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ORIGINAL ARTICLE

Association of altitude and urbanization with hypertension and obesity: analysis of the Nepal Demographic and Health Survey 2016

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Background: Nepal's Himalayan range attracts mountaineers, climbers and tourists from all across the globe. Limited recent evidence suggests that exposure to hypoxia at a higher altitude may be a risk factor for hypertension and a protective factor for obesity. The existing urban–rural disparities in Nepal in health and economic resources may be anticipated in the burden of hypertension and obesity, two rapidly growing public health issues, but they remain largely unstudied. Therefore this study aims to assess the association of altitude and urbanization with hypertension and overweight/obesity in Nepal.

Methods: Data on 10 473 participants from a nationally representative survey, the 2016 Nepal Demographic and Health Survey (NDHS), was used. The NDHS assessed/measured blood pressure, height, weight, urbanization and the altitude of participants' households by following standard procedures. Logistic and linear regression models were used to study the association of altitude (per 100 m increases) and urbanization with hypertension and obesity, or their continuous measurements (i.e. systolic and diastolic blood pressure [SBP and DBP, respectively] and body mass index [BMI]).

Results: The prevalence of hypertension, overweight and obesity was 25.6%, 19.6% and 4.8%, respectively. After controlling for covariates, residents of metropolitan cities had a 30% higher prevalence of overweight/obesity (adjusted prevalence ratio 1.30 [95% confidence interval {CI} 1.11 to 1.52]) than their rural counterparts. For altitude, there was a marginally increased odds of hypertension and overweight/obesity with elevation. Consistently, DBP ($\beta = 0.18$ [95% CI 0.09 to 0.27]) and BMI increased with altitude ($\beta = 0.11$ [95% CI 0.08 to 0.13]).

Conclusion: Urbanization was positively associated with BMI, while altitude showed a marginally positive association with hypertension and overweight/obesity. Given the role of obesity and hypertension in the aetiology of other chronic diseases and subsequently associated mortality and health care costs, residents in urban areas and at higher altitudes may benefit from weight control interventions and BP monitoring, respectively.

Keywords: urbanization, altitude, hypertension, overweight/obesity, Nepal.

Key messages

What is already known on this subject?

- Previous studies assessing the relationship between altitude and prevalence of hypertension in the Tibetan region found a weak association between altitude and hypertension. No studies have examined the effect of urbanization on both blood pressure and body mass index.
- Previous studies suffered from several methodological limitations: small sample size, purposive selection of study sites and a lack of accurate measurement of altitude. Thus the

available evidence cannot be regarded as conclusive. Further, no previous study from Nepal has examined the relationships between a continuous altitude variable, encompassing a wide range of elevations above sea level, and hypertension and overweight/obesity.

What might this study add?

- This study found a modest association between two markers of geographic variation, altitude and urbanization, with hypertension and overweight/obesity in Nepal.
- Statistically significant relationships between altitude and hypertension (2% increase per 100 m) as well as altitude and overweight/obesity (3% increase per 100 m) were found.

What might this study impact on clinical practice?

- While additional studies are needed to establish causality, the assessment of chronic disease risk factors in low-income settings like Nepal should emphasize assessing geographic and contextual factors. Residents in urban areas and those living at higher altitudes could be targeted for blood pressure monitoring and weight control interventions during routine primary care visits.

Introduction

Non-communicable diseases (NCDs) accounted for 71% (40.5 of 56.9 million) of all global deaths in 2016.[1] Cardiovascular disease (CVD) was the leading cause of NCD deaths, with 17.9 million deaths.[1] Hypertension and obesity are both independent risk factors for many NCDs and are responsible for a significant part of the global NCD burden. Affecting more than 1 billion people,[2] hypertension and its complications account for 9.4 million annual deaths[3]; hypertension has been recognized as the leading cause of preventable deaths globally.[4] Obesity, also considered preventable, has nearly tripled since 1975.[5] In 2016, >1.9 billion adults (39%) were overweight and >650 million (13%) were obese.[5] In Nepal, unprecedented growth in the burden of NCDs and associated risk factors in the last decade suggests this small Himalayan nation is in an epidemiological transition.[6] A recent national survey found the prevalence of hypertension and overweight/obesity among Nepalese to be approximately 26% and 21%, respectively.[7]

Although both hypertension and overweight/obesity are well-researched topics, recent evidence suggesting exposure to hypoxia at higher altitudes as a risk factor for hypertension and a protective factor for obesity is interesting.[8,9] Previous studies in Tibet have shown a significant correlation between altitude and hypertension.[10] Similarly, a few epidemiological studies have reported an inverse association between obesity and altitude.[9,11] Although the exact mechanism by which high altitude may be associated with low body mass index (BMI) and high blood pressure (BP) has not yet been elucidated, it has been postulated that continuous exposure to higher altitudes elevates autonomic and sympathetic activities, leading to higher BP.[10] Additionally, residents at higher altitudes are reported to have a lower basal metabolic rate and increased leptin levels, which may decrease energy intake and subsequently lower BMI.[12,13] Other plausible explanations for variations in obesity prevalence with altitude include low birthweight,[14] stunted childhood growth[15,16] and high incidental physical activity.[11] Nevertheless, population-based studies linking high altitude with hypertension and overweight/obesity are limited.

