

Utility of silhouette showcards to assess adiposity in three countries across the epidemiological transition

Tyler Reese (✉ treese@luc.edu)

Loyola University Chicago Stritch School of Medicine <https://orcid.org/0000-0001-6881-2521>

Pascal Bovet

Universite de Lausanne

Candice Choo-Kang

Loyola University Chicago

Kweku Bedu-Addo

Kwame Nkrumah University of Science and Technology

Terrence Forrester

University of the West Indies

Jack Gilbert

University of Chicago

Julia Goedecke

University of Cape Town

Estelle Lambert

University Cape Town

Brian Layden

University of Illinois at Chicago

Lisa Micklesfield

University of Cape Town

Jacob Plange-Rhule

Kwame Nkrumah University of Science and Technology

Dale Rae

University of Cape Town

Bharathi Viswanathan

Unit of Prevention and Control of Cardiovascular Disease

Amy Luke

Loyola University Chicago

Lara Dugas

Loyola University Chicago

Research

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Abstract

Background: The Pulvers' silhouette showcards provide a non-invasive, easy-to-use, and possibly cross-culturally acceptable way of assessing an individual's perception of their body size. This study examined, in three different populations: 1) the relationship between silhouettes and body mass index (BMI), 2) the predictive performance of silhouettes to predict dichotomous adiposity categories, and 3) whether silhouette ranking performed similarly in predicting BMI, waist circumference (WC), and waist-to-height ratio (WHR).

Methods: This study included 751 participants of African-origin from the United States of America (USA), the Republic of Seychelles, and Ghana, from the ongoing cohort Modeling the Epidemiological Transition Study. We assessed the mean BMI for each silhouette rank by country and sex and performed a least-squares linear regression for the silhouette's performance by country and sex. The performance of the silhouettes to predict overweight and obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$), and obesity alone ($\text{BMI} \geq 30 \text{ kg/m}^2$) was examined through a receiver operator curve (ROC) analysis with corresponding sensitivities and specificities. Finally, a ROC analysis area under the curve (AUC) was also performed for the detection of elevated waist circumference (men $\geq 94 \text{ cm}$; women $\geq 80 \text{ cm}$) and waist-to-height ratio (> 0.5) by country and sex.

Results: Mean measured BMI (kg/m^2) in men/women differed largely across countries: 28.9/35.8 in the USA, 28.3/30.5 in Seychelles, and 23.9/28.5 in Ghana. The slope of the relation between silhouette ranking and BMI (i.e., linear regression coefficient and 95% confidence intervals) was similar between sexes of the same country but differed between countries: 3.65 [95% CI: 3.34-3.97 BMI units/silhouette unit] in the USA, 3.23 [2.93-3.74] in Seychelles, and 1.99 [1.72-2.26] in Ghana. Different silhouette cut-offs predicted dichotomous adiposity categories differently in the three countries. For example, a silhouette ≥ 5 had sensitivity/specificity of 77.3%/90.6% to predict $\text{BMI} \geq 25 \text{ kg/m}^2$ in the USA, but 77.8%/85.9% in Seychelles and 84.9%/71.4% in Ghana. Finally, silhouettes predicted BMI, WC, and WHR similarly, within each country and sex, based on Spearman correlations coefficients (continuous scale) and c-statistic (dichotomous classification).

Conclusion: Our data suggest that Pulvers' silhouette showcards can be a useful tool to objectively predict different adiposity measures in different populations when direct measurement cannot be performed. However, population-specific differences in the slopes of the associations, which possibly partly reflect differences in perceptions of one's body size according to country adiposity prevalence, stress the need to calibrate silhouette showcards when using them as a survey tool.

Background

The prevalence of overweight and obesity is increasing in populations spanning the epidemiological transition and may be particularly high in individuals of African-origin.¹⁻⁴ Elevated weight is associated with the development of non-communicable diseases (NCDs), including cardiovascular disease, type 2 diabetes mellitus, hypertension, dyslipidemia, cancers, and sleep apnea.⁵⁻⁸

Because of its simplicity and ease of measurement, body mass index (BMI, kg/m^2) is widely used to assess a person's adiposity. In addition to BMI, waist circumference (WC) and waist-to-height ratio (WHR) correlate well with fat mass as assessed by accurate methods such as computed tomography (CT).⁹⁻¹² However, BMI does not discriminate well between adipose and lean mass, and waist circumference and waist-to-height ratio have been suggested to predict adiposity better.⁹⁻¹¹ Yet, while they may not predict actual adiposity perfectly at the individual level, these simple adiposity markers may reliably predict mean BMI levels and the prevalence of obesity at the population level.^{9,12}

