Association between height and hypertension in the adult Nepalese population: Findings from a nationally representative survey

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Abstract

Background and aims: The burden of hypertension is increasing in Nepal. Different studies have evaluated the relationship between height and blood pressure in different regions, with mixed results. The relationship between height and hypertension has not yet been explored in the Nepalese context. Given this knowledge gap, this study aims to determine the relationship between height and hypertension among Nepalese adults (aged ≥18 years).

Methods: This study utilized the dataset from the Nepal Demographic and Health Survey (NDHS) 2016. Hypertension was defined as systolic blood pressure ≥140 mmHg and/or a diastolic blood pressure ≥90 mmHg. Height, measured in centimeters (cm), was analyzed as a continuous variable. Based on previous evidence, the following covariates were considered: age, sex, presence of overweight or obesity, educational status, household wealth status, and place, province, and ecological zone of residence. Multilevel multivariable logistic regression was done to evaluate the association between height and hypertension. Both crude odds ratio (COR) and adjusted odds ratio (AOR) are reported, along with a 95% confidence interval (CI). Sample weight of NDHS was adjusted during analysis.

Results: Among 13,393 weighted individuals over the age of 18 years, the prevalence of hypertension in Nepal was found to be 21.1% (95% CI, 19.9%-22.4%). In the final multivariable model, after adjusting for relevant covariates, it was found that height was inversely associated with hypertension. For a Nepalese adult, the odds of hypertension decreased by 10% with each 10-cm increase in height (AOR 0.9; 95% CI 0.8-0.9; P = 0.003).
Hypertension—or high blood pressure—epitomizes a global public health concern due to its association with a number of noncommunicable diseases (NCDs), including coronary artery disease, stroke, heart failure, and chronic kidney disease. According to the Global Burden of Disease Study 2017 report, hypertension is the single largest contributor to the global burden of disease and mortality, with a death toll of 10.4 million per year. Hypertension is also responsible for the loss of 20.9% disability-adjusted life years (DALYs) worldwide. In total, a quarter of the world’s adult population is affected by hypertension.

A variety of lifestyle, behavioral, anthropometric, and genetic factors can affect one’s probability of developing hypertension. In particular, the seminal research of Gertler et al in the 1950s first demonstrated an inverse association between stature and coronary heart disease. Further investigations have shown that this relationship extends to blood pressure in general. However, mixed results have been reported regarding the strength of the relationship between height and blood pressure. A sample survey of NCDs in urban Nigerian adults found no association between height and hypertension. On the other hand, nationally representative surveys from the United States, which included results from Caucasian-, African-, and Mexican-American adults, as well as from Bangladesh, Indonesia, and China, have shown an inverse association between these variables. A study of adults in Brazil showed a statistically significant inverse association among women only.

High blood pressure is a leading risk factor for a variety of NCDs throughout the developing world. In particular, low- and middle-income countries (LMICs) shoulder over 80% of the global burden. Nepal, like other LMICs that have previously focused on communicable disease services, is now on the threshold of an epidemiological transition due to the increasing burden of NCDs, including hypertension. As of 2016, around 20% of all Nepalese adults were diagnosed with hypertension. The prevalence of long-term complications due to hypertension (i.e., cardiovascular diseases) is also increasing day-by-day.

There are some studies that have explored the prevalence of hypertension as well as its associated risk factors in a variety of contexts throughout Nepal. Similarly, there are also studies that have measured the height of respondents in order to examine the relation between BMI and hypertension. However, there are no studies that have exclusively examined the association between height and hypertension in the specific context of Nepal. Given the inconsistent evidence regarding the link between height and hypertension, there remains a relevant knowledge gap. Utilization of the nationally representative Nepal Demographic and Health Survey (NDHS) 2016 will provide the clearest picture regarding whether the height of the Nepalese population is associated with their probability of developing hypertension. Determination of height as a risk factor can help policymakers develop more effective and nuanced health promotion campaigns in the future. Therefore, the objective of this study is to assess the association between height and diagnosis of hypertension among adults aged ≥18 years in Nepal.

