RESEARCH



Impact of hypertension knowledge on adherence to antihypertensive therapy: a cross-sectional study in primary health care centers during the 2024 Sudan conflict



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Abstract

Background Hypertension is a global health issue, particularly in low- and middle-income countries. Effective management requires medication adherence, which is often compromised in conflict zones such as Sudan. This study examines the relationship between patients' knowledge of hypertension and their adherence to antihypertensive therapy in Sudan amidst ongoing conflict.

Methods A cross-sectional study conducted across six primary healthcare centers in Al-Dammer, Sudan, included 389 hypertensive patients selected through convenience sampling. Data were collected using face-to-face questionnaire that assessed sociodemographics, medication adherence (GMAS), and hypertension knowledge (HKT). Analyses were conducted in SPSS, with percentages for categorical data, means ± SD for continuous data, and nonparametric tests (Shapiro-Wilk, Kruskal-Wallis) for non-normal distributions.

Results Most participants were female (63%), and 43.7% were over 60 years old. Knowledge levels were categorized as average (57.8%), high (25.2%), and low (17%). Adherence rates were as follows: 1% poor, 2.8% low, 22.6% partial, 26.5% good, and 47% high. A positive correlation was found between knowledge and adherence (r = 0.47, p < 0.001). Major barriers to adherence included affordability (43.4%) and unavailability of medications (36.2%). While 82.3% of participants had a history of controlled hypertension, only 58.4% remained controlled at their most recent measurement, with 41.6% presenting uncontrolled blood pressure, highlighting challenges in sustained hypertension management. Improved adherence was associated with higher income, better education, and controlled blood pressure.

Conclusion Higher hypertension knowledge was significantly associated with better adherence and improved blood pressure control. However, sustained control remains a challenge, as 41.6% of participants had uncontrolled hypertension at their last measurement. Addressing economic barriers and medication shortages through targeted interventions is essential for improving long-term hypertension management in conflict settings.

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Keywords Hypertension, Medication adherence, Patient knowledge, Sociodemographic factors, War, Primary health care centers, Sudan

Introduction

Hypertension (HTN) is often referred to as the "silent killer," characterized by persistently elevated blood pressure levels of 140 mmHg or higher for systolic and 90 mmHg or higher for diastolic readings [1, 2]. This condition can remain asymptomatic for years, causing serious health problems without warning [2]. As of March 2023, the World Health Organization (WHO) reports that approximately 1.28 billion adults aged 30 to 79 worldwide are living with hypertension, with two-thirds of them residing in low- and middle-income countries [3]. This widespread prevalence is alarming as hypertension is a leading contributor to the global burden of cardiovascular diseases, significantly increasing the risk of complications such as coronary artery disease, heart failure, strokes, renal insufficiency, and even blindness in diabetic patients [4, 5].

Effective hypertension management requires both adopting healthier lifestyles and adhering to prescribed antihypertensive medications [6]. However, nonadherence to medication remains a major challenge, complicating efforts to control this widespread health issue [7].

In Sudan, the prevalence of hypertension is notably high, with 41% of adults aged 30–79 years affected, slightly above the global average of 38% [3]. However, control rates are very low, with only 25% of individuals diagnosed, 16% receiving treatment, and just 6% having their condition under control [3]. The ongoing conflict that began in April 2023 has exacerbated these issues, severely disrupting healthcare services and causing a critical shortage of essential medications [8]. This crisis has made managing chronic conditions like hypertension even more difficult, leading to worsened health outcomes [9]. Prior studies indicate significant issues with medication adherence in Sudanese patients, with reports showing a 41.6% nonadherence rate [10] and a 29.5% nonadherence rate in the Eastern Sudan region [11].

Several studies have highlighted the significant prevalence of hypertension in River Nile State. A communitybased study in urban areas reported a 35.7% prevalence, with 22.4% newly diagnosed cases [12]. In rural areas, the prevalence was 38.2%, underscoring the need for improved screening [13]. Among diabetic patients, hypertension was notably high, with 47.6% affected, further reinforcing the strong association between diabetes and hypertension [14].

