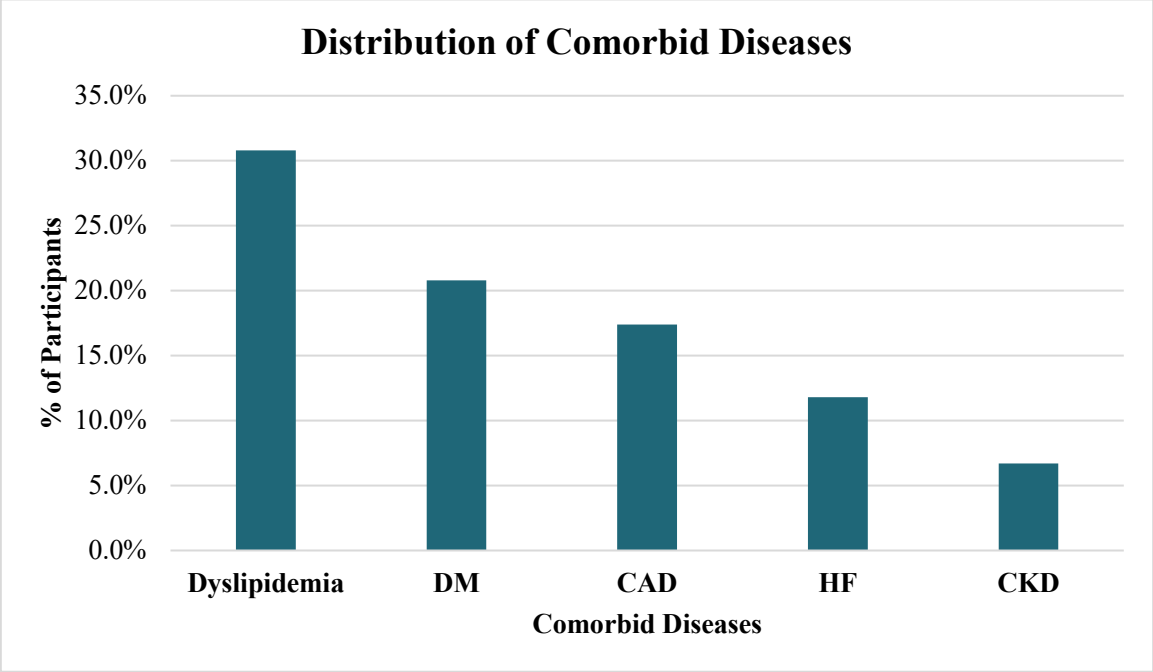
Variable	Diagnosed HTN 187		No previous HTN diagnosis 198		Total
	F	%	F	%	
Family History of HTN					
None	17	9.2	54	27.2	71
First degree	129	68.9	130	65.7	259

Second degree	41	21.9	14	7.1	55
Smoking status					
Not a smoker	83	44.4	101	51.2	184
Quit > 10 years	31	16.6	39	19.6	70
Quit < 10 years	17	9.1	43	21.7	60
Current smoker	56	29.9	15	7.5	71
Exercise frequency (30-40 minutes sessions)					
Never	71	37.9	123	62.1	194
1-3 times/week	77	41.2	37	18.6	114
4-6 times/week	33	17.6	16	8.2	49
Everyday	6	3.3	22	11.1	28
Fatty food consumption					
Never	0	0	0	0	0
Seldom	24	12.8	35	17.6	59
Sometimes	141	75.4	97	49	238
Often	22	11.8	42	21.2	64
Always	0	0	24	12.2	24
Salt consumption per day					
≤Tablespoon/2,300 mg	104	55.7	131	66.2	235
>Tablespoon/2,300 mg	83	44.3	67	33.8	150
BMI					
Underweight	35	18.6	26	13	61
Normal	71	38.0	110	55.4	181
Overweight	53	28.3	54	27.5	107
Obesity	28	15.1	8	4.1	36
Central obesity					
Absent	78	41.7	97	48.9	175
Present	109	63.3	101	51.1	210
TOTAL	**187**	**100.0**	**198**	**100.0**	**385**

PREVALENCE OF COMORBID DISEASES AMONG PATIENTS

Figure 2 presents the distribution of comorbid diseases among participants; 116 participants (30.1%) reported having no chronic diseases, excluding hypertension for some individuals. Conversely, 269 participants (69.9%) indicated the presence of chronic conditions other than hypertension. Among those with chronic diseases, the distribution includes 83 individuals (30.8%) with dyslipidemia, 56 (20.9%) with diabetes mellitus, 47 (17.4%) with coronary artery disease, 32 (11.8%) with heart failure, and 18 (6.7%) with chronic kidney disease. This data highlights the significant burden of chronic diseases in the population studied.

