

# Blood pressure and body mass index in lean rural and semi-urban subjects in West Africa

Sally M. Kerry<sup>a</sup>, Frank B. Micah<sup>a,c</sup>, Jacob Plange-Rhule<sup>a,b,c</sup>, John B. Eastwood<sup>b</sup> and Francesco P. Cappuccio<sup>a</sup>

**Background** Blood pressure (BP) is positively related to body mass index (BMI) in persons of both Caucasian and African origin, but the precise nature of the relationship is unclear.

**Objective** To study the relationship between BP and BMI in a lean African population.

**Design** A community-based cross-sectional study.

**Methods** The BMI and BP were measured in 362 men and 592 women aged 40–75 years living in Ashanti, Ghana. In total, 498 lived in semi-urban areas and 456 in rural villages.

**Results** The BMI was higher among semi-urban women [23.1 kg/m<sup>2</sup> (95% confidence interval (CI), 22.5 to 23.6)] than semi-urban men [20.9 kg/m<sup>2</sup> (95% CI, 20.6 to 21.5)], rural men [19.5 kg/m<sup>2</sup> (95% CI, 19.1 to 19.9)] and rural women [19.9 kg/m<sup>2</sup> (95% CI, 19.5 to 20.3)]. For systolic BP in women older than 52 years and in semi-urban women, the relationship was non-linear. The slope of the line below the change point ('knot') was greater than that above it. There was no evidence of non-linearity in men. For diastolic BP only younger women had a significant 'knot' point at 18 kg/m<sup>2</sup>. Again,

the slope of the line below the 'knot' was greater than that above it. In men, however, there was also evidence of a 'knot' in younger and rural men, with the slope of the line below the 'knot' being less than that above it (unlike in women).

**Conclusions** The relationship between BP and BMI is not linear, and is possibly sigmoid, but this may vary between subgroups. *J Hypertens* 23:1645–1651 © 2005 Lippincott Williams & Wilkins.

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<sup>a</sup>Department of Community Health Sciences and <sup>b</sup>Department of Cellular and Molecular Medicine, St George's, University of London, UK and <sup>c</sup>Komfo Anokye Teaching Hospital, Kumasi, Ghana.

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Correspondence and requests for reprints to Prof. F. P. Cappuccio, Division of Clinical Sciences, Clinical Sciences Research Institute, Clinical Sciences Building, Warwick Medical School, UHCW Campus, Clifford Bridge Road, Coventry CV2 2DX, UK.  
E-mail: f.cappuccio@sgul.ac.uk

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## Introduction

There is a positive association between measures of obesity and blood pressure (BP) in both developed [1–4] and less developed [5–8] countries. In developing countries, the prevalence of obesity and hypertension are known to rise with increasing urbanization. How much of the rise in BP is accounted for by increasing obesity is not known and is difficult to estimate. While hypertension is known to be positively related to body mass index (BMI) in persons of both Caucasian and African origin living in developed countries, most people of African origin living in developed countries have a much higher BMI than their counterparts in Africa [6,9]. Studies in different populations of African origin living in different environments (rural and urban Africa, Caribbean and the United States) suggest that the association between adiposity (as estimated by BMI) and the prevalence of hypertension is constant, so that a large proportion of the difference in the prevalence of hypertension between rural Africa and the

United States may be attributable to excessive weight and/or obesity [6]. However, the nature of the relationship between BMI and BP in predominantly lean African populations is unclear. Some authors [10,11] have found in lean populations a threshold at a BMI of around 21 kg/m<sup>2</sup> below which there is little relationship between BMI and BP, although there is uncertainty as to whether this applies to both men and women. Bell *et al.* [12] have found ethnic differences in the association between BMI and hypertension. How much of the variability is due to different ethnicity and how much to an increasingly Western lifestyle is also unclear.

In Ghana hypertension-related disease is a leading cause of hospital admission among adults [13]. Therefore, the study of the determinants of high BP in this setting is important. We conducted, in the Ashanti region of Ghana, a cluster, randomized trial of the effect of nutrition education with a view to reducing BP. Subjects were

selected for the trial by random sampling from a list of all adults in the villages chosen [14]. The baseline data from the trial provided data on the prevalence of hypertension in the communities and an opportunity to study the relationship between BP and BMI in these semi-urban and rural people, who were also largely from the same ethnic group [15]. We have therefore sought to study the nature of the relationship between BMI and BP in a lean African population.

