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Body Shape Index and Cardiovascular Health: Life's Essential 8 and Crucial 9

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Abstract **Background**: Obesity has been a growing concern to public health and novel measures of body composition could aid prevention efforts. A body shape index (BSI) is a relatively new measure that adjusts waist circumference for height and weight and may be a good predictor of cardiovascular outcomes. The aim of this study was to examine the population-level association between BSI and cardiovascular health (CVH) in adults. **Methods**: The 2017-2020 (pre-pandemic) National Health and Nutrition Examination Survey (NHANES) was used. BSI ($m^{11/6}/kg^{2/3}$) was computed for adults 20+ years of age using measured height, weight, and waist circumference (WC). CVH was assessed using the American Heart Association (AHA) Life's Essential 8 (LE8) metric along with an additional psychological health component that yields Life's Crucial 9 (LC9). Multiple linear regression and multinomial logistic regression were used to regress different forms of CVH onto BSI quartiles while controlling for age, sex, race, and income. **Results**: Approximately 36.6% (95% *CI*: 33.6 – 39.7) of adults had high-risk BSI with rates increasing linearly with age (p < .001). Bivariate correlations showed BSI was indirectly associated with LE8 (r = -.294, p < .001) and LC9 (r = -.289, p < .001). Adults with high-risk BSI had lower mean LE8 (60.6 vs 68.2, p < .001) and mean LC9 (63.9 vs 70.8, p < .001) as compared to their low-risk counterparts. In the fully adjusted model predicting LE8, adults in BSI Q1 (b = 9.3, p < .001), Q2 (b = 3.6, p = .003), and Q3 (b = 2.1, p = .006) had greater LE8 than those in Q4 (p trend < .001). Similarly, the fully adjusted model predicting LC9 showed adults in BSI Q1 (b = 8.5, p < .001), Q2 (b = 3.4, p = .005), and Q3 (b = 1.9, p = .008) had greater LC9 than those in Q4 (p trend < .001). Finally, the fully adjusted multinomial logistic regression model showed adults in BSI Q2, Q3, and Q4 had 1.77, 1.81, and 2.13 (respectively, all *ps* < .05) times the odds of adults in BSI Q1 to have moderate CVH over high CVH. Furthermore, adults in BSI Q2, Q3, and Q4 had 3.57, 4.26, and 5.96 (respectively, all *ps* < .05) times the odds of adults in BSI Q1 to have low CVH over high CVH. **Conclusion**: This study has shown that a novel measure of body composition is predictive of cardiovascular risk in U.S. adults. Specifically, BSI was found to have an indirect relationship with both continuous (i.e., LE8 and LC9) and categorical (i.e., high, moderate, and low CVH) forms of CVH. BSI may be a useful metric to consider in addition to conventional measures when predicting cardiovascular risk in adults.

Keywords: *Body shape index (BSI), Cardiovascular health (CVH), Life's essential 8 (LE8), MVPA, Life's crucial 9 (LC9), Population health*

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1. Introduction

Cardiovascular disease (CVD) is a general term for specific conditions that affect the heart and blood vessels like coronary heart disease, cerebrovascular disease, peripheral artery disease, and atherosclerosis [1]. Heart disease is the leading cause of death in the U.S. with stroke number four, responsible for 702,880 and 165,393 deaths (respectively) in 2023 alone [2]. The risk factors for CVD are widely known and are often the focus of health promotion intervention. The American Heart Association (AHA) has categorized the main risk factors for CVD into those that are behavioral (i.e., *Health behaviors*) and those that are physiological (i.e., *Health factors*) [3]. The AHA has also defined a novel set of metrics based on these risk factors that can be used to describe cardiovascular health (CVH). The first generation of these metrics was the *Life's Simple 7* (LS7) measure that included health behaviors of diet, physical activity (PA), body mass index (BMI), and smoking and health factors of cholesterol, blood glucose, and blood pressure (BP) [4]. An updated metric proposed by AHA is the *Life's Essential 8* (LE8) measure which made a slight alteration by changing BMI to a health factor and adding sleep quality as a health behavior [5]. Additionally, the LE8 uses a new scoring algorithm that assigns points ranging from 0 to 100 for each metric with an overall CVH score as the unweighted average of the eight component scores [5]. More recently, a third generation CVH score has been suggested that adds a measure of psychological health to the LE8 and has been designated *Life's Crucial 9* [6].

A body shape index (BSI) is a more contemporary measure of body composition that attempts to assess waist circumference (WC) with a person's height and body weight removed [7]. BSI has become a useful measure because it has shown to be correlated with percent body fat and uncorrelated with BMI [8]. Moreover, BSI has shown to be a valid predictor of all-cause and cardiovascular-specific mortalities [9]. Given that the AHA CVH metrics include BMI as a health factor score, the extent to which BSI can still predict cardiovascular risk remains unclear. Therefore, the aim of this study was to examine the population-level association between BSI and cardiovascular health (CVH) in adults.