FIGURE 2: DISTRIBUTION OF COMORBID DISEASES AMONG PARTICIPANTS



RISK FACTORS ASSOCIATED WITH HYPERTENSION

Table 5 presents the findings of a statistical analysis of various risk factors associated with HTN (diagnosed and undiagnosed). Age showed a positive coefficient of 0.030 with a p-value of 0.002, indicating that as age progresses, the risk of HTN also rises. Sex was also a significant factor, with a coefficient of 0.087 (p-value 0.029), suggesting that being male is correlated with a higher risk of HTN. Moreover, for a family history of HTN, a coefficient of -0.045 (p-value 0.024) indicates that having a family history of HTN is associated with a lower risk, suggesting that other factors might be influencing this result. This unpredicted result indicates the presence of other mediating factors impacting HTN risk within this sample size. Regular exercise was found to be protective against hypertension, with a coefficient of -0.172 and a p-value of 0.001; increased exercise frequency is significantly associated with lower hypertension risk.

Dietary habits also played a significant role. A strong positive association is indicated by the coefficient of 0.212 (p-value 0.001), showing that higher consumption of fatty foods significantly increases hypertension risk. Another risk factor was daily high salt intake. The coefficient of 0.327 with a p-value of 0.001 indicates a significant positive association, meaning that higher salt consumption significantly raises the risk of hypertension. In addition, a coefficient of 0.132 (p-value 0.002) indicates a significant positive association, suggesting that higher WC increases hypertension risk. Other factors, including marital status, with a coefficient of -0.050 but with a p-value of 0.109, this factor is not statistically significant. The presence of comorbidities with a coefficient of -0.065 (p-value 0.131) indicates no significant effect on hypertension risk. Smoking status with a coefficient of -0.019 and p-value of 0.499 indicates that smoking status does not significantly affect hypertension risk, and BMI with a coefficient of -0.011 (p-value 0.051) suggests an insignificant effect.

TABLE 5: LOGISTIC REGRESSION ANALYSIS OF RISK FACTORS

Risk factors	B	Std. Error	P. value	95.0% Confidence Interval	
				Lower Bound	Upper Bound
Age	.030	.002	.002*	.026	.033
Sex	.087	.039	.029*	.009	.165
Marital status	-.050	.031	.109	-.112	.011
Family history of HTN	-.045	.020	.024*	-.084	-.006
Presence of comorbidity	-.065	.010	.131	-.085	-.046
Smoking status	-.019	.029	.499	-.076	.037
Exercise frequency	-.172	.012	.032*	-.196	-.149

Consumption of fatty food	.212	.013	.001*	.187	.238
Consumption of salt	.327	.032	.001*	.390	.264
Body mass index	-.011	.025	.051	-.059	.038
Central obesity	.132	.043	.002*	.215	.048

DISCUSSION

HTN PREVALENCE AND CONTROL

This study revealed a high prevalence of hypertension (HTN) among adults attending primary health care centers in Karrari Locality, Khartoum State, Sudan, with a total prevalence of 55.1%, including 6.5% undiagnosed cases. This figure is significantly higher than the 20-38.4% prevalence reported in previous international studies [19, 20]. For instance, in Sudan, Omar et al. found an overall prevalence of 40.8%, where 7.3% had been previously diagnosed with HTN, and 33.5% were newly diagnosed [21]. This is higher than our 6.5% of unknown cases but lower than our overall prevalence of 55.1%. This difference is because of factors such as dissimilarities in the demographic configuration and way of life of the populations studied, mostly in international and national studies conducted in different cities. Each region may also have a unique environmental, genetic, or socioeconomic impact that leads to changes in increased blood pressure. For example, high levels of stress, limited access to healthcare, and traditional diets rich in salt and saturated fats prevalent in Sudan may exacerbate the risk of HTN [22]. On the other hand, other countries may experience better health facilities and different related lifestyles. Moreover, existing discrepancies in HC systems could explain the differences; superior HTN detection and diagnosis in some populations may lead to lower prevalence rates [23].

