Original Article

Body Size and Metabolic Health: A Phenotypic Characterisation of an Indigenous African Working Population

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Abstract

Background: An obesity subgroup has been described that do not have the typical metabolic abnormalities associated with obesity. **Aims:** We characterized body size and metabolic phenotypes among public employees. **Materials and methods:** 879 participants were evaluated using WHO-STEP wise approach to non-communicable diseases screening. Body size was classed according to WHO guidelines. Metabolically healthy obesity (MHO) was defined as obesity without elevated blood pressure, diabetes mellitus and reduced HDL-C (< 40mg/dl for men and<50 mg/dl for women respectively). Determinants of MHO were assessed in a logistic regression model adjusting for socio-demographic, clinical and biochemical variables. **Results:** 38.1% (335/879) had normal BMI, 35.5% (312/879) were overweight and 26.4% (232/879) were obese. The prevalence of metabolically healthy normal weight (MHNW), metabolically healthy overweight (MHOWT) and metabolically healthy obese (MHO) was 47.7% (160/335), 32.6% (102/312) and 18.5% (43/232) respectively (p<0.001). Tertiary education (adjusted odds ratio (AOR)=1.59; 95% CI: 1.03-2.47), hypertension (AOR=2.30; 95% CI: 1.58-3.35), hypercholesterolaemia (AOR=1.52; 95% CI: 1.06-2.17) and reduced HDL-C (AOR=2.40; 95% CI: 1.20-4.78) independently predicted generalized obesity, while male sex (AOR=0.10, 95% CI: 0.07-0.16) reduced the risk of generalized obesity by 90%. Age 45 years and older (AOR=0.29; 95% CI: 0.20-0.40, p<0.001), alcohol intake (AOR=0.50; 95% CI: 0.34-0.74, p<0.001), and generalized obesity (AOR=0.31; 95% CI: 0.20-0.47, p<0.001) were protective against MHO. **Conclusion:** A significant proportion of the participants had the MHO phenotype. Body size had an inverse relationship with metabolic health.

Keywords: Metabolically healthy obesity; Body size; Generalized obesity

Introduction

Obesity has assumed a pandemic proportion globally. It is a significant driving force behind the non-communicable diseases (NCDs), especially cardiovascular disease (CVD), hypertension, dyslipidaemia, type 2 diabetes mellitus (T2DM) and some malignancies and their associated morbidity and mortality. A phenotype of obesity called metabolically healthy obesity (MHO) has been recently described where the individuals were traditionally believed not to be at an increased risk of CVD outcomes [1]. However, in recent years there has been conflicting evidence about its benign nature with most studies reporting increased risk of CVD events [2-6] The lack of adverse outcomes in MHO has been attributed to the presence of the protective effects of behavioural and lifestyle factors, in such individuals [4,7-9] thus providing therapeutic opportunities for preventing NCDs and their associated mortality.

There is an increasing prevalence of obesity among indigenous Africans. The prevalence of obesity in West Africa was estimated at 10.0% in a meta-analysis of 28 publications conducted in 2008. This report revealed that the prevalence of obesity in urban West Africa has more than doubled (114%) in just over 15 years [10]. Other recent reports support this rising trend [11-15]. Despite the foregoing, the burden, determinants and significance of MHO in indigenous Africans is however unknown as few reports exist on this subject. Mbanya and colleagues [15] reported that 10.1% of Cameroonians were obese yet metabolically healthy. The only other study to our knowledge was conducted among South African patients with HIV where 18.6% had the MHO phenotype [16].

In response to clinical observations of MHO phenotype in our environment, we conducted a secondary analysis of data obtained from university workers involved in an NCD screening programme in an indigenous African nation. In this report, we characterize body size and associated metabolic phenotypes.

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Materials and Methods

Participants

We utilized data obtained from employees aged 18 -70 years working at the University of Jos that participated in a cross-sectional study on NCDs conducted between February and June 2014. The participants in this study were staff who volunteered to participate in the screening exercise. As at the time of the study, the University workforce comprised a total of 2603 (1793 senior and 810 junior staff). The minimum sample size (380) was calculated from the Kish formula [17] using the prevalence of hypertension (as this was the NCD with the highest prevalence) and a precision of 5%. The 883 participants represented 33.9% of the population. The Human Research Ethics Committee of the Jos University Teaching Hospital approved the study before commencement. All the participants provided written informed consent.

