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Urban-Rural Disparities in the Prevalence, Awareness, Treatment, and Control of Hypertension among Adult Diabetic Patients in Northern State, Sudan: A cross sectional Analytical Community-based Study, 2026

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Abstract

Background

Diabetes and hypertension constitute a dual public health burden, particularly in low-income countries. While urban-rural disparities in healthcare access are well documented, this study aims to compare the prevalence, awareness, treatment, and control of hypertension among adult diabetic patients in rural and urban areas of Northern State, Sudan, in 2026.

Methods

A community-based analytical cross-sectional study was conducted among 595 diabetic adults (320 urban, 275 rural) selected via multi-stage stratified random sampling. Data were collected using interviewer-administered questionnaires and clinical measurements following standardized protocols. Hypertension was defined as systolic blood pressure ≥ 140 mmHg and/or diastolic ≥ 90 mmHg, or current antihypertensive medication use.

Results

The overall prevalence of hypertension was 67.4% (401/595), comprising 42.8% previously diagnosed and 24.5% newly discovered cases. Contrary to expectations, no significant urban-rural differences were observed across all measured parameters: hypertension prevalence of previously diagnosed (42.9% vs. 42.8%, p = 0.964), awareness (62.1% vs. 64.9%, p = 0.959), treatment adherence (86.4% vs. 86.1%, p = 0.938), or blood pressure control among diagnosed patients (31.6% vs. 35.5%, p = 0.966). Despite high treatment adherence, 66.3% of hypertensive patients had uncontrolled blood pressure, and 36.4% of all hypertensive patients remained undiagnosed.

Conclusion

Hypertension affects two-thirds of diabetic adults in Northern State, Sudan, with over one-third of cases unrecognized and two-thirds uncontrolled. The absence of significant urban-rural disparities in disease burden or management challenges conventional assumptions about healthcare access gaps and supports population-based interventions targeting all diabetic patients, regardless of geographic location.

Clinical trial number: Not applicable

1. Background

Diabetes is a chronic illness characterized by elevated levels of blood glucose and disturbed metabolism of fats and proteins [1]. Diabetes is recognized as a significant factor in both mortality and morbidity worldwide, affecting various demographics regardless of geographic location, age group, or gender [2]. The prevalence of diabetes among adults (20-79 years) is approximately 10.5% of the global adult

population, with approximately 589 million people living with diabetes [3]. In the Middle East and North Africa region, the prevalence rises significantly to approximately 32.5% among adults, making it one of the regions most affected by the disease [4]. As a consequence of the rising diabetes prevalence, 1.5 million people died directly from diabetes in 2012 [1].

Hypertension is a frequent, chronic, age-related disorder [5]. Hypertension rates have rasen globally, particularly in low- and middle-income countries (LMICs), according to global Estimates from 2010, approximately 31.1% of adults population (1.39 billion people) worldwide were living with this condition [6]. In patients with diabetes hypertension synergistically accelerate renal function decline, particularly when moderate to severe albuminuria is present, and exacerbates the development of retinopathy, and cerebral diseases [7]. This makes hypertension a key contributor to both microvascular and macrovascular chronic diabetic complications.

While high blood pressure is uncommon at onset of Type 1 Diabetes (T1DM), but emerges as kidney disease progression, contributing to end-stage renal failure. In contrast, many patients with Type 2 Diabetes (T2DM) already have hypertension when they are first diagnosed [8]. Moreover, the pathophysiological links in the co-existence of hypertension and diabetes are profound and multifactorial, with multiple mechanisms playing different roles.

The link between diabetes and hypertension is well established, with 70% of diabetic patient develop hypertension [9]. This means hypertension is about twice as frequent in this group as in the general population. Supporting this epidemiological data confirms that the prevalence of hypertension among diabetic patients is approximately 1.5 to 2.0 times higher than in matched non-diabetic groups [8].

Hypertension is a critical comorbidity in diabetic patients. In Sudan, the dual burden of diabetes and hypertension represents a growing public health crisis, straining an already fragile healthcare system. While studies have documented the overall prevalence of hypertension among diabetic patients to be about 47.7% [10, 11], a critical and unaddressed dimension is the potential inequity in healthcare delivery and outcomes between rural and urban populations. Rural and urban diabetic communities often demonstrate marked variability in the prevalence and management of hypertension [12]. These variables are influenced by different factors, particularly healthcare accessibility, socioeconomic conditions, health-seeking behavior, and behavioral patterns, and these differences might aggravate the risk for developing these conditions and accelerating their complications. Without a clear, evidence-based understanding of where and how disparities exist, public health interventions and clinical programs risk being misdirected, inefficient, or inequitable. Consequently, there is an urgent need for localized research that systematically compares hypertension-related indicators among diabetic adults across rural and urban settings to inform targeted, effective, and equitable health policies and programs. Therefore, this study aims to investigate these disparities in the Northern State of Sudan. The findings will provide basic evidence to inform equitable and effective major health policies and interventions aimed at reducing the hypertension burden in this high-risk population.

