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SUPPLEMENT ARTICLE

Epidemiology/Genetics

BMI-for-age percentile curves for older adults

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Abstract

Objective: The objective of this manuscript is to present BMI-for-age percentile curves for men and women aged 45 to 90 years.

Methods: Weighted empirical percentile estimates were calculated using data from the Canadian Longitudinal Study on Aging (CLSA) comprehensive cohort (2011–2018) according to age and sex. Statistical smoothing procedures were used to generate smoothed curves for the percentile values. Overweight and obesity were defined as BMI greater than the 85th and 95th percentile for age and sex, respectively.

Results: In order to create BMI-for-age percentile curves, $n = 56{,}705$ observations were used ($n = 29{,}961$ individuals at baseline and $n = 26{,}744$ individuals at the first follow-up visit). In men, absolute values for BMI percentiles are lower than those in women, and the decline in BMI begins earlier (i.e., at a younger age). In women, the 95th percentile threshold for BMI is highest between ages 59 and 67 years (i.e., 41 kg/m^2), and in men, the 95th percentile threshold for BMI is highest between ages 51 and 62 years (i.e., 39 kg/m^2).

Conclusions: BMI-for-age percentile curves demonstrate how an individual's BMI value compares with values from a reference population comprising individuals of the same age and sex. This approach has widespread utility to determine eligibility for interventions and as a tool to incorporate into clinical models of care for obesity management in an aging population.

INTRODUCTION

Body mass index (BMI) is used in clinical settings and research studies as a surrogate measure of adiposity. BMI is calculated as weight in kilograms divided by height in meters squared [1, 2]. It is commonly used to assess whether an individual has a healthy body weight given their height. It is easy to calculate with routinely collected, standard anthropometric measures. BMI has inherent value as an inexpensive and easy-to-use tool to assess body weight scaled by height. There are known limitations associated with BMI, especially in older adults, but it has great practical utility [3–5].

BMI categories are used as a classification system for adult men and women over age 20 years [6]. Current guidelines recommend the use of the following standard BMI categories: underweight (BMI < 18.5 kg/m^2); normal weight (BMI 18.5–24.9 kg/m^2); overweight (BMI 25–29.9 kg/m^2); and obesity (BMI > 30 kg/m^2) [7–9]. As the prevalence of obesity has increased substantially over the past half century, the categorical definition of obesity is now further subdivided in the following categories [6, 10]: class I obesity (BMI 30–34.9 kg/m^2); class II obesity (BMI 35–39.9 kg/m^2); and class III obesity (BMI > 40 kg/m^2). In older adults, weight change, change in body composition, height loss, or, most likely, a combination of these factors can all influence BMI values and resulting inferences made using BMI [11–13]. The use of standard BMI categories across the life-span does not reflect our current understanding of changes in adiposity that occur with the aging process or sex differences in adiposity [14–17]. Prior research in large epidemiologic cohort studies has illustrated that body weight and BMI increase throughout early and middle adulthood, peaking at approximately ages 50 to 59 years and then decreasing or remaining stable thereafter [17, 18].

The use of BMI categories to define obesity in older adults may lead to misclassification of true obesity status. Numerous authors have encouraged caution when using BMI > 30 to define obesity in older adults [19, 20]. The American Medical Association Council on Science and Public Health recently concluded that the standard BMI classification system is flawed and may lead to inaccurate conclusions [21]. Prior research has demonstrated that misclassification of obesity status, defined using a BMI cut point of 30, increases with age [4, 20]. In light of this evidence, obesity researchers and clinicians are faced with a challenging situation: BMI has broad utility as a simple and inexpensive anthropometric measure, but it is clear that using a BMI cut point of 30 to define obesity status across the life-span is not accurate.

In pediatric populations, BMI-for-age percentile curves are used instead of fixed BMI categories in recognition of the rapid physical changes that occur as children grow and progress through childhood and adolescence [22]. Older adults also experience many physical changes in late life, but these are not considered when using standard BMI categories to assess obesity. It is important to consider age-related change in body size at both ends of the age distribution. The BMI-for-age percentile curves that we have developed for older adults are a descriptive tool to facilitate comparison among individuals in the population and track individual-level change over time relative to the population. Their application in clinical settings could be similar to the pediatric reference curves developed by the US Centers for Disease Control and Prevention (CDC). Importantly, our BMI-for-age percentile curves are a growth reference (i.e., a tool that provides a common basis for comparison) and not a growth standard, which makes specific value judgments about normal growth targets [23]. The World Health Organization (WHO) publishes growth charts based on international data that are intended to serve as a growth standard for children worldwide, i.e., a basis for defining ideal, healthy growth in children [24]. Our BMI-for-age curves and the CDC BMI-for-age curves are used for a different purpose than the WHO growth standard charts as they are descriptive, not prescriptive. They are a tool for comparison, to monitor individual growth, for screening purposes, and to prompt discussion regarding the potential need for intervention due to body weight [25]. The BMI-for-age curves presented in this manuscript are not intended to be used as a standard to define an ideal or normal level of BMI; they are a descriptor of "what is" rather than a value judgment about "what should be."

In this manuscript, we present a novel approach for defining obesity using BMI-for-age percentile curves in older adults (ages 45–90 years). BMI-for-age percentile curves are a novel descriptive tool that incorporates information on BMI, age, and sex. BMI-for-age percentile curves facilitate a better understanding of how an individual's BMI value compares with values from a standard reference population, as well as how BMI changes with aging. The use of BMI-for-age percentile curves helps to overcome a key methodological challenge when assessing obesity in older adults related to the use of a fixed cut point to define obesity status.

Study Importance

What is already known?

- BMI is an inexpensive and easy-to-use tool to assess body weight scaled by height.
- The use of a BMI cut point of 30 kg/m^2 to define obesity in all adults does not reflect our current understanding of changes in body weight that occur with the aging process or sex differences in adiposity.
- Older adults experience many physical changes in late life, but these are not considered when using standard BMI categories to assess obesity.

What does this study add?

- BMI-for-age percentile curves for older adults are a novel tool to describe how an individual's BMI value compares with that of individuals of the same age and sex.
- Absolute values for BMI percentiles are lower in men than in women.
- BMI-for-age percentile values decrease in both men and women during the aging process; obesity (BMI > 95th percentile) is defined at a lower BMI value in older adults than younger adults.

How might these results change the direction of research or the focus of clinical practice?

- BMI-for-age percentile curves can assist with determining eligibility for intervention (e.g., antiobesity medication, bariatric surgery).
- BMI-for-age percentile curves can be used to monitor individual trajectories in older adults in routine primary or geriatric care settings.
- BMI-for-age percentile curves can be used as a screening tool to identify individuals at high risk or to measure response to weight management interventions.