Evaluation of demographic and behavioural factors

Participants were evaluated using WHO-STEP wise approach to NCDs screening [18]. Details of dietary intake of vegetables and fruits, physical activity, prior history of diabetes and hypertension alongside the use of alcohol and nicotine use were obtained in addition to socio-demographic characteristics were captured using the STEPS 1 and 2 segments of the WHO-STEP wise data capture tool. The intake of less than five servings of fruits and vegetables on most days was regarded as unhealthy diet. Physical inactivity was taken as 150 minutes each week of aerobic physical activity at a moderate level or 75 minutes each week of aerobic physical activity at a vigorous level. Significant alcohol use as the consumption of more than one drink (14 g of pure alcohol) or two drinks (28 g of pure alcohol) per day on most for women and men respectively.

Measurement of cardio-metabolic factors

We measured weight (to the nearest 0.1 kg using the electronic personal weighing scale (Nacal Medical, England), height (to the nearest 0.1 cm) using a metre rule placed against the wall and calculated body mass index (BMI) according to standard recommendations. Blood pressure was measured three times after five minutes rest using OMRON sphygmomanometer (MIT Elite). The first reading was discarded and the last two averaged. Five millilitres of venous blood was drawn from the antecubital vein for casual plasma glucose (CPG), total cholesterol (TC) and high density lipoprotein (HDL-C) in the non-fasted state. All investigations were performed at the APIN laboratories of the Jos University Teaching Hospital using standard reagents on Cobas 311 autoanalyser (ROCHE, Basel, Switzerland).

BMI was categorized according to WHO classification where measurements between 18.5-24.9 kg/m^2, 25.0-29.9 kg/m^2 and >30.0 kg/m^2 were regarded as normal; overweight and obesity respectively [19]. 'Metabolically healthy' status was defined as absence of the following metabolic risk factors: (1) prior hypertension diagnosis or use of anti-hypertensive medication or average BP reading >130/85 mmHg; (2) DM (CPG > 200 mg/dl) and (3) adversely low HDL-C levels (<40 mg/dl in men and <50 mg/dl in women) [20-22]. The MHO phenotype was defined as obese individuals who were "metabolically healthy" [1]. Similarly, individuals with normal and overweight BMI ranges who were "metabolically healthy" were typed as "metabolically healthy normal weight" (MHNW) and "metabolically healthy overweight" (MHOWT) respectively.

Statistical analysis

All statistical analyses were performed using EPI 7.1 (CDC, Atlanta, GA). Descriptive statistics of central tendency and variability was used to present socio-demographic, anthropometric and biochemical variables. Categorical variables are presented as proportions. Obesity was reported as the frequency of BMI >30.0 kg/m^2 divided by the total number of observations expressed as percentage. Similarly, the prevalence of the metabolic phenotypes was calculated by dividing their frequencies by the frequency of obesity expressed as a percentage. Two by two cross tabulations were performed to assess the relationship between the various phenotypes and the variables of smoking status, alcohol use, unhealthy diet and physical inactivity. Clinically relevant variables and those with p values <0.25 on univariate analysis were entered into a multiple logistic regression models to determine the independent predictors of the generalized obese and metabolically healthy phenotypes. Statistical significance was taken as a p value <0.05.

Results

Characteristics of study participants

A total of 883 individuals (521/883; 59.0% males) participated in the study. The final analysis was based on 879 as four individuals were excluded as they were underweight. The mean (SD) age of the participants was 44 (9) years; with the majority (80.8%; 706/879) being married. The socio-demographic characteristics of the participants are as shown in Table 1.

Prevalence of body size and metabolic phenotypes

Table 1 shows the characterization of the body size and metabolic phenotypes with 38.1% (335/879) having normal weight, 35.5% (312/879) overweight and 26.4% (232/879) obese body size phenotypes respectively. The prevalence of MHNW, MHOWT and MHO was 47.7% (160/335), 32.6% (102/312) and 18.5% (43/232) respectively (p<0.001).

The socio-demographic and clinical characteristics of the participants across body size and metabolic phenotypes are shown in Table 1. Participants with the metabolically healthy phenotypes were significantly younger than those without across the BMI classes (p<0.001 for all). A lower proportion of males were metabolically healthy across the body size phenotypes of overweight and obesity. While history of significant alcohol use was similar in the MHO and metabolically unhealthy obese groups (p=0.87), there was a trend towards significance in the overweight group (p =0.05). Significant alcohol use was lower in the MHNW group (p =0.003). Significant differences were also observed between the metabolically healthy and unhealthy groups across the body size phenotypes with respect to waist circumference and waist to hip ratio.