Despite the known importance of patient knowledge in influencing adherence [15], no research has explored how knowledge affects adherence to antihypertensive therapy in conflict zones like Sudan. The WHO reports that Sudan has 1.5 primary healthcare facilities per 10,000 people [16]. This study aims to fill this gap by examining the impact of patients' knowledge about hypertension on medication adherence in primary healthcare centers in Al-Dammer, Sudan. We hypothesize that increased knowledge of hypertension will lead to better medication adherence, even amidst the challenges posed by ongoing conflict. The study aims to provide valuable insights into the role of patient education and highlight the potential of targeted educational interventions to enhance adherence and improve hypertension management in crisisaffected settings.

Methodology

Study design and setting

This observational descriptive, cross-sectional study was conducted in Al-Dammer, the capital of River Nile State in North Sudan, over two months (July 1 to August 30, 2024). Al-Dammer was selected due to its role as a central hub for healthcare services in the state, its accessibility to the researcher, and its diverse patient population, including many internally displaced persons affected by regional conflicts [17].

Among the city's 12 primary healthcare centers, six were selected for the study: Martyr Faisal, Al-Hikma, Al-Akad, Al-Mosiab, Al-Hasaia, and East Al-Firia. These centers were purposefully chosen to ensure a representative sample of patients, reflecting varying admission rates and healthcare access influenced by factors such as health insurance coverage. The selection balanced diversity with feasibility, enabling comprehensive data collection within the study's timeframe.

Definition of controlled hypertension

Controlled hypertension is defined as taking antihypertensive medication with a systolic blood pressure (SBP) < 140 mmHg and diastolic blood pressure (DBP) < 90 mmHg among adults with hypertension [3].

Study population and sampling

Hypertensive patients who had been diagnosed and initiated on treatment prior to the study period, and were actively attending primary healthcare centers during the study timeframe (July 1 to August 30, 2024), were included. Patients with a recent diagnosis who had not yet started treatment were excluded.

The sample size was calculated using Cochran's formula, assuming a prevalence of 50% and a 95% confidence interval [18], resulting in a minimum sample size of 384. A total of 389 patients were recruited. A multistage cluster sampling approach was used to ensure representativeness within the study constraints. In the first stage, six primary healthcare centers were randomly selected from a total of twelve centers. In the second stage, proportional sampling was done within each selected center, based on patient visit rates from monthly records. Finally, convenience sampling was used within each center due to the limited number of hypertensive patients actively seeking care, a constraint imposed by logistical challenges and restricted healthcare access amid ongoing conflict.

Data collection method

Data were gathered using a face-to-face questionnaire consisting of 41 items, divided into three sections: sociodemographic characteristics, the General Medication Adherence Scale (GMAS), and the Hypertension Knowledge Test (HKT). The GMAS includes 11 questions across three categories—adherence behavior, nonadherence due to other conditions, and financial constraints. Responses range from "never" (3 points) to "always" (0 points). The adherence levels were classified as high (30–33), good (27–29), partial (17–26), low (11– 16), or poor (\leq 10) [19–21]. The HKT consists of 19 true/ false and multiple-choice questions assessing knowledge about hypertension, including its management and impacts. Knowledge levels are classified as high (75% correct answers), average (50–75%), or low (< 50%) [22].

The GMAS and HKT used in this study were not developed specifically for this research but were adapted from previously published studies. The Arabic version of the GMAS was translated and validated by Naqvi et al. (2020) for use in a Saudi population [19-21]. The Arabic version of the HKT was translated by the authors of the Saudi study [23], and we obtained permission to use both the Arabic and English versions of these scales in this study.

Data management and analysis

Data were collected by trained data collectors using KoboCollect, a mobile data collection tool. The data were exported to Excel for cleaning, coded, and analyzed in SPSS version 26. Categorical variables were presented as frequencies and percentages (%), and continuous variables were summarized using the mean and standard deviation. GMAS and HKT scores were compared with sociodemographic characteristics using the Mann-Whitney U test. Non-normal distributions of GMAS and HKT scores were assessed using the Shapiro-Wilk test, and the Kruskal-Wallis test was used to compare scores across four groups. The Pearson correlation coefficient was calculated to assess the relationship between GMAS and HKT scores. A *p*-value of <0.05 was considered statistically significant.

Tool modification

To align with Sudanese cultural norms, the data collection tool was modified by excluding questions about alcohol consumption from the HKT, as alcohol use is not common in Sudanese culture. This adjustment ensured the questionnaire's relevance and appropriateness for the study population.