Measures of adiposity that do not rely on actual measurements may be useful in some situations, such as in surveys and studies of public health, anthropology, economics, and marketing, particularly when studies must be performed without direct contact with a person (e.g., mail-order or internet-based) or to avoid the burden of asking respondents to remove clothing. Furthermore, self-reported adiposity (e.g., self-reported height and weight) are prone to reporting bias and can also depend on access to home anthropometric tools like scales and varying cultural views on body size.¹³⁻¹⁹

Initially developed by Stunkard and colleagues, sex-specific silhouette showcards (referred to as "silhouettes" hereafter) can be used to determine one's perception of their body size. This tool relies on presenting to respondents a series of pictures/drawings of distinct body sizes in an increasing sequence, from which respondents select the one they think best reflects their body size.²⁰ Silhouettes should be ethnically ambiguous enough to be used in different cultures, but still detailed enough to be relatable. A variety of silhouette tools have been developed and validated for different populations.²¹⁻²⁴ Pulvers and colleagues created culturally relevant body image silhouette showcards for African Americans (Fig. 1).²⁵ These silhouettes were validated in different populations of African-origin such as Seychelles, the Caribbean, and the USA.²⁵⁻²⁸ While many studies have shown a good association between the silhouettes and adiposity measures, including for the prediction of obesity, most studies have only assessed their validity in a single population at a time.²¹⁻³² Also, only a few studies have directly compared the associations of silhouette ranking between different populations with diverse ethnic backgrounds or with different population mean BMI levels. Assessing the validity of silhouettes to predict adiposity in different populations may be challenging as one's assessment of body image relies on an individual's ability to appraise their current body size and correctly classify their weight relative to objective measurements and, also, considering that cross-cultural evaluation should rely on studies that use the same methodology in different countries.^{29,33-36}

Therefore, our study aims to assess: 1) the relationship between Pulvers silhouette showcard ranking and measured adiposity markers (BMI, WC, and WHR), 2) the performance of silhouette ranking to predict adiposity makers, particularly overweight and obesity based on elevated BMI, and 3) the performance of silhouette ranking to predict BMI, WC, and WHR, in three different African-origin populations representing different stages of social and economic development and different prevalence of obesity.²⁵

Methods

Study Populations and Ethics Approval

This study is a subset analysis from the METS-Microbiome study (R01DK111848) initiated in 2017, for which the protocol has been published.³⁷ The METS-Microbiome study continues yearly measurements of participants initially recruited for the Modeling the Epidemiological Transition Study (METS; R01-DK080763) in five African-origin populations spanning the epidemiologic transition varying by the United Nations Human Development Index (HDI) 2010.^{38,39} The current data were collected between 2018–2019 from participants in metropolitan Chicago, IL, USA (HDI: 0.92), the mixed urban/rural Seychelles islands (0.80), and rural Ghana (0.59).^{37,39} These three sites represent different social and economic development stages and have a largely different prevalence of obesity.³⁹

The METS-Microbiome protocol was approved by the Institutional Review Board of Loyola University Chicago, Chicago, IL, USA (LU 209537); the National Research Ethics Committee of Seychelles and the Committee of Human Research Publication and Ethics of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.³⁷ Written informed consent was obtained from all participants.

The study sample consisted of men and women aged 20–68 years old who were of African-origin except for Seychelles, where both Black-African participants and participants of mixed racial ancestry were included. Approximately 66% of the whole sample identified as female.

Survey and Body Size Silhouette Showcards

The survey component of the METS-Microbiome study consisted of a face-to-face interview performed by centrally trained personnel, capturing participants' sociodemographic status, health-related behaviors, and medical history. Participants were also presented with sex and ethnicity-specific silhouette showcards created by Pulvers (Fig. 1).^{25,27} This nine-image tool displayed sex-specific body sizes in increasing order ranging from very thin to severely obese. To measure participants perceived body size, participants were asked, "In the drawing, which figure best reflects how you think you look with regards to your body shape?". Participants' responses were recorded on a scale from 1 (representing the thinnest silhouette) to 9 (representing the most obese silhouette).