Determinants of obesity and its' phenotypes

Table 2 shows factors associated with generalized obesity. On

Table 1: Characteristics of participants by body size and metabolic phenotypes among 879 workers in a Nigerian university

Variables	Total	Normal			Overweight			Obese		
		MH	MU	P	MH	MU	p	MH	MU	p
n (%)	879 (100)	160 (47.7)	175 (52.2)	-	102 (32.6)	210 (67.3)	-	43 (18.5)	189 (81.4)	-
Age*, years	44 (9)	38)9)	43 (10)	<0.001	41 (9)	46 (9)	<0.001	41 (7)	48 (8)	<0.001
Males	519 (59.0)	132 (82.5)	142 (82.0)	0.92	43 (47.7)	142 (69.9)	<0.001	5 (11.6)	49 (25.9)	0.04
Married, n (%)	706 (80.8)	125 (78.1)	135 (78.4)	0.77	66 (74.1)	175 (87.0)	0.04	37 (86.0)	151 (80.3)	0.66
Years of schooling*	15 (6)	15 (5)	13 (5)	0.03	16 (6)	14 (6)	0.07	15 (6)	15 (6)	0.93
Post-secondary education, n (%)	612 (70.2)	106 (66.2)	102 (59.2)	0.11	66 (73.3)	141 (70.5)	0.48	33 (78.5)	148 (79.1)	0.86
Alcohol	211 (33.2)	32 (20.0)	60 (34.6)	0.003	18 (20.0)	63 (31.0)	0.05	7 (16.2)	29 (15.3)	0.87
Ever smoked	54 (6.1)	14 (8.7)	20 (11.5)	0.39	3 (3.3)	11 (5.4)	0.56	1 (2.3)	3 (1.5)	0.56
Current smoker	25 (2.8)	7 (4.3)	8 (4.6)	0.91	0 (0.0)	8 (3.9)	0.05	0 (0.0)	2 (1.0)	0.66
<3 servings of fruits/ vegetables a day	487 (55.4)	87 (54.3)	98 (56.6)	0.67	56 (62.2)	98 (48.2)	0.02	26 (60.4)	115 (60.8)	0.96
Fruit servings/day ǂ	2 (1-3)	2 (1-3)	2 (1-3)	0.72	2 (1-3)	2 (1-3)	0.40	1 (1-3)	1 (1-2)	0.94
Vegetable servings a day ǂ	2 (1-3)	2 (1-2)	2 (1-3)	0.71	2 (1-3)	2 (1-3)	0.61	1 (1-2)	1 (1-2)	0.71
Physically active	337 (42.9)	81 (50.6)	83 (47.9)	0.62	36 (40.0)	85 (41.8)	0.76	14 (32.5)	69 (36.5)	0.62
Waist-hip ratio*	0.88 (0.8)	0.85 (0.06)	0.87 (0.05)	0.01	0.86 (0.06)	0.91 (0.07)	<0.001	0.86 (0.05)	0.91 (0.1)2	0.009
WC, cm*	91.2 (12.0)	79.4 (6.5)	82.5 (6.3)	<0.001	100.8 (7.8)	104.9 (9.4)	0.008	89.9 (6.8)	94.4 (6.2)	<0.001
SBP, mmHg*	129 (19)	115 (11)	136 (18)	<0.001	116 (12)	137 (19)	<0.001	116 (7)	133 (21)	<0.001
DBP, mmHg*	79 (12)	71 (8)	83 (13)	<0.001	72 (7)	84 (11)	<0.001	73 (5)	83 (12)	<0.001
CPG, mg/dlǂ	85.0 (78.0-97.0)	79.0 (71.1-86.0)	86.1 (79.0-98.5)	0.001	83.7 (77.0-93.0)	87.0 (79.0-101.0)	0.01	82.0 (77.0-91.0)	90.6 (82.0-103.0)	0.001
TC, mg/dl*	193 (43)	176.6 (40.8)	183.5 (43.2)	0.13	194.9 (37.4)	199.8 (43.5)	0.34	192.9 (37.3)	208.4 (44.8)	0.03
HDL-C, mg/dl*	56.6 (16.3)	59.8 (15.6)	59.7 (18.9)	0.97	56.6 (14.0)	52.9 (16.1)	0.06	54.0 (13.1)	55.0 (15.3)	0.69
Hypercholesterolaemia, n (%)	364 (41.4)	40 (25.0)	52 (30.0)	0.30	41 (45.5)	99 (48.7)	0.61	20 (46.5)	104 (55.0)	0.31

