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ScienceDirect

Nutrition Research 29 (2009) 180 – 189

Nutrition Research

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Abdominal obesity explains the positive rural-urban gradient in the prevalence of the metabolic syndrome in Benin, West Africa

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Received 10 October 2008; revised 3 February 2009; accepted 5 February 2009

Abstract

This cross-sectional study was designed to verify the hypothesis that there is a positive rural-urban gradient in the overall prevalence of the metabolic syndrome (MetS) and its components and that the differences are associated with socioeconomic status, a sedentary lifestyle, and poor diet quality. A sample of 541 Beninese adults apparently healthy was randomly selected from rural (n = 170), semi-urban (n = 171), and urban (n = 200) areas. The MetS was defined according to the International Diabetes Federation. Diet and physical activity were assessed with a 3-day recall. Socioeconomic and additional lifestyle information was obtained during personal interviews. A positive rural-urban gradient (rural to semi-urban to urban) was observed for the overall prevalence of the MetS (4.1%, 6.4%, and 11%, respectively; P = .035), which reflected that of abdominal obesity (28.2%, 41.5%, 52.5%; $P < .001$) but not for the other prominent features of the MetS, that is, high blood pressure (HBP; 24.1%, 21.6%, and 26.5%; $P > .05$) and reduced high-density lipoprotein cholesterol (HDL-C; 25.3%, 18.1%, 37.5%; $P < .001$). Diet quality and physical activity were higher in rural and semi-urban compared to urban subjects. Physical activity appeared protective for obesity, HBP, and low HDL-C. Micronutrient adequacy was an independent predictor of HDL-C and was associated with a lower likelihood of HBP. Socioeconomic status was positively associated with abdominal obesity only, which was more widespread in women than in men. This study shows that the nutrition transition is ongoing in Benin and suggests that cardiovascular disease risk could be reduced substantially by promoting physical activity and a more adequate diet.

Keywords: Metabolic syndrome; Rural-Urban gradient; Nutrition transition; West Africa; Human

Abbreviations: ANOVA, analysis of variance; BMI, body mass index; BP, blood pressure; CI, confidence interval; CVD, cardiovascular disease; HBP, high blood pressure; HDL-C, high-density lipoprotein cholesterol; MET, metabolic equivalents; MetS, metabolic syndrome; OR, odds ratio; SD, standard deviation; SES, socioeconomic status; WHO, World Health Organization.

1. Introduction

The metabolic syndrome (MetS) is a cluster of cardiometabolic abnormalities including abdominal obesity, high blood pressure (HBP), dysglycemia, and dyslipidemia [1]. It is recognized as an important risk factor for cardiovascular disease (CVD) [2], which now represents

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doi:10.1016/j.nutres.2009.02.001

the first cause of mortality in the world, even in developing countries [3]. Mortality due to CVD in developing countries is expected to increase from 9 million in 1990 to an estimated 19 million in 2020 [4].

Cardiovascular disease mortality is attributable to the increase of primary risk factors during the last 20 years: HBP, cigarette smoking, excess alcohol consumption, dyslipidemia, dysglycemia, excess body weight, and sedentary lifestyle [5]. Behavioral, social, cultural, and economic factors, as well as low levels of clinical care and preventive policies, are at work [6]. Demographic, epidemiologic, and nutritional transitions driven by socioeconomic changes including urbanization and globalization are major contributors to the increase of CVD risk factors [7].

Studies in sub-Saharan Africa have reported a rising prevalence of cardiometabolic risk factors with urbanization [8,9]. Regarding the underlying factors, socioeconomic status (SES) is often positively associated with obesity, whereas physical activity is reportedly protective [10-13]. However, dietary patterns are still little documented [10,14]. There are reports on the MetS in South Africa, Tanzania, and Cameroon [15-17]. The reported prevalence in Cameroon is lower than in South Africa.

Benin, one of poorest countries in the world, has witnessed a rapid growth of its urban population over the last 2 decades. Changes in urbanization rates are paralleled by increasing overweight and obesity, especially in women [18]. A recent study by our group in Cotonou, Benin's largest city [13], disclosed high prevalence rates of overall (18%) and abdominal obesity (32%), hypertension (23%), and low high-density lipoprotein cholesterol (HDL-C) using the criteria of the World Health Organization (WHO) [19]. Obesity was higher in women than in men and increased significantly with the SES. A longer exposure to the urban environment was independently associated with a higher likelihood of hypertension. Physical activity was the single lifestyle factor most strongly associated with the cardiometabolic risk factors, whereas diet quality was not significantly so.

A similar study conducted on SES, urbanization, and lifestyle in a medium-size city of Benin (Ouidah) and its rural outskirts showed that the prevalence of overall obesity (10.6%) and abdominal obesity (23.8%) was significantly higher in the city compared to the rural area and among women than men. Socioeconomic status and physical activity were independently associated with obesity, whereas urbanization was not [20].

The purposes of this article are to compare the prevalence of the MetS and its components across all 3 study sites in Benin (urban, semi-urban, and rural areas) and to examine their relationship with SES, diet quality, and lifestyle factors. We hypothesized that there is a rural-urban gradient (rural to semi-urban to urban area) in the overall prevalence of the MetS and its components and that SES, lifestyle factors (physical activity, alcohol, tobacco), and diet quality are determinants of this gradient.