2. Methods

Study Design and setting

This research employed a community-based, analytical cross-sectional study design. The cross-sectional design was chosen as it is effective for determining the prevalence of hypertension and associated factors (awareness, treatment, control) at a single point in time and for making comparisons between groups (rural vs. urban).

The study was conducted in the Northern State, one of Sudan's 18 states located in the far north, about 328 km north of Khartoum, the capital of Sudan, bordering Egypt and Libya. It has an area of 348,876 km² and an estimated population of 1,132,000. It is characterized by a predominantly arid landscape and its position along the River Nile bank [13, 14]. The Northern State is divided into 7 localities: Wadi Halfa, Dalgo, Al-Burgaig, Dongola, Al-Golid, Al-Dabbah, and Merowe [13]. The state has been impacted by the internal displacement of thousands of people (13% of the internally displaced) due to the recent war conflict between the Sudanese Armed Forces and the Rapid Support Forces [15, 16].

Study Population

The target populations of this study were selected according to fallowing criteria:

Inclusion Criteria:

1. Adult aged 18 years or above.

2. Confirmed diagnosis of diabetes mellitus by a physician or based on self-report with evidence of medication use.

3. Permanent resident of the Northern State (≥1 year).

Exclusion Criteria:

1. Internally displaced people from other states due to the war conflict.

2. Pregnant women due to physiological changes in Blood Pressure (BP).

3. Individuals with severe mental illness or cognitive impairment preventing informed consent or a reliable interview.

4. Critically ill individuals or those unable to participate in the interview or measurements.

Sampling

The sample size was calculated using the Cochran formula, with a 95% confidence level, a 4% margin of error, and a 70% estimated prevalence of hypertension among diabetics [9].

$n = Z^2 * p(1-p)/e^2$

n = minimum required sample size.

e= desired margin of error (4%).

P = estimated population proportion, prevalence of hypertension in diabetic (70%).

Z = Z-score for 95% confidence level (1.96).

Accounting for a potential non-response rate of 10%, the final minimum sample size was adjusted to 555 participants. The study successfully enrolled 595 participants.

Sampling Technique

A multi-stage stratified random sampling technique was used to ensure representativeness across rural and urban populations:

• Stage 1: Locality Selection: Three of the seven localities were selected by simple random sampling technique. The selected localities were Dongola, Al-Burgaig, and Merowe.

• Stage 2: Stratification by Location: Each locality was divided into urban and rural strata. Lists of different villages and cities were obtained from the official registries of the administrative unit of each locality. The capital city of the locality was non-randomly selected to represent the urban population as it is the biggest city with the largest urban population. Three villages from each locality were selected by a simple random selection technique to represent the rural population.

• Stage 3: Selection of Clusters: A number of communities or neighborhoods were randomly selected from each stratum.

• Stage 4: Household Selection: Within each selected community, households were selected by systematic random sampling.

• Stage 5: Individual Participant Selection: In each household, all adult diabetic patients meeting the inclusion criteria were selected.

Methods of Data Collection

The data were collected over a two-month period by a team of trained data collectors (senior medical students). An interviewer-administered structured questionnaire was devolved for this study, used to gather data on sociodemographic factors, diabetes-related history (type of diabetes, duration since diagnosis, current treatment, self-reported adherence, and last known glycated hemoglobin (HbA1c) result), hypertension-related data (awareness of hypertension diagnosis, duration, family history, knowledge of the diabetes-hypertension relationship, current antihypertensive medication, self-reported

adherence, and self-monitoring behaviors), and lifestyle and behavioral factors (smoking status, alcohol use, and physical activity),[supplementary file 1].

Blood pressure measurements were obtained using calibrated mercury sphygmomanometers fitted with an appropriate cuff size, following the American Heart Association's recommended procedures [17]. For each participant, three consecutive readings were taken on the right arm at two-minute intervals, with the individual seated comfortably and the arm properly supported. The final blood pressure was determined by calculating the mean of these three measurements. Hypertension was defined as a mean systolic pressure of 140 mmHg or higher, a mean diastolic pressure of 90 mmHg or higher, or current pharmacological treatment for a previously established diagnosis. Among hypertensive individuals, controlled blood pressure was defined as an average below 140/90 mmHg. Additionally, participants without a prior diagnosis of hypertension who were found to have an average reading of 140/90 mmHg or higher were classified as having undiagnosed hypertension.