MH= Metabolically Healthy; MU= Metabolically Unhealthy; WC= Waist Circumference; SBP= Systolic BP; DBP= Diastolic BP; CPG= Casual Plasma Glucose; TC= Total Cholesterol; HDL-C= High Density Lipoprotein Cholesterol, ǂ =Median With Interquartile Range,*= Mean SD

Table 2. Independent predictors of generalised obesity among 879 university workers in Jos, Nigeria

Variable	Crude OR	95% CI	p	Adjusted OR	95% CI	p
Sex						
Female	1			1		
Male	0.11	0.08-0.16	<0.001	0.1	0.07-0.16	<0.001
Age years						
18-44	1			1		
≥ 45	1.96	1.45-2.66	<0.001	1.26	0.85-1.85	0.24
Marital status						
Unmarried	1			1		
Married	1.05	0.72-1.53	0.78	1.33	0.85-2.07	0.2
Education						
≤ Secondary	1			1		
Tertiary	0.56	0.39-0.79	0.001	1.59	1.03-2.47	0.03
Cadre						
Senior	1			1		
Junior	0.52	0.39-0.71	<0.001	1.12	0.75-1.67	0.56
Alcohol						
No	1			1		
Yes	0.48	0.32-0.71	0.0002	0.97	0.61-1.56	0.93
Ever smoked						
No	1			1		
Yes	0.02	0.07-0.57	0.0008	0.73	0.24-2.20	0.58
< 3 fruit & Veg servings/ day						
No						
Yes	1			1		
	1.35	0.99-1.85	0.05	1.25	0.87-1.80	0.21
Physically active						
No	1			1		
Yes	0.67	0.49-0.92	0.01	0.97	0.67-1.40	0.9

Hypertension						
No	1			1		
Yes	2.98	2.12-4.19	<0.001	2.3	1.58-3.35	<0.001
Diabetes						
No	1			1		
Yes	2.13	1.30-3.51	0.002	1.58	0.87-2.86	0.12
Hypercholesterolaemia						
No	1			1		
Yes	0.5	0.37-0.67	<0.001	1.52	1.06-2.17	0.02
Low HDL-C						
No	1			1		
Yes	0.56	0.30-1.01	0.05	2.4	1.20-4.78	0.01

Adjustment was made for sex, age, marital status, education, cadre of work, smoking, alcohol, physical activity and hypercholesterolaemia

bivariate analyses all but four variables had some association with obesity. In adjusted analysis, men had a 90% lower odd of being obese (AOR=0.10, 95% CI: 0.07-0.16), while having tertiary or higher level of education was associated with a 41% increased risk of obesity (AOR=1.59; 95% CI: 1.03-2.47). Presence of hypercholesterolemia (AOR=1.52; 95% CI: 1.06-2.17), hypertension (AOR=2.30; 95% CI: 1.58-3.35) and reduced HDL-C (AOR=2.40; 95% CI: 1.20-4.78) were also associated with increased likelihood of generalized obesity (AOR=1.54; 95% CI: 1.07-2.21).

Table 3 shows factors associated with metabolically healthy phenotype. In unadjusted analysis, factors associated with a metabolically healthy phenotype were younger age (18-44 years), junior cadre, no reported alcohol intake, and absence of generalized or central obesity. In adjusted analysis, younger age (AOR=0.29; 95% CI: 0.20-0.40), history of alcohol intake (AOR=0.50; 95% CI: 0.34-0.74), and generalized obesity (AOR=0.31; 95% CI: 0.20-0.47) predicted the presence of metabolically healthy phenotype irrespective of body size. We further determined the independent predictors of the MHO phenotype as shown in Table 4 where only male sex (AOR=0.07; 95% CI: 0.02-0.20) and age ≥ 45 years (AOR=0.36; 95% CI: 0.18-0.74) exhibited significant association.

Discussion

We characterized body size and metabolic phenotypes of a working population in this study and demonstrated that the majority of the study participants were overweight/obese, with an inverse relationship existing between body size and metabolic health phenotypes as the prevalence of the "metabolically healthy phenotype" decreased from 47.7% for normal weight to 32.6% for overweight and 18.5% for obese body sizes respectively. Independent predictors of generalized obesity in this study were sex, education, hypertension, hypercholesterolaemia and reduced HDL-C while age, alcohol intake, and generalized obesity predicted the presence of metabolically healthy phenotype. We found the determinants of MHO phenotype to be younger age and female gender.