More than two-thirds of the global population, mostly in the regions of Central Asia, Eastern Africa and South America, live at an altitude >100 m above sea level[17]; about 83 million live at >2500 m above sea level.[18] In countries of the Hindu Kush Himalayan region, a significant proportion of the population lives at 3000–5000 m above sea level: Afghanistan (55%), Bhutan (59%), Nepal (21%) and Iran (35%).[19] Nepal, a South Asian country nestled in the Himalayas between India and China, has four of the five tallest mountain peaks in the world: Mt. Everest, Mt. Kangchenjunga, Mt. Lhotse and Mt. Makalu.[20] As such, high altitude is an indispensable part of Nepal's identity and attracts mountaineers, climbers and tourists from all across the globe. Furthermore, the distribution of human settlement by altitude varies widely in Nepal, ranging from as low as 59 m above sea level in the Terai region to as high as 4080 m above the sea level in the Dolpa district, one of the highest altitudes for human settlements in the world.[21] Given that a sizeable proportion of the world's population lives at higher elevations, seeking additional evidence for the hypothesized associations between altitude and hypertension and overweight/obesity is compelling. Nepal's geography provides a unique opportunity to explore this understudied issue.

Most research examining the association between altitude and hypertension comes from the Tibetan region.[10] However, the relationship between hypertension and altitude has been shown to differ by region.[10,22] Moreover, the strength of the association between altitude and hypertension is not consistent between the Tibetan plateau and other countries of the Hindu Kush Himalayan region (Supplementary data). Thus findings from the Tibetan region may not be generalizable to other parts of the world (Supplementary data). In Nepal, three previous studies evaluated the association between altitude and hypertension.[23–25] Of these, two studies showed differences in systolic blood pressure (SBP) by altitude,[23,24] whereas one showed no differences.[25] All three studies, none nationally representative, had limitations, including small sample size, altitude range <3000 m and purposive narrow selection of study sites.[24–26]. Using nationally representative survey data including a wide range of altitudes (from 56 to 3700 m above sea level) determined by real-time Global Positioning System (GPS) sensors will overcome some of the limitations of the previous studies and should provide rigorous nationally representative estimates.

Rapid and unorganized urbanization has increased in Nepal in recent decades. This urbanization, coupled with population growth and increased longevity, is believed to be the driver of the epidemiological transition in the country. Notably, urbanization has been shown to impact population health through unhealthy lifestyle changes, such as increases in unhealthy diets and sedentary lifestyles; these may increase the burden of both hypertension and overweight/obesity.[27,28] In recent times, Nepal has witnessed increased internal migration from rural to urban areas, as residents seek better employment and education. Urbanization, and subsequent high population density,[29] has resulted in fewer parks, walking trails and pedestrian lanes in large cities and the Terai region, making active commuting and recreational physical activity almost impossible.[30] Conversely, urbanization also provides benefits, such as increased access to healthcare services and opportunities for better education and employment, and these may improve health outcomes. The associations between urbanization and hypertension and overweight/obesity remain largely unstudied in this region. Lastly, altitude and urbanization serve as counterparts in Nepal's local context, because the most deprived districts in the country are located at high altitudes. Hence it is logical to study them together. Therefore this study aimed to assess the associations of altitude and urbanization with hypertension and overweight/obesity in Nepal.

Methods

Data source

Nationally representative data from the 2016 Nepal Demographic and Health Survey (NDHS) were used. Methodological details of the 2016 NDHS have been previously published.[30] Briefly, the 2016 NDHS used a complex multistage stratified clustered sampling (two- and three-stage clusters in rural and urban areas, respectively). In the first stage, using probability proportional to size methods, a total of 383 primary sampling units (PSUs) or clusters were selected. Then, within each cluster, 30 households were selected. A total of 11 040 households completed the interviews, for a response rate of 99%. A sample of 10 473 participants, 4474 males and 5999 females (unweighted 10 362 participants: 4394 males, 5968 females) ≥25 y of age with an available BP measurement were analysed for this study.

