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Research Article

Body Mass Index Is Associated with Dietary Patterns and Health Conditions in Georgia Centenarians

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Associations between body mass index (BMI) and dietary patterns and health conditions were explored in a population-based multiethnic sample of centenarians from northern Georgia. BMI $\leq$20 and $\geq$25 was prevalent in 30.9% and 25.3% of study participants, respectively. In a series of logistic regression analyses controlled for gender and place of residence, the probability of having BMI $\geq$25 was increased by being black versus white and having a low citrus fruit, noncitrus fruit, orange/yellow vegetable or total fruit and vegetable intake. The probability of having BMI $\leq$20 was not associated with dietary intake. When controlled for race, gender, residence, and total fruit and vegetable intake, BMI $\geq$25 was an independent risk factor for diabetes or having a systolic blood pressure $\geq$140 mmHg or diastolic blood pressure $\geq$90 mmHg, whereas BMI $\leq$20 was a risk factor for anemia. Given the many potential adverse consequences of under- and overweight, efforts are needed to maintain a healthy weight, even in the oldest old.

1. Introduction

Body mass index is a simple index of weight for height that is frequently used in the assessment of nutritional status. A low BMI, or underweight status, is often associated with an increased risk of mortality in seriously ill or hospitalized older adults [1, 2]. Conversely, a high BMI, indicative of overweight or obesity, is associated with an exacerbation in age-related physical and cognitive decline [3, 4] and with an increased prevalence or risk of many chronic health conditions common in older adults such as diabetes, hypertension, and cardiovascular disease [3–5]. Such associations are typically determined across the entire spectrum of older adults (aged 60+), with no further demarcation within this age classification. Our finding of a much higher prevalence of several nutritional deficiencies in centenarians as compared with octogenarians [6, 7], suggests that there is considerable heterogeneity in nutrient status in the “older adult” age group. Likewise, there may also be considerable heterogeneity within the older adult age group with regard to chronic health conditions. Thus, it is not known whether the associations between underweight or overweight/obesity and chronic health conditions as observed in previous studies of older adults extend to the very old.

Dietary intake patterns featuring a high intake of nutrient-dense foods such as cereals, fruits, vegetables, and low-fat meat and dairy products have been associated with a number of favorable health outcomes in adults including a decreased prevalence of obesity [8, 9], lower rates of weight gain over time [10], and better quality of life and improved survival [11]. In contrast, low-nutrient dense dietary patterns with high intakes of sweets, desserts, and high-fat dairy products have been associated with higher rates of obesity and poor nutritional status in older adults [9]. Whether these observations extend to the very old is unknown. Studies comparing energy intakes and dietary intake patterns of centenarians to younger older adult cohorts have generally observed lower energy and/or fat intake in the centenarians, while dietary preferences of centenarians are considerably more varied and dependent of the region of study likely reflecting cultural patterns and cohort differences rather than longevity-related differences *per se* (reviewed [12]). Nonetheless, there can be considerable variation of body weight status within a given group of centenarians [13], though to our knowledge the extent to which this may be associated with potential differences in dietary intake patterns or selected health conditions has not been explored. Thus, the objectives of this study were to explore associations (1) between BMI and dietary habits and (2) between underweight or overweight/obesity and health status in a population-based multiethnic sample of centenarians (98 years and above) from northern Georgia in the USA. It was hypothesized that overweight/obesity, but not underweight, would be associated with poorer dietary habits and that both overweight/obesity and underweight, as well as dietary habits, would be associated with specific health conditions in this population.

2. Methods

2.1. Study Population. This study was a secondary analysis of data collected by the Georgia Centenarian Study, a population-based multidisciplinary study conducted in 44 counties in northern Georgia (USA) from 2002 to 2005. The original study included 244 centenarians (defined as age 98 and older). The sampling procedures and data collection methods have been described elsewhere [6, 14]. Briefly, recruitment of participants from skilled nursing facilities was based on estimates of the institutionalized population of the area according to the 2000 US Census tabulations. The community dwelling participants resided in private residences and personal care homes and were recruited from voter registration lists. Participants were recruited to match census figures for gender and race/ethnicity (white or black; all were non-Hispanic) and were interviewed by trained personnel in their place of residence. All questionnaires and procedures were approved by the University of Georgia Institutional Review Board on Human Subjects.