## 2 | METHODS

### 2.1 | Data source and study design

This study is based on a secondary analysis of the Nepal Demographic and Health Survey (NDHS) 2016. NDHS 2016 was a nationally representative survey aimed at generating the latest data on the basic demographic and health indicators of Nepal. NEW ERA implemented the survey in Nepal between June 2016 and January 2017, supervised by the Nepalese Ministry of Health (MoH). The detailed methodology and data collection procedure of NDHS 2016 have previously been published.

NDHS 2016 followed a stratified cluster sampling of households to collect data. In the rural area, a two-staged sampling technique was used. After selecting primary sampling units (PSUs) using the probability proportional to size (PPS) method, a fixed amount (n = 30) of households were selected from each of the PSUs. In the urban area, a three-staged sampling method was followed. At first, PSUs were selected, and then enumeration areas (EAs) were selected from each PSU. Then, households were selected from the EAs. In the end, data were collected from 11,490 households (5,520 urban households and 5,970 rural households).

### 2.2 | Outcome of interest

The outcome of interest in this study was hypertension among the adult Nepalese population (≥18 years). Blood pressure (BP) was measured by UA-767F/FAC (A&D Medical) BP monitors. The cuff size (small, medium, or large) was used according to the arm circumference of the respondent. For each individual, BP was measured three times, with each measurement separated by at least 5 min. The average of the second and third measurements was used to calculate the BP level.
of the respondents. Hypertension was defined according to the Joint National Committee Seven (JNC7) guideline. Respondents with a systolic blood pressure (SBP) of ≥140 mmHg and/or a diastolic blood pressure (DBP) of ≥90 mmHg were considered to be hypertensive. If the study participant was taking antihypertensive medications during the time of the survey, then he/she was also classified as hypertensive, irrespective of BP level.

### 2.3 Independent variables

The main explanatory variable of interest was height of the respondents, which was considered as a continuous variable, measured in centimeters (cm). Based on previous literature, the considered covariates were age, sex, marital status, educational attainment, household wealth index, body mass index (BMI), and place. Age was categorized for comparability to previous studies. The definition of each category is listed in Table 1.

### 2.4 Statistical analysis

First, a descriptive analysis was conducted, and the findings are presented in frequencies and percentages. Household wealth index was calculated based on principal component analysis of selected assets, ie, construction material type used for roofing and flooring, type of water source, sanitation facilities, electricity, and other belongings (eg, television and bicycle). During the descriptive analyses, sample weight of NDHS 2016 was used. Next, simple and multivariable multilevel logistic regression analyses were conducted to determine factors associated with hypertension. The multilevel logistic regression analysis was conducted considering the complex hierarchical structure of DHS data as well as adjusting for the cluster sampling design. In the final multivariable logistic regression model, a variable was considered significant if the yielded P value was <0.05. To check for multicollinearity among the covariates, variance inflation factor (VIF) was used; no significant multicollinearity was found. Both crude odds ratio (COR) and adjusted odds ratio (AOR) with 95% confidence interval (CI) are reported. All the statistical analyses were done in Stata 13.0 (College Station, Texas, USA).

### 2.5 Ethical considerations

The study protocol, as well as the tools of NDHS 2016, were reviewed and approved by the ethical review board of the Nepal Research Council and ICF International. Before collecting data, informed verbal consent was taken from the heads of the household as well as from the respondents. The corresponding author (RDG) applied for the dataset to the DHS program by submitting the study protocol. DHS program approved the application and provided the dataset.

### 3 RESULTS

The overall sociodemographic characteristics of the respondents are presented in Table 2. A total of 13 393 weighted adult individuals (>18 years of age) were included in the final analyses. The majority of the study participants was female (58.0%), had received no formal education (41.6%), and were from the urban area (61.2%). Among the 13 393 weighted samples, 2827 were classified as hypertensive (21.1%; 95% CI, 19.9%-22.4%). Table 3 shows the results of the logistic regression analyses for the factors evaluated for an association with hypertension. According to the final (adjusted) logistic regression analysis, older age, male sex, overweight or obesity, being in the richest wealth index, and residence in Provinces No. 4 and No. 5 were found to be positively associated