Outcome variables

Hypertension

Using BP monitors (UA-767F/FAC, A&D Medical, San Jose, CA, USA) with three different cuff sizes, trained research assistants under the supervision of a biomarker expert measured BP.[30] Three measurements of BP at 5-min intervals were taken with participants resting in a sitting position. The average of the last two measurements was used as the participant's BP for this study.[14] Both continuous (i.e. systolic and diastolic BP [SBP and DBP, respectively]) and categorical definitions of BP were used in our analyses. Hypertension was categorized using the World Health Organization definition (i.e. SBP ≥140 mmHg or DBP ≥90 mmHg). Participants on antihypertensive medicine, even if their BP was <140/90 mmHg, were defined as hypertensive.

Overweight/obesity

Participant's height and weight were measured using standard protocols, detailed elsewhere.[14] Briefly, BMI was calculated as the ratio of weight (in kilograms) by height squared (in meters) and then categorized into four weight categories: underweight (BMI <18.5 kg/m^2), normal weight (18.5–<25.0 kg/m^2), overweight (25.0–<30.0 kg/m^2) and obese (≥30.0 kg/m^2).[31] To improve the statistical power of logistic regression analyses, weight categories were combined to create a binary outcome variable for overweight/obesity (yes included overweight and obese, no included underweight and normal weight). Both a continuous (i.e. BMI) and categorical definition of weight were used in the analyses.

Exposures of interest

Altitude and urbanization were the two exposures of interest. For urbanization, GPS coordinates of the cluster where participants resided were collected. Using the corresponding residence location, urbanization was categorized from highest to lowest as metropolitan (highly urbanized metropolitan/submetropolitan), municipality and rural area/rural municipality, using the latest urban–rural classification by the government of Nepal following promulgation of a new constitution in 2015.[20]

Altitudes of the survey sites were calculated using GPS coordinates from the 2016 NDHS. The latitude/longitude position of the survey sites was randomly displaced up to 15 km to ensure participants' confidentiality. GPS data were collected by a trained GPS data coordinator using an eTrex 10 model receiver (Garmin, Olathe, KS, USA). Readings were taken at the centre of each primary sampling unit in a relatively open location and saved in the GPS receiver's memory. Further information on the collection of GPS data is available elsewhere.[32] For this study, altitude was used as a continuous variable for the main analyses. We also recoded it into a four-level categorical variable (<500 m, 500–1499 m, 1500–2499 m and ≥2500 m) to show the demographic distribution and to study urbanization by altitude levels in the supplemental analyses.

Other variables

Other variables, used as covariates in this study, included participant's age (10-y categories), sex (male, female), marital status (never married, currently married, formerly/ever married), education level and household wealth index. Education level included four categories: illiterate (no formal education), primary (grade 1–5), secondary (grade 6–10) and higher (grade 11 and above). The wealth index, described in detail previously,[14] was derived using principal component analysis using the information on household characteristics, such as the availability of drinking water sources, toilet facilities, consumer goods etc. The wealth index was then divided into five quintiles: poorest, poor, middle, richer and richest households.

Statistical analyses

All analyses were performed using the svy function in Stata for Windows, version 15 (StataCorp, College Station, TX, USA). The svy function incorporated sample weights and stratified cluster sampling design to provide national estimates. The outcome variables were defined as both continuous (e.g. SBP, DBP and BMI) and categorical (e.g. hypertension and overweight/obesity as binary responses). Binary Poisson regression was run separately for hypertension and overweight/obesity. Crude and adjusted prevalence ratios (APRs) were calculated using univariate and multivariable Poisson models; the latter were adjusted for age, sex, education, marital status, wealth quintile and urbanization (or altitude, depending on model).

The average distribution by elevation level of the outcome variable on a continuous scale (i.e. SBP, DBP and BMI) is presented in box plots. Mean differences by exposures and covariates are presented in forest plots. In simple and multiple linear regression models, the association of urbanization and altitude with SBP, DBP and BMI were assessed separately for each outcome. Multiple linear regression models were adjusted for age, sex, education, marital status, wealth quintile and urbanization (or altitude, depending on model).

Results

Participant characteristics

Table 1 presents characteristics of the study population by urbanization and altitude level. The majority of the participants were <45 y of age (52.6%), female (57%), currently married (86.3%), resided in urban areas (60.6%) and resided at an altitude of <500 m (50.5%). People living at high altitudes (>1500 m) were primarily residing in rural areas and had low socio-economic status (Table 1).

Outcome measures

Overall, the prevalence of hypertension, overweight and obesity was 25.6% (95% [confidence interval {CI} 24.15 to 27.19]), 19.6% (95% CI 18.32 to 20.92) and 4.8% (95% CI 4.12 to 5.55), respectively (Table 1). The prevalence of hypertension and obesity was highest among the residents of metropolitan areas and at elevations <1500 m (Table 1).

