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Body Shape and Healthy Lifestyle Are Independent Predictors of Survival in Older Adults: NHANES 1999 to 2018

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Abstract **Background:** Various body measures have been found predictive of morbidity and mortality in population-based studies. Similarly, links between a healthy lifestyle and health outcomes are well established. However, the extent to which body shape and healthy lifestyle can independently predict death in elderly populations is less clear. **Purpose:** The aim of this study was to determine if measures of body shape and healthy lifestyle can independently predict all-cause mortality in older adults. **Methods:** A baseline sample of 9,610 adults 65+ years of age were included from ten cycles (1999-2018) of NHANES. A body shape index (BSI) was computed using objectively assessed anthropometric measures. A healthy lifestyle index (HLI, 0-to-8) was constructed using four rating scale measures that included physical activity (0-to-2), alcohol consumption (0-to-2), smoking (0-to-2), and BMI groups (0-to-2). To account for confounding health status, chronic conditions and activities of daily living (ADL) were considered. Survival analysis was employed to examine the independent associations between the predictors and risk of all-cause mortality. Linear regression was used to characterize the mortality risk trend across HLI scores by different BSI quartile groups. **Results:** A total of 4,059 all-cause deaths were observed during a mean (median) follow-up of 10.9 (10.8) years. BSI was an independent predictor of mortality with risk decreasing linearly ($p<0.0001$) from 4th (reference), 3rd (HR=0.85, 0.75-0.95), 2nd (HR=0.77, 0.67-0.88), and 1st (HR=0.72, 0.63-0.82) BSI quartiles. Similarly, HLI was an independent predictor with risk increasing linearly ($p<0.0077$) from HLI 7+ (reference), HLI 6 (HR=1.25, 1.01-1.56), HLI 5 (HR=1.27, 1.03-1.57), HLI 4 (HR=1.45, 1.18-1.78), HLI 3 (HR=1.52, 1.22-1.88), HLI 2 (HR=1.85, 1.48-2.30), HLI 1 (HR=2.00, 1.50-2.68), and HLI 0 (HR=2.03, 1.05-3.93). Additionally, predicted hazard means decreased linearly across HLI scores for each BSI quartile group with lower means observed in lower BSI quartile groups. However, a significant quadratic trend was seen in the 1st and 4th BSI quartile groups, indicating a rapid decline in mortality risk beginning at approximately HLI 4 for those BSI groups. **Conclusion:** These findings indicate that body shape and healthy lifestyle each influence mortality risk in older adults. Adopting healthy behaviors and improving abdominal fat metrics should be promoted among adult populations regardless of disease, functioning, and age.

Keywords: *Gerontology, Healthy lifestyle, Body shape index, Mortality, Population health*

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1. Introduction

Several different body measure variables are known predictors of morbidity and mortality in population-based studies of older adults. For instance, body mass index (BMI) is known to correlate with mortality risk in non-frail older populations [1]. Additionally, older adults considered underweight or obese using a measure of BMI have been shown to have higher risk of all-cause mortality [2]. A related but different measure, waist circumference (WC), is a measure of abdominal obesity and is also known to be positively associated with mortality risk in older populations [3]. Often used in clinical settings, percent body fat (PBF) is the amount of body fat as a percentage of body weight. PBF is purported to be a better predictor of health and is also associated with risk of all-cause mortality [4]. A relatively newer body measure, body shape index (BSI), is a measure of abdominal obesity that removes BMI from WC and is correlated with PBF [5]. As such, BSI may be a better predictor of mortality in older populations than either BMI or WC [6,7].

In like manner, connections have been established between a healthy lifestyle and health outcomes. Many studies have used collective measures or indexes, formed by combining several health behaviors, as predictors of mortality [8]. By combining health variables such as BMI, smoking status, alcohol use, physical activity (PA), and diet, researchers are able to garner the power of a single predictor in an analysis without the nuisance of several potentially correlated variables [9]. Studies have used these combined healthy lifestyle variables to predict mortality in many different populations including older adults [9,10].