Participant weight was recorded to the closest 0.1 kg using a digital scale while they wore light clothing. Height was measurement was taken to closest 0.1 cm using a portable stadiometer. Body mass index (BMI) was calculated using the standard formula (kg/m^2).

The last HbA1c level, or the last blood glucose level if HbA1c was unavailable, was obtained from the participants. The patient was considered to have uncontrolled diabetes mellitus (DM) if their last HbA1c was ≥7% (53 mmol/mol) or their last blood glucose was ≥140 mg/dl (7.8 mmol/l).

Data Preparation and Presentation

Completed questionnaires were checked daily for completeness and consistency by field supervisors. Data were then entered into Microsoft Excel software with double-entry verification to minimize errors. The cleaned dataset was exported to the Statistical Package for the Social Sciences (SPSS) version 27 (IBM) for analysis by a professional data analyst. Results are presented using tables, bar charts, and pie charts for clarity.

Data Analysis

1. Descriptive Statistics: Frequencies and percentages were used to describe categorical variables (e.g., sex, residence, awareness status). Means and standard deviations were used for continuous variables (e.g., age, BMI, BP).

2. Analytical Statistics:

• Group Comparisons: Chi-square tests (or Fisher's exact test) were used to compare categorical outcomes (prevalence, awareness, treatment, control) between rural and urban groups. Independent samples t-tests (or Mann-Whitney U tests for non-normal data) were used to compare continuous variables (e.g., mean BP, BMI, and HbA1c) between the two groups. Analysis of Variance (ANOVA) was also employed for multi-group comparisons as shown in the results.

- A p-value of <0.05 was considered statistically significant for all tests.

3. Results

Table 1. **Socio-demographic Characteristics of the adult diabetic patients, (total number = 595).**

Characteristic	Category	Urban (n =320)		Rural (n = 275)		Total (n =595)	p-value
		F*	%	F*	%		
Gender	Male	125	39.1%	108	39.3%	233 (39.1%)	0.917
	Female	195	60.9%	167	60.7%	362 (60.9%)	
Age (years)	18-39	27	8.4%	23	8.4%	50 (8.4%)	0.981
	40-59	153	47.8%	131	47.6%	284 (47.8%)	
	>60	140	43.8%	121	44.0%	261 (43.8%)	
Occupation	Not working	55	17.2%	47	17.1%	102 (17.1%)	0.999
	Housewife	139	43.4%	119	43.3%	258 (43.4%)	
	Self-employed	75	23.4%	65	23.6%	140 (23.5%)	
	Government sector	39	12.2%	33	12.0%	72 (12.2%)	
	Private sector	12	3.8%	11	4.0%	23 (3.8%)	
Educational Level	Illiterate	41	12.8%	36	13.1%	77 (13%)	0.984
	Pre-university	223	69.7%	191	69.5%	414 (69.5%)	
	University or higher	56	17.5%	48	17.5%	104 (17.5%)	
Marital Status	Married	289	90.3%	249	90.5%	538 (90.4%)	0.964
	Unmarried	31	9.7%	26	9.5%	57 (9.6%)	
Income Level	Insufficient	147	45.9%	127	46.2%	274 (46%)	0.879
	Sufficient	173	54.1%	148	53.8%	321 (54%)	

Family Size	≤5	139	43.4%	119	43.3%	258 (43.4%)	0.949
	>5	181	56.6%	156	56.7%	337 (56.6%)	
Number of Family Members with Diabetes	≤2	295	92.2%	254	92.4%	549 (92.3%)	0.944
	>2	25	7.8%	21	7.6%	46 (7.7%)	
Body Mass Index (BMI)	≤30.0	214	66.9%	183	66.5%	397 (66.8%)	0.882
	>30.0	106	33.1%	92	33.5%	198 (33.3%)	
Regular Exercise	Yes	173	54.1%	148	53.8%	321 (54%)	0.906
	No	147	45.9%	127	46.2%	274 (46%)	
Consumption of Foods	High Salts intake	132	41.3%	114	41.5%	246 (41.4%)	0.879
	Adequate Fruits/Vegetables intake	270	84.4%	232	84.4%	349 (58.6%)	
Smoking	Yes	10	3.1%	8	2.9%	18 (3%)	0.975
	No	310	96.9%	267	97.1%	577 (97%)	
Knowledge of Link Between Diabetes and Hypertension	Yes	206	64.4%	177	64.4%	443 (74.5%)	0.975
	No	114	35.6%	98	35.6%	152 (25.5%)	
Family History of Hypertension	Yes	213	66.6%	183	66.5%	396 (66.6%)	0.975
	No	107	33.4%	92	33.5%	199 (33.4%)	