METHODS

Data source

Data from the Canadian Longitudinal Study on Aging (CLSA) were used to create the adult BMI-for-age percentile curves [26]. The CLSA is a research platform designed to investigate aging trajectories and outcomes in a sample of Canadian adults aged 45 years and older [27]. At baseline, a total of 51,339 participants were recruited to participate in the CLSA, divided into a tracking cohort ($n = 21,241$) and comprehensive cohort ($n = 30,097$) [27]. Participants in the tracking cohort had data collected by telephone using computer-assisted technology, and participants in the comprehensive cohort had study visits at home and at 11 data collection sites in seven provinces [27]. Our research will use data from baseline (2011–2015) and the first follow-up visit (2015–2018) of the CLSA comprehensive cohort. The CLSA has a complex sampling design: participants in the comprehensive cohort were recruited from a stratified random sample using provincial health registration databases, random digit dialing of landline telephones, and the Quebec Longitudinal Study on Nutrition and Aging as the sampling frame for the comprehensive cohort [27]. In the comprehensive cohort, recruits were drawn from individuals living within 15 to 50 km (depending on the city and accessibility) of one of 11 purpose-built data collection centers located in seven provinces. CLSA participants will undergo repeated waves of data collection every 3 years for at least 20 years or until death [27]. Use of CLSA data was approved (application identifier 2310002), and this study was approved by the University of Toronto Research Ethics Board (protocol #00044388).

Data analysis

Data from the CLSA baseline and the follow-up visit were used to construct BMI-for-age percentile curves [28]. We created BMI-for-age percentile curves for the total population and separately for men and women. Height and weight were measured in person by trained staff using standardized procedures. Measured height and weight were used to calculate BMI in kilograms per meters squared [29]. For this analysis, we used data for adults aged 45 to 90 years. All data analyses were conducted using RStudio version 2022.07.1.

Reference population

Choosing a reference population is an important first step when creating percentile curves. We used pooled data from the CLSA (2011-2018) as the reference population for this analysis because it is the most recent data available [27, 29]. The reference population is a basis for comparison when creating the BMI-for-age percentile curves [30]. The reference population serves as a standard against which the data are compared, a common benchmark that allows for meaningful assessments of how an individual's BMI value compares with that of individuals from a similar age and sex group [29].

BMI percentile curves

The method used to create BMI-for-age percentile curves is similar to the approach used to create the CDC's pediatric reference charts. Percentile estimates were calculated for the total population and separately for men and women. Data were grouped into 1-year intervals by age and BMI values. Weighted empirical percentile estimates for 1st, 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, 97th, and 99th percentiles were calculated for each age group (in years) from ages 45 to 90.

Statistical smoothing procedures were used to generate smoothed curves for the percentile values. First, locally weighted regression was used to create smoothed percentile curves. Locally weighted regression is a flexible, nonparametric approach that does not assume any prior specifications regarding the distribution of the data. Smoothed curves were fit using the locally estimated scatterplot smoothing (LOESS) procedure [31, 32]. LOESS fits a separate regression line to a subset of data points within a specified region. The region is defined by the choice of smoothing parameter, called the bandwidth. The bandwidth for this analysis was 0.60. In the analysis, each data point is weighted by borrowing information from neighboring data points; closer data points are given a higher weight value, and further data points are assigned lower weights. Next, the LOESS procedure fits a quadratic polynomial (i.e., local polynomial of degree 2) to the weighted data points within a specified bandwidth to predict the value of each individual data point. This locally weighted regression procedure is repeated for each data point, creating a smoothed curve of the empirical percentile values while accounting for nonlinearity in the data.

Following the LOESS smoothing, we used LMS quantile regression with Box Cox transformation to normality to create final smoothed curves [26]. The R function *lms.bcn* was used for this analysis. The LMS method is particularly useful when the measure of interest, in this case BMI, is dependent on time and allows data to be analyzed continuously over time [33]. The Box Cox power transformation was applied to each of the percentile groupings to convert the raw BMI scores to a normal distribution. The following three age-specific LMS parameters were estimated through penalized maximum likelihood: lambda (L); median (M); and the coefficient of variation (S) [26, 28]. LMS parameters were obtained by simultaneously solving for the system of equations. The values for percentile curves can be obtained via the following equations [26]:

$$C_a(t) = M(t)(1 + L(t)S(t)z_a)^{1/L(t)} \text{ for all } L(t) \neq 0 \quad \text{or}$$

$$C_a(t) = M(t)\exp(S(t)z_a) \text{ for all } L(t) = 0$$

where "a" is the lower tail of the percentile, "z_a" is the z score that corresponds to the percentile value, and "t" is age in years. Using this method, age-specific BMI values corresponding to the 1st through 99th percentiles were generated for the total population and separately for men and women. A selected group of percentiles (i.e., the 1st, 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, 97th, and 99th) were then plotted with age in years on the x-axis and BMI in kilograms per meters squared on the y-axis for each sex. For each BMI-for-age percentile curve, dashed lines were used to indicate thresholds for <5th percentile,

TABLE 1 Sociodemographic characteristics of CLSA cohort.

	Baseline (2011–2015)			First follow-up (2015–2018)		
	Overall	Male	Female	Overall	Male	Female
n[a]	29,961	14,711 (49.1)	15,250 (50.9)	26,744	13,188 (49.3)	13,556 (50.7)
Age, mean (SD), y	63.0 (10.2)	63.2 (10.3)	62.7 (10.2)	65.4 (10.0)	65.6 (10.0)	65.2 (10.0)
Ethnicity, frequency (%)						
White	21,287 (71.0)	10,090 (68.6)	11,197 (73.4)	19,206 (71.8)	9170 (69.5)	10,036 (74.0)
Asian	304 (1.0)	164 (1.1)	140 (0.9)	350 (1.3)	188 (1.4)	162 (1.2)
African	181 (0.6)	81 (0.6)	100 (0.7)	80 (0.3)	39 (0.3)	41 (0.3)
Hispanic	81 (0.3)	45 (0.3)	36 (0.2)	53 (0.2)	31 (0.2)	22 (0.2)
Other ethnicity	52 (0.2)	32 (0.2)	20 (0.1)	89 (0.3)	54 (0.4)	35 (0.3)
Missing/skip/not administered	8056 (26.9)	4299 (29.2)	3757 (24.6)	6966 (26.0)	3706 (28.1)	3260 (24.0)
Total household income, frequency (%)						
Less than $20,000	1538 (5.1)	544 (3.7)	944 (6.5)	1155 (4.3)	383 (2.9)	772 (5.7)
$20,000 or more but less than $50,000	6317 (21.1)	2538 (17.3)	3779 (24.8)	5337 (20.0)	2106 (16.0)	3231 (23.8)
$50,000 or more but less than $100,000	9871 (32.9)	5027 (34.2)	4844 (31.8)	9137 (34.2)	4655 (35.3)	4482 (33.1)
$100,000 or more but less than $150,000	5514 (18.4)	3100 (21.1)	2414 (15.8)	4999 (18.7)	2801 (21.2)	2198 (16.2)
$150,000 or more	4794 (16.0)	2801 (19.0)	1993 (13.1)	4494 (16.8)	2674 (20.3)	1820 (13.4)
Refused/don't know/missing	1927 (6.5)	701 (4.8)	1226 (8.0)	1622 (6.1)	569 (4.3)	1053 (7.8)
Marital status, frequency (%)						
Single, never married, or never lived with a partner	2624 (8.8)	1183 (8.0)	1441 (9.4)	2409 (9.0)	1082 (8.2)	1327 (9.8)
Married/living with a partner in a common-law relationship	20,601 (68.8)	11,462 (77.9)	9139 (59.9)	18,306 (68.4)	10,271 (77.9)	8035 (59.3)
Widowed	2790 (9.3)	724 (4.9)	2066 (13.5)	2618 (9.8)	700 (5.3)	1918 (14.1)
Divorced	3150 (10.5)	990 (6.7)	2160 (14.2)	2660 (9.9)	785 (6.0)	1875 (13.8)
Separated	788 (2.6)	349 (2.4)	439 (2.9)	741 (2.8)	347 (2.6)	394 (2.9)
Don't know/missing	8 (0.0)	3 (0.0)	5 (0.0)	10 (0.0)	3 (0.0)	7 (0.1)
Height, mean (SD), cm	168.3 (9.7)	175.3 (7.1)	161.6 (6.6)	168.3 (9.7)	175.3 (7.1)	161.5 (6.6)
Weight, mean (SD), kg	79.7 (17.6)	87.0 (16.0)	72.7 (16.2)	79.8 (17.9)	87.0 (16.3)	72.8 (16.5)
BMI, mean (SD), kg/m^2	28.1 (5.4)	28.3 (4.7)	27.9 (6.0)	28.1 (5.5)	28.3 (4.9)	27.9 (6.1)
BMI category, %						
Underweight (<18.5 kg/m^2)	0.7	0.3	1.0	0.7	0.4	1.1
Normal range (18.5–24.9 kg/m^2)	28.7	23.1	34.2	28.9	23.6	34.1
Overweight (25.0–29.9 kg/m^2)	41.2	47.1	35.6	41.0	46.9	35.2
Obesity (≥30 kg/m^2)	29.3	29.5	29.2	29.4	29.1	29.6