2. Methods and materials

2.1. Subjects and study design

The study was approved by the Ethics Committee of the Faculty of Medicine (Université de Montréal) and by the Ministry of Health in Benin. The subjects, as well as heads of selected households and local authorities, were informed of the purpose and procedures of the study. All participants signed an informed consent form. They were given back their results individually, and those with abnormal values were referred for diagnosis and treatment.

This cross-sectional study is part of a larger multisite research project on the nutrition transition and its relationship with CVD risk factors in adults of African descent living in various contexts. Data collected in Cotonou, the largest city of Benin (metropolitan area); Ouidah, a small-size city located 50 km away from Cotonou (semi-urban area); and the rural area surrounding Ouidah are used for this article. The *small-size city* and the *rural area* were as defined by the Government of Benin [21]. We chose to compare these 3 locations because most studies in developing countries focus on large cities and rural areas, neglecting small towns or semi-urban areas where a good share of the population lives. In Benin, for instance, only 15% of the "urban" population live in large cities, whereas 85% live in smaller cities [21].

Subjects (N = 541) were randomly selected in a rural (n = 170), semi-rural (n = 171), and urban area (n = 200) using census data (urban) or after enumeration of compounds (semi-urban and rural). Eligible participants were Beninese-born adults aged 25 to 60 having lived in the study area for at least 6 months. Subjects with a prior diagnosis of hypertension, diabetes, or coronary heart disease were excluded because of possible modification of their diet and lifestyle. Details of sample size determination and sampling process were published elsewhere [13,20,22].

2.2. Biological and biochemical parameters

Waist circumference and blood pressure (BP) were measured using standard methods as described previously [13,20]. Waist circumference was measured to the nearest 0.1 cm with a flexible nonstretch tape at the midpoint between the lower rib margin and the iliac crest while subjects were standing and breathing normally [20]. Systolic and diastolic BPs were measured on the right arm of seated subjects after a 10-minute rest, using a mercury sphygmomanometer. The mean of 2 readings was used in the analyses. The interval of time between the first and the second reading was at least 20 minutes [13]. Blood samples were collected after a 12-hour overnight fast and were centrifuged within 2 hours. Using standard laboratory methods, fasting plasma glucose, and serum concentrations of total cholesterol, HDL-C and triglycerides were determined [13].

2.3. Definition of the MetS

The International Diabetes Federation (IDF) defines the MetS as abdominal obesity (waist circumference ≥80 cm in women and ≥94 cm in men) combined with 2 or more of any of elevated triglycerides (>1.70 mmol/L), HBP (≥130/85 mm Hg), high fasting glucose (≥ 5.6 mmol/L), and low HDL-C (≥1.29 mmol/L in women and ≥1.03 mmol/L in men) [1]. We used this definition primarily because the cutoffs tend to be lower than in the National Cholesterol Education Program-Adult Treatment Panel III [23] or the WHO [19] definitions, thereby allowing for the early detection of cardiometabolic risk factors.

2.4. Socioeconomic and demographic variables

Socioeconomic information and data on age, sex, place of birth, and history of residence were collected in personal interviews. Education and an SES score were the socioeconomic factors considered. The SES score is a household amenity score used as proxy of household income, much like in the Demographic and Health Surveys of Benin [18]. The items include type of latrine; paid domestic help; ownership of land, motorcycle, car, television, mobile telephone, landline telephone, and refrigerator; electricity, water in the house; type of fuel used for cooking; and wall and floor materials. Cronbach α for the SES score was .71. The SES score was computed separately in each site, and tertiles were used in analyses. Details of items and coding are available elsewhere [13,20].

2.5. Diet quality indicators

Dietary intake was computed on the basis of 3 nonconsecutive 24-hour food recalls conducted over an average period of 1 month. Diet quality was appraised with a micronutrient adequacy score and a "preventive" diet score developed by our group for international use. The micronutrient score was based on adequacy of intake of 14 micronutrients (vitamins A, B6, B12, C and E, thiamine, riboflavin, niacin, pantothenic acid, folic acid, magnesium, calcium, iron, and zinc) according to Food and Agriculture Organization of the United Nations (FAO)/WHO recommended dietary intakes for age and sex [24]. The "preventive" diet score was based on compliance with 8 WHO/FAO dietary guidelines for the prevention of chronic diseases: percentage (%) total fat, % saturated fatty acids, % polyunsaturated fatty acids, cholesterol (mg/day), % sugar, % protein, fiber (g/day), as well as fruits and vegetables (g/day) [25]. For each item, a rating of "1" was given if the intake met the recommendation and "0" if it did not. Further details on dietary methods were published [13,22].

2.6. Alcohol consumption and smoking

Subjects were asked about their habitual drinking patterns. The alcohol consumption score was computed based on both the pattern of alcohol consumption (binge or regular) and the mean quantity of alcohol consumed daily. Four categories were identified, ranging from 0 to 3, from the worst to the best pattern: binge drinkers, regular heavy drinkers, nondrinkers, and moderate alcohol consumption. Smoking was also assessed by asking the respondents about their consumption habits. We distinguished 3 main categories: smokers, ex-smokers, and nonsmokers. For alcohol and tobacco, our questionnaire was based on the STEPwise tool developed by the WHO [26].