2.2. Demographic, Nutrition, and Health Information. Information regarding age, gender, race/ethnicity, living arrangements, health conditions (cardiovascular disease, diabetes, hypertension, etc.), and behaviors (including tobacco and nutritional supplement use) were obtained from each participant (or his/her caregiver) by self-report. Questions regarding food intake, appetite, and weight change were adapted from the Mini-Nutritional Assessment [15, 16] and the response categories for food intake represented current frequency of consumption of food groups, including dairy products (milk, yogurt, and cheese); meat, fish, or poultry; orange/yellow vegetables; green vegetables; citrus and noncitrus fruit and juice. The total food score, ranging from 0 to 5, was based on comparisons with the Dietary Guidelines for Americans [17] 1,600-calorie meal pattern for sedentary older adults, as previously described [16].

Body weight and height were measured by interviewers, obtained from charts or via self-report. In addition, knee height was measured on the right leg, unless contraindicated, to the nearest 0.1 centimeter and used to predict stature as per the formulas of Chumlea et al. [18]. Body mass index (BMI) was calculated as weight (kg)/height (meters)^2. BMI calculated from observed/recorded height and weight was highly correlated with BMI calculated from predicted stature [18] and observed/recorded weight ($r = 0.877$; $P < .0001$). BMI calculated from observed/recorded height and weight was used to form three BMI classifications based on the National Institutes of Health criteria [19] for overweight/obesity and defined as underweight $\leq 20\,\text{kg/m}^2$, normal weight >20 and $<25\,\text{kg/m}^2$, and overweight/obese $\geq 25\,\text{kg/m}^2$. Triceps skinfold (TSF) was measured on the right arm, unless contraindicated, by caliper to the nearest 0.1 millimeter. Mid-arm circumference (MAC) was measured on the right arm, unless contraindicated, to the nearest 0.1 centimeter. Systolic and diastolic blood pressure measurements were obtained with a brachial cuff.

2.3. Biochemical Indices. Nonfasting blood samples were collected as previously described [6, 14]. Hemoglobin was assessed by a clinical diagnostic laboratory (LabCorp, Inc., Burlington, NC) and anemia was defined as hemoglobin <12 g/dL for females or <13 g/dL for males [20].

2.4. Exclusions from Data Analysis. Participants missing data for primary variables of interest were excluded from the present analyses. From the original sample of centenarians, 11 individuals were excluded due to missing data for BMI ($n = 7$; includes one double-amputee), food intake patterns ($n = 1$), average grip strength ($n = 1$), and/or systolic/diastolic blood pressure ($n = 3$). Overall characteristics of the 233 centenarians included in the study are given in Table 1. Compared to the included centenarians ($n = 233$), the excluded centenarians tended to be older (102.6 ± 3.6 versus 100.5 ± 1.9 yrs; $P = .052$), but did not differ in gender (90.9% [excluded] versus 84.6% female), race/ethnicity (72.7% versus 79.0% white), or place of residence (36.4% versus 43.4% skilled nursing facility).

2.5. Statistical Analyses. Means, standard deviations, medians, range of values, and/or frequencies were calculated. Differences between participants with different BMI classifications were assessed with the Wilcoxon rank sum test for continuous variables and Chi square analysis for categorical variables. Probabilities reported are unadjusted for multiple tests. The level of significance was set at $P < .05$.

Because the food groups provide calories, a series of logistic regression analyses were performed with BMI ≤ 20 or BMI ≥ 25 as the dependent variable and gender, race/ethnicity, living arrangements, and reported intake of specific food groups as the independent variables. In addition, because BMI can play a causative role as a risk factor for chronic disease, a second series of logistic regression analyses was performed with diabetes, anemia, or other chronic health conditions as the dependent variable and race, gender, residence, and BMI ≤ 20 or BMI >25 as the independent variables (Model 1). A final series of logistic regression analyses was performed with diabetes, anemia, or other chronic health conditions as the dependent variable and race, gender, residence, total fruit, and vegetable intake and BMI ≤ 20 or BMI >25 as the independent variables (Model 2).

