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ORIGINAL ARTICLE

Association between body mass index and blood pressure across three populations in Africa and Asia

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Despite a growing burden of obesity and hypertension in developing countries, there is limited information on the contribution of body mass index (BMI) to blood pressure (BP) in these populations. This study examines the association between BMI and BP in three populations across Africa and Asia. Data on BMI, BP and other background characteristics of study participants were generated using the World Health Organization STEPwise approach to surveillance (STEPS), at three demographic surveillance sites in Ethiopia, Vietnam and Indonesia. BMI and BP increased along the socioeconomic gradient across the three countries. Mean (s.d.) BMI in men varied between 19.41 (2.28) in Ethiopia to 21.17 (2.86) in Indonesia. A high prevalence of overweight/obesity was noted among Indonesian women (25%) and men (10%), whereas low BMI was widely prevalent in Ethiopia and Vietnam, ranging from 33 to 43%. Mean (s.d.) systolic BP (SBP) among men varied between 117.15 (15.35) in Ethiopia to 127.33 (17.80) in Indonesia. The prevalence of hypertension was highest among women (25%) and men (24%) in Indonesia. Mean BP levels increased with increasing BMI. The risk of hypertension was higher among population groups with overweight and obesity (BMI$\geqslant$25 kg/m^2); odds ratio (95% confidence interval); 2.47 (1.42, 4.29) in Ethiopia, 2.67 (1.75, 4.08) in Vietnam and 7.64 (3.88, 15.0) in Indonesia. BMI was significantly and positively correlated with both SBP and DBP in all the three populations, correlation coefficient (*r*) ranging between 0.23 and 0.27, *P*<0.01. High BP exists in a background of undernutrition in populations at early stages of the epidemiologic transition.
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Introduction

Globally, high blood pressure (BP) is estimated to cause 7.1 million deaths, about 13% of the total. About 62% of cerebrovascular disease and 49% of ischaemic heart disease are attributable to suboptimal BP (systolic >115 mm Hg). Overweight and obesity increase the risks of high BP, coronary heart disease, ischaemic stroke, type II diabetes mellitus and certain cancers. Worldwide about 58% of diabetes mellitus and 21% of ischaemic heart disease are attributable to BMI above 21 kg/m^2.[1]

Developing countries are increasingly faced with the double burden of hypertension and other cardiovascular diseases, along with infection and malnutrition.[2,3] Hypertension places an excessive financial burden on populations and health systems, consuming scarce resources.[4] Population-based preventive approaches are, thus, central for the management of elevated BP in developing countries, where clinic-based care for complications is not a feasible option.[5–7]

Body mass index (BMI) is positively and independently associated with morbidity and mortality from hypertension, cardiovascular disease, type II diabetes mellitus and other chronic diseases.[8] In Caucasian populations, a strong association has been depicted between BMI and mortality.[9,10] A similar association has also been demonstrated among Asian populations.[11–13]

The relationship between BMI and BP has long been the subject of epidemiological research.

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Positive associations between body mass and BP have been documented in Caucasian populations.[14–16] This relationship, however, is not sufficiently explored among lean populations in Africa.

Some studies have documented a consistent, but modest association[16] between BMI and BP, whereas others suggested a BMI threshold at which level the relationship with BP begins.[17] Correlations between BMI and BP in very lean populations in Africa[18,19] and Asia[20,21] have also been reported in earlier studies.

The relationship between BMI and hypertension is of particular interest to developing countries as excess cardiovascular mortality among lean hypertensive subjects has been reported in some longitudinal studies.[22–25] Other studies that have examined the relationship between body weight and cardiovascular mortality also reported a curvilinear relationship with increased risk of mortality among the very lean and very overweight.[26–28]

The present study examines the relationship between BMI and BP in three populations from Africa and Asia that represent different stages in the epidemiologic transition continuum. We intend to find out whether the risk of hypertension is continuously distributed at all levels of BMI, or if there are BMI groups with an increased risk of hypertension in largely lean populations.

This study intends to generate relevant information that helps to understand the patterns of high BP in lean populations as well as in populations where the prevalence of obesity is growing rapidly. Such information would thus be relevant to the prevention and control of hypertension in developing countries.

Materials and methods

The present study was conducted at three demographic surveillance sites (DSS) in Ethiopia, Vietnam and Indonesia. Ethiopia is the least developed of the three countries in comparison with the lowest rates of per capita income, literacy and life expectancy, whereas the two Asian countries exhibit a much better level with respect to these and other indicators. Accordingly, Indonesia is undergoing rapid socioeconomic and epidemiologic transition, whereas Ethiopia is at an earlier stage of the transition, often characterized as a delayed transition, and Vietnam lies in between the two extremes. Differences in basic demographic indicators across the three countries have been discussed elsewhere.[29] The observed socioeconomic and epidemiologic gradients across the three countries offer a unique opportunity to examine the consistency of the relationship between the two important variables, namely BP and BMI.