Body size phenotypes have been extensively studied in indigenous African populations. Overweight and obesity were present in 35.5% and 26.4% of our study participants respectively. Our results do not differ significantly from previous reports from the West African sub-region [14,15,23-26]. In a systematic review of papers published in Nigeria between 2001 and 2012, the prevalence of overweight and obesity ranged from 20.3-35.1% and 8.1-22.2% respectively [22] Recently, Oladimeji and associates [23] reported that 35% and 27% of Nigerians employed in the public service are overweight and obese respectively. Mbanya and colleagues [15] also reported that 36.8% and 18.1% of urban Cameroonians were overweight and obese respectively. In a house to house survey of 2000 Togolese nationals aged 45±10 years old, 25.2% were found to be obese [14] Ziraba and co-workers [24] in a review of Demographic Health Surveys conducted in seven African countries demonstrated that the prevalence of overweight/obesity rose by 35.3% (from 23.2-31.4%) in just 10 years. A study conducted among Ghanaian faculty members revealed that 43% and 13% were overweight and obese respectively [25].

The female gender, possession of tertiary education, hypertension, hypercholesterolemia and reduced HDL-C were the determinants of generalized obesity in this study. The fact that female gender is a risk factor for obesity among Africans has long been established [10,14,15,23]. Some reports show that women are 2-4 times more likely to be obese compared to men [10,14,15,22,23,26]. The association of education with obesity confirms previous reports [10,23,24]. The association of higher education with obesity may reflect the role of urbanization and acquisition of western lifestyle that come with education as it is associated with sedentary jobs and improvement of socio-economic status. As a result, overweight/obesity has been shown to be a malady of the rich in Africa [10,24].

Physical inactivity was not associated with obesity in this study. This is contrary to established scientific knowledge [15,23,26,27]. The apparent lack of association of physical inactivity with obesity may be due to the study design we used. Our study was cross-sectional in nature; hence it is not possible to establish a "cause and effect" relationship between physical inactivity and obesity. In addition to the foregoing the reliance on self-reported physical activity in our study may have introduced recall bias which may have impacted on this finding.

The lack of consensus definition for MHO has influenced the literature on the prevalence of MHO and this must be taken into cognizance for effective comparisons to be made. While most studies used BMI to classify body size phenotypes, a few have measured percentage body size using DEXA with the latter reporting higher rates of obesity [28,29]. To further muddle the horizon, the numbers of cardio-metabolic factors used in the defining metabolic health have ranged from 0-4 [1-6,30]. A fifth of the obese individuals in this study had the MHO phenotype.

Table 3: Independent predictors of the metabolically healthy phenotype among 879 university workers in Jos, Nigeria

Variable	Crude OR	95% CI	p	Adjusted OR	95% CI	p
Sex						
Female	1			1		
Male	1.08	0.81-1.44	0.57	0.71	0.49-1.02	0.06
Age years						
18-44	1			1		
≥ 45	0.28	0.21-0.38	<0.001	0.29	0.20-0.40	<0.001
Marital status						
Unmarried	1			1		
Married	0.78	0.55-1.09	0.15	1.06	0.73-1.55	0.74
Education						
≤ Secondary	1			1		
Tertiary	0.93	0.69-1.27	0.68	1.2	0.83-1.72	0.32
Cadre						
Senior	1			1		
Junior	1.13	1.01-1.76	0.04	0.98	0.69-1.40	0.92
Alcohol						
No	1			1		
Yes	0.62	0.44-0.88	0.007	0.5	0.34-0.74	5E-04
Ever smoked						
No	1			1		
Yes	1.02	0.57-1.82	0.93	1.43	0.75-2.72	0.27
< 3 fruit & Veg servings/ day						
No						
Yes	1			1		
	1.11	0.83-1.48	0.45	1.14	0.83-1.55	0.4
Physically active						
No	1			1		
Yes	1.11	0.84-1.47	0.45	0.98	0.72-1.34	0.93
Generalized obesity						
No	1			1		
Yes	0.34	0.24-0.49	<0.001	0.31	0.20-0.47	<0.001
Hypercholesterolaemia						
No	1			1		
Yes	0.62	0.46-0.83	0.001	0.84	0.61-1.16	0.31

Adjustment was made for sex, age, marital status, education, cadre of work, smoking, alcohol, physical activity and hypercholesterolaemia

Table 4: Independent predictors of metabolically healthy obesity (MHO) among 879 university workers in Jos, Nigeria