Table 1: Characteristics of study participants.

	Mean ± SD, or % (minimum − maximum)
Age (y)	100.5 ± 1.9 (98–108)
Gender	
Women (%)	84.6
Men (%)	15.4
Race	
White (%)	79.0
African American (%)	21.0
Living arrangements	
Skilled nursing facility (%)	43.4
Community (%)	56.6
Total food score[1]	3.1 ± 1.6 (0–5)
BMI (kg/m^2)	22.5 ± 4.2 (14.0– 35.2)
Mid-arm circumference	23.8 ± 4.3 (7.5–37.1)
Triceps skin fold	11.1 ± 5.7 (2.8–34.0)
Blood pressure (mm Hg)	
Systolic	127.7 ± 15.1 (90–190)
Diastolic	73.8 ± 9.4 (38–100)
Hemoglobin (g/dL)	12.0 ± 1.5 (7.5–16.7)

[1]Total food score ranged from 0 to 5 and one point was given for meeting each recommended serving from five food groups as follows: two or more servings of meat, poultry, or fish daily, two or more servings of dairy foods daily, four or more servings of green vegetables weekly, three or more servings of orange or yellow vegetables weekly, and three or more servings of fruit daily [16].

P-values are unadjusted for multiple comparisons, because all comparisons were preplanned. Analyses were conducted using SAS 9.2 (SAS, Cary, NC).

3. Results

Approximately one-third (31.3%) of the centenarians included in the final analytical sample had a BMI of ≤20 (underweight), 43.8% were classified as being in the normal weight range, and 24.9% met the NIH classification for overweight/obesity (BMI ≥25). Triceps skin fold (TSF) and mid-arm circumference (MAC) of centenarians in the lowest BMI classification averaged below the 5th percentile for females 80+ years in USA based on 2003–2006 NHANES data [21]. Both parameters increased with BMI classification in a stepwise manner (data not shown) and were highly correlated with BMI (Pearson Correlation Coefficient between BMI and TSF = 0.482; and between BMI and MAC = 0.624; $P < .0001$ for both).

Chi-square analysis indicated that those with a BMI ≤20 were more likely to be women, live in a skilled nursing facility, eat a modified food diet, have experienced a weight change in the past three months, and have anemia as compared to centenarians classified as normal weight or overweight/obese (Table 2). Conversely, those with a BMI ≥25 were more likely to be black, diabetic, have a higher systolic blood pressure, and/or have a diastolic blood pressure ≥90 mm as compared to centenarians classified as underweight or normal weight. There were no differences according to BMI classification with regard to history of CVD, cancer, stroke, depression, or past or current tobacco use.

Bivariate analysis of diet intake patterns suggested that centenarians with BMI ≤20 had the highest total food scores and were more likely to report eating two or more servings of meat, fish, and poultry per day and three or more total servings of fruit per day as compared with centenarians in the other BMI classifications. In contrast, those with a BMI ≥25 were more likely to report eating less than one serving of citrus or noncitrus fruit per day, less than four servings of orange/yellow vegetables per week, or three total servings of fruit and vegetables per day (Table 2). A series of logistic regression analyses indicated that when controlled for gender, race, and place of residence the odds of having a BMI ≥25 were about two to three times higher in centenarians with lower intakes of citrus and noncitrus fruit (less than one serving per day), orange and yellow vegetables (less than four servings per week), or total fruits and vegetables (less than three servings per day), but were not related to intake of the meat group or dairy group (Table 3). Similar analyses with BMI ≤20 as the dependent variable, failed to show any significant association with dietary intake categories (Table 3).