The median SBP, DBP and BMI was 115 mmHg (interquartile range [IQR] 106–128), 79 mmHg (IQR 72–87) and 21.9 kg/m^2 (IRQ 19.5–24.9), respectively (Table 1). Variation in the distribution of SBP, DBP and BMI by elevation level is shown in box plots (Supplementary Figures 3 and 4). The mean SBP, DBP and BMI were significantly higher among residents at the highest elevation level (≥1500 m) compared with the lowest (<500 m) and among residents in metropolitan areas compared with rural (Figures 1–3). Statistically significant differences in mean SBP, DBP and BMI by covariates were noted (Figures 1–3).

Association of urbanization and altitude with hypertension and obesity

After adjustment for age, sex, education, marital status, wealth index and altitude, participants living in metropolitan areas had a 30% higher prevalence of overweight/obesity (APR 1.30 [95% CI 1.11 to 1.52]) than those living in rural areas (Table 2). In the unadjusted model, participants living in metropolitan and urban areas had a higher prevalence of hypertension and overweight/obesity than their rural counterparts; however, statistical significance was lost when adjusted for covariates (Table 2). For altitude, a slightly increased prevalence of hypertension and overweight/obesity (2% and 3% increases per 100 m increase in elevation level, respectively) was observed; these remained statistically significant when covariates were added (Table 2).

Association of urbanization and altitude with SBP, DBP and BMI

DPB was significantly associated with altitude; DBP increased by 0.18 mmHg ($\beta = 0.18$ [95% CI 0.09 to 0.27]) for every 100-m increase in altitude. For the association of DBP with urbanization as well as the associations of SBP with both urbanization and altitude, the coefficients were moderately higher, although lacking statistical significance (Table 3).

For BMI, a statistically significant positive association was noted with urbanization and altitude. Compared with participants from rural areas, those from metropolitan areas and municipalities had higher BMIs by 0.88 units (95% CI 0.45 to 1.32) and 0.33 units (95% CI 0.03 to 0.64), respectively, in adjusted models (Table 3). Similarly, for each 100-m increase in altitude, BMI increased by 0.11 units (95% CI 0.08 to 0.13) (Table 3).

Findings for both hypertension and obesity were similar and mostly non-significant when analyses were repeated for urbanization by altitude level (Supplementary Table 3).

Discussion

Using a nationally representative sample of the Nepalese population, this study aimed to assess the associations between altitude and urbanization and hypertension and overweight/obesity. We found that altitude was positively associated with both hypertension and overweight/obesity and that living in metropolitan cities was associated with higher odds of overweight/obesity.

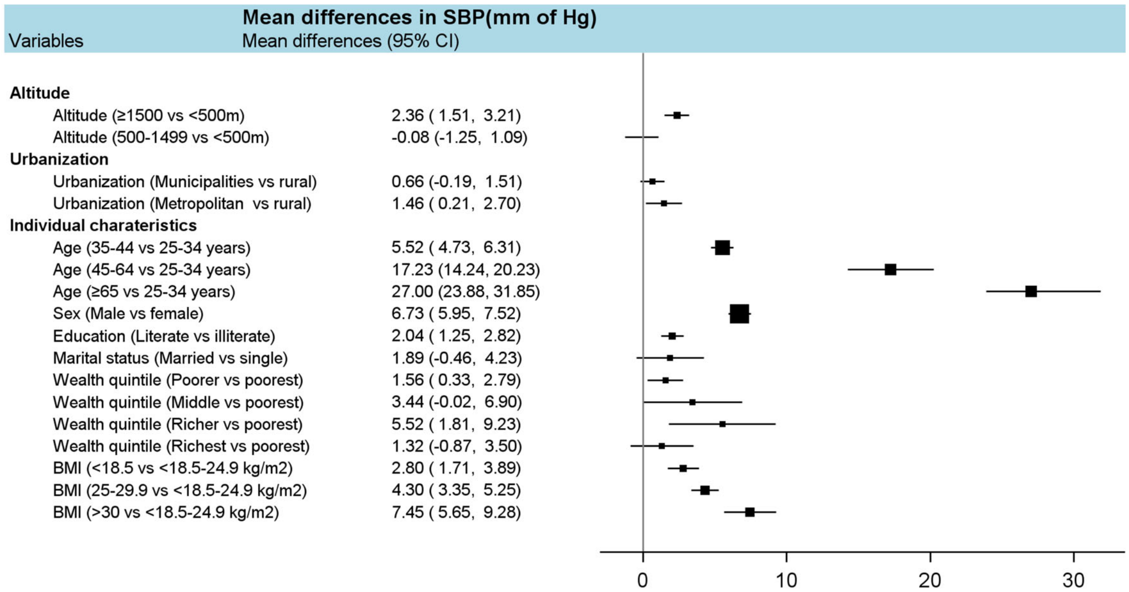
Residents of metropolitan areas had higher odds of overweight/obesity compared with those living in rural areas and residents in metropolitan areas and municipalities had higher BMI than those in rural areas. Our findings are consistent with previous studies from Nepal that found overweight/obesity is significantly less prevalent among residents in rural compared with urban areas.[7,33] Large urban–rural disparities in the distribution of body weight have been documented in the international context as well.[34,35] Higher BMI or overweight/obesity in urban areas may be attributed to increased access to energy-dense processed food, changing dietary patterns from traditional to Western habits,[36] increased sedentary lifestyles[33,37] and reductions in recreational physical activity due to a lack of open public spaces.[38] The lower BMI among rural residents may be explained by food insecurity and malnutrition, a higher level of physical activity from subsistence farming[38] and active commuting by walking. In general, overall poverty, food insecurity and malnutrition have been documented as higher in rural areas of Nepal than urban areas.[39,40] The higher incidental and occupational physical activity among rural residents due to their agriculture-based labour from subsistence farming[38] is potentially conducive to better cardiometabolic health. Although these factors could suggest the potential of higher odds of hypertension in urban areas, consistent with our findings, a previous nationwide survey of NCDs in Nepal found no urban–rural difference in the prevalence of hypertension.[7]