Data for this study were generated through a multicountry project for surveillance of risk factor for non-communicable diseases (NCDs) in Ethiopia, Vietnam and Indonesia.[29] Data were collected during 2003 and 2004 using a common method and instruments across the three countries.

The project employed the World Health Organization (WHO) STEPwise approach to surveillance (STEPS), which is a tool for surveillance of NCDs that aims to generate data that are comparable over time and between countries.[30] The multicountry surveillance project focuses on selected risk factors that are believed to predict a large part of future NCD burden.[31]

The study was conducted in DSS in each of the three countries. The DSS are composed of population cohorts, including urban and rural residents, where routine registration of vital events takes place. The DSS provided the sampling frames for data collection as well as background socioeconomic and demographic data. The population cohorts maintained by the DSS provide opportunities for future follow-up. The three DSS and the sampling method have been described in detail elsewhere.[29]

The present study, focusing on BMI and BP, has a cross-sectional descriptive design, allowing internal comparisons across the three countries, and between the major sociodemographic groups, such as males and females, and urban and rural residents.

Adults in the age group 25–64 years were randomly selected using the DSS database in each country. Pregnancy (in women) and any gross physical abnormality were the only exclusion criteria against the physical measurements.

Sample size was calculated using the ‘formula for single population proportion’. The minimum sample size (250) was determined for the smallest unit or strata in the study, that is, for each 10-year age interval in each sex and residence. In Ethiopia, the sample size was further multiplied in order to allow a stratified analysis between the two sexes, urban and rural residents, as well as across each of the 10-year age category within the range of 25–64 years.

Data were collected using questionnaires and through physical measurements of weight, height and BP, using the WHO STEPS instruments. The questionnaire was translated to the respective local languages in the three countries, with only minor modifications to suit country situations. BP was measured using a digital automatic apparatus (Omron M4). Weight was measured using an ordinary scale (bathroom type), and height was measured using a wooden stadiometer, manufactured locally in the three study sites.

BP was measured, according to WHO guidelines,[32] in a sitting position after the participant rested for at least 5 min. Three measurements were taken with intervals of 3 min between consecutive measurements. In addition, participants were asked whether they were taking any medications for the treatment of hypertension. Average systolic BP (SBP) and diastolic BP (DBP) were determined from the second and third measurements. Hypertension was defined as SBP ⩾ 140 mm Hg or DBP ⩾ 90 mm Hg or self-reported use of antihypertensive medication, with adaptation of the recent WHO definitions.[32] Weight and height were measured with participants standing without shoes and wearing light clothing. Participants stood upright with the head in Frankfort plane for height measurement. Height was recorded to the nearest 0.5 cm, and weight was recorded to the nearest 100 g. BMI was calculated as weight in kilograms over height in metres squared weight (kg)/height $(m)^2$. The conventional BMI cutoff point as well as the recent WHO recommendation of BMI cutoff points for Asian populations,[33] have been used as applicable. The distribution of mean SBP and DBP and hypertension across BMI quintiles in each of the three populations were determined separately for male and female subjects. It is believed that the use of conventional cutoff points along with the distribution of BMI within the respective populations are complementary to each other, and would enable to examine the BMI–BP relationship from different perspectives.

The sampling method and the survey instrument, mainly the questionnaire, have been validated in an earlier pilot study in the three surveillance sites. Individual- or household-based sampling methods had comparable feasibility. Comparison of the digital automatic BP measuring device against the manual (mercury-operated) sphygmomanometer in Vietnam did not reveal any clinically important differences, and the digital device was more convenient for use in the field by lay persons. Test–retest reliability of the BP and anthropometric measurements was high, as demonstrated by a significant ($P<0.01$) correlation; $r^2=0.89$ for mean BMI, 0.71 for mean systolic BP, and 0.61 for mean diastolic BP, from repeat measurements (unpublished).

Local residents, who completed high school education, and who spoke the local language were recruited and trained to serve as data collectors and supervisors. They were trained for three consecutive days to enable them to understand and apply the survey instruments (questionnaire and physical measurements) in a standardized manner. The training also included methods of identifying eligible study subject, appropriate methods of interviewing as well as measurement of BP, weight and height. At the end of the training, a pre-test was carried out in a neighbouring location, after which minor modifications in rephrasing of the translated version were introduced. The data collection team was composed of both male and female subjects. Interviewers were sex-matched with respondents.