2.7. Physical activity

Physical activity was assessed through 3 nonconsecutive 24-hour recalls [20]. Participants were asked about their previous day activities, from the time they got up to the moment they went to bed. Time spent in bed, in various modes of transportation, for main and secondary occupations, for house chores, and for leisure activities was computed from the daily estimated schedule. The intensity level of each activity was estimated in metabolic equivalents (MET) using the compendium of physical activity [27]. We classified subjects as active (≥3 MET, ≥30 min/d) and inactive (≥3 MET, <30 minutes, and <3 MET, any duration) on the basis of WHO guidelines for the prevention of chronic diseases [25].

2.8. Statistical analyses

Data were analyzed using SPSS, version 15.0 (SPSS Inc, Chicago, IL). Results are expressed as means ± standard deviation (SD) or percentage for categorical variables. The differences between men and women were assessed using independent t tests and χ^2 tests as appropriate. Differences among rural, semi-urban, and urban subjects were assessed using χ^2 tests or 1-way analysis of variance (ANOVA) with Tukey post hoc test [28]. Multivariate models were constructed to test the relationship of socioeconomic and lifestyle factors with MetS components, either as continuous or dichotomous variables, using linear and logistic regression, respectively [28]. Standardized β coefficient or odds ratios (ORs) and their respective 95% confidence intervals (CI) are presented in results for linear and logistic regression, respectively. The level of statistical significance was a P value of <.05 for univariate analyses and logistic regression and $P < .10$ for multiple linear regression.

3. Results

3.1. Characteristics of study population

Table 1 shows the socioeconomic and lifestyle characteristics of the study subjects. There was no age difference according to site among men and women. Many people living in the rural area (25.9% in men and 28.2% in women), the semi-urban area (15.1% in men and 25.9% in women), and the urban area (49% in men and 62% in women) were not born in the site where they were now living. The education level was significantly higher in the urban area in both sexes, and men were more educated than women ($P < .001$). No difference was observed in physical

Table 1
Characteristics of study subjects

Characteristics	All		Men			Women		
	Men (n = 271)	Women (n = 270)	Rural (n = 85)	Semi-urban (n = 86)	Urban (n = 100)	Rural (n = 85)	Semi-urban (n = 85)	Urban (n = 100)
Age (mean ± SD) †	37.3 ± 10.1	39.0 ± 10.0*	36.8 ± 9.8	37.1 ± 10.7	37.8 ± 9.8	37.9 ± 10.5	38.9 ± 9.8	40.0 ± 9.6
Place of birth (%)								
Rural	36.5	39.3	74.1	1.2	35.0***	71.8	10.6	36.0***
Semi-urban	37.6	38.1	17.6	84.9	14.0	16.5	74.1	26.0
Urban	25.8	22.6	8.2	14.0	51.0	11.8	15.3	38.0
Education level (%)								
No education	9.6	41.5***	16.5	7.0	6.0***	62.4	36.5	28.0***
Elementary school	35.8	33.3	49.4	36.0	24.0	27.1	37.6	35.0
High school and above	54.6	25.2	34.1	57.0	70.0	10.6	25.9	37.0
Physical activity (%) ‡								
Active	90.0	74.4***	95.3	89.5	86.0	97.6	97.6	35.0***
Inactive	10.0	25.6	4.7	10.5	14.0	2.4	2.4	65.0
Smoking (%)								
Smoker	8.1	0.4***	8.2	11.6	5.0	0.0	1.2	0.0
Ex-smoker	12.9	0.7	9.4	11.6	17.0	0.0	1.2	1.0
Nonsmoker	79.0	98.9	82.4	76.7	78.0	100	97.6	99.0
Alcohol consumption (%)								
Binge drinker	5.9	10.4***	2.4	1.2	13.0***	1.2	4.7	23.0***
Regular high	10.0	6.3	7.1	0	21.0	0	2.4	15.0
Regular moderate	49.8	20.0	57.6	57.0	37.0	30.6	15.3	15.0
Abstinence	34.3	63.3	32.9	41.9	29.0	68.2	77.6	47.0
Diet quality indicators (mean ± SD)								
Micronutrient adequacy score	10.4 ± 2.6	9.61 ± 2.5**	11.8 ± 1.9^{a}	11.6 ± 2.2^{a}	8.33 ± 2.6^{b}	10.7 ± 2.3^{a}	9.93 ± 2.3^{a}	8.43 ± 2.4^{b}
Preventive diet score	5.95 ± 0.9	5.90 ± 0.9	6.12 ± 0.8^{a}	6.16 ± 1.0^{a}	5.62 ± 0.9^{b}	6.07 ± 0.8^{a}	6.06 ± 0.8^{a}	5.62 ± 0.9^{b}

Significant difference between men and women, and across locations: * $P < .05$, ** $P < .01$, *** $P < .001$, as determined by Student *t* test and χ^2 test. Values in the same row that do not share the same superscript letter are significantly different (ANOVA with Tukey post hoc test, $P < .05$).

† Age in years.

‡ Active if ≥30 min/d of moderate physical activity (≥3 MET) and inactive if <30 min/d.

activity in men, whereas women from the urban area were significantly less active than those from both semi-urban and rural areas. Smoking was not common, and it was practically nil in women.

