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RESEARCH

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The relationship between hypertension, anemia, and BMI in women of reproductive age: evidence from a nationwide health study

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Abstract

Background Hypertension, anemia, and malnutrition are significant global health challenges. While prior studies have primarily focused on the prevalence of these conditions in Nepal, no research has investigated the interrelationship among them. Therefore, this study aimed to investigate the association of hypertension with anemia, blood hemoglobin levels, and body mass index (BMI) among women of reproductive age.

Methods Using multilevel logistic regression models, we analyzed nationally representative data from the 2022 Nepal Demographic and Health Survey (NDHS). A total of 4,133 eligible women aged 15–49 were included in this study. Hypertension (systolic pressure ≥ 140 mmHg or diastolic pressure ≥ 90 mmHg), anemia (blood hemoglobin < 12 g/dl), and BMI categories were defined according to the World Health Organization (WHO) guideline. Student's t-test, Pearson's Chi-square, and linear regression analysis were performed in the analysis.

Results The mean age of the participants was 29.78 ± 9.61 years. The prevalence of hypertension was significantly higher in women without anemia than those with anemia (9.0% vs. 5.4%, $p < 0.001$). An inverse association was observed between hypertension and anemia (OR, 0.73; 95% CI: 0.55–0.96; $p < 0.01$). Increased hemoglobin levels (systolic: β, 1.24; 95% CI: 0.14–1.46; diastolic: $\beta = 1.57$, 95% CI: 1.38–1.71) and BMI (systolic: $\beta = 0.89$, 95% CI: 0.80–0.99; diastolic: $\beta = 0.84$, 95% CI: 0.68–0.92) were positively correlated with hypertension. Smoking, overweight, obesity, and increased mid-upper arm circumference (MUAC) were found to increase the risk of hypertension.

Conclusion This study demonstrates a positive association between hypertension and BMI, while anemia was linked to a lower risk of hypertension. The findings suggest that higher hemoglobin levels may serve as an independent risk factor for hypertension. Therefore, regular screening of hemoglobin levels and BMI, along with interventions addressing dietary and lifestyle factors is recommended to mitigate the risk of hypertension.

Keywords Hypertension, Anemia, Body mass index, Blood hemoglobin, Women

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Background

Hypertension, anemia, and malnutrition are prevalent global health concerns that significantly contribute to the rising burden of non-communicable diseases worldwide [1, 2]. Hypertension, a major modifiable risk factor for cardiovascular disease, stroke, kidney failure, and premature death, is especially concerning in resource-limited settings [2]. Over 1 billion people are currently living with hypertension, a number projected to rise to 1.5 billion by 2025 [3, 4]. Anemia, on the other hand, affects 30–50% of women in low- and middle-income countries, leading to adverse maternal and child health outcomes [1, 5, 6]. Obesity and underweight, both on the spectrum of malnutrition, are rising in prevalence in developing countries. Obesity, in particular, is closely associated with hypertension and cardiovascular disease [7, 8]. Together, these conditions impose a significant comorbid burden on global health in countries with limited healthcare infrastructure [9]. Thus, there is a pressing need for a comprehensive understanding of these conditions to mitigate associated risks.

In South Asia, the prevalence of hypertension and anemia is notably high [8, 10]. Hypertension affects approximately 35% of the adult population in this region [10, 11]. Nearly 47% of women of reproductive age in the region suffer from anemia, contributing to maternal morbidity, poor fetal outcomes, and infant mortality [12]. Nepal, in particular, ranks third in South Asia for hypertension prevalence, with 29.4% of its adult population affected, following Pakistan (30.5%) [10]. According to the latest Nepal Demographic and Health Survey (NDHS) of 2022, the prevalence of hypertension and anemia among women was 18% and 34%, respectively [13]. Although efforts to reduce anemia have shown some progress, its prevalence among women of reproductive age in Nepal has stagnated at around 35% for the last decade [8, 12]. The substantial prevalence of these two conditions, especially among women, presents a significant challenge for the country's healthcare system, which is already strained by socioeconomic disparities [7, 12].