Finally, associations between BMI classifications and chronic health conditions were determined in a series of logistic regression analyses that included either BMI ≤20 or BMI ≥25 as an independent variable (Table 4). When controlled for gender, race, and place of residence, the odds of having anemia, based on blood hemoglobin values, were over twofold higher in centenarians with BMI ≤20 versus those with BMI >20 whereas the odds of self-reported CVD tended to be reduced in those in the underweight classification (BMI ≤20; $P = .053$). The latter finding became significant in regression models further controlled for total fruit and vegetable intake (Model 2; $P = .048$). In analyses controlled for gender, race, and place of residence, the odds of having self-reported diabetes or systolic blood pressure ≥140 mmHg were approximately three- and twofold higher, respectively, in centenarians with BMI ≥25 versus those with BMI <25. Being overweight/obese (BMI ≥25) also tended to increase the odds of having diastolic blood pressure >90 mmHg (approximately three-fold; $P = .055$) or cardiovascular disease (approximately twofold; $P = .074$). Further controlling for total fruit and vegetable intake (Model 2) strengthened the associations between BMI ≥25 and diabetes and systolic blood pressure >140 mmHg, and resulted in a significant association between BMI ≥25 and diastolic blood pressure ≥90 mmHg. There were no associations between BMI ≤20 or BMI ≥25 and stroke, depression, or cancer in any of the regression models.

4. Discussion

To our knowledge, this is the first study to explore associations between dietary patterns and body weight status in the oldest old segment of the population. Prevalence of overweight/obesity in this population-based study of

Table 2: Demographics, dietary patterns, and health conditions of centenarians of varying BMI classification: The Georgia Centenarian Study.

	BMI ≤20[1] Median, range, mean ± SD, or %	BMI >20 and < 25[1] Median, range, mean ± SD, or %	BMI ≥ 25[1] Median, range, mean ± SD, or %	*P*
Age	100.5, 98.1–106.0 100.8 ± 1.8	100.2, 98.1–105.2 100.5 ± 1.8	99.6, 98.1–108.5 100.2 ± 2.1	.051
Gender[2]				
Women	34.5 (68)	41.1 (81)	24.4 (48)	.042
Men	13.9 (5)	58.3 (21)	27.8 (10)	
Race[2]				
White	33.2 (61)	46.2 (85)	20.6 (38)	.015
African American	24.5 (12)	34.7 (17)	40.8 (20)	
Living arrangements[2]				
Skilled nursing facility	43.6 (44)	35.6 (36)	20.8 (21)	.002
Community	22.0 (29)	50.0 (66)	28.0 (37)	
B-vitamin supplements[3]				
No	61.6 (45)	63.7 (65)	74.1 (43)	.281
Yes	38.4 (28)	36.3 (37)	25.9 (15)	
Total food score[4]	4.0, 0–5 3.5 ± 1.6[a]	3.0, 0–5 3.0 ± 1.5[ab]	2.0, 0–5 2.8 ± 1.6[b]	.046
<3	37.0 (27)	49.0 (50)	55.2 (32)	.097
≥3	63.0 (46)	51.0 (52)	44.8 (26)	
Meat, fish, poultry intake (servings/day)				
<2	41.1 (30)	57.8 (59)	60.3 (35)	.041
≥2	58.9 (43)	42.2 (43)	39.6 (23)	
Milk and dairy product intake (servings/day)				
<2	45.2 (33)	55.9 (57)	59.6 (34)	.210
≥2	54.8 (40)	44.1 (45)	40.4 (23)	
Green vegetable intake (servings/week)				
<4	6.8 (5)	4.9 (5)	8.6 (5)	.644
≥4	93.2 (68)	95.1 (97)	91.4 (53)	
Orange and yellow vegetable intake (servings/week)				
<3	9.6 (7)	11.8 (12)	20.7 (12)	.148
≥3	90.4 (66)	88.2 (90)	79.3 (46)	
Total fruit (servings/day)				
<3	50.7 (37)	66.7 (68)	70.7 (41)	.034
≥3	49.3 (36)	33.3 (34)	29.3 (17)	
Citrus fruit intake (servings/dly)				
<1	27.4 (20)	34.3 (35)	50.0 (29)	.025
≥1	72.6 (53)	65.7 (67)	50.0 (29)	
Noncitrus fruit intake (servings/day)				
<1	24.7 (18)	34.3 (35)	46.6 (27)	.032
≥1	75.3 (55)	65.7 (67)	53.4 (31)	

Table 2: Continued.