Alcohol consumption varied according to location and sex. In men, binge or regular high consumption was more frequent in the urban area ($P < .001$), whereas moderate consumption or abstinence was more common in the semi-urban and the rural areas. A similar pattern was observed in women, although surprisingly, binge drinking in the urban area appeared more widespread among women than men. The diet quality scores were significantly lower ($P < .05$) in the urban compared to the semi-urban and rural areas, in men as well as in women; there was no difference between men and women (Table 1).

Biological data are presented in Table 2. Body mass index (BMI) was significantly lower in the rural compared to semi-rural and urban areas, in both men and women. Waist circumference was higher in the city compared to the other sites, in men and women. There was no difference in systolic BP, whereas diastolic BP was lower in the urban area than in

Table 2
Biological and clinical data

	All		Men			Women		
	Men (n = 271)	Women (n = 270)	Rural (n = 85)	Semi-urban (n = 86)	Urban (n = 100)	Rural (n = 85)	Semi-urban (n = 85)	Urban (n = 100)
BMI (kg/m^2) †	22.3 ± 3.8	26.0 ± 6.1***	20.9 ± 3.4^{a}	22.3 ± 3.0^{b}	23.4 ± 4.4^{b}	23.1 ± 5.3^{a}	26.4 ± 6.2^{b}	28.1 ± 5.8^{b}
Waist circumference (cm)	82.2 ± 10.4	88.0 ± 13.7***	79.3 ± 7.6^{a}	82.6 ± 9.2^{a}	84.4 ± 12.7^{b}	84.0 ± 12.9^{a}	88.2 ± 14.4^{ab}	91.1 ± 13.1^{b}
Systolic BP (mm Hg)	124.0 ± 16.9	125.7 ± 21.4	123.8 ± 14.2	126.6 ± 16.7	121.9 ± 19.0	126.2 ± 22.7	123.6 ± 16.5	126.9 ± 24.0
Diastolic BP (mm Hg)	76.9 ± 11.4	77.5 ± 12.3	79.0 ± 9.4^{a}	80.5 ± 10.5^{a}	72.0 ± 11.7^{b}	79.4 ± 12.0	77.9 ± 10.4	75.5 ± 13.8
Triglycerides (mmol/L)	0.81 ± 0.5	0.68 ± 0.3***	0.81 ± 0.4	0.73 ± 0.6	0.89 ± 0.4	0.72 ± 0.3^{a}	0.59 ± 0.3^{b}	0.75 ± 0.3^{a}
HDL-C (mmol/L)	1.38 ± 0.5	1.48 ± 0.4**	1.45 ± 0.6^{a}	1.51 ± 0.4^{a}	1.20 ± 0.3^{b}	1.58 ± 0.5^{a}	1.55 ± 0.4^{a}	1.34 ± 0.4^{b}
Fasting plasma glucose (mmol/L)	4.82 ± 0.8	4.83 ± 0.8	4.93 ± 0.5^{a}	4.98 ± 1.0^{a}	4.59 ± 0.6^{b}	4.94 ± 0.6^{a}	4.98 ± 1.2^{a}	4.61 ± 0.5^{b}

Significant difference between men and women: **$P < .01$, *** $P < .001$, as determined by Student *t* tests. Values in the same row that do not share the same superscript letter (a, b, c) are significantly different (ANOVA with Tukey post hoc test, $P < .05$).

† Data are expressed as mean ± SD.

the other sites, but only in men (*P* < .05). Triglycerides tended to be lower in the semi-urban area, but the difference was significant only in women (*P* < .05). Both HDL-C and fasting glucose were significantly lower in the city (*P* < .05), compared with semi-urban and rural areas, in men and in women (Table 2).

3.2. Prevalence of the MetS and its components

As seen in Table 3, a positive rural-urban (rural to semi-urban to urban) gradient was only observed in the overall prevalence of the MetS (4.1%, 6.4%, 11%, respectively; *P* = .035) and abdominal obesity (28.2%, 41.5%, 52.5%, respectively; *P* < .001) but not in other components of the MetS. Low HDL-C was significantly less prevalent (*P* < .001) in the semi-urban area (18.1%) compared with the rural area (25.3%) and the city (37.5%). The prevalence of HBP was similar in the 3 sites (24.1%, 21.6%, and 26.5% for the rural, semi-urban, and urban, respectively), whereas high blood glucose was significantly more prevalent in rural and semi-urban areas compared with the urban site (10%, 14.6%, 4%, respectively; *P* = .002). High triglycerides were uncommon (<3%). Abdominal obesity, HBP, and low HDL-C were the prominent MetS components. The prevalence of the MetS, abdominal obesity, and low HDL-C was significantly higher in women than men (*P* < .01).

3.3. Association of MetS and its components with socioeconomic and lifestyle factors

Table 4 shows the age-adjusted association of the predominant MetS components with socioeconomic and lifestyle factors as determined by logistic regression. Female sex was associated with a much increased likelihood of abdominal obesity (OR, 19.1; 95% CI, 10.7-34.4; *P* < .001).