### Population and methods

In consultation with local health workers, 12 villages (six semi-urban and six rural) from the Kumasi and Ejisu-Juaben Districts of the Ashanti Region of Ghana were selected [14,15]. Between June 2001 and June 2002 the study team visited each village early in the morning to carry out the measurements [14,15]. All members of the team had been trained to take measurements and to carry out procedures according to a standardized protocol developed in the co-ordinating centre in London. A random sample of villagers, aged 40–75 years, were selected from a census of the study villages [14]. Height was measured to the nearest 0.5 cm without shoes using a wooden platform with a height rule. Weight was measured to the nearest 0.5 kg with manual Seca 761 scales (Vogel & Halke, Hamburg, Germany), after participants had removed their outer garments and footwear. BMI was calculated as the weight (kg) divided by the height (m<sup>2</sup>). The BP and pulse rate were measured with an automatic machine (OMRON HEM705CP sphygmomanometer; Omron Matsusaka Co. Ltd, Matsusaka City, Mie-Ken, Japan) and using the appropriate cuff size, after participants had been sitting undisturbed for at least 5 min [15]. Three readings were taken 1 min apart. The first was discarded and the mean of the last two readings used in the analysis. Participants answered a detailed questionnaire on demography, socio-economic status, health, diet, lifestyle and drug therapy.

### Statistical analysis

Age-adjusted means of BP and BMI for men and women in semi-urban and rural villages were estimated by 'random effects' linear regression analysis using the mean age as the reference and allowing for clustering by village. Age-adjusted linear slopes of BP with BMI were also estimated using 'random effects' regression analysis. We divided the subjects into those equal to or above and below the median age of 52 years. All subjects on anti-hypertensive

therapy were excluded from the investigation of non-linearity as they might distort the relationship. The threshold hypothesis was tested using splined regression with a single 'knot' (change point) [11,16] using 'random effects' regression analysis and adjusting for sex and locality (semi-urban or rural) as appropriate. 'Knots' at 18, 19, 20, 21 and 22 kg/m<sup>2</sup> were investigated and the one that made the greatest reduction to the residual sum of the square was chosen as the best fit, as long as the *P* value was less than 0.05. Where the *P* value was greater than 0.05 for all 'knots', a linear relationship was considered to fit best. Since several points might be similar in fit, the *P* values for the change in slope is presented for all points, where *P* is less than 0.10. 'Knots' less than 18 kg/m<sup>2</sup> or greater than 22 kg/m<sup>2</sup> were not investigated as there were too few data points below or above these cut off points in some subgroups of age and sex. To confirm the non-linearity hypothesis, several non-linear terms were investigated. These were logarithm, reciprocal, square and square root of BMI. Each one was fitted in addition to BMI and the contribution of the non-linear terms assessed using the *P* value (see Appendix 1). Finally, graphs were drawn of the different models. All analyses were conducted using Stata Statistical Software [17].

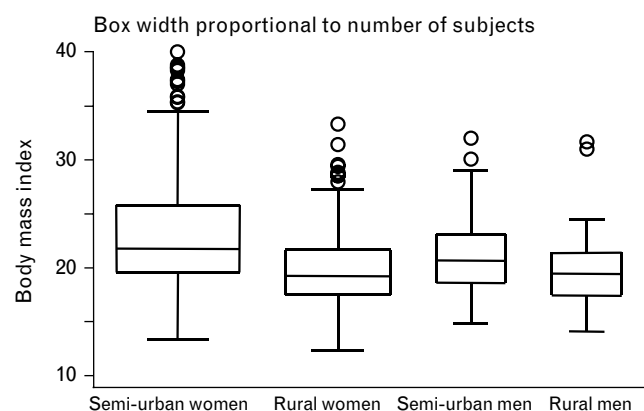
### Results

The original sampling frame was villagers whose age on the census was 40–75 years. On subsequent questioning some selected subjects had ages outside this. They have been excluded from the present analysis. There were 954 participants (362 men and 592 women); of these, 498 were from semi-urban areas and 456 from rural villages. The majority were from the Ashanti tribe. Farming and trading were the main occupations, with more farmers in the rural villages (81 versus 53%). Full details of the characteristics of semi-urban areas and rural villages are reported elsewhere [18]. The average age of participants was 55.0 years. The age-adjusted systolic BP (Table 1) was similar for both sexes while the diastolic BP was 2.5 mmHg [95% confidence interval (CI), 0.7 to 4.2] lower in women than in men. Semi-urban villagers had higher mean BP than rural villagers [difference: systolic BP, 7.3 mmHg (95% CI, 4.2 to 10.4); diastolic BP, 4.1 mmHg (95% CI, 2.4 to 5.8)]. Full details of the distribution of BP and hypertension are reported elsewhere [15]. There were no interactions between gender or locality, and BP. The prevalence of hypertension (BP ≥ 140 and/or 90 mmHg or on drug therapy) was