Studies have shown a significant link between hypertension, anemia, hemoglobin levels, and body mass index (BMI), alongside other risk factors, such as smoking, education level, poor diet, and lack of physical activity [4, 11, 14, 15]. Research suggests that both higher hemoglobin and anemia, characterized by low hemoglobin, can exacerbate blood pressure (BP) [4, 15–17]. Obesity and overweight are also linked to an increased risk of both anemia and hypertension, further complicating the relationship between these conditions [18–20]. In this context, understanding how hemoglobin levels and BMI interact with hypertension is crucial for effective public health interventions.

The combined impact of hypertension, anemia and malnutrition on women's health is a critical and growing concern in Nepal [8, 11]. Despite ongoing national interventions to reduce these conditions, the prevalence remains high, indicating a need for a thorough investigation. There is also a significant gap in understanding and limited evidence regarding the associations between these health conditions [11, 12]. Previous studies have primarily focused on small, region-specific populations or pregnant adolescents, limiting the generalizability of their findings [7, 8, 21]. By analyzing nationally representative, large-scale health survey data, this study aims to provide empirical evidence on the relationship between hypertension, anemia, and BMI among women of reproductive age. The findings will offer new insights and help guide future interventions better tailored to address the burden of hypertension and obesity at the population level.

Methods

Study settings and population

This study utilized data from the 2022 NDHS, a nationally representative survey that provides updated demographic and health information on the people of Nepal. The survey was implemented by the Ministry of Health and Population (MoHP) and took place between January 5 and June 22, 2022. In this nationwide survey, stratification was applied by dividing each of Nepal's provinces into urban and rural areas, creating 14 sampling strata. The sampling followed a two-stage process. In the first stage, 476 primary sampling units (PSUs) were selected using a probability-proportional-to-size method from 248 urban areas and 228 from rural areas. In the second stage, 30 households were randomly selected from each PSU, resulting in a total sample size of 14,280 households: 7,440 urban and 6,840 rural. Among the surveyed households, 15,238 women aged 15–49 were eligible for the NDHS, of whom 14,845 were successfully interviewed, yielding a response rate of 97.42%. Of these 14,845 women, those with unavailable hemoglobin and BP measurements, missing data for covariates, or implausible BMI values were excluded. Details of the NDHS 2022 can be found elsewhere [13].

Clinical variables

BP was measured using a multi-user upper arm BP monitor with automatic inflation and pressure release, and an appropriately sized cuff. BP measurements were collected from women aged 15 and above. Three readings were taken, with intervals of at least 5 min between each measurement. The final BP value was the average of the second and third readings, which was used to classify hypertension. Hypertension was defined as systolic pressure ≥ 140 mmHg and/or diastolic pressure ≥ 90 mmHg according to the World Health Organization (WHO) guideline [22]. Women reported taking any antihypertensive medications were also classified as hypertensive following the National Guidelines for Management of Hypertension in Nepal and prior studies [9, 23, 24]. Blood samples were collected from a finger prick, with hemoglobin levels measured on-site via a HemoCue analyzer. In the NDHS dataset, hemoglobin levels were adjusted for smoking status and altitude [25]. Anemia was defined as hemoglobin levels < 12 g/dl according to WHO guidelines [26]. BMI was categorized based on WHO guidelines for Asian populations [27]. Women with a BMI of < 18.5 kg/m^2, 18.5–22.99 kg/m^2, 23.0–27.49 kg/m^2, and ≥ 27.5 kg/m^2 were considered as underweight, normal weight, overweight, and obese, respectively.

Covariates

In this study, the covariates included age, mid-upper arm circumference (MUAC), pregnancy status (yes, no), education level (no education, primary, high school, college or higher), wealth index (poorest, poorer, middle, richer, richest), residency area (urban, rural), and smoking status (yes, no). The wealth index was determined using principal component analysis, based on the wealth quintiles of household assets [13].