2. Methods

Study design

Data for this study came from the 2017 to March Pre-pandemic 2020 National Health and Nutrition Examination Survey (NHANES) [10]. The original 2019-2020 NHANES cycle was interrupted because of the COVID-19 pandemic and therefore was not considered complete for use. To account for this, the 2019-2020 NHANES cycle was combined with the 2017-2018 NHANES cycle to create a 3.2-year nationally representative pre-pandemic cycle. The 2017 to March Pre-pandemic 2020 NHANES is considered a survey of noninstitutionalized civilian residents of the U.S. and collected data using various methods and procedures. This study specifically used data extracted and merged from demographics, dietary, examination, laboratory, and questionnaire datasets. If a participant 20+ years of age had complete data on all study variables then they were included in the analysis regardless of medical condition or disease.

Assessment of body shape index (BSI)

BSI was computed with objectively assessed body measure variables of height (cm), weight (kg), and WC (cm). The BSI formula divided WC by the product of BMI raised to two-thirds power and height raised to one-half power (i.e., BSI = WC / [$BMI^{2/3} \times height^{1/2}$]). With WC and height converted to units of meters (m) and BMI units of kg/m^2 to yield final BSI units of $m^{11/6}/kg^{2/3}$ [11]. The BSI formula was developed from regression allometry using log height and log weight as predictors of log WC. The power function derived from the log-log regression results in a measure of WC adjusted for height and weight (i.e., height and weight removed from WC). BSI takes on positive values that approximately range in adults between 0.060 to 0.106 $m^{11/6}/kg^{2/3}$ [11]. Larger values of BSI indicate a greater health risk associated with WC. BSI was also converted into two different categorical measures: 1) a BSI quartile variable where Q1 contained those with the lowest BSI scores and Q4 contained those with the highest BSI scores and 2) a BSI risk status variable where a cutoff score of 0.083 was used to determine "low" and "high" risk [12].

Assessment of LE8 and LC9 metrics

A total of thirteen (13) AHA recommended CVH metrics were used in this study. The (1) LE8 composite score was the primary focus and constructed using component scores of (2) diet, (3) PA, (4) nicotine, (5) sleep, (6) BMI, (7) blood lipids, (8) blood glucose, and (9) BP [13]. Additionally, two sub-composite metrics of (10) health behavior and (11) health factors were created from the LE8 metrics. Finally, to examine the proposed contribution of psychological health to CVH, a (12) mental metric was computed to create the (13) LC9 composite score [14].

Each AHA metric has been explained elsewhere but will be briefly noted here [5,14]. The *diet* (i.e., diet quality) metric was assessed by first computing Healthy Eating Index (HEI-2015) individual scores using two days of dietary interview recall (i.e., Total Nutrient Intakes) from NHANES 2017-2020 data and a macro provided by the National Cancer Institute [15]. HEI-15 individual scores were then transformed to percentiles (i.e., 1^{st} to 99^{th}) and then to the diet metric (i.e., 0 to 100) using the AHA LE8 scoring algorithm. The *PA* (i.e., leisure-time PA) metric was assessed by first computing weekly minutes of moderate-to-vigorous PA (MVPA) performed during recreation using survey questions regarding both moderate (MPA) and vigorous PA (VPA). MVPA was computed by adding weekly minutes of MPA with two times weekly minutes of VPA (i.e., MVPA = MPA + 2 × VPA) which was then converted to the PA metric using the AHA LE8 scoring algorithm. The *nicotine* (i.e., nicotine exposure) metric was assessed by first computing a current smoking status variable and then a length of time since having stopped smoking, if smoking status was "former smoker," using survey questions. Additionally, status variables were created that assessed use of a nicotine-delivery system other than cigarettes and exposure to secondhand smoke. The final nicotine metric was computed using the AHA LE8 scoring algorithm where 20 points was subtracted (unless score equaled zero) for secondhand smoke exposure. The *sleep* (i.e., sleep quality) metric was assessed by first computing an average weekly amount (hours/day) of sleep that weighed weekday (5 day) sleep time more than weekdays (2 day) and then the sleep metric was created using the AHA LE8 scoring algorithm.

The *BMI* (i.e., body composition) metric was assessed by simply applying the AHA LE8 BMI scoring algorithm to the BMI variable. The *blood lipids* (i.e., unhealthy cholesterol) metric was assessed by first computing a non-HDL variable (i.e., total cholesterol minus HDL cholesterol) from laboratory data and then applying the AHA LE8 scoring algorithm where 20 points was subtracted (unless score equaled zero) for those taking a lipid lowering drug. The *blood glucose* (i.e., diabetes risk) metric was assessed by first computing a diabetes history status (i.e., yes vs no) variable and then applying the AHA LE8 scoring algorithm to the hemoglobin A1c (HbA1c) laboratory variable. The *BP* (i.e., hypertension) metric was assessed by first computing average systolic BP and average diastolic BP variables from examination data and then applying the AHA LE8 scoring algorithm to both variables where 20 points was subtracted (unless score equaled zero) for those taking a BP lowering drug. The LE8 composite CVH score was computed by simply averaging the eight component scores.