Anthropometric and Adiposity Measurements

Participants completed a health examination, including measured height (m), weight (kg), and waist circumference (cm). Across all sites, standardized equipment and protocols were used, as previously described.³⁷ Body mass index (BMI, weight/height²) was calculated and classified as underweight (BMI < 18.5 kg/m²), normal weight (BMI 18.5–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²) or obese (BMI ≥ 30 kg/m²).⁴⁰ A dichotomous waist circumference (cm) variable was used to classify the presence of central obesity as defined by the International Diabetes Federation (≥ 94 cm in men, ≥ 80 cm in women) for European or African-origin individuals.¹¹ WHR (waist in cm/ height in cm) was calculated and dichotomized using a widely used cut-off point for normal (WHR ≤ 0.5) or increased central obesity (WHR > 0.5).⁴¹

Statistical Analyses

Participant characteristics were summarized using means and 95% confidence intervals. Proportions were calculated and presented as a percent (%) and 95% confidence intervals for categorical variables. Spearman's rank correlation coefficients were used to describe the associations between the self-reported perceived silhouette ranking and BMI, WC, and WHR.

Mean BMI and 95% confidence interval for each silhouette rank was determined by sex and by country. To assess whether the slopes of the relation between silhouette ranking and adiposity markers differed between countries and sex, we estimated the linear regression coefficients (i.e., the change of the three adiposity markers corresponding to 1 silhouette ranking change) by sex and country with accompanying 95% confidence intervals.

The self-reported silhouette showcards were assessed for accuracy in predicting widely used dichotomized adiposity markers, e.g., overweight and obesity (BMI ≥ 25 kg/m²) or obesity alone (BMI ≥ 30 kg/m²), elevated waist circumference (cm, (≥ 94 cm in men, ≥ 80 cm in women) and elevated waist-to-height ratio (WHR > 0.5) using sex and country-specific receiver-operator curve (ROC) analysis.²⁶ We used the area under the curve (AUC, i.e., the c-statistic) and sensitivity and specificity associated with different cut-offs of the silhouettes to predict these dichotomous adiposity categories.

All statistical analyses were performed using STATA SE 12 (StataCorp, College Station, TX, USA).

Results

Demographics

Table 1 shows the main characteristics of the 751 participants from the three countries. Mean age differed slightly across countries and was highest in men in the USA (47.1 years) and lowest in women in Ghana (41.4 years).

Table 1
Characteristics of participants in the USA, Seychelles, and Ghana

	USA		Seychelles				Ghana					
	Men (N = 88)	Women (N = 177)	Men (N = 100)	Women (N = 183)	Men (N = 67)	Women (N = 136)						
Age (years)	47.1	45.9–48.3	45.3	44.3–46.2	45.2	44.2–46.2	44.3	43.4–45.2	45.6	43.4–47.7	41.4	40.0–42.8
Height (cm)	174.8	173.4–176.2	164.8	163.7–165.8	173.6	172.4–174.7	162.1	161.1–163.2	167.9	166.3–169.6	159.1	158.2–160.0
Weight (kg)	88.2	83.6–92.9	97.3	93.8–100.8	85.3	82.0–88.5	80.3	77.4–83.1	67.3	65.0–69.5	71.9	69.5–74.4
BMI (kg/m ²)	28.9	27.4–30.4	35.8	34.5–37.0	28.3	27.3–29.3	30.5	29.5–31.6	23.9	23.1–24.7	28.5	27.5–29.4
Waist circumference (cm)	100.0	96.1–103.6	109.3	106.8–111.9	95.8	93.6–98.1	95.6	93.6–97.5	86.3	83.9–88.7	96.1	94.0–98.1
Waist-to-height ratio	0.57	0.55–0.59	0.66	0.65–0.68	0.55	0.54–0.57	0.59	0.58–0.60	0.52	0.50–0.53	0.60	0.59–0.62
Perceived silhouette (1–9)	4.2	3.9–4.6	6.2	5.9–6.4	4.5	4.3–4.8	5.4	5.1–5.6	4.1	3.6–4.5	5.5	5.1–5.8
Adiposity categories, %												
Underweight (BMI < 18.5 kg/m ²)	2.3	0.0-5.4	0.6	0.0-1.7	2.0	0.0-4.8	0.5	0.0-1.6	1.5	0.0-4.4	1.5	0.0-3.5
Normal weight (BMI 18.5–24.9 kg/m ²)	26.1	16.9–35.4	6.2	2.6–9.8	26.0	17.3–34.7	21.9	15.8–27.9	61.2	49.4–73.0	27.9	20.4–35.5
Overweight (BMI 25-29.9 kg/m ²)	36.4	26.2–46.5	19.2	13.4–25.0	41.0	31.3–50.7	29.0	22.4–35.6	34.3	22.8–45.8	35.3	27.2–43.4
Obese (BMI ≥ 30 kg/m ²)	35.2	25.1–45.3	74.0	67.5–80.5	31.0	21.8–40.2	48.6	41.4–55.9	3.0	0.0-7.1	36.0	27.9–44.1
Central obesity (WC ≥ 94 cm M; ≥ 80 cm W)	55.7	45.1–66.3	96.6	93.9–99.3	54.0	44.1–63.9	88.5	83.9–93.2	29.9	18.6–41.1	92.6	88.2–97.1
Elevated waist-to-height ratio (> 0.5)	73.9	64.5–83.2	94.9	91.6–98.2	79.0	70.9–87.1	83.6	78.2–89.0	44.8	32.6–57.0	90.4	85.4–95.4

Notes: Data are presented as mean or proportions with 95% confidence intervals. BMI: body mass index, M: Men, W: Women.