Living in the city also increased the likelihood of abdominal obesity (OR, 2.19; 95% CI, 1.01-4.74; *P* < .05). However, semi-urban subjects were not at increased risk compared with rural subjects. Both urban (OR, 0.38; 95% CI, 0.20-0.74; *P* < .01) and semi-urban subjects (OR, 0.36; 95% CI, 0.17-0.74; *P* < .01) were less likely to have HBP than rural subjects. Only semi-urban subjects were at lower risk of low HDL-C compared with their rural peers (OR, 0.50; 95% CI, 0.26-0.95; *P* < .05).

A higher level of education was associated with a 54% lower likelihood of abdominal obesity (OR, 0.46; 95% CI, 0.23-0.93; *P* < .05), whereas medium SES level (OR, 2.16; 95% CI, 1.23-3.80; *P* < .01) and high SES (OR, 2.67; 95% CI, 1.49-4.79; *P* < .001) more than doubled the odds. In contrast, a high level of SES was associated with a 54% reduction of the likelihood of HBP (OR, 0.46; 95% CI, 0.25-0.84; *P* < .05).

Physical inactivity nearly trebled the odds of abdominal obesity (OR, 2.93; 95% CI, 1.51-5.71; *P* < .01) and HBP (OR, 2.86; 95% CI, 1.62-5.05; *P* < .001), but it was not associated with low HDL-C. There was no significant association with alcohol consumption.

Table 3
Prevalence of MetS and its components

	Men and women			Men			Women		
	Rural (n = 170)	Semi-urban (n = 171)	Urban (n = 200)	Rural (n = 85)	Semi-urban (n = 86)	Urban (n = 100)	Rural (n = 85)	Semi-urban (n = 85)	Urban (n = 100)
MetS[a]	4.1 (2.0-8.26)	6.4 (3.62-11.2)	11.0 (7.37-16.1)*	0	4.7 (1.4-14.4)	5.0 (1.7-13.9)	8.2 (3.3-19.3)	8.2 (3.3-19.3)	17.0 (9.5-28.7)
Abdominal obesity	28.2 (22.0-35.4)	41.5 (34.4-49.0)	52.5 (45.6-59.3)***	3.5 (0.9-12.9)	14 (6.9-26.2)	22 (13.3-34.2)**	52.9 (39.3-66.2)	69.4 (55.5-80.5)	83 (71.4-90.4)***
High BP	24.1 (18.3-31.1)	21.6 (16.1-28.4)	26.5 (20.9-33.0)	20 (12.9-29.7)	24.4 (16.6-34.5)	25 (17.5-34.3)	28.2 (19.8-38.6)	18.8 (11.9-28.4)	28 (20.1-37.5)
High triglycerides	2.4 (0.91-5.90)	1.8 (0.59-5.04)	2.0 (0.78-5.03)	3.5 (1.2-9.9)	3.5 (1.2-9.8)	3.0 (1.0-8.5)	1.2 (0.2-6.4)	0	1.0 (0.2-5.5)
Low HDL-C	25.3 (19.4-32.3)	18.1 (13.1-24.6)	37.5 (31.1-44.4)***	24.7 (16.8-34.8)	10.5 (5.6-18.7)	31.0 (22.8-40.6)**	25.9 (17.8-36.1)	25.9 (17.8-36.1)	44.0 (34.7-53.8)**
High fasting glucose	10.0 (6.33- 15.4)	14.6 (10.1-20.7)	4.0 (2.04-7.70)**	10.6 (5.7-18.9)	15.1 (9.0-24.2)	4.0 (1.6-9.8)*	9.4 (4.8-17.5)	14.1 (8.3-23.1)	4.0 (1.6-9.8)

Significant difference across sites: * *P* < .05, ** *P* < .01, *** *P* < .001, as determined by χ^2 test.
[a] Data are expressed as percentage (95% CI).

Table 4
Relationship of predominant MetS components with socioeconomic and lifestyle factors[a]

	Abdominal obesity	High BP	Low HDL-C
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Sex			
Male (ref)	1	1	1
Female	19.1 (10.7-34.7) ***	0.68 (0.41-1.13)	1.52 (0.95-2.45)
Place of residence			
Rural (ref)	1	1	1
Semi-urban	1.53 (0.77-3.05)	0.38 (0.20-0.74) **	0.50 (0.26-0.95) *
Urban	2.19 (1.01-4.74) *	0.36 (0.17-0.74) **	0.95 (0.50-1.81)
Education			
No education (ref)	1	1	1
Elementary school	0.68 (0.38-1.25)	0.63 (0.36-1.11)	0.90 (0.53-1.55)
High school and above	0.46 (0.23-0.93) *	0.70 (0.37-1.31)	1.15 (0.63-2.10)
SES score			
Low (ref)	1	1	1
Medium	2.16 (1.23-3.80) **	0.90 (0.54-1.48)	1.32 (0.8-2.18)
High	2.67 (1.49-4.79) ***	0.46 (0.25-0.84) *	1.26 (0.73-2.18)
Physical activity			
Active (ref)	1	1	1
Inactive	2.93 (1.51-5.71) **	2.86 (1.62-5.05) ***	1.51 (0.87-2.63)
Alcohol consumption score			
Regular moderate (ref)	1	1	1
Abstinence	1.80 (0.69-4.72)	1.24 (0.53-2.90)	1.66 (0.77-3.58)
Regular high	2.12 (0.80-5.66)	0.90 (0.37-2.15)	2. 0 (0.95-4.25)
Binge drinker	0.80 (0.46-1.40)	0.89 (0.54-1.46)	1.23 (0.73-2.18)
Micronutrient adequacy score			
Low (ref)	1	1	1
Medium	1.00 (0.58-1.74)	0.87 (0.52-1.44)	0.96 (0.60-1.53)
High	0.78 (0.42-1.47)	0.46 (0.26-0.84) *	0.67 (0.37-1.19)
Preventive diet score			
Low (ref)	1	1	1
Medium	1.00 (0.56-1.78)	1.91 (1.11-3.27) *	1.14 (0.70-1.83)
High	1.46 (0.75-2.86)	1.49 (0.78-2.84)	0.90 (0.50-1.62)