To date, no studies have examined the contribution of both a measure of body shape and a combined measure of healthy lifestyle on mortality in older adults. Thus, the extent to which body shape and healthy lifestyle can independently predict death in older populations is unknown. The aim of this study was to determine if measures of body shape and healthy lifestyle can independently predict all-cause mortality in a representative sample of older U.S. adults.

2. Methods

Study design

This study used ten cycles (1999-2018) of National Health and Nutrition Examination Survey (NHANES) data along with National Center for Health Statistics (NCHS) 2019 public-use linked mortality files [11,12]. The initial dataset consisted of 101,316 adults 0+ years of age and, after exclusions, resulted in a final baseline sample of 9,610 older adults (Figure 1).

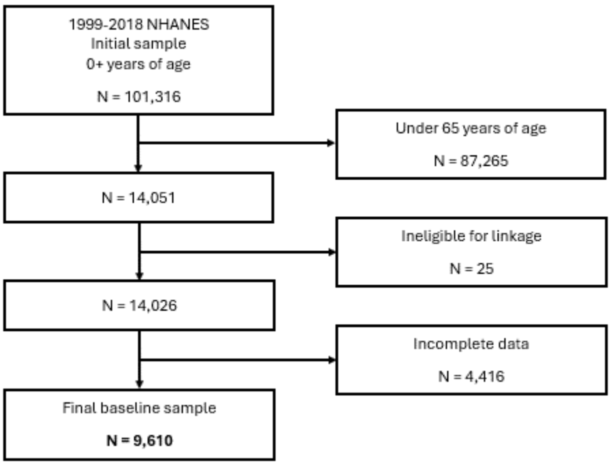

Figure 1. Schematic of study exclusions

Healthy lifestyle index (HLI)

The HLI for this study was created using four health metrics that included alcohol use, smoking, PA, and BMI status [13]. Each health metric was converted to a 3-point rating scale with category values of 0, 1, and 2. Alcohol use was assessed using a series of questions asking participants about their alcohol consumption history and average alcohol consumption. From these responses, an alcohol use metric variable was created that assigned participants to one of three score categories: non-drinker (2), light drinker (1), or moderate-to-heavy drinker (0). Smoking status was assessed using a series of questions asking participants about their lifetime and current smoking habits. From these responses, a smoking metric variable was created that assigned participants to one of three score categories: non smoker (2), former smoker (1), or current smoker (0). PA was assessed by first computing variables indicating if the participant reported typically engaging in any weekly moderate PA (MPA) or vigorous PA (VPA) for at least 10 minutes continuously. From these indicator variables, a PA metric variable was created that assigned participants to one of three score categories of physically active in both MPA and VPA (2), physically active in MPA or VPA only (1), or physically inactive (0). BMI (kg/m^2) status was assessed by first forming the following BMI categories: 1) underweight (BMI < 18.5), 2) normal weight (18.5 ≤ BMI < 25.0), 3) overweight (25.0 ≥ BMI < 30.0), and 4) obese (BMI ≥ 30.0). From these groups, a BMI metric variable was created that assigned participants to one of three score categories: normal weight (2), overweight (1), or underweight/obese (0). Finally, the HLI was created by summing across the four health metric variables, yielding a total score from 0 to 8, with larger values indicating better health.

Body shape index (BSI)

A measure of body shape, body shape index (BSI), was used in this study as a predictor of central obesity as well as for its association with chronic disease and sleep quality [14]. BSI was computed from objectively measured height, weight, and waist circumference (WC) using the following formula: BSI $(m^{11/6}/kg^{2/3})$= WC / $(BMI^{2/3} \times height^{1/2})$ [15]. BSI is considered a measure of WC with a participant's BMI removed with larger values indicative of poor health outcomes. For descriptive purposes, BSI values were converted to T-scores with a mean of 50 and standard deviation (SD) of 10. For modeling purposes, BSI values were categorized into quartiles, where larger quartiles contained higher BSI values.