**Table 1 Age-adjusted means (95% confidence intervals) for body mass index, systolic and diastolic blood pressure in Ashanti, West Africa by gender and area of living**

	<i>n</i>	Body mass index (kg/m <sup>2</sup> )	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
Semi-urban women	318	23.1 (22.5 to 23.6)	129 (126 to 132)	76 (74 to 77)
Rural women	274	19.9 (19.5 to 20.3)	122 (119 to 125)	72 (70 to 74)
Semi-urban men	180	21.0 (20.6 to 21.5)	131 (127 to 134)	78 (76 to 80)
Rural men	182	19.5 (19.1 to 19.9)	123 (119 to 126)	74 (72 to 76)

Fig. 1



Box and whisker plots of body mass index for men and women in rural and semi-urban villages.

29%. While only 3% ( $n = 30$ ) had admitted taking anti-hypertensive medications, they were nevertheless excluded from further analyses.

The population was lean (Fig. 1), with 24% being below  $18 \text{ kg/m}^2$ , a figure used by the World Health Organization as the threshold below which individuals are considered to be underweight [19], and only 15% were overweight ( $> 25 \text{ kg/m}^2$ ). BMI was higher in the

Table 2 Age-adjusted linear slopes (95% confidence intervals) for blood pressure and body mass index (BMI) in Ashanti, West Africa

	<i>n</i>	$\beta^a$ (mmHg SBP per $\text{kg/m}^2$ )	$\beta^b$ (mmHg DBP per $\text{kg/m}^2$ )
Semi-urban women	300	0.67 (0.14 to 1.20)	0.72 (0.44 to 1.00)
Rural women	270	1.26 (0.37 to 2.16)	0.77 (0.33 to 1.21)
All women	570	0.83 (0.37 to 1.29)	0.73 (0.50 to 0.97)
Semi-urban men	174	1.37 (0.24 to 2.49)	0.77 (0.12 to 1.41)
Rural men	180	1.71 (0.53 to 2.87)	0.94 (0.24 to 1.63)
All men	354	1.51 (0.70 to 2.32)	0.85 (0.38 to 1.32)

Interactions not significant. <sup>a</sup>Age-adjusted slope of systolic blood pressure (SBP) on BMI ( $\text{SBP} = \beta_0 + \beta_1 \text{age} + \beta_2 \text{BMI} + \epsilon$ ). <sup>b</sup>Age-adjusted slope of diastolic blood pressure (DBP) on BMI ( $\text{DBP} = \beta_0 + \beta_1 \text{age} + \beta_2 \text{BMI} + \epsilon$ ).

semi-urban villagers, the women in these villages having higher mean BMI than the men (interaction  $P = 0.0023$ ).

There was a significant positive relationship between BP and BMI in all subgroups of gender and locality for both systolic and diastolic BP (Table 2). Slopes ranged from 0.66 to 1.71 mmHg per  $\text{kg/m}^2$  for systolic BP, and from 0.68 to 0.96 mmHg per  $\text{kg/m}^2$  for diastolic BP. The slopes were steeper in men than women, although the distinction between the genders was not significant. Semi-urban women, who had the highest mean BMI, had the lowest slope for both systolic and diastolic BP.