To construct the LC9 metric, a *mental* (i.e., mental health) metric was computed using nine survey questions regarding depression (i.e., the Patient Health Questionnaire, [PHQ-9]). The stem for each item was "How often do you experience…" and the response options include: 0 = "not at all," 1 = "several days," 2 = "more than half the days," and 3 = "nearly every day." Summing responses across the nine items yields a PHQ-9 score (0 to 27) which was then assigned percentiles as done by others [14]. The LC9 composite score was computed by simply averaging nine CVH metric scores (i.e., LE8 component scores and the mental metric score). Lastly, the LE8 composite score was converted to a categorical measure representing different levels of health where scores of 0 to 49 were considered "low", scores of 50 to 79 considered "moderate", and scores of 80 to 100 considered "high" CVH [16].

Assessment of covariates

Demographic variables in this study included age, sex, race, and income. Age was used as a continuous variable, ranging from 20 years to 80+ years, as well as a categorical variable consisting of the following groups: 20 to 24 years, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, and 65+ years. Sex included male and female groups. Race/ethnicity was used as a categorical variable and included White, Black, Hispanic, and Other groups. Lastly, income was used as a continuous variable and computed as a ratio of the family income to poverty, ranging from 0 to 5 as well as a categorical variable of income quartiles where larger quartiles contained families with relatively greater income.

Statistical analyses

The sample demographic characteristics were described overall and by BSI risk groups using weighted percentages and the chi-square test of independence. For demographic variables with order, a logistic regression model was run to produce the Cochran-Armitage trend test. All study variables were described using weighted mean values with adjusted standard errors (SEs) and 95% confidence intervals (CIs). Additionally, Pearson correlation coefficients were computed to describe the bivariate association between BSI and each of the AHA CVH metric variables. The correlation coefficients were weighted and the p-values adjusted using linear regression. To describe the temporal change in LE8 metrics from previous national estimates, current sex-specific estimates were compared to those reported using NHANES 2013 – 2018 data [13]. AHA CVH variables were also described and compared across BSI risk groups (high vs low) using weighted means and adjusted p-values from linear regression. Multiple linear regression was employed to examine the crude and adjusted association between BSI quartile groups and continuous forms of CVH, controlling for age, sex, race, and income. Least squares means were also presented to describe CVH at each level of each predictor variable. Finally, multiple generalized (i.e., multinomial) logistic regression was used to model the three-level categorical CVH variable using BSI quartile as the main predictor and controlling for age, sex, race, and income. Odds ratios (ORs) and their 95% CIs were produced and presented in forest plot displays. A complete case analysis was applied where only participants with data on LE8 and all covariates (N = 5,588) and LC9 and all covariates (N = 5,485) were used. Statistical significance was set at $p < 0.05$ and p-values were reported as 2-sided. All SEs were adjusted for the NHANES sampling design using SAS 9.4 survey procedures [17].

3. Results

Table 1 contains weighted sample characteristics overall and by BSI risk. There was a significantly greater percentage of males (38.5%) with high-risk BSI than females (34.8%, $p = .042$). There was also a significantly greater percentage of White adults (40.7%) with high-risk BSI compared to Black (24.1%), Hispanic (28.5%), and Other (32.8%, $p < .001$). A significant linear trend in high-risk BSI was observed across age group categories ($p < .001$) but not across income quartiles ($p = .117$). Table 2 displays correlations between BSI and the LE8 and LC9 CVH metrics. Negative correlations (all *p*s < .05) were seen between BSI and PA ($r = -.220$), BMI ($r = -.054$), blood lipids ($r = -.164$), blood glucose ($r = -.281$), BP ($r = -.279$), LE8 ($r = -.294$), health behaviors ($r = -.156$), health factors ($r = -.300$), and LC9 ($r = -.289$). Conversely, no correlations were found between BSI and diet, nicotine, sleep, or mental CVH metrics.

Table 3 displays LE8 metric means by sex and compared to reported NHANES 2013 - 2018 values. The general trend seen in this analysis was that females had superior CVH as compared to their male counterparts, as seen with greater mean LE8 (66.7 vs. 64.0, $p = .001$), diet (44.8 vs. 40.6, $p < .001$), nicotine (75.7 vs. 65.2, $p < .001$), sleep (84.9 vs. 83.1, $p = .033$), blood lipids (69.9 vs. 66.5, $p = .007$), blood glucose (83.4 vs. 81.2, $p = .043$), and BP (70.1 vs. 64.7, $p < .001$). Conversely, males had greater mean PA (54.6 vs. 48.3, $p = .008$) than their female counterparts. No sex difference was observed for the BMI metric. Table 4 displays CVH metrics by BSI risk. The obvious trend seen in this analysis was that the high-risk BSI group saw inferior CVH as compared to their low-risk counterparts, as seen with lower mean LE8 (60.6 vs. 68.2, $p < .001$), PA (39.9 vs. 58.0, $p < .001$), BMI (54.6 vs. 57.7, $p = .028$), blood lipids (64.4 vs. 70.4, $p < .001$), blood glucose (73.4 vs. 87.5, $p < .001$), BP (57.0 vs. 73.5, $p < .001$) and LC9 (63.9 vs. 70.8, $p < .001$). No BSI risk differences were observed for the diet, nicotine, sleep, or mental metrics.