Ethical approval

Ethical approval was obtained from the Ethical Committee at the Community Medicine Department, Khartoum University. Approval was also secured from the Primary Healthcare Administration at Al-Dammer locality. Informed consent was obtained from all participants, who were informed about the study's aims and their right to withdraw at any time. All data were anonymized and kept confidential.

Results

Participant characteristics

This study included 389 hypertensive patients, who were distributed among six primary healthcare centers (PHCCs) according to the rate of patient visits to each center. In terms of patient distribution in PHCCs, 59.6% were found at the Martyr Faisal Center. Further details are provided in Fig. 1 below.

In total, 43.7% were over 60 years old, with more than half of them being female (63%). Additionally, 18% were displaced due to the current armed conflict. A total of 77.1% were married, and nearly half of them were illiterate (49.4%). A total of 43.4% of the patients reported difficulty buying their medications due to cost, and 36.2% reported difficulty due to unavailability. The prevalence of patients with controlled hypertension was 82.3%, while those with uncontrolled blood pressure during the last measurement constituted 41.6%. Further details are provided in Table 1 below.

Adherence patterns and knowledge levels in hypertensive patients

The mean GMAS score was 27.7 (SD 4.57). We observed that 47% and 26.5% of patients had high adherence and good adherence, respectively, whereas only 1% of them had poor adherence (Table 2). Regarding hypertension knowledge, the mean score was 12.32 (SD 2.88), with more than half of the patients having average knowledge (57.8%). Further details are provided in Table 2 below.

Adherence and its associated factors

Analysis of GMAS scores in relation to patients' sociodemographic characteristics revealed that higher GMAS scores were significantly linked to older age (Z=2.897, p=0.004), higher income (Z=2.536, p=0.011), having controlled hypertension (Z=3.180, p=0.01), and having



Fig. 1 Sample distribution among primary healthcare centers in Al-Dammer. This figure illustrates the distribution of hypertensive patients across six primary healthcare centers (PHCCs). The Martyr Faisal Center had the highest number of patients, accounting for 59.6% of the total sample

a normal last measurement of BP (Z = 3.628, p < 0.0001). Further details are provided in Table 3 below.

Knowledge and its associated factors

When the differences in the HKT scores in terms of sociodemographic characteristics were measured, a higher HKT score was more strongly associated with being more educated (Z=4.517, p<0.001), displaced (Z=3.019, p=0.003), and having higher income (Z=4.948, p<0.0001). More details are provided in Table 4 below.

Correlation between GMAS and HKT scores

Figure 2 shows a significant positive correlation between the GMAS score and the HKT score (r = 0.047; p < 0.0001). This finding indicates that an increase in the GMAS score is correlated with an increase in the HKT score. The result is demonstrated in Fig. 2 below.

Factors influencing medication adherence: a regression analysis

In the regression analysis, several factors were found to significantly influence medication adherence. Control of hypertension was a strong predictor, with those who had better control showing significantly greater adherence (B = -2.699, p < 0.0001). Similarly, a higher level of knowledge about hypertension positively affected adherence (B = 0.065, p < 0.0001). Difficulty in finding medicines due to cost also had a notable impact, with those reporting higher costs showing lower adherence (B = 0.378, p < 0.0001). Age group and marital status were also significant predictors, although with smaller effects; older age groups and married individuals were associated with

better adherence (Age group B = 1.251, p = 0.022; Marital status B = 0.626, p = 0.031). The last recorded blood pressure level was positively related to adherence (B = 1.553, p = 0.001). In contrast, factors such as gender, monthly income, educational level, and displacement status did not significantly impact adherence. Additionally, difficulty in finding medicines due to unavailability did not significantly affect adherence (B = 0.207, p = 0.390). Further details are provided in Table 5 below.

Discussion

This study explored hypertension knowledge and medication adherence among hypertensive patients in Al-Dammer, Sudan, revealing moderate knowledge levels and varying adherence patterns. Most patients demonstrated average knowledge of hypertension, with a strong link between higher knowledge and improved adherence. This highlights the potential of educational interventions to enhance hypertension management, particularly in conflict-affected areas.