Abbreviations: CLSA, Canadian Longitudinal Study on Aging.
[a]Excludes pregnant women and individuals with missing BMI data.

5th to 84th percentile, 85th to 94th percentile, and >95th percentile groups. These groupings are consistent with the thresholds used in the CDC pediatric BMI-for-age curves to identify individuals who have underweight, normal weight, overweight, and obesity [34]. Finally, BMI values corresponding to z scores of ±3.0 standard deviation (SD), −2.5 SD, 2.0 SD, 1.5 SD, 1.0 SD, and 0.5 SD were calculated by solving the LMS equations.

RESULTS

Demographic information on the study population is presented in Table 1. There were $n = 56{,}705$ total observations included in the analysis: 29,961 individuals from the CLSA comprehensive cohort at baseline and 26,744 individuals from the CLSA comprehensive cohort at the first follow-up visit. At both the baseline and follow-up visits,

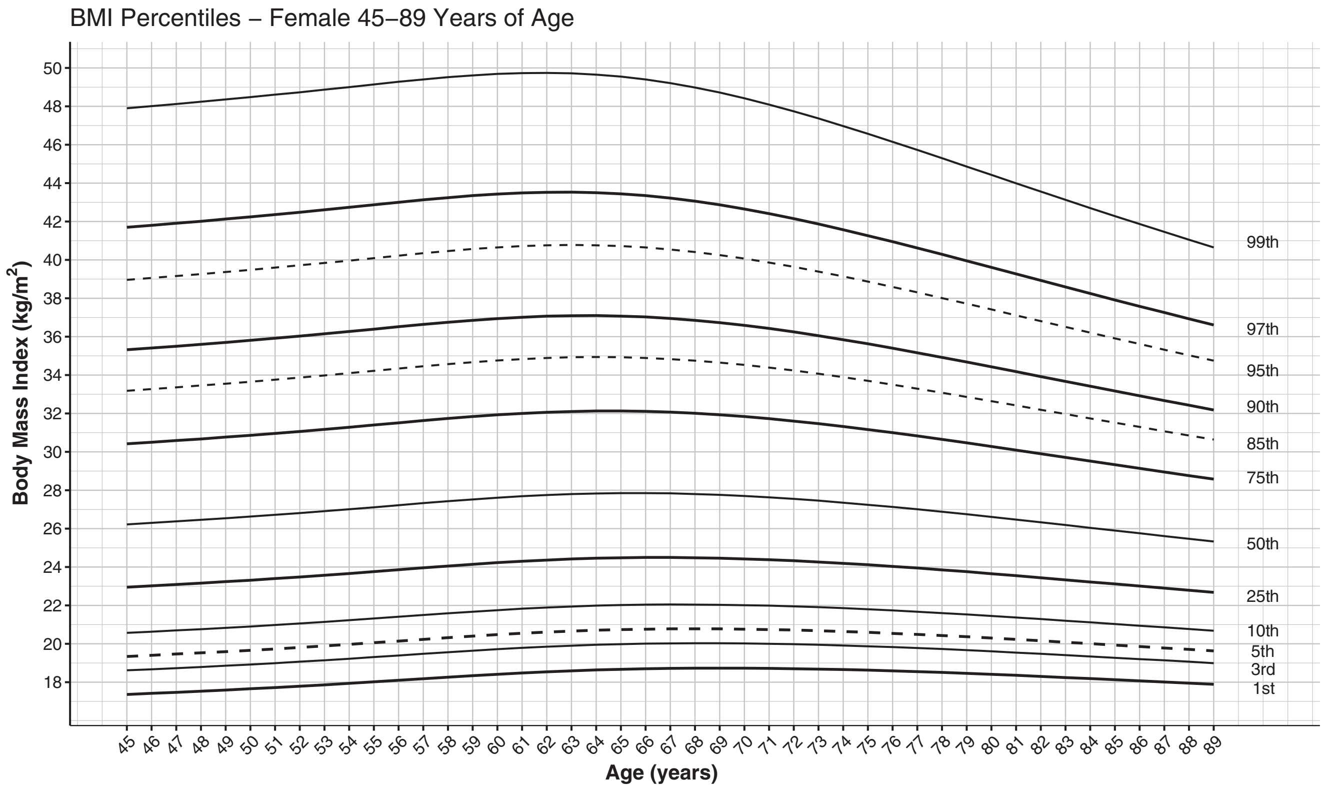

FIGURE 1 BMI-for-age percentile curve for women aged 45 to 89 years.