Statistical analysis

All the statistical analyses were done in SAS (Version 9.4.). We conducted a weighted sample analysis to account for the complex survey design of the NDHS 2022. Data were presented using descriptive statistics, including frequencies, percentages, and mean ± SD. The normality of the data was assessed using the Shapiro-Wilk test and Q-Q plots. Differences between the groups were assessed using the Chi-square test for categorical variables and the student's t-test for continuous variables. Linear regression analysis was employed to examine the relationship between BMI, hemoglobin levels, and systolic and diastolic blood pressure values. Multilevel logistic regression models were conducted to analyze the association between hypertension and anemia. The models were developed as follows: Model 1 was unadjusted; Model 2 was adjusted for age, education, wealth index, marital status, and residency; and Model 3 included additional adjustments for pregnancy, smoking, BMI, and MUAC based on Model 2. Additionally, the association between baseline characteristics and hypertension was evaluated using multivariable logistic regression analysis. Beta coefficients (β) and odds ratios (ORs) with 95% confidence intervals (CIs) were estimated. Multicollinearity was assessed using the variance inflation factor. A p-value of < 0.05 was considered statistically significant for all analyses.

Ethical considerations

We obtained approval from the Demographic and Health Survey (DHS) to access and use the dataset for this study (no. 2024-08-05). All data are publicly available and accessible from the DHS official website (https://www.dhsprogram.com/data). The 2022 NDHS received ethi cal approval from the Institutional Review Board of ICF International in the United States (no. 180657.0.001. NP.DHS.01). This study adhered to the principles outlined in the Declaration of Helsinki. ICF International ensured that the survey complied with U.S. Department of Health and Human Services regulations for the protection of human subjects. During the NDHS 2022, written informed consent was obtained from all adult participants. For participants under 18, consent was obtained from their parents or guardians, along with assent from the minors themselves.

Results

Among the 14,845 women, 4133 eligible women (weighted) aged 15–49 years were included in the analysis. The mean age of the participants was 29.78 ± 9.61 years, with a mean BMI of 23.01 ± 4.36 kg/m² and a mean hemoglobin level of 12.41 ± 4.36 g/dl. The mean systolic and diastolic blood pressure readings were 109.21 ± 14.76 mmHg and 73.97 ± 10.42 mmHg, respectively. The baseline characteristics of the participants according to the presence of hypertension are presented in Table 1. The prevalence of hypertension was significantly higher in women without anemia compared to those with anemia (9.0% vs. 5.4%, p < 0.001). Women with hypertension had higher mean hemoglobin levels, BMI scores, MUAC, and age compared to those without hypertension (all p < 0.001). Significant differences were also observed between hypertension and other baseline variables, such as education level, marital status, pregnancy status, smoking status, and wealth index.

Table 2 presents the results of the multilevel logistic regression model for hypertension and anemia. Hypertension was inversely associated with anemia after adjusting for all covariates in model 3 (OR, 0.73; 95% CI: 0.55–0.96; p < 0.01). Notably, the risk of hypertension significantly decreased as additional covariates were adjusted.

The effect of age, BMI, MUAC, and hemoglobin levels on systolic and diastolic BP is illustrated in Fig. 1. Increased age (systolic: β = 0.55, 95% CI: 0.41–0.64; diastolic: β, = 0.36, 95% CI: 0.33–0.41), BMI (systolic: β = 0.89, 95% CI: 0.80–0.99; diastolic: β = 0.84, 95% CI: 0.68–0.92), MUAC (systolic: β = 0.97, 95% CI: 0.92–1.16; diastolic: β = 1.11, 95% CI: 1.01–1.24), and hemoglobin levels (systolic: β, 1.24; 95% CI: 0.14–1.46; diastolic: β = 1.57, 95% CI: 1.38–1.71) were significantly correlated