Although hypertensive treatments are present, controlling HTN is still a major challenge across many populations. The associated factors are insufficient follow-up to treatment, poor follow-up care access, or poor interaction between patients and providers about the significance of strict blood pressure control. Cultural factors may also play a role, with some patients depending more on conventional medicine or altering advised treatment procedures based on non-scientific judgements rather than following clinical guidelines.

Mouhtadi et al. found an uncontrolled HTN prevalence of 45%(18), and Balouch et al. reported an increased rate of 56.9%, which is higher than the results of our study as 41.1% of participants had uncontrolled HTN [24, 25]. In addition, other studies conducted by Alawneh et al. and Mirzaei et al. found increased rates at 60% [26] and 61.1% [27], and Calas et al. observed a rate of 69.8% [28]. These results showed that the population of our study is likely to have improved management of HTN as compared to previously reported studies, and it is because of better treatment approaches or careful following of prescribed treatments [22, 25, 26, 28]. More research is needed to find the reasons for these variations and examine the influence of healthcare measures on HTN control.

In our study, we found that 6.5% of the participants had a prevalence of undiagnosed HTN. The prevalence of undiagnosed HTN in our study was found to be 6.5%. This can be due to inadequate health education, less accessibility of checkups, or extra expense problems that rarely allow individuals to get annual checkups. Because of the lack of regular screenings and community-based treatment, underprivileged regions like Sudan ignore undiagnosed illnesses like HTN. This emphasizes the need for stronger healthcare strategies and campaigns for awareness.

HTN RISK FACTORS

In this study, logistic regression analysis shows that age was a significant determinant of HTN with a p-value of 0.002, indicating that the chances of developing HTN increase with age (B = 0.030). This finding aligns with broader literature, including studies by Calas et al. [28], Rahman et al. [29], Godara et al. [19], Nimi et al. [30], Mekonene et al. [20], and Omar et al. [21], all of which identified age as a significant risk factor. The physiological changes in vascular structure, such as arterial stiffness, may explain the consistent association between advancing age and HTN.

Sex also demonstrated a significant relationship with HTN in our study (p = 0.029), with men at slightly higher risk than women (B = 0.087). This finding is consistent with Balouchi et al. [24], who reported higher HTN prevalence among men, and Santosa et al. [31], who noted that men had higher prevalence rates (43% in Sweden and 39% in China) compared to women (29% in Sweden and 36% in China). This is further supported by Godara et al. [19] and Mekonene et al. [20].
In contrast, marital status was not significantly associated with HTN, diverging from studies like those of Calas et al. [28] and Noor [16], which identified being single as a risk factor. This discrepancy may stem from cultural or social differences in the populations studied.

Surprisingly, family history exhibited an inverse relationship with HTN (p = 0.024), which contradicts existing literature where family history is generally considered a risk factor. One possible explanation is that individuals with a known family history of HTN may be more vigilant about their health, leading to early interventions and better management of their condition. Exercise frequency was strongly associated with a reduced risk of HTN (B = -0.172, p < 0.032), supporting the well-documented benefits of physical activity in lowering blood pressure, as noted by Calas et al. [28]. Conversely, consumption of fatty foods emerged as a significant risk factor for HTN (B = 0.212, p < 0.001), aligning with previous studies linking high-fat diets to elevated blood pressure. This underscores the necessity of dietary interventions in HTN management. Similarly, salt consumption was identified as a significant risk factor for HTN (B = 0.327, p < 0.001), consistent with extensive evidence linking high salt intake to increased blood pressure. This finding reinforces ongoing recommendations to reduce salt consumption as a key strategy in preventing and managing HTN.

Interestingly, our study found that BMI was not a significant predictor of HTN (p = 0.051), diverging from most studies that link higher BMI to increased HTN risk. This difference may arise from the comparable BMI levels among participants with diagnosed and undiagnosed HTN, which could lead to similar risks [32]. Additionally, other lifestyle factors, such as dietary habits or physical activity levels, may have influenced this relationship, potentially masking the impact of BMI on HTN outcomes.

While the presence of chronic diseases was statistically insignificant, this may be due to individuals with chronic conditions being more likely to receive medical care, including HTN. This contrasts with studies that typically link chronic diseases to higher HTN prevalence [33, 34]. Similarly, smoking status did not show a significant association with HTN, which also differs from previously established risk factors and is supported by Gao et al. [35].