The WHO-CDC Epidemiologic Information (EPI Info) statistical software version 6.04 was used to enter data into a computer. SPSS Version 11 and STATA version 8 statistical softwares were used for data analysis. Each of the three samples was age weighted in accordance with the age composition of the source population so that each sample becomes representative to the respective DSS population. Mean values of BP, weight, height and BMI were determined. Populations were also classified based on BMI quintiles and other conventional cutoff points. Distribution of mean BP and prevalence of hypertension at different BMI levels are also presented.

Analyses were carried out separately for each country and stratified by sex and age group. Logistic regressing analyses were carried out to determine the odds of hypertension across the two sexes, age groups and a range of BMI categories, while controlling for possible confounding. Correlations between continuous variables were examined using correlation coefficients.

Ethical clearance for the study was obtained from responsible academic or government institutions in the respective countries. Ethical clearance was obtained from the Faculty of Medicine, Addis Ababa University in Ethiopia, the Faculty of Medicine, Gadjah Mada University in Indonesia and from the Scientific and Ethical Committee in Biomedical Research, Hanoi Medical University in Vietnam. Appropriate ethical conduct was maintained throughout the study.

Results

A total of 8014 individuals in the age group 25–64 years, from DSS in Ethiopia ($n=4050$), Vietnam ($n=2020$) and Indonesia ($n=1944$), participated in the study. The samples from Ethiopia and Indonesia included both urban and rural residents, whereas only rural residents were represented in the sample from Vietnam. Overall, 52.5% of the study participants were female subjects (Table 1).

Measurements of weight and height were available from 7675 non-pregnant study participants, for whom the BMI could be calculated. Of the 339 study participants for whom BMI was not determined, 216 (2.7%) were pregnant women. And of the remaining 123 study participants (1.5%), weight was not measured in 96 and height was not measured in 89 individuals (with both measurements lacking in some individuals).

The mean weight and height varied between male and female subjects, and across the three study populations. Thus, Ethiopian men and Indonesian women weighed heavier than their counterparts. Ethiopian men and women were also taller than their counterparts. The resulting mean BMI (s.d.) in men varied between 19.41 (2.28) in Ethiopia and 21.17 (2.86) in Indonesia. Mean BMI (s.d.) was the lowest in Ethiopian women, 19.17 (2.50), and highest in Indonesian women, 22.65 (3.84) (Table 2).

Conventional BMI cutoff points were applied to classify the study populations into underweight ($BMI<18.5\,kg/m^2$), normal BMI ($18.5\geqslant BMI<25\,kg/m^2$) and overweight or obese ($BMI\geqslant 25\,kg/m^2$). The resulting distribution revealed a widespread

Table 1 Description of selected sociodemographic characteristics of the three study populations

	Ethiopia (n = *4050*) *Number (%)*	*Vietnam* (n = *2020*) *Number (%)*	*Indonesia* (n = *1944*) *Number (%)*
Residence			
Urban	1195 (29.7)		187 (9.7)
Rural	2855 (70.3)	2020 (100)	1757 (90.3)
Sex			
Male	1767 (48.7)	993 (47.4)	984 (47.0)
Female	2283 (51.3)	1023 (52.5)	960 (53.0)
Age (years)			
25–34	1778 (45.8)	511 (31.1)	493 (20.5)
35–44	1131 (28.2)	515 (32.3)	495 (32.7)
45–54	640 (17.2)	504 (25.3)	506 (26.4)
55–64	501 (8.6)	490 (11.2)	450 (20.4)
Education			
No formal education	2820 (66.8)	53 (1.9)	126 (6.6)
1–6 years of schooling	830 (22.1)	1588 (79.7)	1122 (58.7)
More than 6 years of school	400 (11.0)	374 (18.3)	695 (34.7)
Occupation			
Farmer or daily laborer	1751 (45.7)	1381 (72.1)	892 (45.4)
Merchant or government employee	780 (19.1)	209 (11.6)	314 (16.6)
Housewife	1299 (22.5)	68 (2.2)	430 (23.2)
Others (including students, or unemployed persons)	214 (5.7)	346 (14.1)	308 (14.8)

Table 2 Distribution (mean (s.d.)) of anthropometric and BP measurements, and BMI among the three study populations