Every 100-m increase in altitude was associated with higher odds of hypertension and overweight/obesity (see Table 2). Furthermore, BMI increased with increasing elevation. Consistent with our findings, a previous study conducted in two

Table 1. Baseline characteristics of study participants (N=10 473)

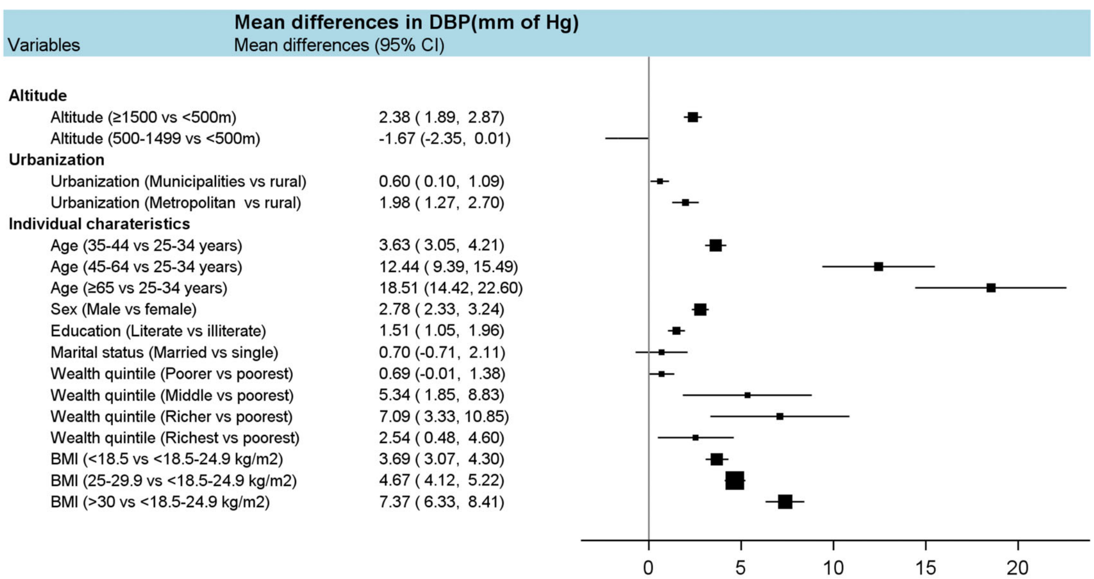
Characteristics		Urbanization						Altitude								Total	
		Metropolitan		Municipality		Rural area		<500 m		500–1499 m		1500–2499 m		≥2500 m			
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Total		1608	15.4	4729	45.2	4136	39.5	5288	50.5	3937	37.6	1206	11.5	42	0.4	10 473	100
Age (years)	25–34	531	33.1	1389	29.4	1102	26.6	1598	30.2	1078	27.4	329	27.3	17	40.0	3021	28.9
	35–44	418	26.0	1155	24.4	906	21.9	1226	23.2	969	24.6	275	22.8	9	22.4	2480	23.7
	45–54	291	18.1	892	18.9	761	18.4	974	18.4	738	18.7	221	18.3	11	27.2	1944	18.5
	55–64	191	11.9	678	14.3	690	16.7	777	14.7	579	14.7	201	16.7	3	7.4	1560	14.9
	≥65	176	10.9	615	13.0	677	16.4	713	13.5	574	14.6	179	14.9	2	3.0	1468	14.0
Sex	Male	685	42.6	2015	42.6	1774	42.9	2256	42.7	1700	43.2	502	41.6	18	42.7	4474	42.7
	Female	922	57.4	2714	57.4	2362	57.1	3032	57.3	2238	56.8	704	58.4	24	57.3	5999	57.3
Education level[a]	Illiterate	478	29.7	2238	47.3	2469	59.7	2784	52.6	1682	42.7	693	57.5	25	61.2	5185	49.5
	Primary	239	14.9	887	18.8	707	17.1	841	15.9	767	19.5	216	17.9	10	23.4	1833	17.5
	Secondary	531	33.0	1109	23.4	712	17.2	1169	22.1	966	24.5	213	17.6	4	9.1	2352	22.5
	Higher	359	22.3	492	10.4	245	5.9	488	9.2	522	13.2	84	7.0	3	6.3	1096	10.5
Marital status	Never married	83	5.2	130	2.7	84	2.0	112	2.1	132	3.4	51	4.2	2	4.5	296	2.8
	Currently married	1367	85.1	4120	87.1	3552	85.9	4640	87.8	3342	84.9	1020	84.6	38	91.0	9040	86.3
	Formerly/ever married	157	9.8	480	10.1	500	12.1	536	10.1	464	11.8	135	11.2	2	4.5	1137	10.9
Place of residence	Metropolitan							758	14.3	832	21.1	18	1.5	0	0.0	1608	15.3