Anthropometric and Adiposity Measures

All measures of size, including height, weight, and adiposity, tended to be highest in the USA, intermediate in Seychelles, and lowest in Ghana, and be higher in women than men in each country, e.g., mean BMI (kg/m²) in men/women was 28.9/35.8 in the USA, 28.3/30.5 in Seychelles and 23.9/28.5 in Ghana (Table 1), with similar trends for WC and WHR. The mean values of adiposity measures and the prevalence of the adiposity categories were lowest in men from Ghana. The prevalence (%) of obesity in men/women (BMI ≥ 30) followed a similar decreasing trend: 35.2/74.0 in the USA, 31.0/48.6 in Seychelles, and 3.0/36.0 in Ghana (Table 1). The prevalence of elevated WC exceeded 88.5% in women from all three countries. Men in the USA and Seychelles had an intermediate prevalence of elevated WC (55.7% and 54.0% respectively) versus Ghanaian men (29.9%). Finally, the prevalence of elevated WHR (> 0.5) exceeded 70% in men and women from all countries, except in men from Ghana (44.6%) (Table 1). The different adiposity markers used in this study inter-correlated quite strongly in men and women. Correlations coefficients were 0.91 for men/0.77 for women for the association between BMI and WC, 0.94/0.80 for the association between BMI and WHR, and 0.96/0.95 for the association between WC and WHR in the USA; 0.89/0.91, 0.91/0.92, and 0.94/0.95 in Seychelles; and 0.88/0.91, 0.90/0.90, and 0.92/0.96 in Ghana.

Correlations between Silhouette Showcards and Continuous Adiposity Measures

Table 2 shows the Spearman's correlation coefficients of the relationship between the perceived self-reported silhouette rankings with BMI, WC, and WHR, by country and sex. These coefficients ranged between 0.71 and 0.80 in men and women in all countries, except in men in Ghana (0.55-0.58), ($p < 0.001$ for all coefficients).

Table 2

Spearman correlation coefficients (*r*) between self-reported silhouette ranking and continuous adiposity measures in men and women from the USA, Seychelles, and Ghana

	Men	95% CI	Women	95% CI
USA, N	<i>88</i>		<i>177</i>	
BMI (kg/m ²)	0.77	0.66–0.87	0.79	0.73–0.85
WC (cm)	0.72	0.60–0.83	0.74	0.67–0.82
Waist-to-height ratio	0.75	0.64–0.86	0.75	0.68–0.82
Seychelles, N	<i>100</i>		<i>183</i>	
BMI (kg/m ²)	0.78	0.71–0.87	0.80	0.74–0.85
WC (cm)	0.76	0.66–0.86	0.77	0.71–0.84
Waist-to-height ratio	0.79	0.70–0.88	0.76	0.70–0.83
Ghana, N	<i>67</i>		<i>136</i>	
BMI (kg/m ²)	0.56	0.39–0.73	0.74	0.67–0.82
WC (cm)	0.55	0.37–0.73	0.73	0.65–0.82
Waist-to-height ratio	0.58	0.41–0.75	0.71	0.63–0.80
Notes: BMI: body mass index (kg/m ²). WC: waist circumference (cm), CI: confidence intervals; <i>N</i> : sample size. The <i>P</i> -value for all correlations is < 0.001.				

Relationship between silhouette ranking and measured BMI

Table 3 shows a graded increase in mean BMI according to silhouette ranking by sex and country. The table also depicts the least-squares linear regression coefficients by sex and country between participants' measured BMI and the self-reported silhouettes. Regression coefficients (i.e., slopes of the regression lines) were higher in women compared to men in all three countries. Regression coefficients were significantly lower in Ghana than in the other two countries for both men and women. In the USA and Seychelles, an increase in 1 silhouette unit was associated with an increase of 3.05–3.75 BMI units (kg/m²) but only 1.15–2.06 BMI units in Ghana. Nearly identical trends were observed for WC and WHR (Supplementary tables 1 and 2). A robust regression analysis, which lessens the influence of outliers on the regression coefficient estimates, was also performed, and estimates were almost identical as those in the least-squares linear regression.