***F= Frequency**

The total number of participants was 595, urban participants constituted 320 (53.8%), while females were 362 (60.8%). There was no significant difference between the rural and urban participants with regards to socio-demographic characteristics as shown in Table 1. The sample was demographically homogeneous between urban and rural areas; predominantly females, married, housewives, with

intermediate education, had limited income, knew the link between hypertension and diabetes and had positive family history of hypertension.

Table 2. **Diabetes-Related Characteristics by Residence, (total number = 595).**

Characteristic	Category	Urban (n=320)		Rural (n=275)		Total (n =595)	p-value
		F	%	F	%		
Type of Diabetes	Type 1	29	9.1%	25	9.1%	54 (9%)	0.998
	Type 2	183	57.2%	157	57.1%	340 (57.1%)	
	Unsure	108	33.8%	93	33.8%	201 (33.9%)	
Duration Since Diagnosis (Years)	≤10	155	48.4%	133	48.4%	288 (48.4%)	0.976
	11-20	113	35.3%	97	35.3%	210 (35.3%)	
	>20	52	16.3%	45	16.4%	97 (16.3%)	
Current Treatments Used	Diet only	11	3.4%	10	3.6%	21 (3.5%)	0.964
	Oral tablets	215	67.2%	185	67.3%	400 (67.2%)	
	Insulin	83	25.9%	71	25.8%	154(25.9%)	
	Insulin + Oral tablets	11	3.4%	9	3.3%	20 (3.4%)	
Adherence to Diabetes Treatment	Yes	265	82.8%	228	82.9%	493 (82.8%)	0.994
	No	55	17.2%	47	17.1%	102 (17.2%)	
Blood Sugar Monitoring	Blood glucose level	133	41.6%	114	41.5%	247 (41.5%)	0.975
	HbA1c	147	45.9%	127	46.2%	274 (46%)	
	Did not monitor blood sugar	40	12.5%	34	12.4%	74 (12.5%)	
Latest HbA1c/ estimated A1c (Among those tested)	Controlled	86	30.7%	74	30.7%	160* (30.7%)	0.899
	Uncontrolled	176	62.8%	151	62.6%	327* (62.7%)	

***among 521 of participants (monitoring blood sugar), 14 of them did not remember their last HbA1c, and 20 did not remember last blood glucose**

With regards to clinical, treatment and laboratory related characteristics of the study participants as demonstrated in Table 2, no statistically significant differences were found between urban and rural diabetic patients. The high proportion of "Unsure" regarding the type of diabetes might indicate poor knowledge or differentiation between diabetic types, necessitating better education. More than half of the patients were taking oral anti-diabetic medications, a high proportion (83%) were adherent to their medication but near two-thirds had poor glycemic control.

Table 3. **Characteristics of hypertension by residence, (total number = 595).**

Characteristic	Category	Urban (n=320)		Rural (n=275)		Total	p-value
		F	%	F	%		
Diagnosed with Hypertension	Yes	137	42.8%	118	42.9%	255 (42.8%)	0.964
	No	183	57.2%	157	57.1%	340 (57.2%)	
Duration Since Hypertension Diagnosis (Years)	≤15	99	72.3%	85	72.0%	184 (72.1%)	0.887
	>15	38	27.7%	33	28.0%	71 (27.9%)	
Adherence to Hypertension Treatment (among diagnosed)	Yes	118	86.1%	102	86.4%	220 (86.3%)	0.938
	No	19	13.9%	16	13.6%	35 (13.7%)	
Attendance at Regular Follow-up (among diagnosed)	Yes	91	66.4%	78	66.1%	169 (66.3%)	0.924
	No	46	33.6%	40	33.9%	86 (33.7%)	
Hypertension Complications (among diagnosed)	Yes	31	22.6%	27	22.9%	58 (22.7%)	0.924
	No	106	77.4%	91	77.1%	197 (77.3%)	
Type of Complication (among those with complications)	Cardiovascular	19	61.3%	16	59.3%	35 (60.3%)	0.924
	Renal	6	19.4%	6	22.2%	12(20.6%)	
	Cerebral hemorrhage	4	12.9%	3	11.1%	7 (12%)	
	Multiple complications	2	6.5%	2	7.4%	4 (6.9%)	

Table 3 demonstrates the prevalence and clinical characteristics of hypertension among the study population. Participants already diagnosed with hypertension comprised about 43%, with good adherence to treatment and regular follow up. There were no statistically significant differences between rural and urban participants.