Table 5 displays the unadjusted regression analysis predicting LE8 and LC9 scores with BSI quartile groups. Findings showed that adults in BSI Q1 ($b = 12.8$, $p < .001$), Q2 ($b = 6.2$, $p < .001$), and Q3 ($b = 3.3$, $p < .001$) had significantly greater LE8 than those in Q4 and showed linear trend ($p < .001$). Similarly, the unadjusted model predicting LC9 showed that adults in BSI Q1 ($b = 11.5$, $p < .001$), Q2 ($b = 5.6$, $p < .001$), and Q3 ($b = 3.0$, $p < .001$) had significantly greater LC9 than those in Q4 and showed linear trend ($p < .001$).

Figure 1 provides a visual display of the LE8 score trend lines across BSI quartile groups for each age group and indicates a significant indirect linear trend in means for all ages less the 65-to-85-year group. Figure 2 displays the same LE8 by BSI quartile group plot but for the different sex groups and indicates a significant indirect linear trend in mean LE8 scores for males and females. Figure 3 also displays the same LE8 by BSI quartile group plot for the different race groups and indicates a significant indirect linear trend in mean LE8 scores for all four race groups. Figure 4, finally, displays the same plot across income quartile groups and indicates a significant indirect linear trend in mean LE8 scores for each group. Similar demographic group trends were observed for LC9 means across BSI quartile groups (data not shown).

Table 1. Weighted percentages of sample characteristics overall and by body shape index (BSI) risk

	Overall				BSI Risk (%)			
Characteristic	*N*	%	*LL*	*UL*	High	*LL*	*UL*	*p*
Overall	5,588	100	-	-	36.6	33.6	39.7	<.001
Sex								.042
Female	2,847	51.2	49.0	53.4	34.8	31.7	38.0	
Male	2,741	48.8	46.6	51.0	38.5	34.5	42.5	
Age Group (yr)								<.001
20 to 24	427	9.1	7.8	10.5	9.2	6.2	12.1	
25 to 34	898	18.3	16.1	20.6	13.8	10.4	17.3	
35 to 44	886	16.7	14.6	18.7	22.2	18.0	26.4	
45 to 54	910	16.7	14.5	18.8	33.4	29.5	37.3	
55 to 64	1,150	19.2	16.8	21.7	52.3	44.8	59.9	
65+	1,317	20.0	16.9	23.1	69.7	66.4	72.9	
Trend								<.001
Race								<.001
White	2,169	67.0	62.3	71.8	40.7	36.8	44.6	
Black	1,378	9.8	7.2	12.4	24.1	20.9	27.3	
Hispanic	1,177	14.3	11.4	17.2	28.5	25.0	32.1	
Other	864	8.8	7.1	10.6	32.8	29.1	36.6	
Income Quartile								.095
Q1 (low)	1,400	16.1	14.1	18.0	35.7	31.1	40.2	
Q2 (low-middle)	1,397	19.0	17.3	20.7	41.6	37.3	45.9	
Q3 (high-middle)	1,395	28.0	25.6	30.5	37.1	31.8	42.4	
Q4 (high)	1,396	36.9	33.4	40.4	34.1	29.1	39.1	
Trend								.117

Note. BSI is body shape index in $m^{11/6}/kg^{2/3}$. BSI risk groups indicate health risk using a cutoff of .083. Group p values are for χ^2 test of independence testing for association between each characteristic and BSI risk groups (high vs low). Trend p values are for Cochran-Armitage trend test.

Table 2. Correlations between BSI and cardiovascular health (CVH) metrics

Variable	*Mean*	*SE*	*LL*	*UL*	*r*	*p*
BSI	0.0814	0.0001	0.0811	0.0817	-	-
Diet	42.8	1.18	40.35	45.19	-.010	.637
PA	51.3	1.45	48.34	54.33	-.220	<.001
Nicotine	70.6	0.99	68.55	72.61	-.045	.162
Sleep	84.0	0.62	82.75	85.28	-.045	.100
BMI	56.5	0.92	54.65	58.44	-.054	.018
Blood lipids	68.2	0.92	66.32	70.10	-.164	<.001
Blood glucose	82.3	0.55	81.19	83.46	-.281	<.001
BP	67.5	0.86	65.71	69.24	-.279	<.001
LE8	65.4	0.60	64.18	66.63	-.294	<.001
Health behaviors	62.2	0.88	60.36	63.99	-.156	<.001
Health factors	68.6	0.58	67.44	69.84	-.300	<.001
Mental	91.3	0.33	90.58	91.95	-.021	.420
LC9	68.3	0.54	67.17	69.41	-.289	<.001

Note. All LE8 metrics N = 5,588. Mental and LC9 N = 5,485. CVH metrics each range from 0 to 100 where higher scores indicate greater CVH. BSI is body shape index in $m^{11/6}/kg^{2/3}$. Pearson correlations (r) are for each variable and BSI.