Table 3
Mean BMI by silhouette number, country, and sex

	USA (N=265)			Seychelles (N=283)						Ghana (N=203)							
		Men	Women	All	Men	Women	All	Men	Women	All	Men						
	N (all)	Mean	CI	Mean	CI	Mean	CI	N (all)	Mean	CI	Mean	CI	Mean	CI	N (all)	Mean	CI
Silhouette 1	4	20	0-40.4	21	15.3-27.4	20	15.6-25.3	0	*	*	*	*	*	*	8	22	1-2
Silhouette 2	14	23	20.6-25.4	25	19.4-29.8	23	21.2-25.4	20	21	19.1-23.4	22	20.6-22.3	21	20.5-22.3	16	21	1-2
Silhouette 3	24	25	23.1-26.2	25	23.1-26.4	25	23.4-25.9	21	24	22.3-26.0	23	20.7-25.2	24	22.1-24.9	28	23	2-2
Silhouette 4	40	28	26.3-29.1	28	25.7-29.5	28	26.5-28.8	67	26	25.0-27.0	26	24.8-26.9	26	25.2-26.6	26	24	2-2
Silhouette 5	43	30	27.4-32.0	31	29.5-32.2	31	29.3-31.7	63	30	28.5-31.2	29	27.5-30.5	29	28.3-30.4	38	25	2-2
Silhouette 6	57	33	29.7-35.6	35	33.5-36.1	34	33.2-35.6	55	33	30.6-35.6	31	30.1-32.7	32	30.7-33.0	37	26	2-2
Silhouette 7	40	41	35.1-47.1	38	36.3-40.5	39	36.8-40.8	38	36	34.1-38.4	35	33.4-36.8	35	33.8-36.7	27	29	2-3
Silhouette 8	25	48	0-126	41	38.6-43.8	42	39.0-44.5	17	37	*	43	38.7-47.2	43	38.6-46.6	17	26	*
Silhouette 9	18	55	*	50	46.6-53.4	50	46.7-53.7	2	*	*	45	29.8-59.5	45	29.8-59.5	6	*	*
Reg coeff	265	3.51	2.98-4.04	3.75	3.28-4.21	3.65	3.34-3.97	238	3.05	2.56-3.54	3.34	2.94-3.74	3.23	2.93-3.54	203	1.15	0-1

Notes: BMI: body mass index, USA: United States of America; CI: 95% confidence interval; Intersect: Intersection point of linear regressions; Reg coeff: Linear regression coefficient. Mean BMI's rounded to the nearest whole number.

Self-reported silhouette as a discriminator of overweight and/or obesity

Table 4 shows that the sensitivity of silhouettes 4, 5, 6, and 7 to identify men and women who were overweight and obese, or only obese, decreased with increasing silhouette ranking. For silhouette ≥ 4 , the sensitivity to predict BMI ≥ 25 ranged between 91.4-96.7%, and was 98.8-100% to predict BMI ≥ 30 , while for silhouette ≥ 7 , sensitivity ranged from 26.9-41.2% to predict BMI ≥ 25 and was 45-68.65% to predict BMI ≥ 30 . For silhouette ≥ 4 , the specificity of predicting BMI ≥ 25 ranged between 47.9-68.8% and was 24.5-38.8% to predict BMI ≥ 30 . For silhouette ≥ 7 , sensitivity ranged from 98.8-100% to predict BMI ≥ 25 and was 90.1-98.2% to predict BMI ≥ 30 .

Table 4
Sensitivity and specificity of self-selected silhouette ratings to predict overweight and obesity, or obese only in USA, Seychelles, and Ghana

		Overweight and Obesity		Obesity	
		Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Silhouette ≥ 4	USA	91.4	68.8	98.8	38.8
	Seychelles	96.7	47.9	99.2	24.5
	Ghana	93.3	52.4	100.0	34.2
Silhouette ≥ 5	USA	77.3	90.6	92.0	67.0
	Seychelles	77.8	85.9	95.0	62.6
	Ghana	84.9	71.4	100.0	51.3
Silhouette ≥ 6	USA	59.7	96.9	79.0	88.4
	Seychelles	52.4	98.6	75.0	86.5
	Ghana	66.4	90.5	92.2	73.7
Silhouette ≥ 7	USA	35.6	100.0	49.4	97.1
	Seychelles	26.9	100.0	45	98.2
	Ghana	41.2	98.8	68.6	90.1

Notes: Overweight and Obesity: BMI ≥ 25 kg/m²; Obesity: BMI ≥ 30 kg/m².