	Municipality							2412	45.6	1951	49.5	352	29.1	15	36.5	4729	45.2
	Rural area							2118	40.1	1156	29.4	836	69.4	27	63.5	4136	39.5
Wealth index	Poorest	37	2.3	676	14.3	1206	29.1	242	4.6	970	24.6	674	55.9	33	79.2	1919	18.4
	Poorer	79	4.9	1022	21.6	955	23.1	872	16.5	852	21.6	325	27.0	7	17.8	2056	19.6
	Middle	158	9.8	1014	21.4	920	22.2	1460	27.6	518	13.2	111	9.3	2	3.0	2091	20.0
	Richer	329	20.5	1073	22.7	802	19.4	1582	29.9	565	14.4	57	4.7	0	0.0	2204	21.0
	Richest	1005	62.5	944	20.0	253	6.1	1132	21.4	1033	26.2	38	3.1	0	0.0	2203	21.0
BMI[b]	Underweight	108	6.7	734	15.5	813	19.6	1037	19.6	458	11.6	156	13.0	5	11.3	1655	15.8
	Normal weight	741	46.1	2814	59.5	2637	63.8	3052	57.7	2264	57.5	841	70.2	35	84.1	6192	59.1
	Overweight	565	35.2	930	19.7	557	13.5	966	18.3	924	23.5	160	13.4	2	4.6	2052	19.6
	Obese	181	11.2	223	4.7	97	2.3	202	3.8	257	6.5	42	3.4	0	0.0	501	4.8
	Median (Q1–Q3)	24.6 (21.5–27.6)		22.0 (19.6–25.0)		21.1 (19.0–23.6)		21.6 (19.1–24.6)		22.6 (20.1–25.9)		21.3 (19.5–23.7)		20.3 (19.4–22.2)		21.9 (19.5–24.9)	
Hypertension	No	1089	67.7	3515	74.3	3184	77.0	4095	77.4	2744	69.7	911	75.5	38	91.0	7788	74.4
	Yes	519	32.3	1214	25.7	952	23.0	1193	22.6	1193	30.3	295	24.5	4	9.0	2685	25.6
	SBP, median (Q1–Q3)	117 (107–131)		116 (106–129)		115 (105–128)		114 (105–127)		117 (107–131)		115 (106–128)		106 (101–118)		115 (106–128)	
	DBP, median (Q1–Q3)	80 (74–88)		79 (72–86)		78 (71–86)		77 (71–85)		80 (73–88)		79 (73–88)		74 (67–82)		79 (72–87)	

Q1: quartile 1; Q3: quartile 3.
[a]Seven missing.
[b]74 missing.



Abbreviation: BMI: Body Mass Index; SBP: Systolic Blood Pressure.

Figure 1. Mean differences in SBP by exposure and covariate characteristics (N=10 473). The size of the square is inversely proportional to the variance of mean differences (95% CI).



Abbreviation: BMI: Body Mass Index; DBP: Diastolic Blood Pressure.