Data are expressed as OR 95% CI. Sample size, N = 541. Logistic regression not performed for diabetes and high triglycerides because of very low prevalence rates.

[a] Logistic regression (enter) adjusted for age.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

A high micronutrient adequacy score reduced the odds of HBP by 54% but showed no association with the other cardiometabolic risk factors (OR, 0.46; 95% CI, 0.26-0.84; $P < .05$). Paradoxically, we observed elevated odds of HBP with a moderately preventive diet score compared to a low score (OR, 1.91; 95% CI, 1.11-3.27; $P < .05$).

Multiple linear regression models of the cardiometabolic risk factors as continuous variables on socioeconomic and lifestyle variables are given in Table 5. In model 1, socioeconomic and lifestyle variables are the independent variables (along with age and sex). In model 2, we included waist circumference as independent variable to control for its effect on other cardiometabolic risk factors.

In model 1, waist circumference was positively associated with urban residence ($\beta = .084$, $P < .10$) and high SES ($\beta = .20$, $P < .001$). In contrast, waist circumference was inversely related to physical activity ($\beta = -.156$, $P < .001$) and alcohol consumption ($\beta = -.091$, $P < .05$). Systolic and diastolic BPs were both inversely associated with urban residence ($\beta = -.10$, $P < .05$ and $\beta = -.291$, $P < .001$, respectively) and physical activity ($\beta = -.168$, $P < .001$ and $\beta = -.149$, $P < .01$, respectively) in model 1. These associations of BP remained significant in model 2 and were therefore independent of waist circumference.

Triglycerides were positively associated with SES ($\beta = .070$, $P < .10$) and inversely with physical activity ($\beta = -.138$, $P < .01$) in model 1. In model 2, the inverse association of triglycerides with physical activity remained significant ($\beta = -.098$, $P < .05$) but less strongly than in model 1, whereas the association with SES was no longer significant, meaning that these associations were mediated by waist circumference, at least partly.

In model 1, HDL-C was positively associated with physical activity ($\beta = .099$, $P < .05$), micronutrient adequacy ($\beta = .115$, $P < .05$), and (moderate) alcohol consumption ($\beta = .084$, $P < .10$). However, HDL-C was inversely associated with urban residence ($\beta = -.130$, $P < .05$) and SES ($\beta = -.085$, $P < .10$). The association of HDL-C with

Table 5
Relationship between cardiometabolic risk factors and socioeconomic and lifestyle variables [a]

	Waist circumference	Systolic BP	Diastolic BP	Triglycerides	HDL-C	Fasting plasma glucose
Model 1						
Urban residence [b]	0.084 *	−0.10 **	−0.291 ****	0.007	−0.130 **	−0.158 ***
Education [c]	0.003	0.00	0.027	−0.046	0.049	0.044
SES level [d]	0.201 ****	−0.012	0.009	0.070 *	−0.085 *	0.065
Physical activity [e]	−0.156 ****	−0.168 ****	−0.149 ***	−0.138 ***	0.099 **	−0.002
Micronutrient adequacy score	0.034	−0.007	−0.015	−0.015	0.115 *	0.068
Preventive diet score	0.014	−0.026	−0.013	0.062	−0.001	0.010
Alcohol consumption [f]	−0.091 **	0.034	0.006	0.003	0.084 *	0.067
Model 2						
Waist circumference		0.220 ****	0.234 ****	0.253 ****	−0.190 ****	0.229 ****
Urban residence [b]		−0.119 **	−0.311 ****	−0.014	−0.114 **	−0.166 ****
Education [c]		−0.001	0.027	−0.047	0.50	0.043
SES level [d]		−0.056	−0.030	0.033	−0.047	0.032
Physical activity [e]		−0.134 ***	−0.112 **	−0.098 **	0.069	0.034
Micronutrient adequacy score		−0.015	−0.023	−0.023	0.122 ***	0.061
Preventive diet score		−0.029	−0.017	0.058	0.002	0.010
Alcohol consumption [f]		0.054	0.028	0.026	0.067	0.086 **

Data are expressed as standardized β coefficient. Sample size, n = 541.
[a] Multiple linear regression (enter) adjusted for age and sex.
[b] Area of residence (0 = rural, 1 = semi-urban, 2 = urban).
[c] Education (0 = no education, 1 = elementary school, 2 = high school and above).
[d] Household amenity score as SES indicator (0 = low, 1 = medium, 2 = high).
[e] Physical activity (0 = inactive, 1 = active).
[f] Alcohol consumption score (0 = binge drinker, 1 = regular high, 2 = abstinence, 3 = regular moderate).
* $P < .10$.
** $P < .05$.
*** $P < 0.01$.
**** $P < .001$.

micronutrient adequacy score ($\beta = .122$, $P < .01$) and urban residence ($\beta = -.114$, $P < .05$) remained significant in model 2 and was therefore independent of waist circumference, whereas its association with physical activity, SES level, and alcohol consumption was no longer significant, indicating that it was waist circumference dependent.