Figure 2 depicts the proportion of participants categorized as normal weight, overweight, or obese for the middle four silhouettes (4–7). While the BMI categories for each silhouette rank showed a large dispersion, there were apparent differences in the country's pattern of distribution. Silhouettes 4 and 5 captured the largest proportion of overweight participants in the USA, and Seychelles, while silhouettes 5 and 6 captured most overweight participants in Ghana. When assessing obesity status, silhouette 7 in the USA, Seychelles, and Ghana captured most of the obese participants.

Performance between silhouette ranking to BMI, waist circumference, and waist-to-height ratio in detecting adiposity

Table 5 shows the sex and country-specific AUCs (i.e., c-statistic) of silhouette ranking to predict overweight or obesity status (BMI ≥ 25 kg/m²) or obesity alone (BMI ≥ 30 kg/m²). AUCs ranged between 0.79 and 0.92 in men and between 0.87 and 0.97 in women, with little differences by sex or country. Similar AUC values were found for silhouette ranking to predict elevated WC and WHR.

Table 5. Performance of self-reported silhouette ranking to predict overweight and obese BMI, elevated waist circumference, and elevated WHR, in the USA, Seychelles, and Ghana

Country	Sex	Overweight or Obesity		Obesity		Elevated WC		Elevated WHR	
		AUC	95% CI	AUC	95% CI	AUC	95% CI	AUC	95% CI
USA	M	0.79	0.70-0.89	0.88	0.81-0.95	0.82	0.74-0.90	0.84	0.75-0.93
	W	0.97	0.95-0.99	0.88	0.83-0.94	0.96	0.93-1.00	0.94	0.89-0.98
	All	0.91	0.86-0.95	0.91	0.87-0.94	0.91	0.88-0.95	0.91	0.88-0.95
Seychelles	M	0.87	0.80-0.93	0.86	0.82-0.95	0.85	0.77-0.92	0.88	0.80-0.96
	W	0.91	0.87-0.95	0.89	0.85-0.94	0.91	0.84-0.97	0.89	0.84-0.94
	All	0.89	0.86-0.93	0.89	0.86-0.93	0.87	0.83-0.92	0.88	0.84-0.93
Ghana	M	0.85	0.76-0.94	0.92	0.83-1.00	0.77	0.65-0.88	0.83	0.73-0.92
	W	0.87	0.80-0.93	0.87	0.82-0.93	0.88	0.79-0.96	0.86	0.77-0.95
	All	0.87	0.82-0.92	0.90	0.86-0.94	0.81	0.75-0.87	0.84	0.79-0.90

Notes: M: men, W: women, BMI: body mass index (kg/m²), WC: waist circumference (cm), WHR: waist-to-height ratio, AUC: area under the curve, 95% CI: 95% confidence interval. Overweight or obesity: BMI ≥ 25 kg/m²; Obesity: BMI ≥ 30 kg/m²; Elevated WC: M ≥ 94 cm; W ≥ 80 cm; Elevated WHR > 0.5.

Discussion

This study continues on the foundation established by Pulver and colleagues in creating the silhouette showcards and subsequent validation in populations of African-origin.²⁵⁻²⁷ Our data suggest that the Pulvers' silhouette showcards may be a useful tool for predicting objective body size such as BMI, WC, and WHR, in different populations of mainly African-origin. However, the relationship between silhouettes and adiposity markers differed according to the country. Overall, our data suggest that silhouettes may be a useful tool to predict actual adiposity measures, conditional to adequate calibration for a specific population.

BMI and other adiposity measures correlated strongly with silhouette ranking in all populations. However, the magnitude of the linear regression coefficients between silhouette ranking and actual adiposity markers differed between the three countries in this study. For example, an increase of 1 silhouette unit was associated with an increase of 3–4 BMI units (kg/m^2) in the USA and Seychelles but only 1–2 BMI units in Ghana. This difference suggests varying perceptions of one's body shape according to mean population BMI. One may speculate that in the USA and Seychelles, where mean population BMI is high, individuals with adiposity are more inclined to view a large body shape as normal compared to populations (e.g., Ghana) where mean population BMI is lower. Again, this altered view suggests that silhouette showcards need to be specific (i.e., calibrated) to different populations when used for predicting individuals' actual adiposity. From a prevention perspective, the differences in perceptions of one's body size across populations may suggest larger tolerance for larger body shapes in populations with high adiposity levels. Overall, this underlies that silhouettes can have a role for assessing adiposity in populations when direct measurements cannot be made (i.e., for surveillance purposes, as evaluated in this study), but also for assessing perceptions and attitudes of people for weight control programs.