	Ethiopia		*Vietnam*		*Indonesia*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Weight (kg)	56.23 (7.52)	47.93 (7.10)	51.47 (6.60)	45.67 (6.66)	54.37 (8.85)	50.68 (9.55)
Height (cm)	170.18 (6.59)	157.50 (5.80)	162.33 (5.75)	152.74 (5.63)	159.98 (6.46)	149.35 (5.42)
BMI (kg/m²)	19.41 (2.28)	19.17 (2.50)	19.51 (2.15)	19.53 (2.48)	21.17 (2.86)	22.65 (3.84)
SBP (mm Hg)	117.15 (15.35)	108.84 (15.55)	123.32 (16.40)	113.77 (15.68)	127.33 (17.80)	124.13 (20.92)
DBP (mm Hg)	75.28 (10.10)	70.72 (10.46)	75.03 (11.41)	69.86 (10.28)	78.10 (11.02)	78.56 (11.26)
BMI category (kg/m²), n (%)						
BMI <18.5	648 (36.7)	881 (42.7)	338 (32.5)	354 (35.3)	141 (14.0)	103 (11.0)
BMI 18.5–24.99	1,044 (60.8)	1,132 (55.1)	624 (65.8)	618 (62.8)	744 (76.2)	596 (64.0)
BMI $\geqslant 25.0$	44 (2.5)	44 (2.2)	18 (1.8)	21 (1.9)	93 (10.0)	222 (25.0)

Abbreviations: BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.

prevalence, varying between 33 and 43%, of low BMI among Ethiopian and Vietnamese study participants, whereas, a remarkably high prevalence of overweight/obesity was noted among Indonesian women 25% and men 10% (Table 2). On the other hand, the use of another BMI cutoff point that is recommended for Asian populations revealed a much higher prevalence of overweight or obesity, about 42 and 20% among Indonesian women and men, respectively, and about 7% among Vietnamese men and women (not presented in table).

Mean systolic BP (s.d.) among men varied between 117.15 (15.35) in Ethiopia and 127.33 (17.80) in Indonesia. Among women in the three populations, Ethiopian women had the lowest mean SBP 108.84 (15.55) mm Hg, and Indonesian women had the highest 124.13 (20.92) mm Hg. Mean diastolic BP (s.d.) was also highest among Indonesian men and women, and lowest among Vietnamese men and women. (Table 2; Figure 1). Generally, both mean SBP and mean DBP increased along with increasing BMI quintiles. The increase in mean SBP begins around the second BMI quintile for Indonesian men and women, corresponding to mean (s.d.) BMI = 19.8 (0.4) kg/m², and among Vietnamese men, mean (s.d.) BMI = 18.2

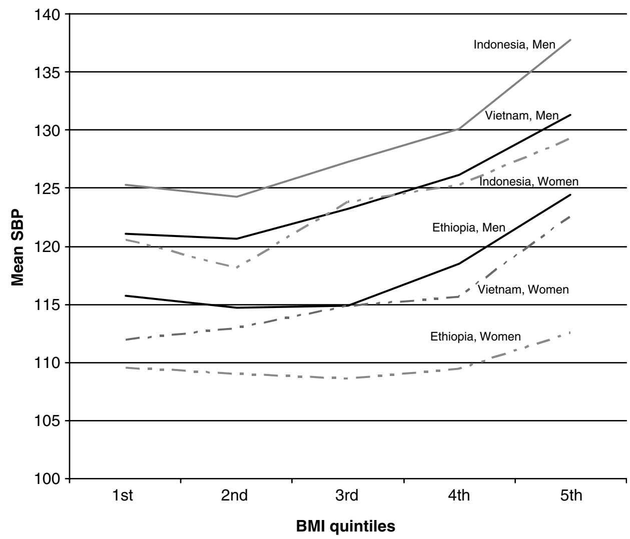

Figure 1 Distribution of systolic BP across BMI quintiles among adults in the three study sites.

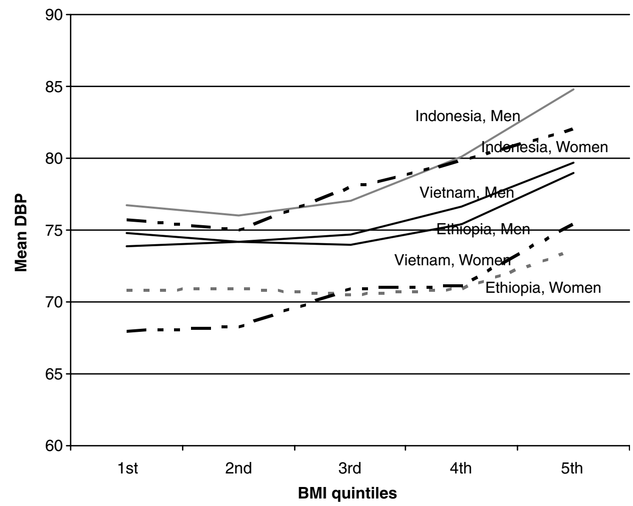

Figure 2 Distribution of diastolic BP across BMI quintiles among adults in the three study sites.