Variable	Crude OR	95% CI	p	Adjusted OR	95% CI	p
Sex						
Female	1			1		
Male	0.37	0.14-1.00	0.04	0.07	0.02-0.20	<0.001
Age years						
18-44	1			1		
≥ 45	0.18	0.09-0.39	0.01	0.36	0.18-0.74	0.005
Marital status						
Unmarried	1			1		
Married	1.55	0.61-3.94	0.35	1.94	0.82-4.57	0.12
Education						
≤ Secondary	1			1		
Tertiary	1.09	0.49-2.40	0.22	1.35	0.61-2.99	0.45
Cadre						
Senior	1			1		
Junior	1.66	0.85-3.23	0.13	1.30	0.64-2.65	0.45
Alcohol						
No	1			1		
Yes	1.07	0.43-2.64	0.87	1.11	0.45-2.77	0.81
Ever smoked						
No	1			1		
Yes	1.47	0.14-14.54	0.73	2.03	0.22-18.34	0.52

< 3 fruit & Veg servings/ day						
No	1			1		
Yes	1.11	0.54-2.24	0.76	1.19	0.61-2.32	0.59
Physically active						
No	1			1		
Yes	0.83	0.41-1.69	0.62	0.98	0.50-1.92	0.95
Hypercholesterolaemia						
No	1			1		
Yes	0.71	0.36-1.38	0.31	1.28	0.66-2.45	0.45

Adjustment was made for sex, age, marital status, education, cadre of work, smoking, alcohol, physical activity and hypercholesterolaemia

Only few studies have related body size phenotypes to metabolic health among indigenous Africans for us to compare our results with. While our finding is similar to that reported among HIV infected persons accessing care and treatment in South Africa (18.6%) [16] a lower prevalence of 10.1% has been reported among Cameroonians in a large community survey [15]. Our finding corroborates previous reports from other continents where the prevalence ranges from 16.4% to 19% [31-34]. It is however lower than the 24.4% to 47.7% in other reports [28,35,29] Much lower figures of 3.0% and 8.6% among Chinese and Spaniards respectively have been reported [35,36] These varying prevalence figures reflect the impact of different MHO definitions, selection bias and population characteristics in these studies.

We also assessed the determinants of MHO in this study. Reports of the impact of age and gender on MHO have been conflicting. While younger women tended to have more of MHO in our study and in many others, some studies have reported no gender association [29-31,33,34,36]. Older age has been associated with MHO in the Chinese and Brazilian series [30,35]. Another factor we studied was physical activity. Physical activity and other lifestyle factors have been proposed to be the reason why individuals with MHO may not suffer adverse outcomes [4,7-9]. We did not find any significant association of physical activity with MHO in this study. This is in consonance with the finding of some reports [31,33,34]. Nonetheless our study was not designed to elucidate this association.

Our study has implications for public health as overweight/ obesity is a modifiable risk factor for NCD morbidity and mortality. We found that a large proportion of overweight and obese participants in this study were metabolically unhealthy. In the absence of timely and appropriate intervention we face a worsening of the NCD epidemics. Concerted efforts from government and its agencies, health care workers and other stake holders are needed to forestall this problem.

This study had some limitations. The highly selected nature of the participants limits the generalizability of the findings to the community. In addition, we neither measured insulin resistance nor glucose in the fasted state hence the used of overt diabetes mellitus as a cardiometabolic factor. Finally, we did not measure serum triglyceride which is one of the recognised cardiometabolic factors. These impacted on our definition of the metabolic phenotype. The strength of our study however, lies in the stringent criterion used in defining the MHO phenotype. Whereas our study defined MHO as obesity without any metabolic abnormality, most studies defined MHO as obesity without 1-4 metabolic factors [2-6,37,38].

Conclusion

In conclusion, we found that the greater majority of the participants in this study were overweight or obese. The findings of this study suggest an inverse relationship between body size and metabolic health and identify opportunities for intervention in order to succeed in the fight against the growing NCD epidemic. Finally, we established that MHO was impacted by age and gender. Further studies are needed to fully characterize these body size and metabolic phenotypes in the general community and elucidate their outcomes.

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Author Contributions

EIA, MOA, PAA and ANO conceptualized the study. EIA, MOA, PAA, ANO, ZMG, BJF and FGI collected the data. EIA and PAA conducted data analysis. EIA and PAA interpreted the data and wrote the draft manuscript. All authors approved the final manuscript

Conflict of interest

All authors declare no conflict of interest.

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