Activities of daily living (ADL)

A measure of functional limitations was assessed using a 4-itemactivities of daily living (ADL) scale. Each ADL item asked participants how much difficulty they experience completing certain tasks. For this study, the ADL scale considered the tasks of 1) dressing themselves, 2) walking between rooms, 3) getting in and out of bed, and 4) eating with a knife, fork, and cup. A common response scale was used ranging from *no difficulty* to *unable to do the activity*. A final two-group ADL status variable was created with participants considered to either have no difficulty on all tasks or at least some difficulty on any task.

Chronic conditions

A chronic conditions variable was created from nine different disease conditions that included 1) coronary heart disease, 2) congestive heart failure, 3) coronary heart disease, 4) angina pectoris, 5) heart attack, 6) stroke, 7) emphysema, 8) chronic bronchitis, and 9) arthritis. If a participant indicated they were told by a doctor or other health professional that they had the condition, they were assigned a '1', otherwise a '0'. A final two-group chronic conditions status variable was created with participants considered to either have no chronic conditions or at least one chronic condition.

Assessment of covariates

For descriptive and statistical adjustment purposes, age, sex, race, and income variables were created. Age was used as a continuous variable, ranging from 18 years to 80+ years, as well as a grouping variable for descriptive purposes. Sex included males and female and dummy coded when appropriate (1=male and 0=female). Race/ethnicity was used as a categorical variable and included White, Black, Hispanic, and Other groupings. 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 grouping variable (quartiles) for descriptive purposes.

Statistical analyses

The sample was described using weighted percentages across HLI groups with 95% confidence intervals (CIs). The Rao-Scott chi-square (X^2) statistic was used to test for differences in HLI group percentages across demographic and health status characteristics. Additionally, linear regression was used to test for difference in BSI across HLI groups for each demographic and health status characteristic. Cox regression survival analysis was employed to examine the independent associations between the predictors and risk of all-cause mortality. Linear regression was used to characterize the trend in mortality risk across HLI scores by different BSI quartile groups. SAS version 9.4 survey procedures were used for all analyses [16,17].

3. Results

A total of 4,059 all-cause deaths were observed during a mean (median) follow-up of 10.9 (10.8) years. A larger percentage of female (44.6%), 80+ years (46.2%), other race (53.6%), high income (39.5%), disease free (43.4%), and functionally healthy (39.1%) adults were categorized in the high HLI (HLI 5-8) group, as compared to their respective counterparts (Table 1). Additionally, BSI values were greater among adults in the low HLI (HLI 0-2) group for males (p=0.0004) but not females (Table 2). Similar trends in BSI were observed in the 65-69 and 70-79 year age groups, White and Black groups, and the top three income quartile groups. Additionally, significantly greater BSI was observed in the low HLI (HLI 0-2) group in both ADL status groups, although, those with functional limitation had significantly (HLI int p=0.0347) greater BSI than their healthy counterparts.

BSI was an independent predictor of mortality with risk decreasing linearly (p<0.0001) from 4th (reference), 3rd (HR=0.85, 0.75-0.95), 2nd (HR=0.77, 0.67-0.88), and 1st (HR=0.72, 0.63-0.82) BSI quartiles (Table 3). Similarly, HLI was an independent predictor with risk increasing linearly (p<0.0077) from HLI 7+ (reference), HLI 6 (HR=1.25, 1.01-1.56), HLI 5 (HR=1.27, 1.03-1.57), HLI 4 (HR=1.45, 1.18-1.78), HLI 3 (HR=1.52, 1.22-1.88), HLI 2 (HR=1.85, 1.48-2.30), HLI 1 (HR=2.00, 1.50-2.68), and HLI 0 (HR=2.03, 1.05-3.93) (Figure 2). Finally, mean hazard decreased linearly across HLI scores for each BSI quartile group with lower means observed in lower BSI quartile groups (Figure 3). However, a significant quadratic trend was observed in the 1st and 4th BSI quartiles, indicating a substantial drop in hazard at approximately HLI 4 for those BSI groups (Figure 4).