The relationship between silhouettes and adiposity markers can differ according to sex in the same population. Using different silhouette showcards, regression coefficients for the relationship between silhouettes and BMI (kg/m^2 per silhouette unit) were, for examples, 0.73 for men and 0.81 for women among white Americans (with mean BMI of $25.5 \text{ kg}/\text{m}^2$ in men and $24.1 \text{ kg}/\text{m}^2$ in women) and 0.73 for men and 0.80 in Japanese women (with mean BMI of $23.3 \text{ kg}/\text{m}^2$ in men and $21.5 \text{ kg}/\text{m}^2$ in women) and 0.80 for men and 0.81 for women in Seychelles (with mean BMI of $26.4 \text{ kg}/\text{m}^2$ in men and $29.3 \text{ kg}/\text{m}^2$ in women).^{21,22,26} It is therefore likely that the same linear regression models can be used in men and women for calibration of the association between silhouettes and BMI (or other adiposity markers) within the same population, as long as mean BMI in the population is similar in both sexes. Inversely, as our data in Ghana suggest, different predictive models may need to be developed in men and women when mean BMI markedly differs between men and women in the same population. Differences in the slopes of the associations between silhouettes and BMI (and other adiposity markers) may also partly depend on different sex-specific perceptions of body shape, and this question necessitates further studies.

The country and sex-specific associations between silhouettes and adiposity markers were quite similar when using BMI, WC, and WHR. This relationship is not unexpected as BMI, WC, and WHR quite strongly and similarly inter-correlate with each other, e.g., correlation coefficients of 0.77 to 0.96 in our study, which is consistent with correlations found in other studies.⁴² However, the fact that these associations between silhouettes and BMI, WC, and WHR (and the associations between these adiposity markers and objectively measured fat mass) are still not extremely strong, implies that silhouettes would not be a reliable tool to predict adiposity at the individual level (sensitivity and specificity are not optimal), but they can be useful when assessing adiposity levels (e.g., the prevalence of obesity, mean BMI) at a population level, conditional on appropriate calibration in a specific population. More generally, our data suggest that a subjective two-dimensional pictorial body size assessment (silhouette drawings) can be a useful tool for predicting a volumetric dimension (adiposity), at least at the population level.

This study's main strength was the use of the identical methodology in the three countries, allowing us to make direct comparisons between populations of the same racial origin and that the three populations differed largely according to mean adiposity levels and socioeconomic development stages. However, the study also has limitations. First, although the study was designed to include participants of African-origin in all sites, in order to control for ethnic differences, persons from mixed origin were also included in varying but small proportions, particularly in Seychelles. Second, the study included middle-aged adults, and the findings may not necessarily extend to older or younger individuals. Third, Pulver's silhouette tool presents body size silhouettes from thinnest to heaviest, which could lead to reporting bias. Future studies should examine if presenting the silhouettes in random order would gather different results. Fourth, survey administrators presented silhouettes to the participants; further studies should assess if results would differ if participants had assessed their silhouettes in the absence of assisting personal. Finally, our analysis, according to sex, was limited because of the limited sample size.

Conclusions

This study supports the utility of Pulver's silhouette showcards as a useful tool to predict adiposity in populations in settings where body size cannot be measured directly, conditional to adequate adjustment (i.e., calibration) of the associations between silhouette ranking and actual adiposity markers. Although this was not the aim of this study, our results also emphasize potential benefits of using silhouettes to assess individuals' perceptions and attitudes in the context of weight control programs at clinical or public health levels.²⁵

Declarations

Ethics approval and consent to participate:

The METS-Microbiome protocol was approved by the Institutional Review Board of Loyola University Chicago, Chicago, IL, USA (LU 209537); the National Research Ethics Committee of Seychelles and the Committee of Human Research Publication and Ethics of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Written informed consent was obtained from all participants.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare they have no competing interests.

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Author Contributions:

T.O.R. led the analysis and writing of the manuscript with the assistance of L.R.D. and P.B.. A.L. and L.R.D. led the design of the METS-Microbiome cohort study with the collaboration of T.E.F., J.P.-R., P.B., and E.V.L.. All the authors provided critical revisions of the manuscript and approved the final manuscript.