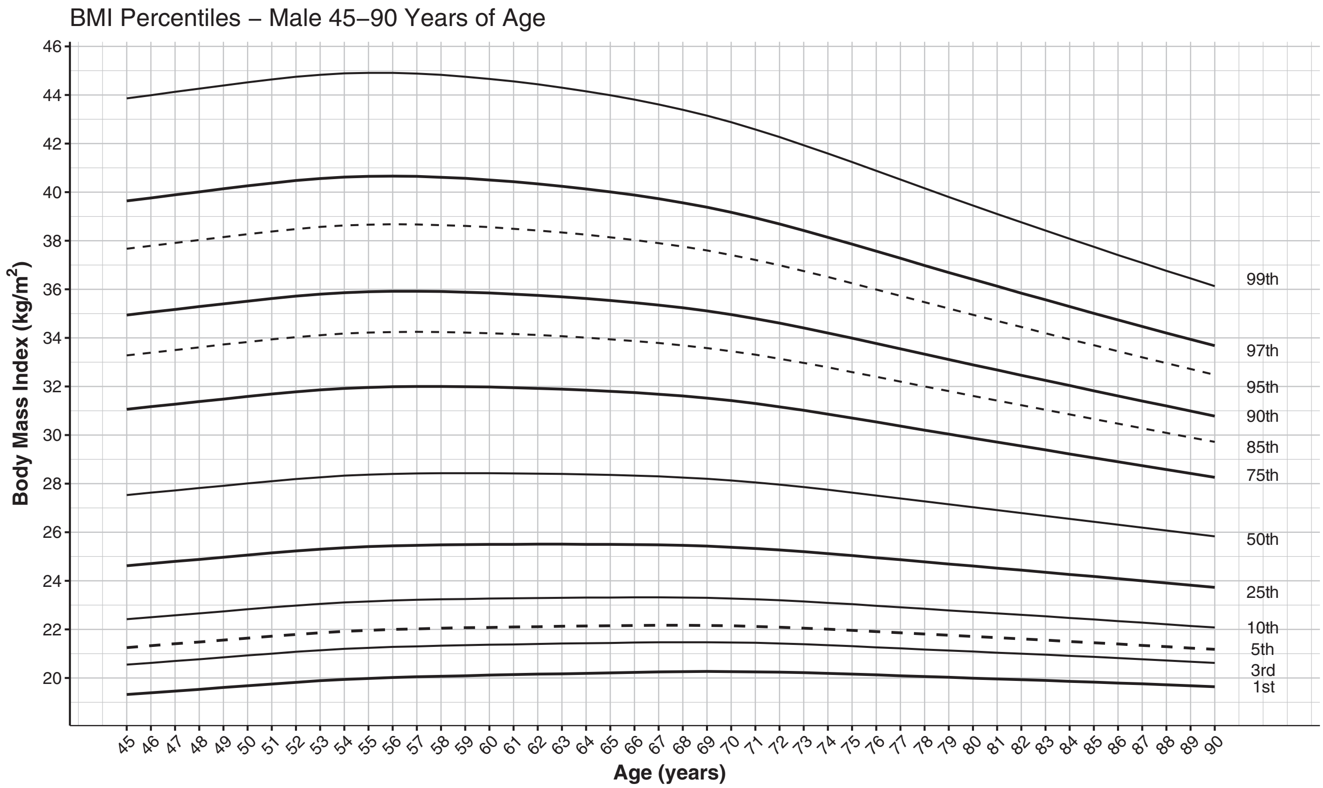

FIGURE 2 BMI-for-age percentile curve for men aged 45 to 90 years.

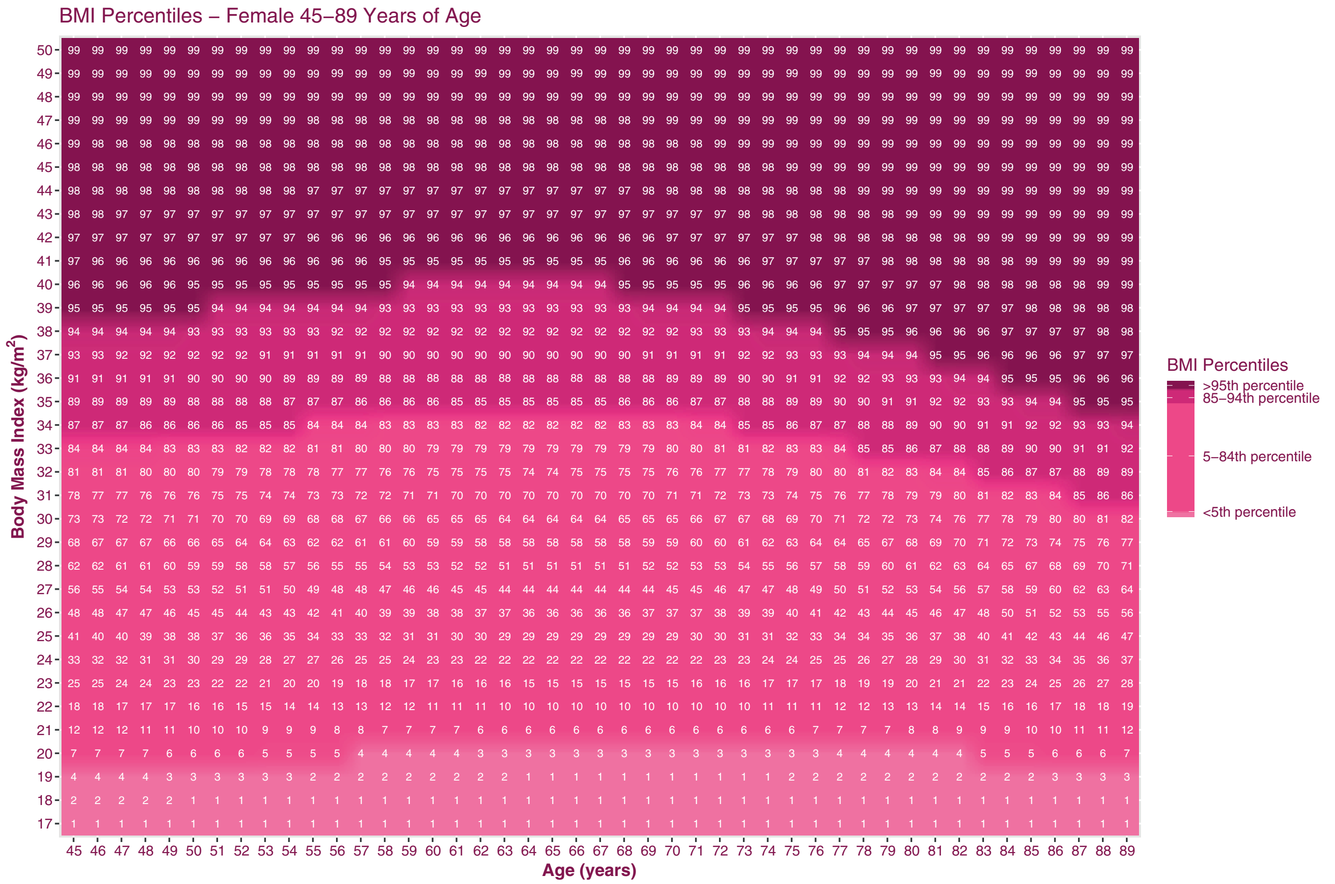

FIGURE 3 BMI percentiles by age and BMI for women.

the sample was 49.3% male, with a mean (SD) age of 63.0 (10.2) years at baseline and 65.4 (10.0) years at the first follow-up. The majority of the study population self-identified as "Caucasian." The mean (SD) BMI in the study population was 28.1 (5.5) kg/m^2 across both study visits. The proportion of individuals in each of the CDC/WHO BMI categories was approximately the same at both visits. There were more women than men in the BMI 18.5 to 24.9 category (i.e., 23% men and 34% women) but more men than women in the BMI 25 to 29.9 category (i.e., 47% men and 35% women). The was an equal distribution of men and women in the highest BMI category, i.e., ≥30 kg/m^2. Examination of the sociodemographic variables presented in Table 1 indicates that the participants had similar characteristics at both time points.