Knowledge levels among hypertensive patients

This study revealed modest knowledge levels among hypertensive patients, with 57.8% demonstrating average knowledge, 25.2% high knowledge, and 17% low knowledge levels. These findings are comparable to those in Saudi Arabia, where over half of participants showed moderate knowledge [23].

In the U.S., a higher level of understanding was noted, with 44% of respondents answering all questions correctly, reflecting the benefits of stronger health education systems and frequent healthcare engagement [24]. Similarly, in Poland, 54.7% of participants demonstrated good

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 Table 1
 Socio-demographic characteristics of the hypertensive patient (n=389)

Variable	Number	Percentage
Age group		
18–30 years	4	1.0%
31–40 years	24	6.2%
41-50 years	63	16.2%
51–60	128	32.9%
60years	170	43.7%
Gender		
Male	144	37%
Female	245	63%
Monthly income		
<100,000	233	59.9%
100,000-200,000	108	27.8%
More than 200,000	48	12.3%
Displacement status		
Not displaced	319	82%
Displaced	70	18%
Education level		
Illiterate	192	49.4%
Primary school	84	21.6%
Secondary school	63	16.2%
University	37	7.5%
Higher studies	13	3.3%
Marital status		
Single	13	3.3%
Married	300	77.1%
Divorced	9	2.3%
Widow	67	17.2%
Difficulty in finding medicines because		
they are expensive during war		
Always	169	43.4%
Often	121	31.2%
Sometimes	55	14.1%
Never	44	11.3%
Difficulty in finding medicines because		
they are unavailable during war		
Always	117	30.1%
Often	141	36.2%
Sometimes	91	23.4%
Never	40	10.3%
Having controlled hypertension		
Yes	320	82.3%
No	69	17.7%
What was your last measurement		
regarding control?		
Controlled	227	58.4%
Uncontrolled	162	41.6%

knowledge, though 40% had average knowledge, and 5.3% had poor knowledge, indicating better awareness compared to this study's population [25]. On the other hand, Sri Lanka reported significantly lower knowledge levels, with nearly 92% of patients lacking even moderate understanding. This underscores the challenges posed by

Table 2 Descriptive statistics for the general medication adherence scale (GMAS) and Hypertension knowledge test (HKT) (*n*=389)

Variables	N (%)
GMAS score (mean ± SD)	27.7±4.57
Level of adherence	
Poorly adherence score 0–10)	4 (1%)
Low adherence score (11–16)	11 (2.8%)
Partial adherence score (17–26)	88 (22.6%)
Good adherence score (27–29)	103 (26.5%)
High adherence score (30–33)	183 (47%)
HKT score (mean ± SD)	12.32 ± 2.88
Low score (< 50%)	66 (17%)
Average score (50 – 75%)	225 (57.8%)
High score (75%)	98 (25.2%)

Table 3	Differences	in GMAS s	core in re	lation to	the socio)-
demogra	aphic charac	teristics of	the hype	rtensive	patients	(n=389)

Factor	GMAS Score (Mean±SD)	Z-test	P-value
Age group			
≤50 years	26.77 ± 4.678	2.897	0. 004 **
50 years	28 ± 4.479		
Gender			
Male	27.96 ± 4.10	0.034	0.973
Female	27.59 ± 4.83		
Monthly income			
0 -100,000	27.47 ± 4.44	2.536	0.011 **
100,001-200,000	28.11 ± 4.76		
Educational level			
High school or below	27.72 ± 4.46	0.723	0. 470
Bachelor's degree or higher	27.8 ± 5.299		
Displacement status			
Not displaced	27.79 ± 4.57	0.824	0.410
Displaced	27.44 ± 4.62		
Having controlled hypertension	on		
Yes	28.2 ± 3.95	3.180	0.001 **
No	25.51 ± 6.3		
Last measurement BP level			
Normal or low	28.37 ± 4.10	3.628	< 0.0001**
Elevated or high	26.82 ± 5.03		

limited access to healthcare and public health initiatives in resource-constrained settings [26]. These comparisons highlight the influence of healthcare infrastructure, public health policies, and socioeconomic factors on patient knowledge levels globally, emphasizing the need for targeted educational programs in less developed regions.