Table 3. Life's Essential 8 (LE8) metrics by sex and compared to reported previous NHANES values

	Male					Female					
CVH Metrics	*Mean*	*SE*	*LL*	*UL*	*Mean**	*Mean*	*SE*	*LL*	*UL*	*Mean**	*p*
Diet	40.6	1.19	38.13	43.05	38.1	44.8	1.36	42.03	47.65	51.9	<.001
PA	54.6	2.14	50.17	58.97	54.0	48.3	1.46	45.25	51.28	49.2	.008
Nicotine	65.2	1.22	62.64	67.67	63.1	75.7	1.14	73.38	78.09	75.1	<.001
Sleep	83.1	0.77	81.51	84.69	84.0	84.9	0.70	83.45	86.32	85.3	.033
BMI	56.5	1.43	53.60	59.50	57.8	56.5	1.08	54.32	58.77	57.1	.997
Blood lipids	66.5	1.12	64.14	68.76	64.8	69.9	1.05	67.72	72.04	69.9	.007
Blood glucose	81.2	0.88	79.34	82.98	76.8	83.4	0.64	82.12	84.75	80.0	.043
BP	64.7	1.12	62.38	67.00	67.6	70.1	1.06	67.94	72.31	73.8	<.001
LE8	64.0	0.65	62.69	65.38	63.6	66.7	0.75	65.17	68.26	68.1	.001

Note. N = 5,588. Mean* values are from NHANES 2013-2018 which excluded adults if they were 80+ years of age, if they were pregnant or breastfeeding, if they had history of cardiovascular disease, or if they had incomplete interviews or examinations [13]. LE8 metrics each range from 0 to 100 where higher scores indicate greater CVH. t statistic p-values are testing for mean difference between sex groups.

Table 4. Cardiovascular health (CVH) metrics by BSI risk

	High-risk BSI				Low-risk BSI				
CVH Metrics	*Mean*	*SE*	*LL*	*UL*	*Mean*	*SE*	*LL*	*UL*	*p*
Diet	42.6	1.26	40.00	45.18	42.9	1.46	39.85	45.89	.860
PA	39.9	1.71	36.34	43.38	58.0	1.64	54.61	61.34	<.001
Nicotine	69.4	1.72	65.86	72.93	71.3	1.52	68.13	74.39	.483
Sleep	83.6	0.80	81.95	85.23	84.3	0.85	82.52	86.01	.565
BMI	54.6	0.98	52.53	56.58	57.7	1.17	55.28	60.11	.028
Blood lipids	64.4	1.26	61.77	66.95	70.4	0.90	68.59	72.28	<.001
Blood glucose	73.4	1.08	71.14	75.57	87.5	0.60	86.27	88.76	<.001
BP	57.0	1.14	54.67	59.35	73.5	0.96	71.54	75.51	<.001
LE8	60.6	0.41	59.74	61.44	68.2	0.75	66.65	69.74	<.001
Health behaviors	58.9	0.87	57.06	60.65	64.1	1.10	61.82	66.36	<.001
Health factors	62.3	0.52	61.24	63.40	72.3	0.72	70.81	73.78	<.001
Mental	90.8	0.62	89.56	92.11	91.5	0.46	90.57	92.45	.425
LC9	63.9	0.40	63.09	64.72	70.8	0.69	69.41	72.23	<.001

Note. All LE8 metrics N = 5,588. Mental and LC9 N = 5,485. CVH metrics each range from 0 to 100 where higher scores indicate greater CVH. BSI is body shape index in $m^{11/6}/kg^{2/3}$. BSI risk groups indicate health risk using a cutoff of .083. t statistic p-values are testing for mean difference between BSI risk groups.

Table 5. Unadjusted regression analysis predicting LE8 and LC9 scores with BSI quartile groups

	Life's Essential 8 (LE8)				Life's Crucial 9 (LC9)			
Parameter	*Mean*	*Estimate*	*SE*	*p*	*Mean*	*Estimate*	*SE*	*p*
Intercept	-	59.7	0.45	<.001	-	63.1	0.43	<.001
BSI								
Q1	72.4	12.8	0.99	<.001	74.6	11.5	0.96	<.001
Q2	65.9	6.2	0.92	<.001	68.7	5.6	0.91	<.001
Q3	63.0	3.3	0.65	<.001	66.1	3.0	0.62	<.001
Q4	59.7	ref	-	-	63.1	ref	-	-
Trend				<.001				<.001

Note. LE8 model N = 5,588. LC9 model N = 5,485. Mean values are least squares means. The intercept for each model represents the predicted outcome score for the reference level of BSI group. Each BSI group estimate (slope) is the difference between that group and the intercept. Trend p values are from linear contrasts.