Table 1 Baseline information according to hypertension

Variables	Women aged 15–49 years (*n*, 4133)		
	Hypertension (*n*, 319)	No Hypertension (*n*, 3814)	*p*-value
Anemia			
No	241 (9.0)	2439 (91.0)	< 0.001
Yes	78 (5.4)	1375 (94.6)	
Hemoglobin (g/dl)[#]	12.94 ± 1.64	12.36 ± 1.60	< 0.001
BMI (kg/m^2)[#]	25.83 ± 5.12	22.76 ± 4.21	< 0.001
MUAC (cm)[#]	27.59 ± 3.24	25.81 ± 3.02	< 0.001
Age, years[#]	37.49 ± 8.30	29.14 ± 9.44	< 0.001
Education level			
No education	122 (11.7)	919 (88.3)	< 0.001
Primary	104 (8.2)	1164 (91.8)	
High school	84 (5.2)	1526 (94.8)	
College or higher	9 (4.2)	296 (95.8)	
Marital status			
No	34 (3.8)	863 (96.2)	< 0.001
Yes	285 (8.8)	2952 (91.2)	
Currently pregnant			
No	318 (8.0)	3634 (92.0)	< 0.001
Yes	1 (0.6)	180 (99.4)	
Wealth index			
Poorest	65 (8.5)	701 (91.5)	0.042
Poorer	51 (6.5)	730 (93.5)	
Middle	85 (9.6)	797 (90.4)	
Richer	48 (6.0)	756 (94.0)	
Richest	70 (7.8)	831 (92.2)	
Residency			
Urban	218 (7.7)	2609 (92.3)	0.985
Rural	101 (7.7)	1206 (92.3)	
Smoking			
No	305 (7.5)	3756 (92.5)	0.002
Yes	14 (19.4)	58 (80.6)	
BMI group			
Normal	93 (5.1)	1716 (94.9)	< 0.001
Underweight	16 (2.9)	534 (97.1)	
Overweight	96 (8.7)	1005 (91.3)	
Obese	114 (16.9)	559 (83.1)	

[#]Mean (standard deviation), Chi-square test for categorical variables and t-tests for continuous variables, *BMI* Body mass index, *MUAC* Middle-upper arm circumferences, *n* frequency, statistically significant at $p < 0.05$

Table 2 Multilevel logistic regression models for the association between hypertension and anemia

	Hypertension in women (OR, 95% CI)		
	Without anemia	With anemia	*p*-value
Model 1[a]	1.00	0.57 (0.44–0.75)	< 0.001
Model 2[b]	1.00	0.64 (0.48–0.84)	< 0.001
Model 3[c]	1.00	0.73 (0.55–0.96)	0.009

OR Odds ratio, *CI* Confidence intervals, statistically significant at $p < 0.05$

[a]Model 1. unadjusted

[b]Model 2. adjusted for age, education, wealth index, marital status, and residency

[c]Model 3. adjusted for age, education, wealth index, marital status, residency, pregnancy, smoking, BMI, and MUAC

with increased systolic and diastolic BP in women aged 15–49 years.

The impact of covariates on hypertension in women is depicted in Table 3. Smoking (OR, 2.94; 95% CI: 1.61–5.34), no education level (OR, 2.89; 95% CI: 1.46–5.70), married status (OR, 2.43; 95% CI: 1.69–3.49), overweight (OR, 1.78; 95% CI: 1.32–2.38), and obesity (OR, 3.83; 95% CI: 2.82–5.05) were found to increase the risk of hypertension. However, the residency status of women was not significantly associated with hypertension.

Discussion

Hypertension is a major global health problem associated with an increased risk of cardiovascular disease [4]. In particular, it has become a more critical health issue in Nepal. Given the scarcity of studies examining the association between hypertension, anemia, and BMI, analyzing these relationships can improve diagnosis, management, and control of the disease. Therefore, we utilized nationally representative health survey data to investigate these relationships in women aged 15–49 years. In this study, a strong positive association was observed between hypertension, hemoglobin levels, and BMI, whereas, hypertension was inversely correlated with anemia.