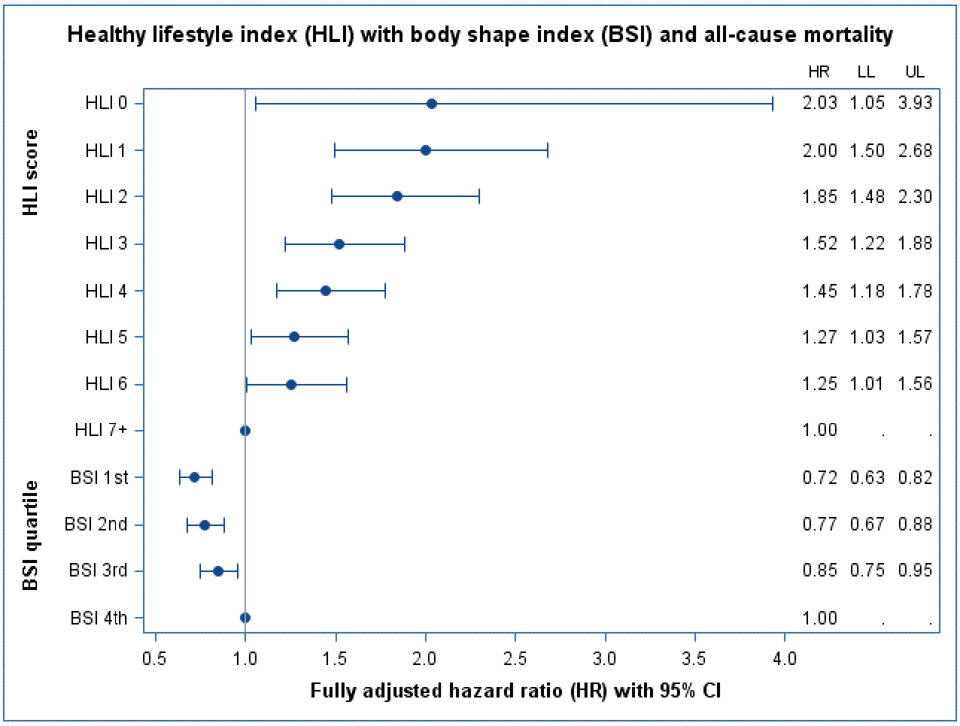

Figure 2. Hazard ratio (HR) statistics for HLI score and BSI quartile group. Note. HRs are adjusted for age, sex, race, income, chronic conditions status, and ADL status

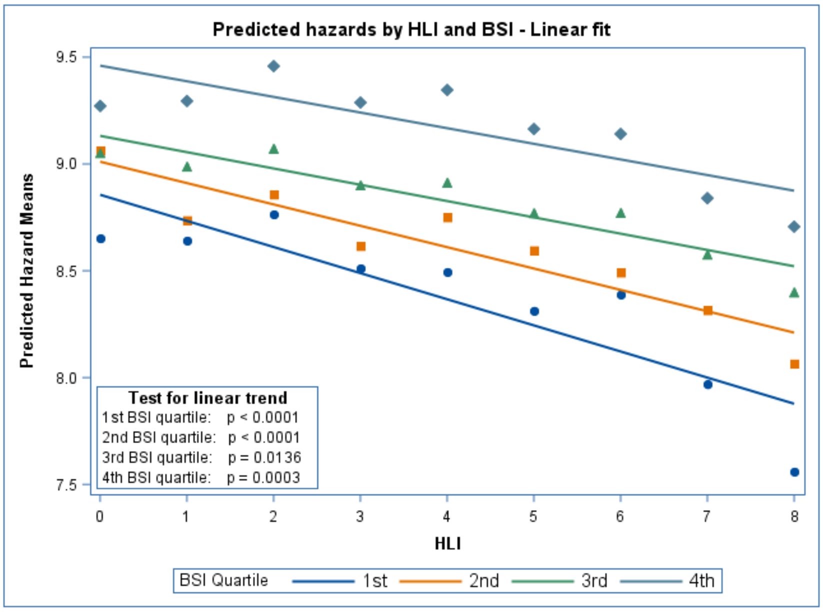

Figure 3. All-cause mortality risk across HLI score by BSI quartile. Note. Predicted means are from fully adjusted Cox regression model. Linear trend tested using contrasts across HLI score