(0.33) kg/m^2. For Ethiopian men, the increase with mean SBP starts around the third BMI quintile, mean (s.d.) BMI = 18.95 (0.29) kg/m^2. For Vietnamese and Ethiopian women, however, a marked increase in mean SBP begins only after the fourth BMI quintile, which correspond to mean (s.d.) BMI = 20.44 (0.39) and 20.1 (0.41) kg/m^2, respectively (Figure 1).

Indonesian men and women had the highest mean DBP values, followed by Vietnamese and Ethiopian men. A marked increase in mean DBP appears to start around the third BMI quintile, except for Vietnamese and Ethiopian women for whom a similar increase begins after the fourth BMI quintile. The third BMI quintile corresponds to mean (s.d.) BMI = 21.19 (0.47) kg/m^2 in Indonesian men, 21.38 (0.47) kg/m^2 in Indonesian women, 19.28 (0.29) kg/m^2 in Vietnamese men and 18.95 (0.29) kg/m^2 in women (Figure 2).

Among male populations in the three countries, the correlation coefficient between BMI and SBP varied from 0.21 to 0.25, whereas it varied between 0.07 and 0.20 for female populations. The correlation with DBP showed similar pattern, varying between 0.17 and 0.25 among male populations and 0.10 to 0.24 among female populations. The lowest correlation coefficient between BMI and SBP or DBP was observed among female subjects in Ethiopia.

When the data from the three countries were pooled together for each sex, the resulting correlation coefficient was slightly higher, ranging from 0.23 to 0.27. Combining the two sexes yields a correlation coefficient between BMI and SBP of 0.25 and between BMI and DBP of 0.24 (Table 3).

Further examination of the slope describing the linear relationship of mean SBP and DBP with BMI quintiles was significantly different from zero (positive slope) at BMI > 19.0 kg/m^2, with SBP slope (95% confidence interval (CI)) of 1.58 (1.27, 1.89) in male subjects, and at BMI > 20.0 kg/m^2 with DBP slope (95% CI) of 1.08 (0.83, 1.33). Similarly, in female subjects, the slopes of SBP and DBP across BMI quintiles were significantly different from zero at the same value of BMI > 19.5 kg/m^2, with SBP slope (95% CI) of 1.07 (0.79, 1.34), and DBP slope (95% CI) of 0.78 (0.61, 0.96) (graph not shown).

Table 3 Correlation coefficients of BMI with SBP and DBP in male and female subjects across the three study populations

BMI	*SBP*		*DBP*	
	Male	*Female*	*Male*	*Female*
Ethiopia	0.226	0.069	0.174	0.097
Vietnam	0.251	0.204	0.219	0.232
Indonesia	0.212	0.183	0.245	0.236
All countries	0.268	0.251	0.227	0.271

Abbreviations: BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.
Note: All correlations are significant at $P < 0.01$.

Both SBP and DBP were significantly and positively correlated with age in both male and female subjects across the three countries. Highest correlation coefficients, 0.38 for male and 0.4 for female subjects, between age and SBP were observed among the Indonesian population. Among female subjects in Vietnam, a high correlation coefficient was observed with SBP (0.38) and DBP (0.30). The coefficients were lower among the Ethiopian male and female subjects, varying between 0.11 and 0.27.

There were no significant correlations between age and BMI among male subjects in the three countries. Among female subjects, however, negative correlations were observed in Ethiopia ($r = -0.18$, $P < 0.01$) and Indonesia ($r = -0.07$, $P < 0.05$) (Table 4).

Age-weighted prevalence of hypertension was highest among women and men in Indonesia, 25 and 24%, respectively, followed by men in Vietnam

(19%) and Ethiopia (12%). The lowest prevalence was observed among women in Vietnam (9%) and Ethiopia (8%). The prevalence of hypertension showed a consistent gradient across the three countries, lowest in Ethiopia and highest in Indonesia (Table 5). The proportion of individuals under any treatment for hypertension was 42 (0.98%) in Ethiopia, 77 (2.76%) in Vietnam and 32 (1.58%) in Indonesia.