Among all participants who were not known hypertensive, 146/340 (42.9%) had high blood pressure (≥140/90), making the total number of participants with hypertension to be 401 (67.4%), this is

demonstrated in Figure 1. The overall awareness rate of hypertension (known hypertensive/Total hypertensive%) was 63.6%.

Table 4. **Mean systolic and diastolic blood pressure levels among rural and urban, (total number=595).**

Group	N	Mean Systolic (mmHg)	Standard Deviation	Mean Diastolic (mmHg)	Standard Deviation	p-value
All Patients	595	137.5	19.5	83.3	10.1	-
Urban	320	135.2	19.8	81.5	11.5	-
Rural	275	139.5	22.1	84.1	13.2	-
Diagnosed	255	144.3	21.4	85.6	12.8	0.023
Undiagnosed	340	130.5	17.2	78.9	10.5	
Diagnosed (Urban)	137	140.5	20.1	84.2	11.9	0.017
Diagnosed (Rural)	118	145.8	23.5	88.1	13.8	
Undiagnosed (Urban)	183	130.1	16.8	78.5	10.2	0.449
Undiagnosed (Rural)	157	131.9	18.5	80.3	11.3	

The mean blood pressure levels (systolic & Diastolic) were higher among rural compared to urban population and were also higher among known hypertensive individuals compared to newly diagnosed participants as shown in Table 4.

Table 5. **Blood pressure parameters among rural and urban, (total number = 595).**

Characteristic	Category	Urban		Rural		Total	p-value
		F	%	F	%		
Current BP Reading for All Participants	<140/90	192	60.0%	165	60.0%	357 (60%)	0.975
	≥140/90	128	40.0%	110	40.0%	238 (40%)	
Hypertensive Patients (Diagnosed)	Controlled	49	35.5%	37	31.6%	86 (33.7%)	0.966
	Uncontrolled	89	64.5%	80	68.4%	169 (66.3%)	
Undiagnosed for Hypertension	Normal BP	107	58.4%	87	55.4%	194 (57%)	0.908
	Elevated Undiagnosed (Unaware)	74	40.5%	72	45.8%	146 (43%)	
Total number of hypertensive (known + new) is 401 (67.4%, n = 595)							
Awareness Rate	Known hypertensive	137	64.9%	118	62.1%	255 (63.6%)	0.959
Unawareness rate	Newly diagnosed	74	35.1%	72	37.9%	146 (36.4)	0.998

Nearly two third of diagnosed individuals 66.3% had uncontrolled BP despite good treatment adherence, but regular follow-up and consistent BP measurement were less than optimal, which may explain why they were uncontrolled. Complications were not rare, about 23% of known hypertensive patients developed complications related to hypertension that necessitates intensified prevention efforts. The overall awareness rate of hypertension was 63.6%. There were no statistically significant differences between rural and urban participants with regards to blood pressure levels, control rate and undiagnosed hypertension as demonstrated in Table 5.

Discussion

Prevalence of Hypertension

The overall prevalence of hypertension was 67.4% (comprising 42.9% previously diagnosed plus 24.5% newly discovered cases). This aligns closely with global estimates that hypertension affects approximately 70% of patients with diabetes [18], and is close to Middle East and North Africa (MENA) data, which reports a pooled prevalence of 56% among diabetic patients [19]. A multinational study from the Middle East and Africa cohort similarly found that over 40% of diabetic patients had hypertension [20]. Nationally, our findings showed a high prevalence of hypertension among diabetic patients,

comparable to previous Sudanese studies reporting 47.7% in a survey at a diabetes healthcare facility [11] and 47.4% prevalence among diabetics in El-Gezira State [21], as well as 47.6% in northern Sudan [10]. The slightly higher rate in our study may reflect the inclusion of undiagnosed cases identified through active blood pressure measurement. This may also be explained by the increasing prevalence of diabetes in the MENA region and in Sudan [4, 22].

Our findings on management reveal both strengths and gaps. The high treatment adherence rates for hypertension 86.3% and diabetes 82.8% are commendable and exceed those often reported in similar resource-limited settings and are even higher than in some high-income areas [23]. Even with high treatment adherence, disease control was suboptimal; 66.3% of hypertensive patients had uncontrolled BP (Rural: 68.4% vs. Urban: 64.5%, p = 0.966). The predominant use of monotherapy (amlodipine-based, 72.9% of hypertensive patients) aligns with standard first-line treatment protocols [17].