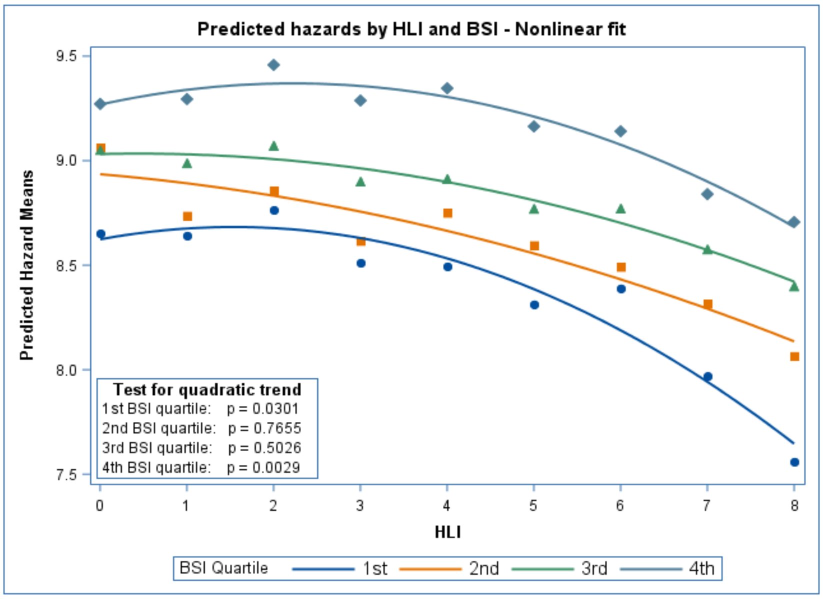

Figure 4. All-cause mortality risk across HLI score by BSI quartile. Note. Predicted means are from fully adjusted Cox regression model. Quadratic trend tested using contrasts across HLI score

Table 1. Sample characteristics across healthy lifestyle index (HLI) categories

	Healthy Lifestyle Index (HLI) Categories									
	Low (HLI 0-2)			Moderate (HLI 3-4)			High (HLI 5-8)			X^2
Characteristic	%	*LL*	*UL*	%	*LL*	*UL*	%	*LL*	*UL*	*p*
Overall	17.0	15.96	18.01	45.86	44.56	47.17	37.2	35.78	38.54	<.0001
Sex										<.0001
Female	11.9	10.77	13.11	43.48	41.90	45.06	44.6	42.81	46.35	
Male	23.1	21.37	24.85	48.76	46.69	50.83	28.1	26.19	30.07	
Age (yr)										<.0001
65 to 69	21.0	18.96	23.04	44.42	41.52	47.32	34.6	31.57	37.59	
70 to 79	17.1	15.73	18.54	47.74	45.77	49.72	35.1	33.12	37.12	
80+	9.6	8.36	10.85	44.18	41.83	46.52	46.2	43.84	48.60	
Race/Ethnicity										<.0001

	Healthy Lifestyle Index (HLI) Categories									
	Low (HLI 0-2)			Moderate (HLI 3-4)			High (HLI 5-8)			X^2
Characteristic	%	LL	UL	%	LL	UL	%	LL	UL	p
White	16.6	15.51	17.78	46.18	44.65	47.71	37.2	35.54	38.80	
Black	21.4	19.08	23.65	47.78	44.75	50.80	30.9	28.16	33.55	
Hispanic	19.1	17.08	21.17	47.14	43.88	50.40	33.7	30.87	36.61	
Other	12.4	8.14	16.76	33.94	28.46	39.41	53.6	47.33	59.90	
Income quartile										.0479
1st	19.9	17.50	22.29	44.40	41.56	47.24	35.7	32.63	38.79	
2nd	16.3	14.43	18.07	47.08	44.68	49.48	36.7	34.35	38.98	
3rd	17.6	15.57	19.54	47.09	44.54	49.63	35.4	32.51	38.21	
4th	15.7	13.78	17.62	44.80	42.12	47.48	39.5	36.55	42.44	
Has a disease										<.0001
No	14.1	12.47	15.71	42.50	40.20	44.81	43.4	41.11	45.71	
Yes	18.5	17.21	19.70	47.57	45.92	49.22	34.0	32.38	35.58	
ADL problem										<.0001
No	15.9	14.73	17.05	45.01	43.59	46.43	39.1	37.51	40.69	
Yes	21.6	19.38	23.92	49.52	46.81	52.23	28.8	26.30	31.37	