Previous studies have reported a significant positive association between hemoglobin levels and hypertension [4, 9, 17, 20, 28, 29]. A study from China demonstrated a positive correlation between hemoglobin and both systolic ($r = 0.075$) and diastolic ($r = 0.272$) BP, which aligns with our study [17]. However, another study identified an association only with diastolic BP [30]. Studies from Korea [31], Sudan [9], and Ethiopia [32] also reported that hemoglobin levels in participants with hypertension were significantly higher than in those without hypertension. The risk of hypertension increases with higher hemoglobin levels, even after adjusting for covariates such as age, disease history, smoking, and BMI. Lee et al.'s nationwide study showed that increases in hemoglobin concentration were associated with increases in systolic and diastolic BP by 2.6 and 3.2 mmHg, respectively [28]. Similarly, a study by Atsma et al. using linear regression analysis found that for each unit increase in hemoglobin levels, BP increased by 1.3 mmHg in men and 1.8 mmHg in women [33]. A cross-sectional study of 9,398 Iranian adults also reported a 1.09 mmHg increase in BP for every unit rise in hemoglobin levels [4]. In our study, we observed an increase of 1.24 mmHg in systolic BP and 1.57 mmHg in diastolic BP for each unit increase in hemoglobin levels. These findings strongly support the existing evidence of a positive relationship between hemoglobin levels and hypertension. In contrast, a study using both cross-sectional and longitudinal designs found no association between hemoglobin or anemia and hypertension [15], which may be attributed to the study