The most striking and potentially important finding is the lack of statistically significant differences between urban and rural residents across most parameters: HTN prevalence, treatment complexity, awareness rate, and achieved blood pressure control. This contrasts with the common paradigm of a health access gap favoring urban areas.

Hypertension prevalence was nearly identical among previously diagnosed patients (urban: 42.8% vs. rural: 42.9%, p = 0.964). Blood pressure control rates among diagnosed hypertensive patients showed no statistical difference (urban: 35.5% vs. rural: 31.6%, p = 0.966). Furthermore, the proportion of undiagnosed hypertension (those with blood pressure ≥ 140/90 mmHg who were considered unaware) was slightly higher in the rural area, with no statistically significant differences (urban: 40.5% vs. rural: 45.8%, p = 0.908).

This homogeneity contrasts with global literature, which often demonstrates significant urban-rural gradients. For example, a meta-analysis of 62 studies involving 108,110 participants found that slum residents were 35% more likely to be hypertensive than rural dwellers [24]. Other research has shown that awareness and treatment were significantly lower in rural compared to urban communities in low-income countries [25]. However, our findings align with recent meta-analyses demonstrating narrowing urban-rural differences in low-income countries, from 5.75% (1990–2004) to 1.38% (2005–2020) [26]. The absence of disparities in our study may reflect an epidemiological transition, demographic similarity, and equitable health information access in Northern Sudan. The overall awareness rate 63.6% substantially exceeded the 46.5% reported in the multinational Prospective Urban Rural Epidemiology (PURE) study and the 40.8% observed in low-income countries. Treatment adherence among aware individuals 86.3% was comparable to the 87.5% in PURE. However, uncontrolled blood pressure among treated patients 66.3% is double the global challenge (32.5% in PURE). Monotherapy predominated 73%, mainly amlodipine 72.9%, contrasting with PURE, where 30.8% received combination therapy. The 42.9% undiagnosed hypertension patients remains concerning and aligns with the 46.5% awareness gap reported globally [27].

Factors Associated with Hypertension and Poor Control

Consistent with the literature, age (91.6% >40 years) [12, 27], obesity (33% with BMI > 30) [11, 12, 27], physical inactivity (46%), high salt intake (41%), and family history (66%) were prevalent. Importantly, 34% of diagnosed patients lacked regular follow-up, and 40.4% had not measured their BP for > 3 weeks, explaining the 68.4% uncontrolled rate despite high reported adherence. Complications affected 23% (60% cardiovascular), underscoring the clinical significance of optimal control [18] and consistent with the association between hypertension and retinopathy reported nationally [11].

Limitations

The cross-sectional design prevents causal inference, and single-state conduct limits generalizability. Self-reported data (adherence, lifestyle) are subject to recall and social desirability bias, as evidenced by the discordance between high reported adherence (> 80%) and poor objective control (66% uncontrolled BP). Non random selection of capital cities to represent urban areas may have introduced selection bias. Reliance on recalled HbA1c with 6% missing data compromises glycemic control assessment. These limitations highlight the need for longitudinal studies with objective measures and broader population inclusion.

Conclusion

This study demonstrates a high prevalence of hypertension among diabetic adults in Northern Sudan. Contrary to expectations, a significant urban-rural disparity was absent in prevalence, awareness, treatment adherence, or control rates. While the awareness rate 63.6% and treatment adherence (86.3%) are commendable, control remains suboptimal, with 66.3% having uncontrolled hypertension, and 36.4% of hypertension cases remaining undiagnosed.

Abbreviations

AHA
American Heart Association
ANOVA
Analysis of Variance
BMI
Body Mass Index
BP
Blood Pressure
DM
Diabetes Mellitus
HbA1c
Glycated Hemoglobin
HTN

Hypertension
IDF
International Diabetes Federation
LMICs
Low- and Middle-Income Countries
MENA
Middle East and North Africa
mmHg
Millimeters of Mercury
PURE
Prospective Urban Rural Epidemiology
SD
Standard Deviation
SPSS
Statistical Package for the Social Sciences
T1DM
Type 1 Diabetes Mellitus
T2DM
Type 2 Diabetes Mellitus
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

This study was conducted in Accordance with the principles of the Declaration of Helsinki. Prior to the commencement of the study, ethical clearance was obtained from the Community Medicine Department, Faculty of Medicine, University of Dongola, as well as from the Ethics Committee of the Northern State Ministry of Health for each locality as they requested (Approval ID not applicable). Permissions were obtained from the administrative personnel and community leaders of each selected locality, city, or village. Written informed consent was obtained from every participant after a detailed explanation of the study's purpose, procedures, potential benefits (free BP check and referral if needed), and risks (minimal, related to time and discomfort from the BP cuff), in a language they understand, informed consent for illiterate participants obtained from their legal guardians. All participants were assured of the confidentiality of their personal information, and their right to withdraw from the study at any time without any consequences.