Smoothed BMI-for-age percentile curves are presented for men and women aged 46 to 90 years (Figures 1 and 2) for the 1st, 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, 97th, and 99th percentiles. LMS parameters that were used to create the smoothed percentiles are included in the online Supporting Information. In both men and women, BMI percentile values increase in middle age and then begin to decrease with aging. In women, the maximum BMI in the 99th percentile is nearly 50 kg/m^2 when it peaks between ages 62 and 64. In men, the maximum BMI in the 95th percentile is 45 kg/m^2 when it peaks between ages 54 and 57. In men, the absolute values for BMI percentiles are lower than in women, and the decline in BMI begins earlier (i.e., at a lower age). In women, the BMI value corresponding to the 50th percentile of the distribution is highest at 28 kg/m^2 between ages 64 and 68 years and consistently declines thereafter. In men, the 50th BMI percentile exceeds 28 kg/m^2 from ages 51 to 71 years before declining. Change in BMI over time is smallest in the lowest BMI percentile groupings (i.e., <25th percentile). There is little variation in BMI below the 10th percentile as men and women aged. In contrast, in the high percentile categories, there is marked decline in BMI percentiles with aging. By age 89 years, BMI values corresponding with the 99th, 97th, and 95th percentiles are 41, 37, and 35 kg/m^2 in women and 36, 34, and 32 kg/m^2 in men, respectively. The peak of the 50th percentile in men is between 28 and 29 kg/m^2, and the peak of the 99th percentile is just over 45 kg/m^2. The decline in the 99th percentile by age 89 years is 36 kg/m^2.

An alternative visual representation of BMI-for-age percentile values is illustrated in Figure 3 for women and in Figure 4 for men. The shading in the figures describes the percentile groupings, with lighter colors representing low BMI percentiles and darker colors representing high BMI percentiles. The groupings are based on the CDC categories used for pediatrics, i.e., <5th percentile, 5th to 84th percentile, 85th to 94th percentile, and >95th percentile groups. These charts are intended to facilitate the use of the BMI percentile scores: by following the BMI value on the y-axis corresponding to the individual's BMI and corresponding age from the x-axis, it is possible

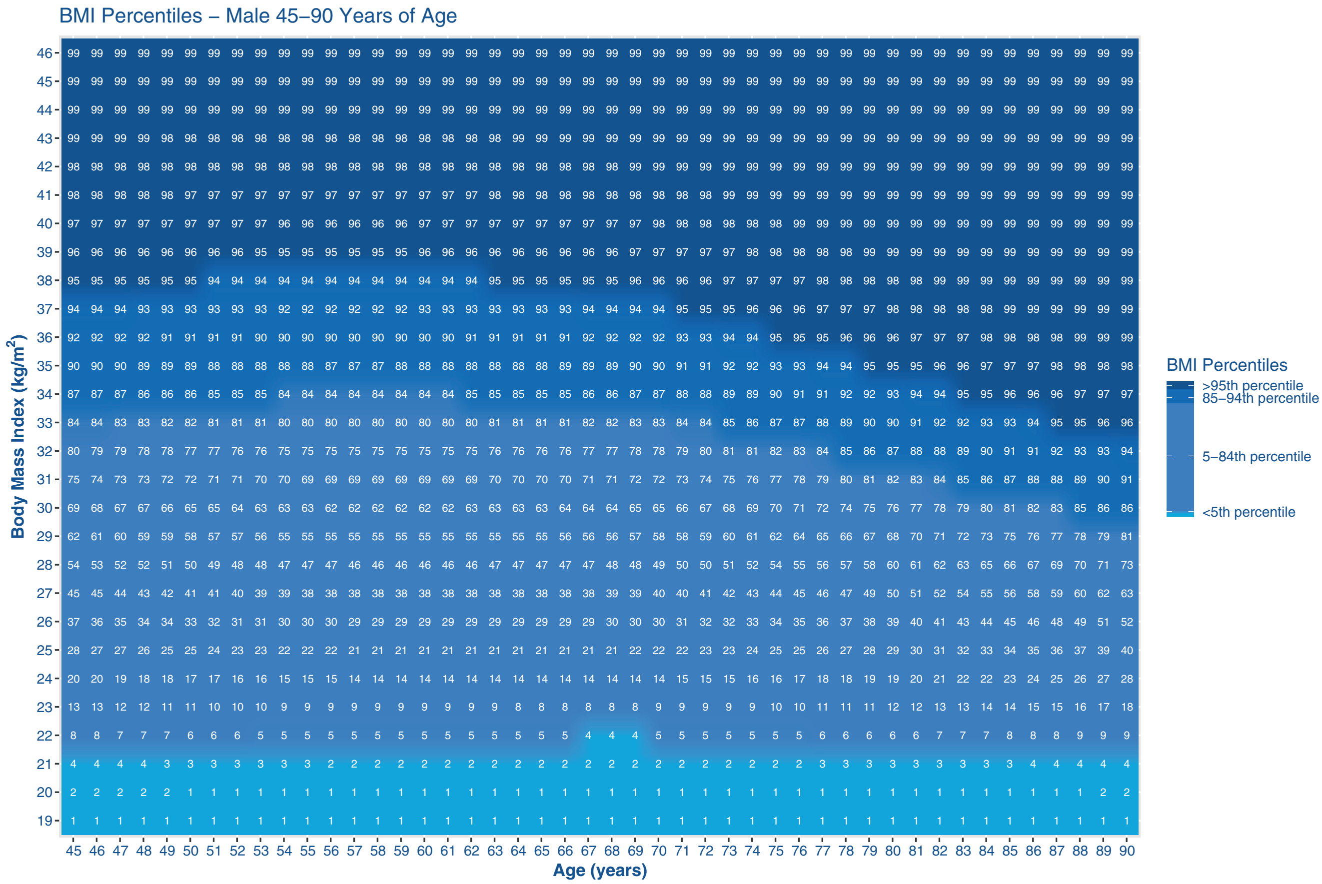

FIGURE 4 BMI percentiles by age and BMI for men.

to see the percentile value. In women, the lower bound of the 5th to 84th percentile category ranges from 20 kg/m^2, and the upper bound is 34 kg/m^2. The overweight grouping, defined by the CDC as values from the 85th to 94th percentiles, ranges from BMI of 32 to 40 kg/m^2. The category corresponding to obesity (>95th percentile) ranges from BMI of 35 to 50 kg/m^2. In men, the BMI values corresponding to the 5th to 84th, 85th to 94th, and >95th percentile categories are 22 to 34, 30 to 38, and 33 to 45 kg/m^2, respectively.