The age-specific prevalence of hypertension increased with age and along BMI quintiles. However, the extent of this association varied between different age groups and BMI quintiles, as well as across the three countries. The rise in the prevalence of hypertension was more drastic at age group 55–64 years and fifth BMI quintiles. A decline in the prevalence of hypertension was also noted at the second and third BMI quintiles compared to the first quintile. Although this decline is evident in the graphic distribution of hypertension across BMI quintiles in each of the three countries (Figure 3), it was significantly lower only among Ethiopian men. Thus, Ethiopian men in the second and third BMI quintiles, corresponding to mean (s.d.) BMI of 17.97 (0.29) and 18.96 (0.29) kg/m^2, respectively, have significantly lower odds of hypertension compared to those in the first, mean (s.d.) BMI = 16.55 (0.79) kg/m^2; odds ratio (OR) = 0.56, 95% CI (0.33, 0.95), and last OR = 0.44, 95% CI (0.32, 0.92), respectively. This observation suggests that extremely low levels of BMI (severe underweight) among adults may be associated with high BP. Among Ethiopian women, the prevalence of hypertension ranged from 7.0 to 8% with no marked increase along BMI quintile (Table 5).

Selected biological, sociodemographic, nutritional and behavioural characteristics that are considered as possible determinants of hypertension were subjected to a logistic regression analysis. The

Table 4 Correlation coefficients of age with BMI, SBP and DBP in male and female subjects across the three study populations

Age	*SBP*		*DBP*		*BMI*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Ethiopia	0.187	0.273	0.114	0.116	−0.015*	−0.175
Vietnam	0.197	0.357	0.223	0.304	−0.039*	0.038*
Indonesia	0.384	0.40	0.255	0.149	−0.027*	−0.074 ($P<0.05$)
All countries	0.285	0.386	0.194	0.211	0.019*	0.012*

Abbreviations: BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.
Note: All correlations, except those marked with (*) are significant at $P<0.01$.

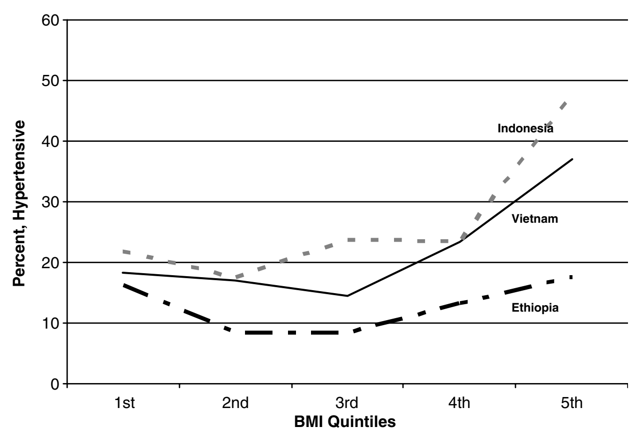

Figure 3 Distribution of hypertension across BMI quintiles among men in the three study sites.

Table 5 Distribution of hypertension[a] across age groups and BMI quintiles in males and female subjects among the three study populations

	Ethiopia Number (%)		*Vietnam Number (%)*		*Indonesia Number (%)*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Age group (years)						
25–34	62 (8.8)	62 (5.8)	24 (10.0)	10 (3.7)	28 (11.3)	14 (5.7)
35–44	55 (11.2)	43 (6.7)	49 (18.6)	16 (6.4)	34 (13.5)	48 (19.7)
45–54	50 (16.1)	36 (10.9)	58 (24.0)	31 (11.8)	77 (30.3)	74 (29.4)
55–64	68 (26.4)	51 (21.0)	91 (36.8)	67 (27.8)	102 (44.0)	99 (45.4)
All ages (25–64)	235 (12.3)	192 (8.2)	222 (19.3)	124 (9.4)	241 (23.6)	235 (24.9)
BMI quintile (country-specific)						
1st	45 (**15.0**)	39 (7.7)	36 (15.3)	20 (7.2)	50 (21.0)	31 (20.2)
2nd	29 (**7.7**)	28 (6.6)	32 (14.7)	15 (5.0)	39 (16.6)	26 (16.1)
3rd	30 (**7.6**)	28 (7.3)	33 (12.6)	21 (9.9)	56 (22.7)	32 (23.2)
4th	52 (**12.4**)	34 (8.7)	43 (20.7)	23 (8.8)	41 (21.9)	53 (26.3)
5th	60 (**16.0**)	33 (7.7)	70 (32.3)	42 (16.7)	54 (46.4)	87 (33.0)

Abbreviations: BMI, body mass index.
[a]Hypertension is defined as systolic blood pressure ⩾140 mm Hg, or diastolic blood pressure ⩾90 mm Hg, or if a person is taking antihypertensive treatment.