### TABLE 1 List of variables considered for the study

| Study Variables | Description and Categories |
|-----------------|---------------------------|
| Outcome variable| Blood pressure of the study participants (0 = normal blood pressure; 1 = hypertension) |
| Explanatory variables | |
| Age | Age of the study participants in years (0 = 18-29 y; 1 = 30-49 y; 2 = 50-69 y; 3 = ≥70 y) |
| Sex | Sex of the study participants (0 = female; 1 = male) |
| Overweight/obesity | Presence of overweight/obesity in the study participants measured by body mass index (BMI) in kilogram (kg)/meter² (m²) [0 = No (BMI < 23 kg/m²); 1 = Yes (BMI ≥ 23 kg/m²)] |
| Education | Education level of the study participants (0 = no formal education; 1 = primary; 2 = secondary; 3 = college or higher) |
| Household wealth status | Household wealth quintile (0 = poorest; 1 = poorer; 2 = middle; 3 = richer; 4 = richest) |
| Place of residence | Type of the cluster (0 = urban; 1 = rural) |
| Province of residence | Province of residence of the respondents (0 = Province 1; 1 = Province 2; 2 = Province 3; 3 = Province 4; 4 = Province 5; 5 = Province 6; 6 = Province 7) |
| Ecological zone of residence | Topological zone of residence of the respondents in Nepal (0 = mountains; 1 = hills; 2 = the Terai [plain land]) |
| Height | Height of the study participants in centimeter (cm) |

*Considered as a continuous variable. In the regression model, the unit of height was 10 cm.
### TABLE 2  Distribution of the respondents according to blood pressure status, n (%) (N = 13 393)

| Characteristics | Overall, N = 13 393 | Blood Pressure Status |
|-----------------|----------------------|-----------------------|
|                 | n, % | n, % | n, % |
| **Age (in years)** | | | | |
| 18-29 | 4337 32.4 | 266 6.1 | 4071 93.9 |
| 30-49 | 5002 37.4 | 1083 21.7 | 3919 78.3 |
| 50-69 | 3188 23.8 | 1101 34.5 | 2087 65.5 |
| ≥70 | 866 6.5 | 377 43.5 | 489 56.5 |
| **Sex** | | | | |
| Male | 5620 42.0 | 1429 25.4 | 4191 74.6 |
| Female | 7773 58.0 | 1398 18.0 | 6375 82.0 |
| **Obese/overweight** | | | | |
| No | 8567 64.0 | 1342 15.7 | 7224 84.3 |
| Yes | 4826 36.0 | 1485 30.8 | 3342 69.2 |
| **Education** | | | | |
| No formal education | 5572 41.6 | 1365 24.5 | 4207 75.5 |
| Primary | 2172 16.2 | 474 21.8 | 1698 78.2 |
| Secondary | 3699 27.6 | 680 18.4 | 3019 81.6 |
| Tertiary | 1950 14.6 | 308 15.8 | 1642 84.2 |
| **Household wealth status** | | | | |
| Poorest | 2396 17.9 | 449 18.7 | 1947 81.3 |
| Poorer | 2594 19.4 | 548 21.2 | 2046 78.8 |
| Middle | 2666 19.9 | 475 17.8 | 2191 82.2 |
| Richer | 2917 21.8 | 554 19.0 | 2363 81.0 |
| Richest | 2820 21.1 | 801 28.4 | 2019 71.6 |
| **Place of residence** | | | | |
| Urban | 8191 61.2 | 1831 22.4 | 6360 77.6 |
| Rural | 5202 38.8 | 996 19.2 | 4206 80.8 |
| **Provinces** | | | | |
| Province 1 | 2365 17.7 | 475 20.1 | 1889 79.9 |
| Province 2 | 2748 20.5 | 440 16.0 | 2308 84.0 |
| Province 3 | 2933 21.9 | 732 24.9 | 2202 75.1 |
| Province 4 | 1380 10.3 | 398 28.8 | 982 71.2 |
| Province 5 | 2184 16.3 | 509 23.3 | 1675 76.7 |
| Province 6 | 674 5.0 | 109 16.1 | 565 83.9 |
| Province 7 | 1109 8.3 | 164 14.8 | 945 85.2 |
| **Ecological region** | | | | |
| Mountains | 856 6.4 | 155 18.1 | 701 81.9 |
| Hills | 5895 44.0 | 1426 24.2 | 4469 75.8 |
| The Terai | 6642 49.6 | 1246 18.8 | 5396 81.2 |
| **Height, cm** | | | | |
| Median (IQR) | 155 150-185 | 155 149-162 | 155 150-162 |