Tables 2 and 3 include BMI values corresponding to *z* scores calculated using the LMS smoothing parameters by age. The tables indicate how an individual's BMI value compares with the average of all individuals in the population of a similar age and sex. *z* scores are interpreted as the distance, in SD units, between the data point and mean value. Absolute values of *z* scores less than 1 (i.e., $|Z| < 1$) indicate that the BMI value is within 1 SD of the mean value. *z* scores between 1 and 2 indicate that the BMI value is between 1 and 2 SD from the mean; >2 indicates that the data are more than 2 SD from the mean, and >3 indicates that the data are more than 3 SD units from the mean. The *z* score values also indicate the probability of a data point occurring within a normal distribution: 68% of the values have a *z* score between −1 and 1, 95% of values fall between −2 and 2, and 99.7% of values have *z* scores between −3 and 3. Tables 2 and 3 extend the results presented in Figures 1 and 2, demonstrating empirically that BMI *z* scores change according to age. In women, a *z* score of −2.0 corresponds with increasing BMI values from 18.3 to 19.7 kg/m^2 in those aged 47 to 72 years and then a decreasing BMI value from 19.7 to 18.8 kg/m^2 in those aged 72 to 89 years. A *z* score of 2.0 corresponds with increasing BMI values from age 47 (BMI 43.2) to 65 years (BMI 45.1) and then decreasing to 38.3 kg/m^2 by age 89 years. In the youngest age group of men (i.e., 46 years), 2 SD units below the mean (*z* score of −2.0) equals BMI of 20.2 kg/m^2. The BMI value for men corresponding with a *z* score of 2.0 increases up to age 63 years (BMI 21.1) and remains stable up to age 74 years before declining to 20.4 kg/m^2 by age 90 years. A *z* score of 2.0 equals BMI of 40.7 kg/m^2 in men aged 46 years, increasing to 41.7 kg/m^2 in men aged 55 to 59 years, and then declining to 34.6 kg/m^2 by age 88 years. In women, extreme percentile values ($|Z| > 2.0$) ranged from 15.7 to 18.3 kg/m^2 at the low end and from 43.3 to 61.0 kg/m^2 at the high end. In men, $|Z| > 2.0$ was 17.7 to 19.8 kg/m^2 at the low end and 37.5 to 53.0 kg/m^2 at the high end.

DISCUSSION

In this manuscript, we present BMI-for-age percentile curves for older adults using data from the CLSA. The BMI-for-age curves highlight

TABLE 2 Age-specific BMI *z* score values for women aged 45 to 89 years.

Age, y	−3.0 SD	−2.5 SD	−2.0 SD	−1.5 SD	−1.0 SD	−0.5 SD	0.5 SD	1.0 SD	1.5 SD	2.0 SD	2.5 SD	3.0 SD
45	15.73	16.91	18.26	19.82	21.62	23.73	29.22	32.88	37.43	43.21	50.77	61
46	15.78	16.97	18.32	19.88	21.68	23.8	29.31	32.97	37.53	43.32	50.89	61.13
47	15.83	17.02	18.38	19.94	21.75	23.87	29.39	33.06	37.63	43.43	51	61.25
48	15.89	17.08	18.44	20.01	21.82	23.94	29.48	33.16	37.73	43.54	51.12	61.38
49	15.94	17.14	18.5	20.07	21.89	24.02	29.57	33.25	37.83	43.65	51.24	61.51
50	16	17.2	18.57	20.14	21.97	24.1	29.66	33.35	37.94	43.77	51.37	61.64
51	16.06	17.26	18.64	20.22	22.04	24.18	29.75	33.46	38.05	43.89	51.49	61.77
52	16.12	17.33	18.71	20.29	22.13	24.27	29.85	33.57	38.17	44.01	51.63	61.9
53	16.19	17.4	18.79	20.37	22.21	24.36	29.96	33.68	38.29	44.14	51.76	62.04
54	16.26	17.48	18.86	20.46	22.3	24.46	30.07	33.79	38.41	44.27	51.9	62.18
55	16.34	17.56	18.95	20.54	22.39	24.56	30.18	33.91	38.54	44.41	52.04	62.32
56	16.41	17.64	19.03	20.63	22.49	24.66	30.29	34.03	38.67	44.54	52.17	62.45
57	16.49	17.71	19.11	20.72	22.58	24.76	30.41	34.15	38.79	44.66	52.3	62.57
58	16.56	17.79	19.2	20.81	22.67	24.85	30.51	34.26	38.91	44.78	52.41	62.66
59	16.63	17.87	19.28	20.89	22.76	24.94	30.61	34.37	39.01	44.88	52.5	62.73
60	16.7	17.94	19.35	20.97	22.84	25.03	30.7	34.46	39.1	44.96	52.57	62.77
61	16.77	18.01	19.42	21.04	22.92	25.1	30.78	34.53	39.17	45.02	52.6	62.76
62	16.82	18.07	19.48	21.1	22.98	25.17	30.84	34.59	39.21	45.05	52.6	62.7
63	16.88	18.12	19.54	21.16	23.03	25.22	30.88	34.62	39.23	45.05	52.56	62.6
64	16.92	18.17	19.58	21.2	23.07	25.26	30.91	34.64	39.23	45.01	52.48	62.43
65	16.96	18.2	19.62	21.23	23.1	25.28	30.92	34.62	39.19	44.94	52.35	62.21
66	16.99	18.23	19.64	21.26	23.12	25.29	30.9	34.59	39.13	44.83	52.17	61.92
67	17.01	18.25	19.66	21.27	23.13	25.29	30.87	34.53	39.04	44.69	51.95	61.58
68	17.02	18.26	19.66	21.27	23.12	25.27	30.82	34.46	38.92	44.51	51.69	61.18
69	17.03	18.27	19.66	21.26	23.1	25.24	30.75	34.36	38.78	44.31	51.39	60.73
70	17.04	18.27	19.66	21.25	23.08	25.2	30.67	34.24	38.61	44.07	51.05	60.23
71	17.04	18.26	19.64	21.22	23.04	25.15	30.57	34.1	38.43	43.81	50.68	59.69
72	17.03	18.25	19.62	21.19	23	25.09	30.46	33.95	38.22	43.53	50.28	59.12
73	17.02	18.23	19.6	21.16	22.95	25.02	30.33	33.79	38	43.23	49.86	58.52
74	17	18.2	19.56	21.11	22.89	24.95	30.2	33.61	37.76	42.91	49.42	57.9
75	16.98	18.18	19.53	21.06	22.82	24.86	30.06	33.43	37.52	42.58	48.97	57.26
76	16.96	18.14	19.48	21.01	22.75	24.77	29.91	33.23	37.26	42.23	48.5	56.62
77	16.93	18.11	19.44	20.95	22.68	24.68	29.75	33.03	37	41.88	48.03	55.96
78	16.9	18.07	19.39	20.88	22.6	24.58	29.59	32.82	36.73	41.53	47.56	55.31
79	16.86	18.02	19.33	20.82	22.51	24.47	29.42	32.61	36.45	41.17	47.08	54.65
80	16.83	17.98	19.27	20.75	22.43	24.36	29.25	32.39	36.17	40.81	46.59	54
81	16.78	17.93	19.21	20.67	22.33	24.25	29.08	32.17	35.89	40.44	46.11	53.34
82	16.74	17.88	19.15	20.59	22.24	24.13	28.9	31.95	35.61	40.08	45.63	52.7
83	16.7	17.82	19.09	20.52	22.15	24.02	28.72	31.73	35.33	39.72	45.16	52.06
84	16.65	17.77	19.02	20.44	22.05	23.9	28.55	31.5	35.05	39.36	44.69	51.44
85	16.61	17.71	18.96	20.36	21.95	23.78	28.37	31.28	34.77	39	44.23	50.82
86	16.56	17.66	18.89	20.28	21.86	23.67	28.19	31.07	34.5	38.65	43.77	50.22
87	16.52	17.6	18.82	20.2	21.76	23.55	28.02	30.85	34.22	38.3	43.32	49.63
88	16.47	17.55	18.76	20.12	21.66	23.43	27.84	30.63	33.95	37.96	42.88	49.04
89	16.42	17.49	18.69	20.04	21.57	23.32	27.67	30.42	33.68	37.62	42.44	48.46

TABLE 3 Age-specific BMI *z* score values for men aged 45 to 90 years.