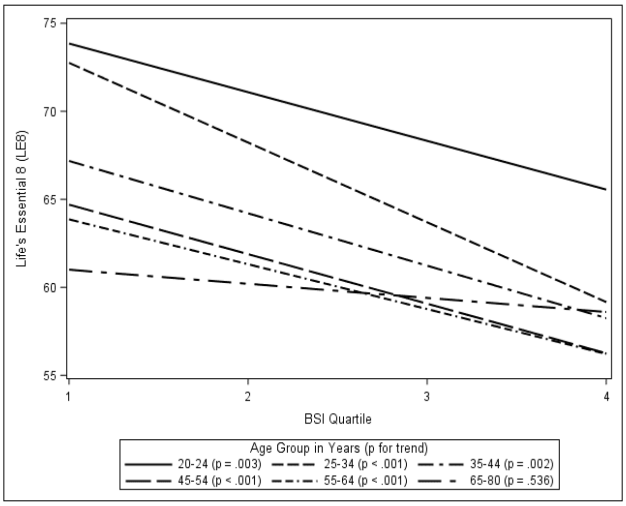

Figure 1. LE8 score trend lines across BSI quartile by age group

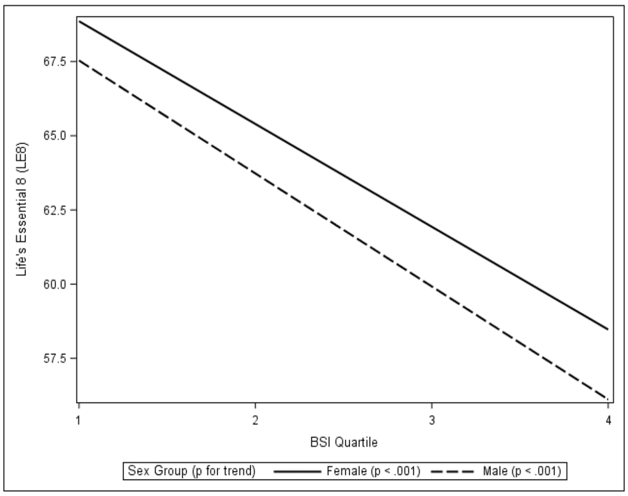

Figure 2. LE8 score trend lines across BSI quartile by sex group

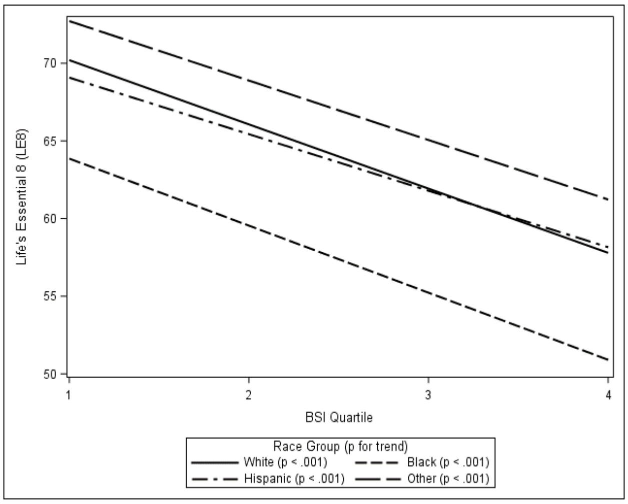

Figure 3. LE8 score trend lines across BSI quartile by race group

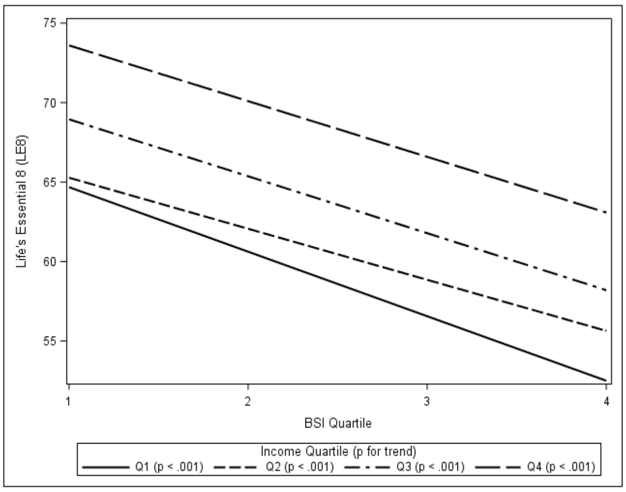

Figure 4. LE8 score trend lines across BSI quartile by income group

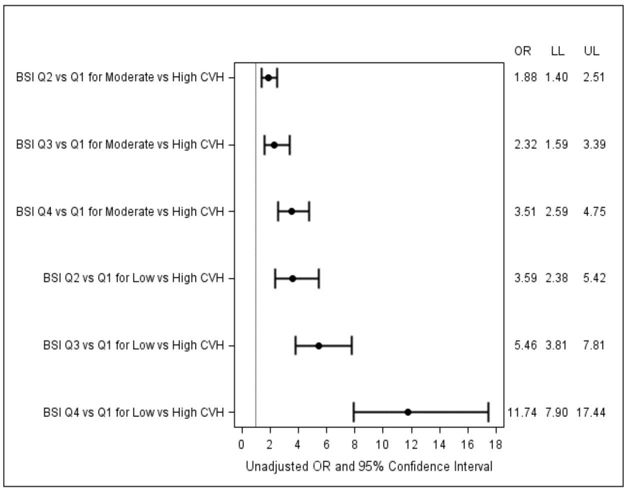

Figure 5. Forest plot of unadjusted ORs and 95% CIs from multinomial logistic regression

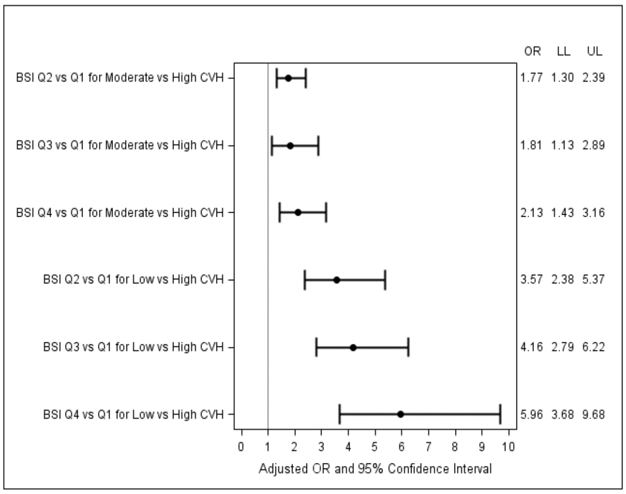

Figure 6. Forest plot of fully adjusted ORs and 95% CIs from multinomial logistic regression

Table 6. Adjusted regression analysis predicting LE8 and LC9 scores with BSI quartile groups

	Life's Essential 8 (LE8)				Life's Crucial 9 (LC9)			
Parameter	*Mean*	*Estimate*	*SE*	*p*	*Mean*	*Estimate*	*SE*	*p*
Intercept	-	56.0	1.67	<.001	-	59.4	1.58	<.001
BSI								
Q1	69.4	9.3	1.13	<.001	71.8	8.5	1.09	<.001
Q2	63.8	3.6	1.12	.003	66.8	3.4	1.11	.005
Q3	62.2	2.1	0.68	.006	65.2	1.9	0.64	.008
Q4	60.1	ref	-	-	63.4	ref	-	-
Trend				<.001				<.001
Sex								
Female	65.3	2.9	0.78	.001	67.9	2.3	0.75	.006
Male	62.4	ref	-	-	65.7	ref	-	-
Age Group (yr)								
20 to 24	69.9	ref	-	-	72.2	ref	-	-
25 to 34	67.0	-2.9	1.40	.047	69.5	-2.7	1.28	.043
35 to 44	63.3	-6.6	1.51	<.001	66.2	-6.0	1.39	<.001
45 to 54	61.1	-8.8	1.55	<.001	64.3	-7.9	1.45	<.001