Note. N = 9,610. HLI is the healthy lifestyle index. p-values are from the Rao-Scott chi-square (X^2) statistic testing for the association between HLI category and each characteristic. % is the weighted percentage estimate. LL and UL are the lower and upper limits, respectively, of the 95% confidence interval (CI) estimating the %.

Table 2. Body shape index (BSI, T-score) by sample characteristics across healthy lifestyle index (HLI) categories

	Healthy Lifestyle Index (HLI) Categories										
	Low (HLI 0-2)			Moderate (HLI 3-4)			High (HLI 5-8)			INT	F
Characteristic	Mean	LL	UL	Mean	LL	UL	Mean	LL	UL	p	p
Overall	51.0	50.42	51.64	49.90	49.50	50.31	48.5	48.00	49.03		<.0001
Sex										.0029	
Female	48.3	47.12	49.41	47.14	46.52	47.77	47.1	46.46	47.78		.1778
Male	52.8	52.08	53.45	52.90	52.48	53.32	51.2	50.52	51.88		.0004
Age (yr)										.2588	
65 to 69	49.8	48.77	50.75	47.88	47.20	48.55	46.0	45.10	46.86		<.0001
70 to 79	51.6	50.93	52.28	50.30	49.71	50.90	48.6	47.90	49.21		<.0001
80+	53.6	52.19	54.98	52.51	51.75	53.27	51.8	50.99	52.55		.0339
Race/Ethnicity										.0798	
White	51.5	50.82	52.20	50.19	49.71	50.67	48.6	47.99	49.19		<.0001
Black	46.9	46.02	47.87	46.00	45.16	46.85	45.0	44.00	46.01		.0271
Hispanic	51.1	49.85	52.41	50.14	49.25	51.02	50.3	49.29	51.26		.4946
Other	50.7	48.44	52.93	51.66	50.38	52.95	49.5	48.12	50.87		.0754
Income quartile										.0049	
1st	51.4	50.24	52.47	50.29	49.31	51.27	50.6	49.73	51.41		.3374
2nd	52.5	51.29	53.81	50.64	49.87	51.40	49.1	48.11	50.18		.0003
3rd	50.7	49.46	51.97	50.29	49.63	50.96	48.0	47.21	48.79		<.0001
4th	50.1	49.09	51.21	48.94	48.29	49.60	47.7	46.82	48.56		.0078
Has a disease										.6945	
No	51.0	49.80	52.11	49.71	49.04	50.38	48.1	47.45	48.77		<.0001
Yes	51.1	50.35	51.77	49.99	49.51	50.47	48.8	48.08	49.48		<.0001
ADL problem										.0347	
No	50.6	49.84	51.29	49.77	49.35	50.20	48.1	47.56	48.71		<.0001
Yes	52.5	51.46	53.50	50.41	49.60	51.22	50.7	49.53	51.91		.0055

Note. N = 9,610.HLI is the healthy lifestyle index. F statistic p-values are from linear regression models predicting BSI across HLI group. INT p-values are from linear regression HLI-by-characteristic interaction test. BSI means are least squares means from linear regression. LL and UL are the lower and upper limits, respectively, of the 95% confidence interval (CI) estimating BSI means.