Fasting plasma glucose was inversely associated with urban residence in both models ($P < .01$). Surprisingly, the positive association with alcohol consumption, which was merely a trend in model 1, became significant in model 2 ($\beta = .086$, $P < .05$).

4. Discussion

This study is the first to report on the MetS and its relationship with socioeconomic, dietary, and lifestyle factors in rural, semi-urban, and urban adults in West Africa. It confirms the existence of a rural-urban gradient (rural to semi-urban to urban) in the prevalence of the MetS and abdominal obesity but not in other MetS components. Abdominal obesity, HBP, and low HDL-C were the principal components of the MetS in the study population. Urban residence was independently associated with abdominal obesity and low HDL-C but also with lower fasting plasma glucose. Semi-urban residence appeared protective for low HDL-C, whereas semi-urban or urban living was associated with lower BP. Physical activity appeared protective for obesity and HBP, and micronutrient adequacy, for low HDL-C.

The positive obesity gradient observed in this study can be ascribed to the nutrition transition process that is ongoing in developing countries [29], with shifts in diet and lifestyle patterns under the influence of urbanization, globalization, and economic growth. The changes first appear in cities before reaching less urbanized areas and expose the people to obesity and other nutrition-related chronic diseases [29]. In this study, we did not observe links between obesity and diet quality indicators in the multivariate models. However, both the micronutrient and the prevention scores were significantly and positively correlated with BMI and waist circumference in univariate correlations, whether they were adjusted for total energy intake (data not shown). This is likely due to the confounding effect of lifestyle and SES. In other studies, obesity was reportedly associated with the nutrition transition [29] and with poor micronutrient adequacy [30], but physical activity and SES were not controlled for. We found that physical activity was lower in the city compared with semi-rural and rural dwellers, especially in women, who were particularly prone to obesity. Furthermore, we observed a SES gradient of obesity in each study site (data not shown). Therefore, physical activity and the SES largely explain the rural-urban gradient of obesity. The higher risk of obesity with higher affluence is typical of the early stages of nutrition transition as observed elsewhere in Africa [11], and the risk may be modulated by physical activity. Main occupation and transportation means were major contributors to physical activity, and most women were only involved in small trade and household chores that are not physically demanding [20], which in part explains the higher obesity prevalence among women than men. Other studies in Africa have also highlighted the key role of physical inactivity in the high or low prevalence of obesity and other cardiometabolic risk factors such as HBP [12,31,32], as observed in this study. The lower likelihood of obesity that we observed with higher education could reflect an emerging change in the traditionally positive social attitude toward fatness in West African women, which is conducive to obesity [33]. The opposite effects of SES and education on the odds of obesity underline the importance of considering separately these 2 socioeconomic variables in epidemiological studies.

A much higher prevalence of MetS was reported in urban women of South Africa (48.5%) compared to our study, which is ascribed to a higher national income and urbanization level in that country compared to Benin [17]. However, the prevalence of MetS in our study was considerably higher than in the Cameroon where the reported rate was 0.0% and 1.2% in rural and urban men, respectively, and 0.3% and 1.5% in rural and urban women, respectively, with the International Diabetes Federation definition of MetS [16]. This is so even if high total cholesterol was used instead of low HDL-C as a criterion in the above study, which would be expected to inflate the rate of dyslipidemia. Furthermore, the inclusion of subjects previously diagnosed with diabetes or HBP, unlike in our study, should also have contributed to a higher prevalence of the MetS in Cameroon [16]. Obviously, the observed prevalence of the MetS in this study would be higher if we had not excluded subjects with a previous diagnosis of diabetes and HBP. Unfortunately, the observed prevalence of the MetS in the semi-urban area could not be compared with data from other studies in Sub-Saharan Africa because such data are not available.

The absence of a rural-urban gradient for HBP and low HDL-C despite high overall prevalence rates suggests that the nutrition transition process related to chronic diseases may first impact on the rate of obesity before being reflected in other cardiometabolic risk factors [29,34], or that factors other than the nutrition transition are relatively more important as determinants of HBP or low HDL-C in the study population. Age, genetic factors, family history, and nutritional status in early life are among the numerous determinants potentially implicated [35,36]. Chronic infection or inflammation related to poverty, lack of care, and unhealthy lifestyles may all contribute to high rates of HBP [37]. Fetal programming can also be a partial explanation [38], with elevated BP in childhood persisting into adulthood [39]. Genetic factors, obesity, smoking, alcohol consumption, and physical activity were shown to influence HDL-C in the general population [36]. It is also possible, given that our study was conducted only in Benin, that low HDL-C reflects a genetic influence [40], in addition to gene-environment interactions, including gene-diet interactions [41]. The observed positive and independent association of the micronutrient adequacy score with HDL-C as well as with lower odds of HBP suggests that a higher risk of CVD may result from inadequate micronutrient intake [42]. The positive and independent association of moderate alcohol consumption with HDL-C in our study tends to support a protective role as reported in the literature [43]. However, this association was no longer significant when the model included waist circumference, suggesting that the principal effect of low alcohol consumption compared with high or binge drinking is related to lower abdominal obesity.