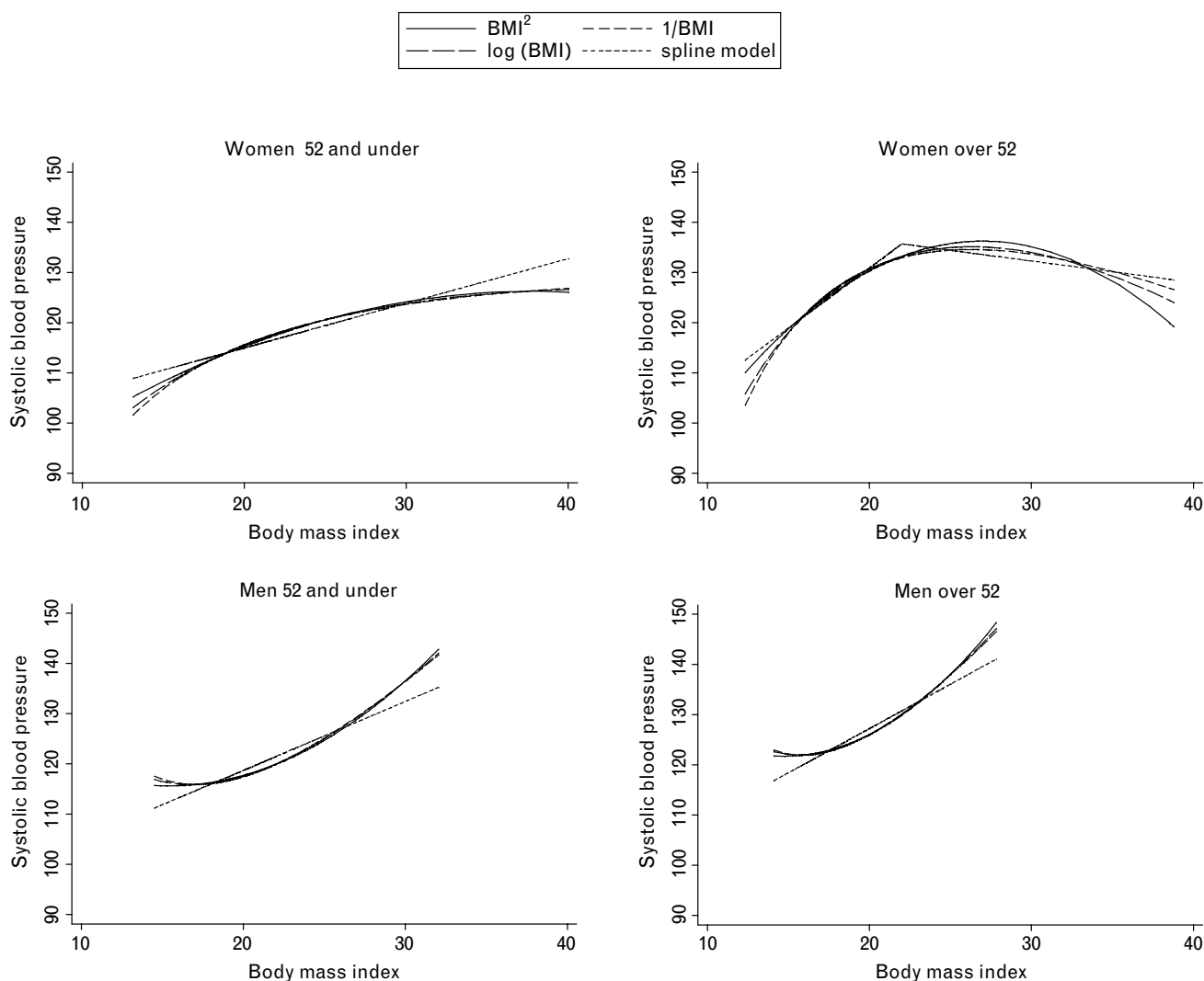
Table 3 presents evidence of the presence of a 'knot' for systolic BP in older and in semi-urban women. In these subgroups the slope of the line below the 'knot' is greater

Table 3 Slopes (95% confidence intervals) for systolic and diastolic blood pressure on body mass index in men and women, and *P* values for different 'knots'