Figure 2. Mean differences in DBP by exposure and covariate characteristics (N=10 473). The size of the square is inversely proportional to the variance of mean differences (95% CI).

high-elevation districts in Nepal also found a positive association between SBP and altitude.[23] Likewise, a randomized clinical trial found that exposure to higher altitude was associated with increases in BP,[41] and another study found elevated nocturnal BP among healthy children during a 3-week stay at a high altitude.[42] However, in contrast to our findings, the CRONICAS Cohort Study in Peru reported a decreased risk of hypertension (incident rate ratio 0.74 [95% CI 0.58 to 0.95]) among individuals living at higher altitudes.[22] Differences in study populations may explain these discriminant findings. A systematic review of 24 studies, with a total of 40 854 participants, showed that the average SBP increased by 17 mmHg (95% CI 0.2 to 33.8, p=0.05) for participants

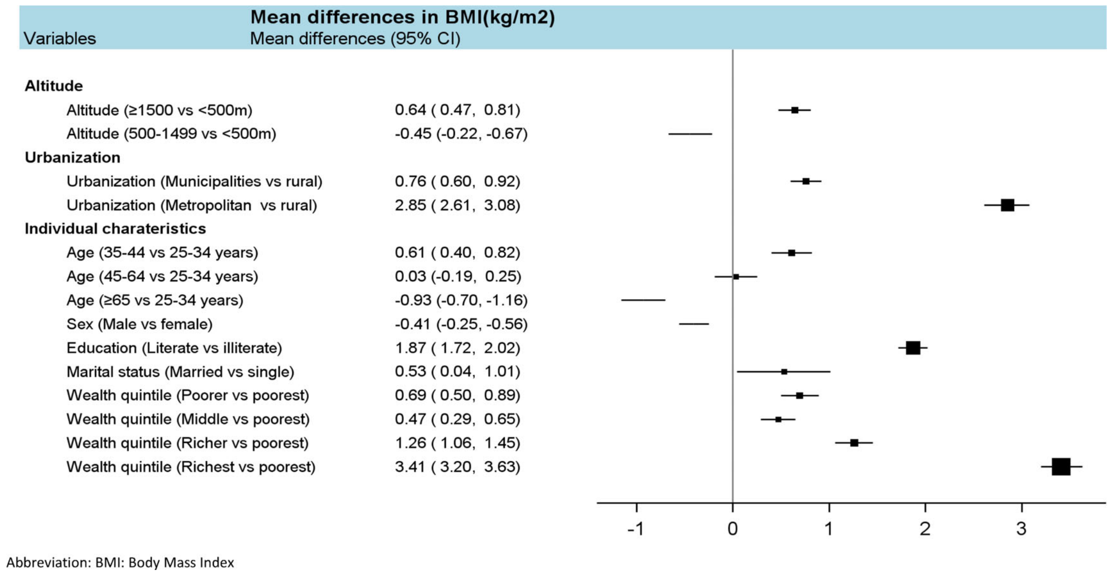


Figure 3. Mean differences in BMI by exposure and covariate characteristics (N=10 473). The size of the square is inversely proportional to the variance of mean differences (95% CI).

Table 2. Association of urbanization and altitude with hypertension and overweight/obesity: crude and adjusted binary logistic regression models (N=10 474)

	Hypertension				Overweight/obesity			
Characteristics	PR	95% CI	APR[a]	95% CI	PR	95% CI	APR[a]	95% CI
Urbanization								
Metropolitan	1.40*	1.14–1.72	1.17	0.97–1.40	2.94*	2.47–3.50	1.30*	1.11–1.52
Municipalities	1.12	0.99–1.26	1.09	0.96–1.22	1.54*	1.30–1.84	1.10	0.96–1.27
Rural areas	1		1		1		1	
Altitude (per 100 m increases)	1.01*	1.00–1.02	1.02*	1.01–1.03	1.01	0.99–1.02	1.03*	1.02–1.04

[a]Adjusted for age, sex, education, marital status, wealth quintiles and urbanization (or altitude).
*Significant findings at $p<0.05$.
PR: prevalence ratio.

of Tibetan origin and decreased by 5.9 mmHg (95% CI −19.1 to 7.3, p=0.38) for participants of non-Tibetan origin.[26] Furthermore, a meta-analysis of eight cross-sectional studies among inhabitants of Tibet found a 2% increase in hypertension prevalence per 100 m in altitude.[10] While the underlying mechanism for these risk differences is poorly understood, evidence gleaned thus far suggests that altitude may impose a risk for hypertension differently for Tibetan and non-Tibetan populations.