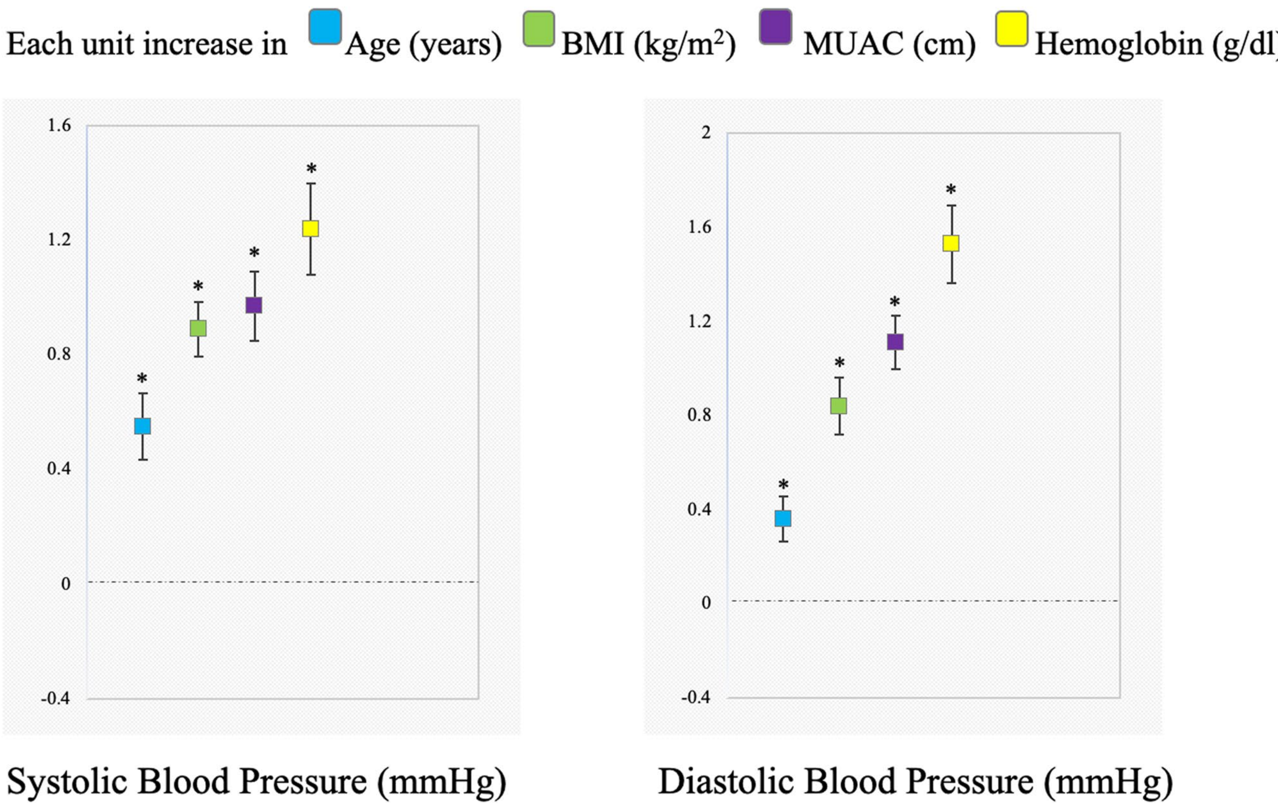

Fig. 1 Effect of age, BMI, MUAC, and hemoglobin levels on hypertension. BMI, body mass index; MUAC, middle-upper arm circumferences; *statistically significant at $p < 0.05$

Table 3 Odds of hypertension risk among women across baseline parameters

Parameters	OR, (95% CI), *p*-value
Education level (ref. college or higher)	
No education	2.89 (1.46–5.70), 0.002
Primary	1.94 (0.98–3.84), 0.056
High School	1.20 (0.60–2.38), 0.604
Marital status (ref. no)	2.43 (1.69–3.49), 0.001
Currently pregnant (ref. no)	0.08 (0.02–0.46), 0.005
Wealth index (ref. richest)	
Poorest	1.10 (0.77–1.57), 0.580
Poorer	0.82 (0.56–1.19), 0.313
Middle	1.27 (0.91–1.77), 0.152
Richer	0.74 (0.51–1.09), 0.141
Residency (ref. rural)	1.12 (0.88–1.37), 0.403
Smoking (ref. no)	2.94 (1.62–5.34), < 0.001
BMI group (ref. normal)	
Underweight	0.55 (0.51–1.71), 0.034
Overweight	1.78 (1.32–2.38), < 0.001
Obese	3.83 (2.82–5.05), < 0.001

OR Odds ratio, *CI* Confidence interval, *BMI* Body mass index, statistically significant at $p < 0.05$

design and insufficient adjustment for covariates. In our study, after adjusting for BMI and MUAC, anemia was inversely associated with hypertension. However, larger studies have shown no such association after similar adjustments [9, 15]. We observed that women who were overweight or obese had a higher risk of developing hypertension. A study from Ghana reported a higher incidence of hypertension in obese and overweight participants [5], which is consistent with our findings. A cross-sectional study among 7,907 adults found a 67% prevalence of hypertension in overweight participants [18]. Studies from China [34] and South Asian nations, including India and Bangladesh [11] also revealed a dose-response relationship between BMI, BP, and hypertension. The risk of hypertension was 1.6 times higher in overweight individuals and 3.09 times higher in obese individuals compared to those with normal BMI in Asian populations [34].

The mechanisms by which hemoglobin levels, anemia status, and BMI influence hypertension are complex and not yet fully understood. Some studies suggest that elevated hemoglobin levels may cause blood vessel constriction and increase blood viscosity, leading to higher blood pressure [9, 31]. Elevated hemoglobin levels can also damage endothelial cells and reduce the availability of nitric oxide, a critical factor in vasodilation, thereby contributing to increased BP and hypertension [3, 35]. Significant changes in growth patterns, lifestyle, sodium intake, eating habits, and behavior are also likely to affect both hemoglobin and BMI levels [6, 15, 20, 34]. Women, in particular exhibit a lower adaptive response to rising hemoglobin levels, resulting in higher blood pressure [4]. Additionally, covariates such as smoking, marital status, education level, age, MUAC, and income have been found to significantly influence the association between hypertension, BMI, and hemoglobin levels [3, 11, 17–19, 34]. Our findings also suggest that these factors play a crucial role in these associations. Thus, understanding the physiological mechanisms and risk factors behind the increase in BP, BMI, and hemoglobin levels can help inform alternative approaches to hypertension management at the clinical practice and community level.