55 to 64	60.7	-9.2	1.60	<.001	64.0	-8.2	1.42	<.001
65+	61.3	-8.5	1.54	<.001	64.7	-7.4	1.39	<.001
Race								
White	65.0	5.0	0.73	<.001	67.7	4.2	0.66	<.001
Black	60.0	ref	-	-	63.5	ref	-	-
Hispanic	65.6	5.7	0.70	<.001	68.5	4.9	0.65	<.001
Other	64.9	4.9	0.95	<.001	67.6	4.0	0.91	<.001
Income Quartile								
Q1 (low)	59.1	ref	-	-	61.8	ref	-	
Q2 (low-middle)	62.1	3.0	0.73	<.001	65.2	3.4	0.68	<.001
Q3 (high-middle)	64.7	5.6	0.74	<.001	67.7	5.9	0.70	<.001
Q4 (high)	69.6	10.6	0.54	<.001	72.5	10.7	0.53	<.001

Note. LE8 model N = 5,588. LC9 model N = 5,485. Mean values are least squares means. The intercept for each model represents the predicted outcome score when all variables in the table are at their reference level. Each variable group estimate (slope) is the difference between that group and its reference group, holding all other variables constant. Trend p values are from linear contrasts.

Table 6 displays the multiple regression models fully adjusted for age, sex, race, and income. These findings showed that adults in BSI Q1 (b = 9.3, p < .001), Q2 (b = 3.6, p = .003), and Q3 (b = 2.1, p = .006) had significantly greater LE8 than those in Q4 and showed linear trend (p < .001). Similarly, the fully adjusted model predicting LC9 showed that adults in BSI Q1 (b = 8.5, p < .001), Q2 (b = 3.4, p = .005), and Q3 (b = 1.9, p = .008) had significantly greater LC9 than those in Q4 and showed linear trend (p < .001).