*Row percentage.*

### TABLE 3  Results of logistic regression analyses to compare crude and adjusted ORs for the factors associated with hypertension

| Traits | COR (95% CI) | P Value | AOR (95% CI) | P Value |
|--------|--------------|---------|--------------|---------|
| Age (in years) | | | | |
| 18-29 | Ref. | Ref. |
| 30-49 | 4.4 (3.8-5.1) | <0.001 | 3.7 (3.1-4.3) | <0.001 |
| 50-69 | 8.9 (7.6-10.3) | <0.001 | 8.0 (6.8-9.6) | <0.001 |
| ≥70 | 14.6 (12.0-17.8) | <0.001 | 14.2 (11.3-17.8) | <0.001 |
| **Sex** | | | | |
| Female | Ref. | Ref. |
| Male | 1.6 (1.5-1.8) | <0.001 | 1.7 (1.5-2.0) | <0.001 |
| **Overweight/obesity** | | | | |
| No | Ref. | Ref. |
| Yes | 2.7 (2.5-3.0) | <0.001 | 2.4 (2.1-2.7) | <0.001 |
| **Education** | | | | |
| No formal education | Ref. | Ref. |
| Primary | 0.8 (0.7-0.9) | <0.001 | 1.1 (0.9-1.2) | 0.40 |
| Secondary | 0.5 (0.5-0.6) | <0.001 | 1.0 (0.9-1.2) | 0.60 |
| College or higher | 0.4 (0.4-0.5) | <0.001 | 1.0 (0.8-1.2) | >0.99 |
| **Household wealth status** | | | | |
| Poorest | Ref. | Ref. |
| Poorer | 1.1 (1.0-1.3) | 0.07 | 1.2 (1.0-1.4) | 0.06 |
| Middle | 1.0 (0.9-1.2) | 0.80 | 1.1 (0.9-1.3) | 0.2 |
| Richer | 1.1 (1.0-1.3) | 0.10 | 1.2 (1.0-1.4) | 0.2 |
| Richest | 1.7 (1.4-2.0) | <0.001 | 1.5 (1.1-1.8) | 0.002 |
| **Place of residence** | | | | |
| Urban | 1.2 (1.0-1.4) | 0.01 | 1.1 (1.0-1.3) | 0.2 |
| Rural | Ref. | Ref. |
| **Provinces** | | | | |
| Province 1 | Ref. | Ref. |
| Province 2 | 0.8 (0.6-1.0) | 0.04 | 0.9 (0.7-1.2) | 0.8 |
| Province 3 | 1.3 (1.0-1.7) | 0.02 | 1.1 (0.8-1.4) | 0.7 |
| Province 4 | 1.6 (1.3-2.0) | <0.001 | 1.4 (1.0-1.8) | 0.03 |
| Province 5 | 1.2 (0.9-1.5) | 0.2 | 1.3 (1.1-1.7) | 0.03 |
| Province 6 | 0.8 (0.6-1.0) | 0.06 | 1.0 (0.7-1.3) | >0.90 |
| Province 7 | 0.7 (0.5-0.9) | <0.001 | 0.8 (0.6-1.1) | 0.20 |
| **Ecological region** | | | | |
| Mountains | Ref. | Ref. |
| Hills | 1.6 (1.2-2.1) | <0.001 | 1.2 (0.9-1.6) | 0.20 |
| The Terai | 1.2 (0.9-1.6) | 0.20 | 1.0 (0.7-1.4) | 0.80 |
| Height (per 10 cm) | 1.0 (0.9-1.0) | 0.70 | 0.9 (0.8-0.9) | 0.003 |

Note. The final model was adjusted for age, sex, presence of overweight/obesity, education, household wealth status, place of residence, province of residence, ecological region and height (in 10 cm).

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; COR, crude odds ratio.
with hypertension ($P < 0.05$). In the final multivariable model, after adjusting for age; sex; presence of overweight or obesity; educational status; household wealth status; and place, province, and ecological zone of residence, it was found that height was inversely associated with hypertension: For a Nepalese adult, the odds of hypertension decreased 10% with each 10-cm increase in height (AOR 0.9; 95% CI 0.8-0.9; $P = 0.003$).