Notably, our analysis revealed that central obesity, as measured by WC, was related to HTN, with a regression coefficient of B = 0.132 and a significance level of p = 0.002. This finding aligns with the known positive correlation between central obesity and HTN. A related study in Sudan by Noor [16] found that central and gross obesity was linked to uncontrolled blood pressure, while another study by Omar et al. [21] reported that being overweight was not a significant risk factor for HTN among their participants. This challenges the conventional understanding that higher body weight directly contributes to increased blood pressure. The differing results suggest that the relationship between obesity, both overall and central and HTN may not be straightforward. Cultural, environmental, or genetic factors may impact weight and obesity in the Sudanese population, and for that reason, blood pressure regulation is affected. More research is required to understand the intricate relations between the composition of the body, lifestyle factors, and HTN, allowing targeted measures for different populations.

Our findings underscore the need for targeted hypertension screening and control strategies in Sudan, particularly among older adults, men, and those with central obesity. Public health policies should prioritize raising awareness about HTN risk factors, promoting healthy lifestyles, and ensuring regular blood pressure screening in primary healthcare settings. Given the relatively low proportion of undiagnosed cases, ongoing community-based screening programs seem effective but should be expanded. Additionally, policy makers should consider developing culturally tailored health education campaigns to improve dietary habits and physical activity levels. Strengthening healthcare infrastructure, training providers in risk-based patient management, and integrating non-pharmacological interventions into HTN care can contribute to better long-term outcomes.

This study raises several important questions for further exploration. First, the observed inverse relationship between family history and HTN warrants deeper investigation to understand behavioral adaptations or healthcare-seeking tendencies. Second, the insignificant association of BMI with HTN contradicts many established findings, suggesting that local dietary patterns or genetic factors may modulate obesity-related risk. Longitudinal studies are needed to assess causal relationships and clarify these unexpected results. Future research should also evaluate the effectiveness of current HTN management programs, examine barriers to treatment adherence, and explore how cultural beliefs influence HTN diagnosis and control. Additionally, national-level studies with larger and more diverse samples could provide a clearer picture of HTN patterns across Sudan.

CONCLUSION

In this study, the prevalence of HTN was found to be high in the Karrari Locality of Sudan. The results of this study reveal that there is an urgent need for better public health measures on early diagnosis, awareness, and practical management of HTN. Age, sex, lifestyle preferences, dietary habits, and physical activity are the main factors that contribute to HTN. Health outcomes can be improved, and the burden of HTN in various populations can be decreased by resolving these factors. Future research is essential to elucidate further the complex relationships between obesity, lifestyle, and hypertension, ultimately informing strategies to combat this growing health challenge.

STRENGTHS AND LIMITATIONS

This study provides recent and context-specific data on hypertension prevalence, control, and undiagnosed cases among adults attending primary healthcare centers in Sudan, addressing a major evidence gap in a low-resource setting. The use of standardized blood pressure measurements, JNC-8 criteria, and multistage random sampling across multiple PHCs strengthens the internal validity of the findings. However, the cross-sectional design limits causal interpretation. In addition, the relatively small sample size (n = 385) and the single-locality setting within Khartoum State may restrict the generalizability of the results to the wider metropolitan population or rural regions. Self-reported lifestyle data may also be subject to reporting bias.

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COMPETING INTEREST

The authors declare no competing interest in relation to this study.

INFORMED CONSENT

Informed consent was obtained from the administrations of the health centers, as well as from all participants involved in the study. This process ensured that both the institutions and individuals were fully aware of the study's purpose, procedures, and their rights regarding participation, thereby adhering to ethical research standards.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by SMBE, SKF, RA, RASH, RAAE, AH, MH, and EAA. The first draft of the manuscript was written by SMBE, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

LIST OF ABBREVIATIONS

BMI: Body mass index
CO: Central obesity
CRF: Classical risk factors
DBP: diastolic blood pressure
HTN: Hypertension
JNC: Joint National Committee
LMIC: Low- and middle-income countries
NCRFs: Non-classical risk factors
PHC: Primary Health Care
SBP: Systolic blood pressure
SD: Standard deviation
SPSS: Statistical Package for Social Sciences

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