Figure 5 displays a forest plot of the unadjusted multinomial logistic regression model ORs with 95% CIs. These statistics indicate that an adult in BSI Q2, Q3, and Q4 had 1.88, 2.32, and 3.51 (respectively, all *ps* < .05) times the odds of an adult in BSI Q1 to have moderate CVH over high CVH. Furthermore, an adult in BSI Q2, Q3, and Q4 had 3.59, 5.46, and 11.74 (respectively, all *ps* < .05) times the odds of an adult in BSI Q1 to have low CVH over high CVH. Figure 6 displays results of the same multinomial logistic regression analysis but fully adjusted for age, sex, race, and income. These statistics indicate that an adult in BSI Q2, Q3, and Q4 had 1.77, 1.81, and 2.13 (respectively, all *ps* < .05) times the odds of an adult in BSI Q1 to have moderate CVH over high CVH. Furthermore, an adult in BSI Q2, Q3, and Q4 had 3.57, 4.26, and 5.96 (respectively, all *ps* < .05) times the odds of an adult in BSI Q1 to have low CVH over high CVH.

4. Discussion

The purpose of this study was to examine the extent to which a population-level association exists between BSI and CVH in adults. This research found that BSI has in fact a robust indirect association with CVH and provided this evidence in three different procedures: 1) bivariate correlation analysis, 2) multivariate analysis of continuous CVH metrics, and 3) multivariate analysis of CVH status categories. Specifically, results from the bivariate correlation analysis showed that BSI was indirectly associated with both LE8 and LC9 composite scores, indirectly associated with both composite sub-scores of health behaviors and health factors, as well as indirectly associated with component scores of PA, BMI, blood lipids, blood glucose, and BP. It is also worth highlighting that BSI had a stronger correlation with the health factor metrics than health behavior metrics. Furthermore, since BSI was not associated with diet, nicotine, sleep, or mental metrics, it may be the case that BSI has less influence on behavioral health. Similarly, multivariate analysis of the continuous CVH metrics indicated a strong negative dose-response association between LE8 and BSI quartile groups, where LE8 scores decreased substantially as participants moved from low BSI quartiles to higher quartiles. This finding was consistent in both unadjusted and fully adjusted models predicting both LE8 and LC9 scores. Lastly, the multivariate analysis of CVH status categories (i.e., low, moderate, and high CVH) may have provided the more monumental of findings. That is, BSI quartile groups were able to predict membership to all three CVH category groups and did so in negative dose-response manner.

No studies to date have published data on the association between BSI and either AHA CVH metrics. However, several studies have examined the association between BSI and specific cardiovascular risk factors such as dyslipidemia, diabetes, hypertension, and high body fat [18,19,20,21]. Studies have also shown BSI as an independent predictor of cardiovascular disease, cardiovascular events, and cardiovascular mortality [22,23,24]. Thus, the current literature can indirectly support the findings from this study where BSI was found to be an independent predictor of the AHA LE8 and LC9 CVH scores. Final noteworthy discussion points are 1) the low correlations between BSI and the health behavior metrics as well as 2) the lack of correlation between BSI and the mental health metric, which fundamentally defines the LC9 concept. Both latter points lack data in the literature due to the short existence of the LE8 and LC9 metrics in medical research. Thus, future research is needed to better understand the influence of BSI on psychosocial and behavioral risk factors related to CVH.

Although the strengths in this study are underscored by its use of 1) a nationally representative sample of noninstitutionalized U.S. adults, 2) a robust diet quality assessment from two days of diet recall, 3) clinical laboratory assessments of blood lipids and blood glucose, and 4) physical examinations conducted by trained professionals who assessed bodily measures and repeated BP measurements, the research still has limitations that require comment. One limitation is universal to all cross-sectional research but needs to be stressed. That is, results from this study should not be confused as cause-and-effect evidence. This study is not purporting in any way that high-risk values of BSI cause cardiovascular risk to an adult. It is however stipulating that an association between BSI and CVH is present in this population and that future research is warranted to better understand the mechanisms underlying the relationship. A second limitation worth noting is the use of self-reported assessments of diet, PA, nicotine use, sleep, and mental health. Behavioral assessments using questionnaire methods have potential for several different biases and measurement errors [25]. However, survey items used by NHANES have a long history of use and are generally considered to have acceptable psychometric properties [26]. In sum, results from this study should not be considered without also considering the above-mentioned weaknesses.

5. Conclusions

This study has shown that a modern measure of body composition can predict cardiovascular risk in U.S. adults. BSI was found to have a negative dose-response relationship with both continuous forms of LE8 and LC9. Additionally, BSI was able to predict membership to categorical CVH values of high, moderate, and low CVH in a similar dose-response manner. BSI may be a useful metric to consider in addition to conventional measures when predicting cardiovascular risk in adults.

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