Table 6 Determinants of high blood pressure in the three study populations (logistic regression analysis)

	Ethiopia		*Vietnam*		*Indonesia*	
	Adjusted OR (95% CI)		*Adjusted OR (95% CI)*		*Adjusted OR (95% CI)*	
BMI category						
<18.5	1.00		1.00		1.00	
18.5–24.99	1.14	(0.90, 1.46)	1.33	(0.92, 1.89)	1.62	**(1.19, 2.19)**
25.0+	2.47	**(1.42, 4.29)**	2.67	**(1.75, 4.08)**	7.64	**(3.88, 15.0)**
Sex						
Male	1.00		1.00		1.00	
Female	0.53	**(0.37, 0.77)**	0.37	**(0.24, 0.56)**	0.77	(0.55, 1.06)
Age (years)						
25–34	1.00		1.00		1.00	
35–44	1.32	(0.95, 1.82)	2.05	**(1.30, 3.24)**	2.16	**(1.44, 3.23)**
45–54	2.17	**(1.53, 3.07)**	3.02	**(1.94, 4.71)**	4.70	**(3.18, 6.99)**
55–64	4.69	**(3.31, 6.64)**	7.67	**(4.93, 11.9)**	10.4	**(6.98, 15.5)**
Education						
No formal education	1.00		1.00		1.00	
1–6 years of schooling	0.86	(0.60, 1.23)	0.52	(0.62, 1.07)	1.22	(0.78, 1.92)
More than 6 years of schooling	1.12	(0.73, 1.71)	0.50	(0.23, 1.07)	1.23	(0.74, 2.04)
Occupation (main)						
Farmer or daily laborer	1.00		1.00		1.00	
Merchant or government employee	1.34	(0.89, 2.04)	1.20	(0.76, 1.90)	1.18	(0.83, 1.68)
Housewife	1.24	(0.82, 1.87)	0.93	(0.46, 1.88)	0.87	(0.61, 1.24)
Others (unemployed persons, students, etc.)	1.16	(0.68, 1.99)	0.80	(0.55, 1.14)	1.12	(0.78, 1.60)
Residence						
Rural	1.00				1.00	
Urban	1.42	**(1.02, 1.96)**			1.32	(0.91, 1.94)

Abbreviations: CI, confidence interval; OR, odds ratio.

analysis was conducted separately for each of the three study populations, and the resulting OR and 95% CI are presented in Table 6.

The BMI along with sex and age were found to be significant determinants of hypertension across the three study populations. The odds of hypertension were more than sevenfold among overweight and obese individuals in Indonesia, OR = 7.64, 95% CI (3.88, 15.0). The risk of hypertension was also significantly high at BMI $\geqslant$ 25 kg/m^2 in Ethiopia (OR = 2.47, 95% CI (1.42, 4.29)) and Vietnam (OR = 2.67, 95% CI (1.75, 4.08)). Women in Ethiopia and Vietnam had significantly lower risk of hypertension, OR = 0.53, 95% CI (0.37, 0.77), and OR = 0.37, 95% CI (0.24, 0.56). The odds of hypertension rose steadily with age across the three populations. Age groups 45–54 and 55–64 years had significantly higher odds of hypertension compared to the youngest age group 25–34 years. A slightly higher risk of hypertension was noted among urban residents compared to the rural ones in Ethiopia, OR = 1.42, 95% CI (1.02, 1.96).

Discussion

In this study, we examined the relationship between BMI and BP among three populations in Africa and Asia. The three study samples were composed of predominantly rural and peri-urban populations, engaged in farming or manual labour. Thus, findings from these study populations may be much different from the situation at the national level in the respective countries.

In addition to ethnic background, most socio-demographic, behavioural and anthropometric characteristics are closely similar between the Vietnamese and Indonesian study populations, varying markedly from the Ethiopian sample. Race or ethnicity, biological, behavioural and environmental factors, including diet and nutrition, have been implicated as determinants of BP within and across populations.[34–36] This study, however, did not attempt to compare or explain the difference in BP between the three countries.

A significant positive correlation between BMI and SBP or DBP was observed in all the population sub-groups, although the correlation coefficients were weak (less than 0.30). The correlations were comparable across male and female subjects, with the exception of female subjects in Ethiopia, where the correlation was much lower. Significant correlation of BMI to SBP and DBP, in men and women, was reported by studies in Tanzania[37] and Nigeria.[38]

The mean BMI in the Ethiopian women (19.17) was the least among the three populations. The linear relationship between BMI quintiles and BP in the Ethiopian women revealed a significant slope (different from zero) at a BMI > 19.5 kg/m^2 for both SBP and DBP. Thus, it is possible that a significant linear correlation between BMI and BP among Ethiopian women is limited to those with a BMI > 19.5 kg/m^2, lying in the third to fifth quintiles. The week correlation between BMI and BP in Ethiopian women may also be partly explained by the high prevalence of undernutrition (42.7%) along with low prevalence of hypertension (8.2%). The prevalence of hypertension in the Ethiopian women did not vary markedly across BMI quintiles, suggesting that BMI might not be an important determinant of BP in this group. Lack of linear correlation between BMI and BP in lean populations was also reported by another study.[39]