The current findings highlight that hypertension, anemia, and BMI are interrelated and significantly impact women's health. Notably, study indicate that higher hemoglobin levels could be a key risk factor for the hypertension risk among women of reproductive. In the context of the increasing burden of hypertension, particularly amidst the ongoing nutritional transition in developing nations like Nepal [1, 11], these findings are crucial for improving overall health outcomes. Since hypertension is preventable, early diagnosis and treatment are vital in reducing the burden of non-communicable diseases in this region [7, 11]. However, poor awareness, low use of antihypertensive medications, and inadequate healthcare infrastructure continue to pose significant challenges, contributing to a substantial clinical and economic burden of hypertension at the national level [7, 14]. Therefore, strategies aimed at reducing elevated blood hemoglobin and BMI levels and promoting healthy lifestyle behavior could have a significant impact on lowering mortality and morbidity associated with hypertension.

The strength of this study lies in its use of a nationally representative large-scale dataset and multilevel regression models. To our knowledge, this is the first study to analyze the association between hypertension, anemia, hemoglobin levels, and BMI in women aged 15–49 years in Nepal. Given the significant prevalent of multifactorial diseases such as hypertension, these findings can guide government authorities, policymakers, and healthcare professionals in developing evidence-based intervention programs to reduce the associated risk. However, there are some limitations to consider. Due to the cross-sectional nature of the study, causal relationships cannot be established. Therefore, further prospective longitudinal and clinical studies are needed to elucidate these associations. Additionally, this study utilized secondary data, which may limit control over the study design. As hypertension is considered multifaceted [9], other confounding factors such as physical activity, lipid profiles, iron supplementation, psychological stress, and a history of medical conditions like diabetes were not included in the analysis. This highlights the need for further studies that consider these factors for a more comprehensive understanding of the associations between hypertension, anemia, and BMI. Since our study focused exclusively on women aged 15–49 years, future studies stratified by age groups, gender, or education status would provide deeper insights into these relationships across the broader population.

In conclusion, this study showed that increased hemoglobin levels and BMI were positively correlated with hypertension, suggesting that hemoglobin levels, in addition to BMI, serve as an independent risk factor for hypertension. However, women with anemia had a lower risk of developing hypertension. Key factors that significantly elevated the odds of hypertension included low education levels, smoking, married status, overweight, and obesity. Further clinical longitudinal studies should investigate the underlying mechanisms and causal pathways to validate these associations. Additionally, considering blood hemoglobin levels in targeted nutritional and lifestyle interventions could help reduce the risk of hypertension.

Authors' contributions
SR Acharya: Conceptualization, Methodology. SR Acharya: Acquisition, Data curation, Editing, Investigation. SR Acharya, S Pahari, D Timilsina, S Acharya, N Ray: Writing- original draft. SR Acharya: Writing-critical review. SR Acharya: Statistical analysis.

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Data availability
The datasets generated during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
We obtained approval from the Demographic and Health Survey (DHS) to access and use the dataset for this study (no. 2024-08-05). All datasets are secondary, publicly available and accessible from the DHS official website (https://www.dhsprogram.com/data). The 2022 NDHS received ethical approval from the Institutional Review Board of ICF International in the United States (reference number: 180657.0.001.NP.DHS.01). This study adhered to the principles outlined in the Declaration of Helsinki. ICF International ensured that the survey complied with U.S. Department of Health and Human Services regulations for the protection of human subjects. During the NDHS 2022, written informed consent was obtained from all adult participants. For participants under 18, consent was obtained from their parents or guardians, along with assent from the minors themselves.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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