	<i>n</i>	'best fit' knot <sup>a</sup>	<i>P</i> value	slope 'below' knot	slope 'above' knot	<i>P</i> values for all knots <sup>b</sup>				
				slope 'without' knot	18	19	20	21	22	
Systolic blood pressure										
Women										
< 52 years	299	None		0.89 (0.34 to 1.43)	0.064	ns	ns	ns	ns	ns
≥ 52 years	271	22	0.024	2.40 (0.78 to 4.02)	-0.43 (-1.70 to 0.84)	0.215	0.083	0.044	0.028	0.024
Rural	270	None		1.26 (0.37 to 2.16)	ns	ns	ns	ns	ns	ns
Semi-urban	300	21	0.021	2.76 (0.91 to 4.62)	0.15 (-0.54 to 0.84)	0.087	0.037	0.027	0.021	0.033
All women	570	22	0.033	1.88 (0.82 to 2.94)	0.24 (-0.47 to 0.95)	0.044	0.044	0.052	0.036	0.032
Men										
< 52 years	176	None		1.37 (0.47 to 2.27)	ns	ns	ns	ns	ns	ns
≥ 52 years	178	None		1.76 (0.40 to 3.13)	ns	ns	ns	ns	ns	ns
Rural	180	None		1.71 (0.53 to 2.88)	ns	ns	ns	ns	ns	ns
Semi-urban	174	None		1.37 (0.24 to 2.49)	ns	ns	ns	ns	ns	ns
All men	354	None		1.51 (0.70 to 2.32)	ns	ns	ns	ns	ns	ns
Diastolic blood pressure										
Women										
< 52 years	299	18	0.034	3.23 (1.07 to 5.39)	0.77 (0.45 to 1.10)	0.034	ns	ns	ns	ns
≥ 52 years	271	None		0.49 (0.11 to 0.86)	ns	ns	ns	ns	ns	ns
Rural	270	None		0.77 (0.33 to 1.21)	ns	ns	ns	ns	ns	ns
Semi-urban	300	None		0.72 (0.44 to 1.00)	ns	0.061	0.071	0.089	ns	ns
All women	570	None		0.73 (0.50 to 0.97)	ns	ns	ns	ns	ns	ns
Men										
< 52 years	176	21	0.047	-0.01 (-1.07 to 1.05)	1.60 (0.66 to 2.55)	0.108	0.054	0.052	0.047	0.05
≥ 52 years	178	None		0.84 (0.11 to 1.57)	ns	ns	ns	ns	ns	ns
Rural	180	19	0.027	-0.90 (-2.66 to 0.86)	1.93 (0.82 to 3.04)	0.033	0.027	0.074	0.081	0.071
Semi-urban	174	None		0.77 (0.12 to 1.41)	ns	ns	ns	ns	ns	ns
All men	354	None		0.85 (0.38 to 1.32)	0.082	0.092	ns	ns	ns	ns

<sup>a</sup>Best fit 'knot' is that which makes the greatest reduction in the residual sum of the squares. <sup>b</sup>ns,  $P > 0.1$ .

Fig. 2



Non-linear functions of the relationships between body mass index (BMI) ( $\text{kg}/\text{m}^2$ ) and systolic blood pressure (mmHg) in women (top) and men (bottom), younger than (left) and older than or equal to (right) 52 years of age.

than that above it. Although 'knots' at 22 and 21  $\text{kg}/\text{m}^2$  fitted best for older and semi-urban women, respectively, other 'knot' points were also significant. For systolic BP in men there was no evidence of non-linearity. For diastolic BP only younger women had a significant 'knot' point at 18  $\text{kg}/\text{m}^2$ . Again, the slope of the line below the 'knot' was greater than that above it. In men, however, there was also evidence of a 'knot' in younger and rural men, with the slope of the line below the 'knot' being less than that above it (unlike in women). When other non-linear terms were investigated, the *P* values for different functions of BMI were similar within each subgroup. Figures 2 and 3 confirm the 'knot' points identified and that the non-linear regression models show similar relationships to the spline regression. The exception is for diastolic BP in young women, where the change in slope is not reflected in the non-linear model.