4 | DISCUSSION

This study aimed to investigate the association between stature and hypertension in the adult Nepalese population. Utilizing a nationally representative sample, this study found an inverse association between height and hypertension in the adult Nepalese population. This is, to the best of our knowledge, the first nationally representative study done in the Nepalese setting that specifically investigated the association between stature and hypertension.

Besides height, the findings of the study reiterated some of the factors known to be associated with hypertension in various populations: older age, male sex, higher socioeconomic status, and overweight and obesity. The study also found a higher likelihood of hypertension among residents of Province No. 4 (officially known as Gandaki Pradesh) and Province No. 5, which is consistent with previous studies. Public health promotion programs should focus on raising awareness about hypertension among these groups.

The findings of our study are consistent with a similar study from Bangladesh. Hoque et al (2014) found an almost 30% reduction in the odds of hypertension in the group whose height was in the fourth quartile compared to those in the first quartile. Also, Song et al (2016) found an association between height and reduced SBP, pulse pressure, and prevalence of hypertension in the Chinese population aged 37 to 94 years. Moving away from the Asian setting, a similar phenomenon was also observed in Latin America. Data from Colombia, using a prospective cohort study, found that shorter stature in the elderly population was associated with hypertension. Studies done in Brazil have also suggested this inverse association between height and hypertension. Schooling et al. (2007) demonstrated that the association between height and elevated blood pressure is not clear until adjusting for the potential confounder of BMI. In the present study, we also adjusted for the effect of BMI in the final model and found a statistically significant inverse association between height and hypertension. Possible reasons for the varied findings of previous studies, including that done in Nigeria, which found no association between height and hypertension, may be related to differences in sample size and target group. For example, the previously mentioned study included only civil servants, which may not be generalizable to the whole population. A study with a nationally representative sample in the Nigerian context can settle this issue.

There are several explanations that could be put forward as to why height may be inversely associated with hypertension. Genetic factors that influence growth may be associated with hypertension. Anatomically, the coronary vessel diameter increases with height, which reduces the risk of atherosclerosis. Other factors inversely associated with proper childhood growth (ie, inadequate infant and toddler feeding, smoking habits of the parents, poor socioeconomic status, among others) are also directly associated with hypertension and subsequent cardiovascular disease risk in adulthood. This study did not have data on these factors, which limited our capability for analysis. Longitudinal studies should be carried out in the South Asian setting to determine the effects of maternal and early child nutrition on the occurrence of hypertension in adult life. Another important aspect is that adult height is nonmodifiable. It was found that most of the stunting occurs before the age of 2 years (often beginning in utero) and catch-up in linear growth is limited beyond this age. Furthermore, evidence indicates that short adult height in low- and middle-income countries (LMICs) is largely driven by environmental conditions (including adequate nutrition and resources, history of infectious disease, and socioeconomic condition). As a result, short adult height might be situated in the causal pathway, between environmental conditions (exposure) and hypertension (outcome). It is, thus, important for public health promotion programs to continue their efforts against malnutrition and stunting.

The strength of this study is that it utilized a nationally representative sample to investigate the association between height and hypertension. The findings of this study are generalizable to the target population in Nepal. Furthermore, NDHS 2016 utilized validated questionnaires and calibrated tools to collect data, which limits the probability of measurement error. The main limitation of the study, on the other hand, is that due to the cross-sectional nature of the survey, the temporal relationship between the outcome (hypertension) and explanatory variable (height) could not be established. As a result, we cannot establish a causal association between height and hypertension. Data on other potential confounders, including family history of hypertension, dietary habit, physical activity pattern, history of diabetes mellitus, and tobacco and alcohol use, which are known to affect hypertension, were not collected by the NDHS 2016. As such, we could not adjust for those confounders during the analysis.

5 | CONCLUSIONS

The high prevalence of hypertension is a public health problem in Nepal. While addressing known risk factors, NCDs prevention programs in Nepal should also focus on raising awareness among individuals with low stature for the prevention of hypertension. Further longitudinal studies are recommended to include genetic and social/environmental determinants of stature in the analysis.

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The lead author (Rajat Das Gupta) had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT
The lead author (Rajat Das Gupta) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the Demographic and Health Surveys (DHS) Program. Restrictions apply to the availability of these data. Data are available with the permission of the DHS at https://dhsprogram.com/data/dataset/Nepal_Standard-DHS_2016.cfm?flag=0.

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