Urbanization and associated diet and lifestyle shifts may thus contribute to higher obesity [44] and lower HDL-C [45]. The observed positive and independent association of urban residence with abdominal obesity is reported in several studies[11,13] and was discussed in a previous article [20]. The inverse and independent association of urbanization with HDL-C can be linked with the urban diet, typically higher in cholesterol and saturated fat compared to rural and semi-urban diets usually higher in polyunsaturated fat [46].

At variance with other reports [47], we observed a lower level of BP and glycemia in urban than rural and semi-urban subjects. It may be that BP and diabetes are better screened in the city and, therefore, that more undiagnosed cases were present in the semi-urban and rural sites because subjects previously diagnosed were excluded from the study. This is suggested by the much higher number of excluded subjects in the city as compared to the other study areas (33 vs 9 subjects, respectively). The fact that the inverse association between urban residence and BP was not independent of abdominal obesity also suggests a modulation by physical activity, which was inversely and independently associated with both abdominal obesity and BP in multiple regression models. The effect of urban residence may be partly confounded with SES because a higher SES was found to be associated with a lower likelihood of HBP, and urban subjects may be better off than their peers in semi-urban or rural locations. The SES score was computed on the same basis in all 3 sites, but the level (low, medium, high) was based on tertiles within each site.

Rural to urban migration is often associated with an increased risk of metabolic abnormalities [48]. However, little is known about reverse migration. For example, a study on migration and urbanization in French-speaking West Africa showed that new trends in migration flows are emerging [49]. In our study, a sizeable proportion of subjects living in the rural of semi-urban sites were born in the city, which shows that migration is bidirectional: from rural to city areas and from city to semi-urban and rural areas, especially when the density of population increases rapidly in cities. These new trends in migration may affect the cardiometabolic risk prevalence in each study area [15].

Defining what is urban and what is rural is an issue, which we discussed previously [20]. We used the official criteria of

Benin, which include the urbanization status of the last 10 years, to distinguish urban (larger city), semi-urban (small-size city), and rural locations [21]. We also examined the place of birth (rural, semi-urban, or urban) and total duration of urban or rural residence to characterize urbanization. However, the place of birth and the total duration of urban or rural residence were not significantly associated with studied risk factors and were therefore dropped.

Are there some commonalities among the study sites that are relevant to the health concerns of the study? In other words, is the semi-urban group more rural, or urban, or is it distinct from both? Lifestyles in the semi-urban area were very similar to the rural area's for diet quality indicators (higher than urban), alcohol consumption patterns (less binge and regular high consumption than urban subjects), and inactive lifestyle (women only); smoking patterns did not differ across sites. For cardiometabolic risk factors, the semi-urban subjects were also more similar to the rural than urban group but only in terms of a lower prevalence of low HDL-C and a higher prevalence of hyperglycemia. Interestingly, mean triglycerides were significantly lower in semi-urban women than in rural and urban sites; a similar trend (nonsignificant) was also observed in men. The 3 locations were different for general obesity (as well as for education), with progressively higher rates with urbanization. Therefore, the semi-urban area is distinct from the rural and from the urban strata and should be considered separately in future studies of this kind.

Several limitations are acknowledged. The cross-sectional nature of the study did not allow causality inferences between socioeconomic and lifestyle factors, and cardiometabolic risk. Sample size was large enough considering the breadth and depth of the data collected on diet and lifestyles, but it proved insufficient to perform multivariate analyses for diabetes and high triglycerides because of the low prevalence of these conditions in the study sample because subjects previously diagnosed with hypertension and diabetes were excluded. The fact that the dietary quality scores used in this study were not validated against other instruments such as the Healthy Eating Index [50] or Diet Quality Index International [51] may be another limitation. The higher likelihood of HBP with the intermediate preventive diet score in logistic regression models, for example, was unexpected and may be due to some limitations of our score. This score, based on the WHO/FAO dietary guidelines for the prevention of chronic diseases [25], requires further testing and may be found more appropriate if the component subscores are graded rather than simply dichotomous. The use of three 24-hour recalls provides for a good and novel evaluation of physical activities, but it would have been interesting to validate this method with the accelerometer [52].

In conclusion, we reported a rural-urban positive gradient for the prevalence of the MetS, which mirrors that of abdominal obesity, but not for the other prominent components of MetS, that is, HBP and low HDL-C. High SES levels and physical inactivity were the main determinants of this gradient, whereas low micronutrient adequacy was associated with HBP and lower HDL-C. The high prevalence of abdominal obesity, HBP, and low HDL-C underlines the vulnerability of the study population to CVD, especially urban women. The risk could be reduced with physical activity and a more adequate diet. Therefore, the promotion of an active lifestyle (walking, cycling) and improving diet quality through traditional sources of micronutrients such as fruits and vegetables, legumes, and local cereals are needed.

Acknowledgment

The authors gratefully acknowledge the assistance of all members of the TRANSNUT/ISBA/IRSP research teams and the subjects for their participation. The authors also thank the Canadian Institute for Health Research for supporting this study.

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