Predictors of knowledge

Our study revealed that higher income, better education, and displacement status were significant predictors of hypertension knowledge. Higher-income patients likely had greater access to healthcare resources, while bettereducated individuals could better understand and retain

Table 4	Differences in HKT score in relation to the socio-	
demogra	aphic characteristics of the hypertensive patients (r	1=389)

Factor	HKT score	Z-test	P-value	
	(Mean ± SD)			
Age group				
≤50 years	12.63 ± 2.85	0.988	0.323	
<50 years	12.23 ± 2.89			
Gender				
Male	12.33 ± 3.02	3.34	0.731	
Female	12.32 ± 2.79			
Monthly income				
0 -100,000	11.77 ± 2.84	4.948	< 0.0001**	
100,00-200,000	13.15 ± 2.74			
Educational level				
High school or below	12.06 ± 2.77	4.517	<.0001**	
Bachelor's degree or higher	14.10 ± 2.98			
Displacement status				
Not displaced	12.11 ± 2.94	3.019	0.003 **	
Displaced	13.31 ± 2.33			
Having controlled hypertensi	on			
Yes	12.45 ± 2.76	1.603	0. 109	
No	11.72 ± 3.34			
Last measurement BP level				
Normal or low	12.56 ± 2.74	1.893	0.058	
Elevated or high	12±3.04			

health information. Displaced patients may have benefited from targeted healthcare interventions.

Similar findings were reported in a study conducted in Saudi Arabia, where predictors included higher education, income, older age, and participation in medical programs [27]. Another study from Poland confirmed that higher education and gender influenced knowledge Page 6 of 9

levels, with women showing slightly better understanding, though not statistically significant [25]. These comparisons highlight the consistent role of socioeconomic and educational factors in determining patient knowledge about hypertension across different populations.

Adherence levels to antihypertensive medication

The adherence levels in our study varied, with a mean score of 27.7 (SD 4.57). A majority of participants (47%) showed high adherence, indicating a positive trend, while 22.6% had partial adherence, suggesting room for improvement. Although poor (1%) and low adherence (2.8%) were minimal, these levels indicate barriers that may require targeted interventions.

These findings are consistent with those from the Qassim region of Saudi Arabia, where 51.3% of participants had high adherence, 22.3% had good adherence, 2.4% had low adherence, and 1.5% had poor adherence [23]. In Manggis, Bali, adherence was 65.9% [28], and in a study from Pakistan, which enrolled 450 hypertensive patients (mean age 54.5 years, SD 10.6), 25.6% had good adherence, 36.7% had moderate adherence, and 37.8% were nonadherent [29]. While our study shares similar adherence patterns with these regions, the nonadherence rate in our study is higher, suggesting that local factors, such as healthcare access and patient education, may contribute to the variation. These findings highlight the need for region-specific strategies to address barriers to medication adherence, as poor adherence remains a significant issue globally [30-32].



Fig. 2 Correlation between GMAS score and HKT score. A significant positive correlation was observed between the GMAS (General Medication Adherence Scale) score and the HKT (Hypertension Knowledge Test) score (r=0.47; p < 0.0001), indicating that higher medication adherence is associated with better hypertension knowledge

Table 5 Regression analysis of factors influencing blood pressure control in hypertensive patients

variable	Beta (Regression)	Stan- dard	t-value	R ²	F statistic	<i>P</i> -value (Beta)
	-	error				
Age group	1.251	0.545	2.297	0.013	5.247	0.022**
Gender	-0.366	0.480	-0.76	0.002	0.582	0.446
Monthly income	0.436	0.473	1.3	0.005	1.348	0.179
Educational level	0.083	0.694	0.120	0.000	0.014	0.905
Marital status	0.626	0.290	2.161	0.012	4.669	0.031**
Displacement status	-0.347	0.604	-0.575	0.001	0.330	0.566
Having control hypertension	-2.699	0.592	-4.559	0.051	20.708	<.0001**
Last measurement BP level	1.553	0.464	3.346	0.028	11.197	0.001**
Difficulty in finding medicines because they are expensive during war	0.378	0.218	6.309	0.093	39.799	<.0001**
Difficulty in finding medicines because they are unavailable during war	0.207	0.241	0.860	0.002	0.740	0.390
Knowledge level	0.065	0.015	4.359	0.047	19.003	< 0.001**

Predictors of adherence

According to our data, multiple predictors were associated with increased adherence, including older age, higher income, reasonable hypertension control, and normal or low last BP measurements. Conversely, other factors, such as being female, being married, being unemployed, being nonsmokers, having a longer duration of HTN as well as its treatment, educational level, family support, comorbidities, health insurance, number of pills, regular follow-up, and experiencing complications due to HTN, have been indicated in other studies [26, 33, 34].