Age, y	−3.0 SD	−2.5 SD	−2.0 SD	−1.5 SD	−1.0 SD	−0.5 SD	0.5 SD	1.0 SD	1.5 SD	2.0 SD	2.5 SD	3.0 SD
45	17.68	18.88	20.21	21.71	23.4	25.33	30.08	33.05	36.54	40.7	45.71	51.85
46	17.75	18.94	20.28	21.78	23.48	25.41	30.18	33.16	36.66	40.83	45.85	52
47	17.81	19.01	20.35	21.86	23.57	25.5	30.28	33.27	36.78	40.95	45.99	52.15
48	17.88	19.08	20.43	21.94	23.65	25.59	30.39	33.38	36.9	41.08	46.13	52.3
49	17.95	19.16	20.51	22.02	23.73	25.68	30.49	33.49	37.01	41.21	46.26	52.45
50	18.02	19.23	20.58	22.1	23.82	25.77	30.59	33.6	37.13	41.33	46.39	52.58
51	18.09	19.3	20.66	22.18	23.9	25.86	30.69	33.7	37.24	41.45	46.51	52.71
52	18.15	19.37	20.73	22.26	23.98	25.94	30.78	33.79	37.34	41.55	46.62	52.82
53	18.21	19.43	20.79	22.32	24.05	26.02	30.86	33.88	37.42	41.63	46.7	52.9
54	18.26	19.48	20.85	22.38	24.11	26.08	30.92	33.94	37.48	41.69	46.76	52.94
55	18.3	19.53	20.89	22.42	24.16	26.12	30.96	33.98	37.52	41.72	46.78	52.95
56	18.34	19.56	20.93	22.46	24.19	26.16	30.99	34	37.54	41.73	46.77	52.92
57	18.37	19.59	20.96	22.49	24.22	26.18	31.01	34.01	37.53	41.71	46.73	52.85
58	18.39	19.62	20.98	22.51	24.23	26.19	31.01	34	37.51	41.67	46.67	52.75
59	18.42	19.64	21	22.53	24.25	26.2	31	33.99	37.48	41.62	46.59	52.63
60	18.44	19.66	21.02	22.54	24.26	26.21	30.99	33.96	37.44	41.55	46.48	52.48
61	18.47	19.68	21.04	22.56	24.27	26.21	30.97	33.92	37.38	41.47	46.36	52.3
62	18.49	19.7	21.05	22.57	24.28	26.21	30.95	33.88	37.32	41.37	46.23	52.11
63	18.51	19.72	21.07	22.58	24.28	26.2	30.92	33.84	37.24	41.27	46.07	51.89
64	18.54	19.74	21.09	22.59	24.28	26.2	30.88	33.78	37.16	41.15	45.9	51.66
65	18.56	19.76	21.1	22.6	24.28	26.19	30.84	33.72	37.07	41.02	45.72	51.4
66	18.59	19.78	21.12	22.61	24.28	26.18	30.8	33.65	36.97	40.87	45.52	51.12
67	18.61	19.8	21.13	22.61	24.28	26.16	30.74	33.57	36.85	40.71	45.3	50.82
68	18.63	19.82	21.14	22.61	24.27	26.13	30.68	33.47	36.72	40.53	45.05	50.48
69	18.64	19.83	21.14	22.6	24.25	26.1	30.6	33.36	36.57	40.33	44.78	50.12
70	18.65	19.83	21.13	22.59	24.21	26.05	30.51	33.24	36.4	40.11	44.48	49.73
71	18.65	19.82	21.12	22.56	24.17	25.99	30.4	33.09	36.21	39.86	44.16	49.3
72	18.65	19.81	21.09	22.52	24.12	25.92	30.28	32.94	36.01	39.59	43.82	48.85
73	18.64	19.79	21.06	22.48	24.06	25.84	30.14	32.76	35.79	39.31	43.45	48.38
74	18.62	19.77	21.03	22.43	24	25.76	30	32.58	35.56	39.02	43.08	47.9
75	18.61	19.74	20.99	22.38	23.93	25.67	29.85	32.4	35.32	38.71	42.69	47.4
76	18.59	19.71	20.95	22.32	23.86	25.58	29.7	32.2	35.08	38.41	42.3	46.91
77	18.57	19.68	20.91	22.27	23.78	25.48	29.55	32.01	34.83	38.1	41.91	46.41
78	18.55	19.65	20.87	22.21	23.71	25.39	29.39	31.82	34.59	37.79	41.52	45.91
79	18.53	19.62	20.83	22.16	23.64	25.29	29.24	31.62	34.35	37.49	41.14	45.42
80	18.51	19.59	20.79	22.1	23.56	25.2	29.09	31.43	34.11	37.18	40.76	44.94
81	18.5	19.57	20.75	22.05	23.49	25.1	28.94	31.24	33.87	36.88	40.38	44.46
82	18.48	19.54	20.71	21.99	23.42	25.01	28.79	31.05	33.63	36.59	40.01	43.99
83	18.46	19.51	20.66	21.94	23.35	24.92	28.64	30.87	33.4	36.29	39.64	43.53
84	18.44	19.48	20.62	21.88	23.27	24.82	28.49	30.68	33.16	36	39.27	43.07
85	18.42	19.45	20.58	21.82	23.2	24.73	28.34	30.49	32.93	35.71	38.91	42.62
86	18.4	19.42	20.54	21.77	23.13	24.63	28.19	30.3	32.7	35.42	38.55	42.17
87	18.38	19.39	20.49	21.71	23.05	24.54	28.04	30.12	32.47	35.14	38.2	41.73
88	18.35	19.35	20.45	21.65	22.97	24.44	27.89	29.93	32.24	34.86	37.85	41.3
89	18.33	19.32	20.4	21.59	22.9	24.34	27.74	29.75	32.01	34.58	37.51	40.88
90	18.3	19.28	20.35	21.53	22.82	24.25	27.59	29.57	31.79	34.3	37.17	40.46

changes in BMI from midlife through older age and differences in men and women. Information on age and sex is not currently integrated into the standard approach to classifying individuals according to BMI; individuals are categorized as having underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obesity (>30 kg/m^2), regardless of their age or sex. Using data from a cohort of adults aged 46 to 90 years, we calculated BMI-for-age percentiles and *z* scores that allow for comparison of BMI of an individual of a specific age and sex with similar individuals in the reference population. We also used CDC cut points (<5th percentile, 5th–84th percentile, 85th–95th percentile, and >95th percentile) to define BMI groups by age.