Despite some contrary findings in the literature,[22,24] biological plausibility supports our finding of a higher prevalence of hypertension by elevation level. Altitude constitutes a hypobaric and hypoxic environment. Thus lower oxygen levels are available for physiological and metabolic processes at higher altitudes,[43] and this may exert deleterious effects on blood viscosity, ventilation and the acid–base balance.[44] Due to sustained hypoxic pulmonary vasoconstriction, and the resulting increased sympathetic and parasympathetic activities, chronic hypoxia is likely to lead to elevated BP and trigger right-sided heart failure.[44] Therefore the association we found between altitude and hypertension seems mainly driven by physiological factors such as altitude-induced hypoxia[45,46] and activation of the autonomic and sympathetic nervous systems.[46] Second, in addition to residence in a hypoxic environment,[47] diet and physical activity may also partially contribute to the potential association, as studies have documented both high-sodium dietary practices and increased alcohol consumption in populations living at higher altitudes.[7,10]

Our findings suggest a slightly increased likelihood of BMI at higher altitudes, in contrast with a few epidemiological studies conducted among Spanish university graduates, Tibetans and the military population living at higher altitudes that reported an inverse association between obesity and altitude.[9,11,48] Based on interventional human trials, which showed a loss of appetite and

Table 3. Association of SBP, DBP and BMI with urbanization and altitude: simple and multiple linear regression (N=10 473)

	SBP (mmHg)				DBP (mmHg)				BMI (kg/m²)			
	Crude model		Adjusted model[a]		Crude model		Adjusted model[a]		Crude model		Adjusted model[a]	
Characteristics	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Urbanization												
Metropolitan	1.75	−0.62 to 4.13	1.23	−1.01 to 3.46	2.47*	0.71 to 4.23	1.24	−0.42 to 2.91	3.15*	2.56 to 3.74	0.88*	0.45 to 1.32
Municipality	0.84	−0.88 to 2.56	1.11	−0.58 to 2.80	0.74	−0.43 to 1.92	0.56	−0.59 to 1.72	0.98*	0.56 to 1.40	0.33*	0.03 to 0.64
Rural area	1		1		1		1		1		1	
Altitude (per 100 m increase)	0.11	−0.01 to 0.23	0.11	−0.02 to 0.23	0.16*	0.08–0.25	0.18*	0.09 to 0.27	0.05*	0.01 to 0.08	0.11*	0.08 to 0.13

[a]The model was adjusted for age, sex, education, marital status, wealth quintiles and urbanization (or altitude).
*Significant findings at $p<0.05$.

decreased body fat under hypoxic conditions, [49–51] the role of hypoxia as a hypophagic agent seems plausible. However, evidence garnished so far is weak and causality is yet to be established. The literature suggests that the development of obesity is multifactorial and complex; however, in simple terms, overweight/obesity can be understood as an imbalance between energy intake and energy output.[5] It is possible that ethnicity could explain our findings of a positive association between BMI and altitude. An earlier study conducted at 1400 m above sea level in Bhaktapur, Nepal revealed that people of Tibeto-Burman origin were 1.9 times more likely to be overweight/obese (>25 kg/m^2) and 2.1 times more likely to be hypertensive compared with Indo-Aryans.[52] Future studies have the opportunity to revisit the BMI–altitude relationship by exploring differences by ethnicity.

Strengths and limitations

Using a large and nationally representative sample, this is the first large-scale study from Nepal examining the association between urbanization and altitude and hypertension and obesity. Measurements of outcome and explanatory variables were not by self-report; standardized measurement protocols were followed. Our cross-sectional study design is a limitation, as no causality can be inferred. Variables such as the level of physical activity and dietary practices, which are important factors impacting hypertension and overweight/obesity, were not available, thus their confounding effect cannot be ruled out. Further, we lacked information on ethnicity as well as the duration of residence at altitude and thus could not determine whether the associations found vary by ethnicity and/or duration of residence at certain altitudes. Additional potential unexplored confounders include the use of antihypertensive medication, pre-existing medical conditions and genetic and other environmental factors (e.g. climate change, latitude, etc.). Future studies have the opportunity to explore these.

Conclusions

This nationwide cross-sectional study found a high prevalence of hypertension and overweight/obesity among Nepalese adults. Marginally positive associations were found between altitude and hypertension and altitude and overweight/obesity. Although evidence on the potential association between altitude and hypertension is mixed, and causality is yet to be established, given the large population of highlanders around the world and the well-established role of hypertension in the aetiology, mortality and financial burden associated with CVD, increased monitoring of BP among people living at higher elevations in Nepal may be warranted. Additionally, the positive association between urbanization and BMI calls for increased awareness of the problem as well as efforts to build environments conducive to healthy lifestyles among urban residents. Given the role of obesity in the progression of other chronic diseases, residents in urban areas may also benefit from weight control interventions.

Supplementary data

Supplementary data are available at *International Health* online (http://inthealth.oxfordjournals.org/).

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