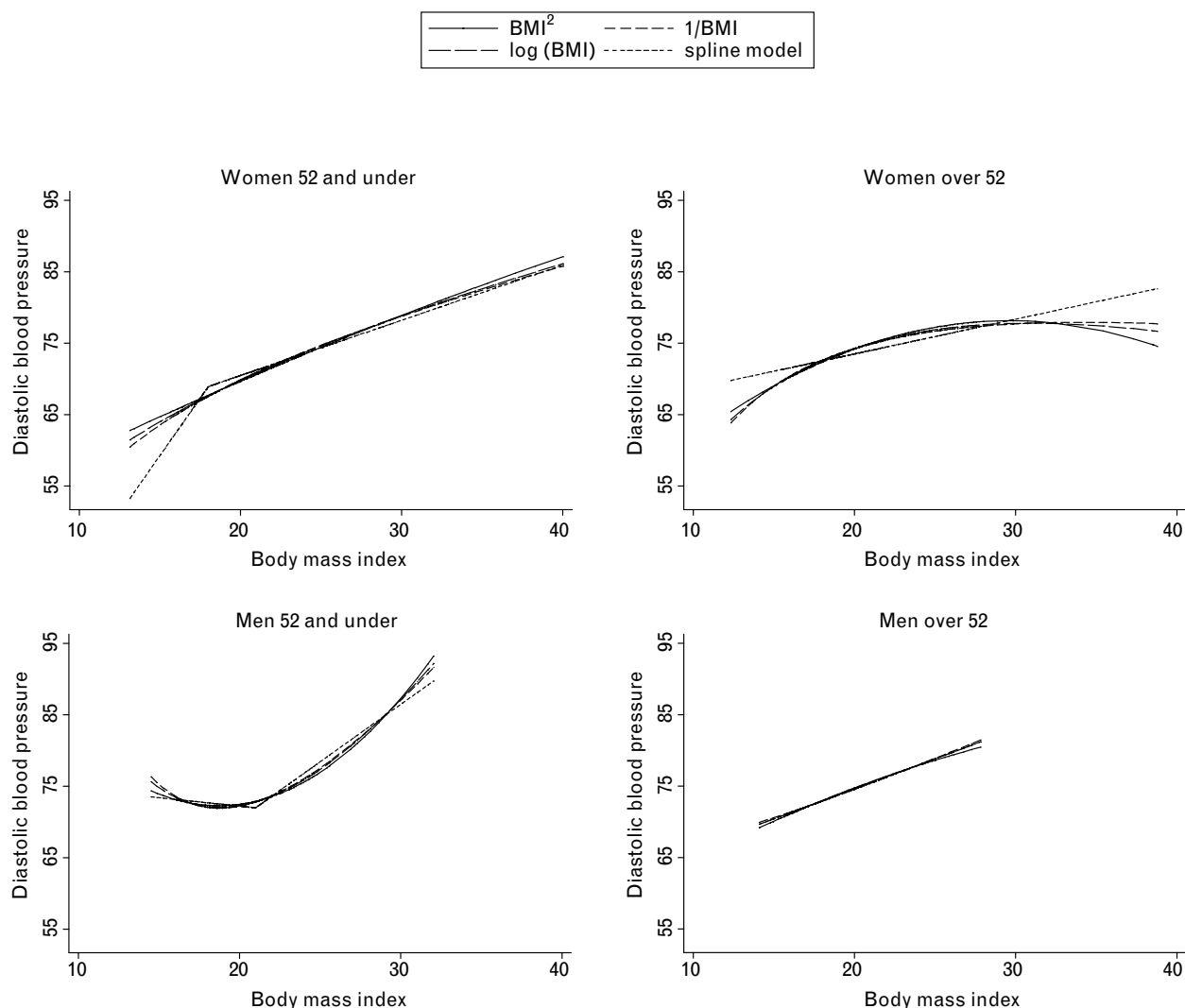
## Discussion

The present study shows that the relationship between BMI and BP is not linear in a lean West African population. However, the shape of the relationship varies by subgroups. In older and semi-urban women a threshold effect was observed (with 'knots' between 19 and 22  $\text{kg}/\text{m}^2$ ), above which decreasing BMI was not associated with decreasing BP. In men, thresholds were detected for diastolic BP only — although, unlike women, decreasing BMI was not associated with decreasing BP below this.

## Strengths and weaknesses

An important strength of this study is that 98.5% of subjects are from a single ethnic group. In other words, unlike so many studies, ethnic heterogeneity is not a problem [11,12]. Another important strength is that fewer

Fig. 3



Non-linear functions of the relationships between body mass index (BMI) ( $\text{kg/m}^2$ ) and diastolic blood pressure (mmHg) in women (top) and men (bottom), younger than (left) and older than or equal to (right) 52 years of age.

than 3% of the participants were on anti-hypertensive drugs, and in those that were the BP was poorly controlled [15]. Nevertheless, we carried out the analyses excluding the latter. We have therefore been able to observe the relationship between BP and BMI uninfluenced by drug treatment. This is a major difference between our study and the majority of those in more developed countries where a significant proportion of subjects with high BMI will be on anti-hypertensive drugs. The present analysis has used individual BP values rather than categories of BP as defined by definitions of hypertension. This avoids the use of arbitrary cut-off points for a continuous variable with subsequent loss of power and possible bias due to the categories chosen.