In pediatric populations, BMI-for-age percentiles are used to compare individual children and adolescents with a reference population with children of the same age and sex [22, 28, 35]. There are separate BMI-for-age growth charts for male individuals and female children aged 2 to 20 years [28]. Pediatric BMI-for-age charts are used as a tool in clinical settings to track growth trajectories and identify deviation from individual growth curves [36]. The CDC advises that BMI-for-age curves can be used in clinical settings to identify children who have overweight (BMI 84th–95th percentile) or obesity (BMI > 95th percentile) [37]. Recently, the CDC released extended charts for children who are >97th percentile of BMI-for-age, which reflects an increased prevalence of pediatric obesity in the population [22]. BMI-for-age is also commonly used in research studies focused on pediatric overweight or obesity. The CDC also publishes anthropometric reference data for adults in the United States, including percentile values for BMI, based on the annual National Health and Nutrition Examination Survey (NHANES). However, the reference data published by the CDC group individuals into 10-year age groups and include all adults over age 80 years in one category. These groupings limit our ability to understand overweight and obesity in older adults [38]. The sample sizes for older age groups are also relatively small, e.g., for the 2015 to 2018 published anthropometric reference data, there are only 359 women and 331 men over age 80 years in the sample. To our knowledge, the CDC does not publish percentile curves for adult populations.

BMI-for-age percentile charts move beyond a one-size-fits-all approach to using BMI categories to measure obesity in older adults. The use of fixed BMI categories makes an implicit assumption that BMI-related risk thresholds are constant for all adults. Current evidence does not support this assumption [39–42]. The nadir of the BMI-mortality curve differs across populations and by comorbidity, ranging from BMI of ~23 to 27, depending on the composition (i.e., age distribution) of the population under study [41, 43–45]. The hazard ratio for mortality is higher for men than women at a given BMI value, and the BMI of minimum mortality differs by age group [41]. BMI categories are also frequently criticized because they do not and cannot quantify an individual's body composition or body fat distribution. Using imaging modalities (e.g., dual-energy x-ray absorptiometry scan) to measure body fat would be a more accurate approach for defining obesity or body composition. However, in most clinical settings or large-scale research projects, measuring body composition is not possible. BMI is correlated with body fat, but it is not a perfect proxy [19, 46]. We suggest that one path forward is to reframe the discussion around BMI in older adults so that BMI is viewed as a screening test for obesity, rather than a diagnostic measure for obesity. Screening tests are commonly used in medicine in public health, not to diagnose disease but to indicate a need for additional testing. Prior research has demonstrated that using a BMI cut point of 30 has high specificity when compared with measured body fat [47].

There are many potential applications of BMI-for-age percentile curves in older adults in clinical settings. Weight loss and weight gain are clinically relevant indicators and would be reflected in changing BMI-for-age percentile values. There is important information to be gained from understanding whether a patient is deviating from their individual BMI-for-age curve. For instance, unintentional weight loss may be a clinically relevant indicator of disease, in which case a physician might order additional testing if they are seeing a patient who dropped from the 50th to 25th BMI-for-age percentile without intentionally trying to lose weight via diet, exercise, or medication. BMI-for-age percentile curves could be particularly useful in primary care and geriatrics as both commonly involve annual weight and height measurement. Importantly, BMI-for-age percentiles could be used as a tool for better communicating with patients to frame discussions related to high BMI. Labeling patients as "obese" or "overweight" according to their BMI category may invoke feelings of shame or personal failing, whereas using quantitative indicators is more in line with how we typically measure clinical indicators of disease risk, such as low-density lipoprotein cholesterol or hemoglobin A1C. Having a discussion with a patient regarding their BMI-for-age value being in the 97th percentile and explaining that that their BMI is greater than 97% of individuals of the same age and sex is a more considerate, patient-centered approach than using labels that have a stigma attached. Moreover, BMI-for-age percentiles may be a more productive starting point for discussions regarding the need for medication for obesity treatment and/or lifestyle modification. They could also be used as an objective indicator of success in patients who are actively trying to lose weight. BMI-for-age percentiles could also be used in hospital settings where BMI is often considered when making treatment decisions. BMI categories are commonly used when determining risk prior to elective surgery, including bariatric surgery, and are considered part of risk stratification algorithms for anesthesiology [48]. Using BMI-for-age percentiles may better identify older individuals who would benefit from bariatric surgery because our results demonstrate that BMI thresholds to define obesity (>95th BMI percentile) decrease with age. Recent research has demonstrated that bariatric surgery can be a safe and effective option to treat obesity in patients over age 65 years [49]. Finally, BMI-for-age percentiles could be incorporated into clinical models of care in geriatrics to identify individuals at high risk of adverse obesity-related outcomes such as frailty or falls.

An important strength of this research is the use of a large data set of older adults. This research calls attention to the need to move beyond standard BMI categories in older adults. Understanding antecedents and consequences of obesity in older adults is predicated on the valid measurement of obesity status. BMI could always be used as a continuous measure (i.e., kilograms per meters squared) to assess obesity-related risk, but this is likely less meaningful or interpretable for individual patients. The use of BMI-for-age percentile values will help to better identify individuals at increased risk, leading to more appropriate screening, intervention, and management than is currently possible based on fixed BMI categories. A limitation of this research is that the basis for comparison and calculation of the percentile values depends on the reference population chosen. These curves may not apply to older adults in other populations, particularly if the distribution of BMI or other demographic characteristics in the population is very different. The CLSA includes a high percentage of White participants, which may not be representative of the Canadian population. This also precludes important analyses of heterogeneity according to race and/or ethnicity in the present work. Further work examining BMI-for-age curves among more diverse populations is necessary. In future research, it will be important to carefully assess the generalizability of these BMI-for-age curves in other populations in the United States and internationally. The current approach also does not allow for the assessment of change in population trends over time (i.e., cohort effects), a potentially important consideration if this approach were expanded to include BMI measures over a longer time frame.

Worldwide, adults over age 65 years are the fastest growing population group, and there has been a concomitant rise in obesity in this age group. Standardized approaches for measurement of obesity status in older adults, accounting for changes in BMI that occur with aging, is an important step toward better management of weight and weight-related comorbidities in this high-risk population [50]. The BMI-for-age percentile curves presented in this manuscript are intended to be used as a descriptive tool to improve measurement of overweight and obesity in older adults. This is an important step toward overcoming a methodological challenge that has affected research and clinical care of older adults with obesity. The validity of research examining the link between obesity and health outcomes in older adults is predicated on accurate assessment of obesity status.

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CONFLICT OF INTEREST STATEMENT

The authors declared no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data are available from the Canadian Longitudinal Study on Aging (CLSA) (www.clsa-elcv.ca) for researchers who meet the criteria for access to deidentified CLSA data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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