In our study, SBP and DBP were positively correlated with age while BMI was not, or was negatively correlated in some cases. Thus, BP increased with increasing age, while the BMI did not change significantly, or may have even decreased among females in Ethiopia and Indonesia. A significant correlation between SBP and age was also reported in a study from India.[40]

We hypothesize that declining economic opportunities and lack of access to health and other social services are commonly encountered by adults and elderly people in low-income settings. In such populations, the cumulative exposure to poverty and diseases, and nutritional deprivation throughout childhood, adolescence and adulthood might contribute to progressive decline of the BMI. This is evidenced by the high prevalence of undernutrition (low BMI) among men and women in Ethiopia and Vietnam.

The age-specific prevalence of hypertension increased consistently with increasing age (group), in all the population sub-groups, with a more steep increase at the age group 55–64 years. A similar pattern has been reported in other studies.[39,41]

The prevalence of hypertension at different BMI quintiles revealed a steep rise beginning at the fourth and fifth quintiles, mainly among the Indonesian and Vietnamese study participants. In a study that examined ethnic differences in the strength of association between BMI and hypertension, higher prevalence of hypertension was associated with higher BMI levels in different ethnic groups.[42] Significant associations between BMI and BP have also been documented in lean Chinese populations.[43,44]

The association between BMI and BP has been widely reported across populations in Asia, Latin America, United States and Canada. In a study that included five Latin American populations (urban) and seven Asian populations (four urban, three rural), significant positive relationships of similar magnitude were observed between BMI and BP, despite differences in mean BMI levels between the populations studied.[11,45]

The volume of research on cardiovascular diseases and risk factors is extremely low in Africa.[46] Among the very few studies available from the African continent on the BMI and BP relationship, one reported that BMI was associated positively with BP in the urban population of Dar es Salaam, Tanzania.[41]

In our study, a peculiar distribution of hypertension along BMI quintiles was evident among the Ethiopian men, with significantly higher prevalence of hypertension at extreme quintiles of BMI, first and fifth, compared to the second and third. The observed distribution of hypertension suggests that undernutrition, where it is widely prevalent, may be an important risk factor for hypertension. In light of the elevated risk of morbidity and mortality among lean hypertensive subjects,[22–25] a careful evaluation of the contribution of undernutrition to hypertension, and other cardiovascular morbidity and mortality, among adults in developing countries would be relevant.

In the present study, logistic regression analysis identified age and overweight or obesity as significant determinants of hypertension across the three populations. Similar findings have been reported in other studies.[40,46–48] In Ethiopia and Vietnam, hypertension was significantly more prevalent among men than women. Urban residence was also associated with increased risk of hypertension in Ethiopia. A higher urban prevalence of hypertension was also reported in a multicentre study among elderly people in Bangladesh and India.[49] A significantly higher mean SBP and DBP among urban than rural men was reported in elderly populations of North India.[41]

The relationship between BMI and BP in this study might be potentially confounded by dietary salt intake and physical activity levels, both of which are difficult to standardize and measure across populations in different countries.

The study demonstrated that BMI is closely associated with BP in countries at different stages of socioeconomic and epidemiologic transition. Mean BP levels increase with increasing BMI categories. The risk of hypertension is higher among population groups with overweight and obesity. It is also possible that populations with very low BMI levels could have an increased risk of hypertension, a hypothesis that needs to be tested through more analytical studies.

The high prevalence of undiagnosed or untreated hypertension, and the possible association with adult malnutrition necessitates that these countries should put more efforts towards the prevention of hypertension in populations, along with early detection and treatment of individuals at high overall risk of cardiovascular disease (CVD).

Until such time that regular screening for common CVD risk factors become feasible in developing countries (opportunistic) screening for hypertension should be promoted at every contact with healthcare providers. Efforts are needed to reverse the prevailing notion that hypertension is the problem of rich countries or obese people only.

What is known and what this study adds

What is known about the topic:

- Hypertension is closely associated with obesity in the developed world.[8]
- A linear relationship between mean BMI and blood pressure is commonly demonstrated in developed countries.[14–16]

What this study adds:

- Hypertension exists in a background of undernutrition in developing countries.
- In lean populations, extremely low or high BMI levels may both be associated with increased risk of hypertension.

Abbreviations: BMI, body mass index.

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