Over the whole range of BMI, the relationship between BP and BMI may be sigmoid and may shift between

populations as the percentage of body fat for a given BMI changes. In our study the different subgroups by gender and locality had different distributions of BMI, making comparison between them difficult in the presence of non-linearity. In particular, very few rural participants were overweight, making it difficult to assess the relationship among overweight people in rural villages. It is clear that only very large studies within a single population are likely to have sufficient data across the whole range of BMI to demonstrate the relationship.

#### Comparison with other studies

Our findings are consistent with a threshold for women over 52 years above which BP does not increase with increasing BMI. This is not consistent with what has been found by both Bunker *et al.* [10] and Kaufman *et al.* [11]. However, we also found a significant relationship in men

younger than 52 years consistent with a previous study [10]. The subjects in our study were much leaner than those in the Kaufman *et al.* study, and the presence of a considerable number of underweight subjects may have influenced the results. The classification of people with BMI below 18 kg/m<sup>2</sup> as underweight stems from the observation that the relationship between mortality is J-shaped [20,21], with increasing mortality below a BMI of 18 kg/m<sup>2</sup>.

Bunker *et al.* [10] also observed a threshold above which BP does not increase with increasing BMI in both men and women, but the findings were not significant in their regression analysis. The Kaufman *et al.* study [11] did not find such a threshold but found that the slope of the line was flatter in women over 45 years old compared with women under 45 years old.

### Possible explanations of findings

The BMI is an indirect measure of fatness. Indeed, the percentage of body fat for a given BMI is higher in women than in men and in those with sedentary as compared with active lifestyles. It is therefore possible that differences between studies and between communities may be explained by the measure of fatness used [22,23]. In populations of African origin, however, the percentage of body fat, as measured by bio-electrical impedance or by measurement of the waist or hip circumference, has not been found to be a better predictor of BP than BMI [24]. More recently, the importance of resting energy expenditure (REE) — and therefore the role of the metabolically active fat-free body mass — has been studied in populations both in Africa and in the USA [25,26]. In particular, REE does not differ between rural Nigerians and US blacks [25] — therefore not explaining the different rates of obesity in these groups. Furthermore, after adjustment for REE, the relationships between BMI (and other measures of adiposity) and BP disappear, suggesting that metabolic processes represented by REE may mediate the effect of body size on BP [26]. Extensions of these observations to other African populations and the identification of the putative metabolic processes involved are needed. It is also conceivable that the presence of variable levels of competing 'risk factors' might alter the relationship between BMI and BP.

### Implications

Our study supports the hypothesis that the relationship between BP and BMI is not linear but is probably sigmoid. However, there does not appear to be consensus as to the point (or points) on the BMI distribution where the BP starts to rise with BMI and where it ceases to rise. The difficulties in modelling this complex relationship are compounded by the different BMI distributions observed in different communities, such that some communities will have very few underweight individuals

while other communities may have very few individuals that are overweight. More and larger studies are needed to provide data at both ends of the BMI distribution in order to clarify the relationships within and between communities.

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**Appendix 1: P values for adding in a non-linear function of body mass index (BMI) in different subgroups in addition to age, BMI and locality (where appropriate)**

	<i>n</i>	1 / BMI	√ BMI	BMI <sup>2</sup>	Log(BMI)
Systolic blood pressure					
Women					
< 52 years	299	0.26	0.32	0.38	0.30
≥ 52 years	271	0.03	0.02	0.01	0.02
Rural	270	0.67	0.66	0.65	0.66
Semi-urban	300	0.03	0.04	0.04	0.03
All women	570	0.02	0.02	0.02	0.02
Men					
< 52 years	176	0.23	0.24	0.26	0.24
≥ 52 years	178	0.47	0.45	0.44	0.46
Rural	180	0.18	0.17	0.17	0.17
Semi-urban	174	0.69	0.78	0.88	0.75
All men	354	0.31	0.34	0.38	0.33
Diastolic blood pressure					
Women					
< 52 years	299	0.42	0.61	0.81	0.54
≥ 52 years	271	0.17	0.11	0.08	0.13
Rural	270	0.91	0.89	0.89	0.90
Semi-urban	300	0.17	0.20	0.23	0.19
All women	570	0.25	0.26	0.27	0.25
Men					
< 52 years	176	0.04	0.04	0.04	0.04
≥ 52 years	178	0.95	0.97	0.88	0.99
Rural	180	0.03	0.03	0.03	0.03
Semi-urban	174	0.82	0.86	0.91	0.85
All men	354	0.15	0.16	0.18	0.16