Consent for publication

Not Applicable.

Availability of data

The Dataset used and analyzed during the current study, are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

Al-Mowafag Anwer Omer and Mohamed Osman Abdelaziz; developed the research concept, and drafted and reviewed the study reports and manuscript. Roaa Ebrahim Bashir, Moshtaha Emadeldin, Asma Siddeeg, Haniss Mustafa, Asma Mahmoud, and Selsabeel Abd Alraheim; designed the data collection process and revising the manuscript. Outhman Alsadiq performed the statistical analysis and interpreted the data. All authors read and approved the final manuscript.

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Figures

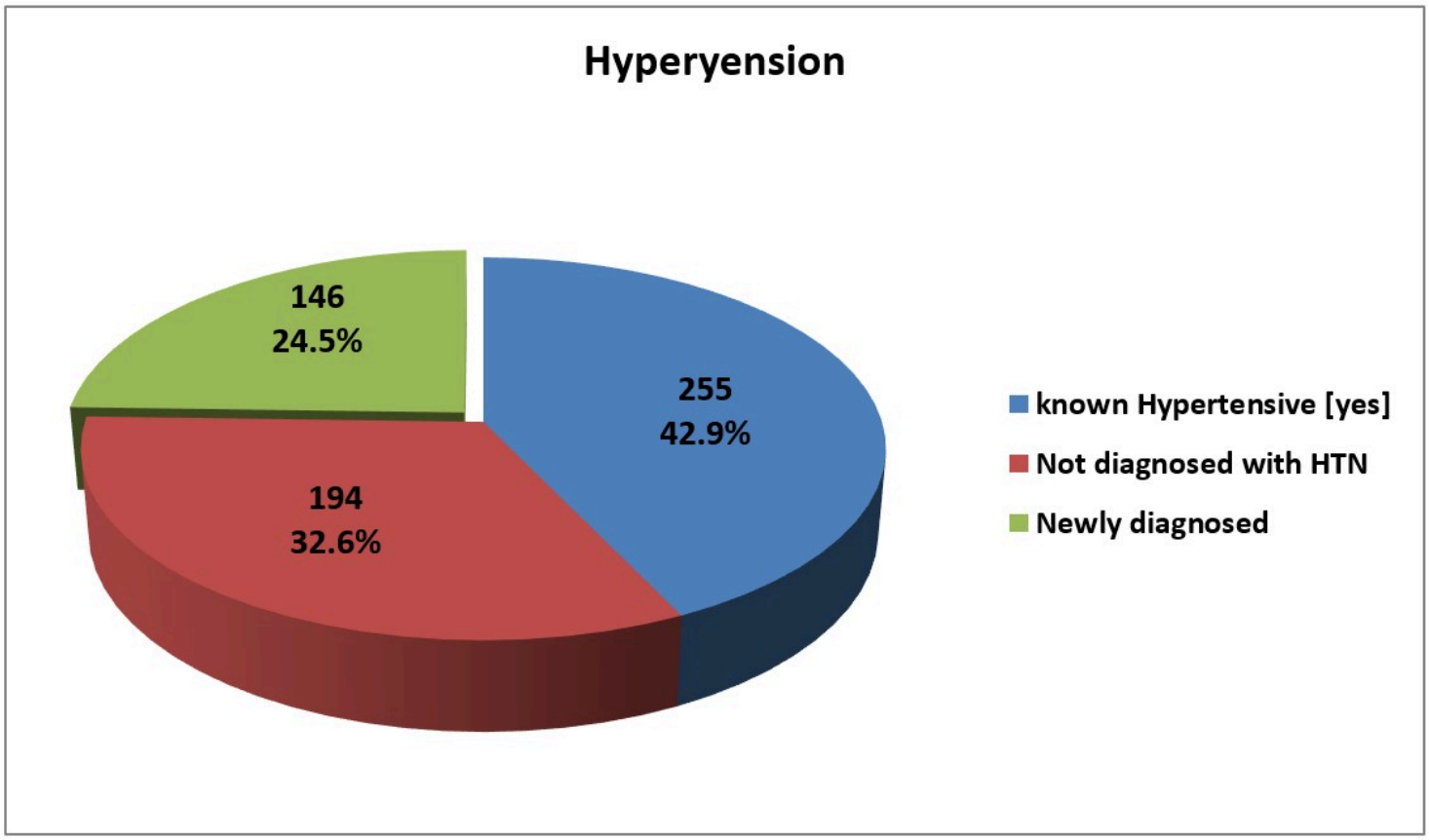


Figure 1

Overall prevalence of diagnosed and newly discovered hypertension, (total number = 595).