Table 3. Cox proportional hazard models associating healthy lifestyle index (HLI), psychological distress, chronic conditions, and functional limitations with all-cause mortality

	Unadjusted			Demographic adjusted			Fully adjusted		
Characteristic	*HR*	*LL*	*UL*	*HR*	*LL*	*UL*	*HR*	*LL*	*UL*
HLI score									
HLI 0	1.95	1.06	3.61	2.63	1.48	4.68	2.03	1.05	3.93
HLI 1	1.74	1.34	2.28	2.31	1.74	3.08	2.00	1.50	2.68
HLI 2	1.94	1.54	2.45	2.13	1.73	2.62	1.85	1.48	2.30
HLI 3	1.58	1.25	1.99	1.69	1.37	2.09	1.52	1.22	1.88
HLI 4	1.56	1.25	1.96	1.56	1.28	1.91	1.45	1.18	1.78
HLI 5	1.36	1.09	1.71	1.34	1.09	1.64	1.27	1.03	1.57
HLI 6	1.36	1.09	1.71	1.27	1.02	1.58	1.25	1.01	1.56
HLI 7+	1.00	ref		1.00	ref		1.00	ref	
p for trend		.0476			<.0001			.0077	
BSI quartile group									
1st	0.48	0.43	0.55	0.69	0.61	0.78	0.72	0.63	0.82
2nd	0.57	0.50	0.65	0.75	0.65	0.85	0.77	0.67	0.88
3rd	0.68	0.61	0.76	0.83	0.74	0.93	0.85	0.75	0.95
4th	1.00	ref		1.00	ref		1.00	ref	
p for trend		<.0001			<.0001			<.0001	
Has a disease									
No	1.00	ref		1.00	ref		1.00	ref	
Yes	1.60	1.46	1.75	1.45	1.32	1.59	1.32	1.19	1.45
ADL problem									
No	1.00	ref		1.00	ref		1.00	ref	
Yes	1.76	1.58	1.96	1.64	1.50	1.80	1.23	1.18	1.28

Note. N = 9,610. HLI is the healthy lifestyle index. Cox proportional hazard models estimate the hazard ratio (HR) and its 95% CI. LL and UL are the lower and upper limits, respectively, of the 95% CI estimating the HR. p for trend is testing linear trend in HR across HLI categories and BSI quartiles. The unadjusted models each include a single categorical predictor variable. The demographics adjusted model includes age, sex, race, and income. The fully adjusted model includes the four predictors as well as age, sex, race, and income.

4. Discussion

The two most important findings from this study include 1) that HLI and BSI were found to be independent predictors of all-cause mortality and 2) the risk of mortality declined as HLI scores increased across all BSI quartiles with lower trending risk observed in lower BSI groups. The HLI used in this study was also negatively correlated with mortality risk with each HLI score predictive of mortality. A similar HLI, different only in how PA was assessed, showed the same results in a large, pooled sample of older U.S. adults [18]. Albeit this study did not include BSI as a main independent predictor. BSI, however, has been shown useful in predicting all-cause mortality proportionally in large national studies [19,20]. Thus, previous findings have in segments corroborated the current findings from this study. In sum then, this research provides novel evidence for the independent associations between HLI and BSI in predicting all-cause mortality in linear fashion in older adults.

The limitations in this study require at least brief mention. First, a large percentage of the baseline sample were excluded due to missing data. Moreover, the current study did not replace these data and instead used a complete-case analysis procedure. Missing data can be problematic for both statistical power and biased estimations. The current study, however, did not suffer from low statistical power. However, it cannot be ruled out that some data were missing due to non-random events. Second, three of the four health metrics used to create the HLI in this study were assessed using participant-reported means. Therefore, it is possible that the HLI scores suffer from some response bias. In sum, the study findings should be considered along with these limitations.

5. Conclusions

These findings indicate that body shape and healthy lifestyle each influence mortality risk in older adults. Additionally, HLI was negatively associated with mortality risk across all BSI quartiles with lower trending risk observed in lower BSI groups. Adopting healthy behaviors and improving abdominal fat metrics should be promoted among adult populations regardless of disease, functioning, or age.

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