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Abbreviations

BMI	Body Mass Index
HDI	Human Development Index
USA	United States of America
METS	Modeling the Epidemiological Transition Study
ROC	Receiver-Operator Curve
AUC	Area Under the Curve
WC	Waist Circumference
WHR	Waist-to-height ratio
NCDs	Non-Communicable Diseases
CT	Computed tomography
IDF	International Diabetes Federation
CI	Confidence Interval
M	Men
W	Women
Sey	Seychelles

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Figures

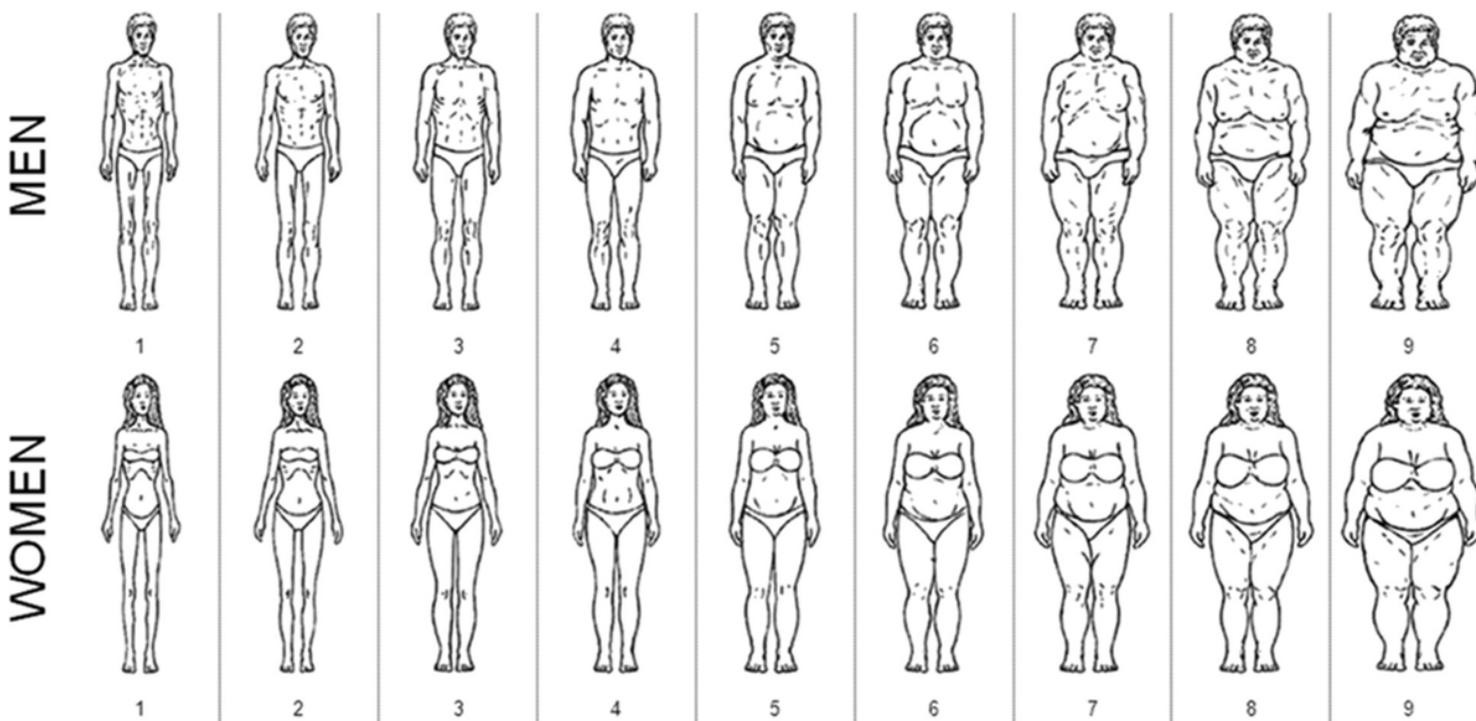


Figure 1

Pulvers' silhouettes designed for populations of African-origin (source: Pulvers 2004, Obesity Res.)

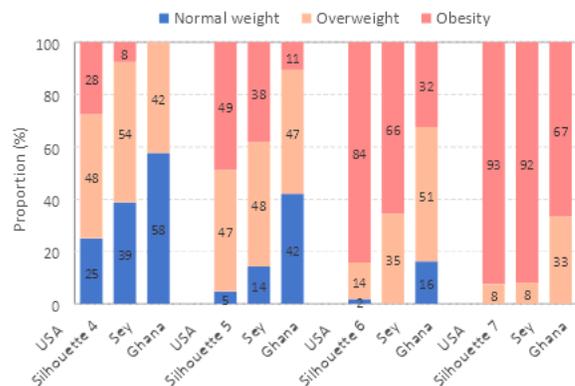


Figure 2

Proportion with normal weight, overweight, and obese within each silhouette category in the USA, Seychelles, and Ghana. Notes: N weight: normal weight (BMI 18.5-24.9 kg/m²); Overweight (BMI 25.0-29.9 kg/m²); Obese (BMI ≥ 30 kg/m²); Sey: Seychelles.

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