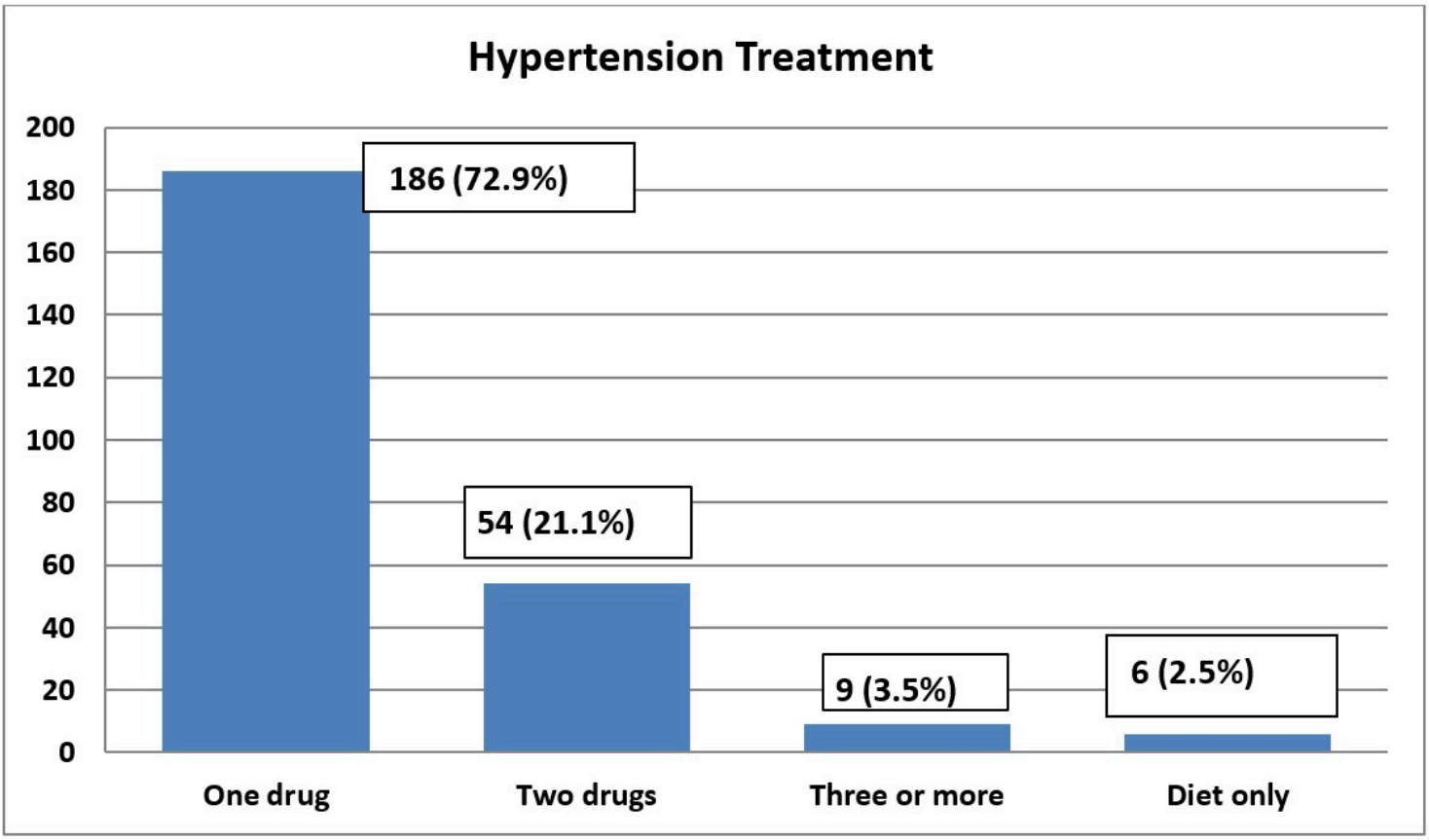


Figure 2

Treatment types of hypertension among rural and urban, (n = 255).

Supplementary Files

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- Supplementaryfile1Questionnaire.pdf