Relationship between knowledge and adherence

One key finding of this study was the positive relationship between knowledge of hypertension and adherence to antihypertensive medication. This suggests that greater knowledge about hypertension is associated with improved adherence to prescribed treatments. In their study, Akoko et al. examined 221 hypertensive patients in the Bamenda Health District, Cameroon. They reported that 14% of participants with sufficient knowledge about hypertension had a high compliance rate of 74.2%, whereas 25.8% were noncompliant. In contrast, among the 86% of participants who lacked adequate knowledge, only 38.9% were compliant, and 61.1% were noncompliant [35]. These findings are consistent with those reported by other researchers [25, 28, 36, 37].

Contradicting these findings, two studies present contrasting results regarding the relationship between knowledge and adherence. The Lagos study involving 200 adults revealed that although participants had adequate knowledge and positive perceptions of hypertension, adherence rates to medication were low [31]. Additionally, the Tanggulangin study, which assessed 65 participants, revealed a statistically significant but moderate negative correlation between knowledge and adherence. The Spearman Rho test revealed a correlation coefficient of -0.331 (p=0.007), suggesting that while increased knowledge was associated with decreased adherence, the relationship was not strong. This finding indicates that while knowledge about hypertension plays a role, other factors may also significantly impact adherence to medication [38].

Barriers to adherence in terms of cost and availability of medications

Cost of medicines A substantial proportion of patients (43.4%) consistently found it difficult to purchase their medicines due to high costs during the war. This financial barrier to accessing medications was echoed by 31.1% of the respondents who often experienced similar difficulties. This highlights a major issue where economic constraints significantly impact medication adherence.

Availability of medicines Difficulty due to the unavailability of medicines was reported by 30.1% of participants as a consistent problem, whereas 36.2% experienced it often. This finding indicates that supply chain disruptions also play a critical role in adherence challenges. In contrast, only 10.3% of patients reported never facing this issue, underscoring that unavailability is a more frequent concern than cost. The *p*-value for the difficulty due to unavailability was insignificant, suggesting that while unavailability is a notable problem, its effect may not be as consistently impactful as cost. However, both issues contribute to the overall challenge of medication adherence during war.

Limitation

Although a multistage cluster sampling approach was used, convenience sampling within selected healthcare centers may limit the generalizability of the findings. The cross-sectional design restricts causal inference between knowledge, adherence, and sociodemographic factors. Reliance on self-reported data for medication adherence and knowledge introduces the risk of recall bias. Additionally, the study may not have fully addressed all potential influences on adherence, such as psychological or environmental factors, including stress, patientphysician interactions, medication side effects, and comorbidities.

Conclusion

In conclusion, enhancing hypertension knowledge plays a crucial role in improving medication adherence, with factors such as higher income, older age, and well-controlled hypertension further supporting better adherence outcomes. Despite the challenges posed by the ongoing conflict, integrating patient education into healthcare policies remains essential for promoting adherence and achieving better health outcomes in conflict-affected settings. Future longitudinal research is needed to establish causality and explore additional factors influencing adherence under such difficult conditions.

Abbreviations

HTN	Hypertension
WHO	World Health Organization
PHCCs	Primary healthcare centers
HKT	Hypertension knowledge test
GMAS	General medication adherence scale
SPSS	Statistical Package for Social Sciences

Supplementary Information

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Supplementary Material 1 Supplementary Material 2

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Author contributions

MR envisioned the study and took charge of the overall design and supervision. AM and EM were involved in data collection and conducted the preliminary analysis. HM contributed to data interpretation and helped in drafting the manuscript. LA critically reviewed the manuscript and offered substantial intellectual input. All authors reviewed and approved the final manuscript.

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Data availability

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

Declarations

Consent for publication

The study was conducted according to the Helsinki Declaration, consent for publication was obtained from all participants as part of the informed consent process. The participants were informed that the data collected would be used for research purposes and that the findings would be published in scientific journals without revealing their identities.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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