	BMI ≤20[1] Median, range, mean ± SD, or %	BMI >20 and < 25[1] Median, range, mean ± SD, or %	BMI ≥ 25[1] Median, range, mean ± SD, or %	*P*
Orange and yellow vegetable intake (servings/week)				
<4	23.3 (17)	24.5 (25)	41.4 (24)	.038
≥4	76.7 (56)	75.5 (77)	58.6 (34)	
Total fruit and vegetables (servings/day)				
<3	17.8 (13)	25.5 (26)	37.9 (22)	.033
≥3	82.2 (60)	74.5 (76)	62.1 (36)	
Needs help at mealtime				
Yes	42.5 (31)	29.4 (30)	24.1 (14)	.060
No	57.5 (42)	70.6 (72)	75.9 (44)	
Eats a typical diet of regular foods				
Yes	50.0 (36)	77.4 (79)	74.1 (43)	.0003
No-foods modified	50.0 (36)	22.6 (23)	25.9 (15)	
Body weight change in past 3 months				
Loss	28.2 (20)	20.6 (20)	12.3 (7)	.040
Gain	15.5 (11)	7.2 (7)	19.3 (11)	
No	56.3 (40)	72.2 (70)	68.4 (39)	
Appetite loss in past 3 months				
Yes (moderate/severe)	11.3 (8)	13.9 (14)	5.3 (3)	.249
No loss	88.7 (63)	86.1 (87)	94.7 (54)	
Systolic BP, mmHg	122, 90–160 124.4 ± 14.5[a]	125, 100–165 126.2 ± 12.7[a]	130, 110–190 134.4 ± 17.6[b]	.0013
<140	86.3 (63)	81.4 (83)	67.2 (39)	.022
≥140	13.7 (10)	18.6 (19)	32.8 (19)	
Diastolic BP, mmHg	72, 56–100 73.0 ± 8.5	73, 46–100 73.2 ± 8.8	75, 38–100 76.0 ± 11.1	.261
<90	95.9 (70)	96.1 (98)	86.2 (51)	.031
≥90	4.1 (3)	3.9 (4)	13.8 (8)	
Diabetes[5]				
Yes	8.2 (6)	3.9 (4)	15.5 (9)	.036
No	91.8 (67)	96.1 (98)	84.5 (49)	
Anemia[6]				
Yes	63.2 (43)	44.4 (44)	47.4 (27)	.048
No	36.8 (25)	55.6 (55)	52.6 (30)	
CVD[5]				
Yes	58.9 (43)	61.8 (63)	69.0 (40)	.482
No	41.1 (30)	38.2 (39)	31.0 (18)	
Cancers[5]				
Yes	31.5 (23)	31.4 (32)	24.1 (14)	.574
No	68.5 (50)	68.6 (70)	75.9 (44)	
Stroke[5]				
Yes	23.3 (17)	21.6 (22)	22.4 (13)	.964

Table 2: Continued.

	BMI ≤20[1] Median, range, mean ± SD, or %	BMI >20 and < 25[1] Median, range, mean ± SD, or %	BMI ≥ 25[1] Median, range, mean ± SD, or %	P
No	76.7 (56)	78.4 (80)	77.6 (45)	
Depression[5]				
Yes	20.6 (15)	11.8 (12)	10.3 (6)	.163
No	79.4 (58)	88.2 (90)	89.7 (52)	
Current or past tobacco use[5]				
Yes	25.0 (18)	31.4 (32)	28.1 (16)	.654
No	75.0 (54)	68.6 (70)	71.9 (41)	
Current tobacco use[5]				
Yes	1.4 (1)	3.9 (4)	3.5 (2)	.612
No	98.6 (71)	96.1 (98)	96.5 (55)	

[a,b]Means with different superscripts are significantly different, $P < .05$.
[1]$n = 73$ for BMI ≤20; $n = 102$ for BMI > 20 and < 25; $n = 58$ for BMI ≥ 25.
[2] Percentages add up to 100% across a row. Number of participants represented by each percentage is included in brackets ().
[3]B vitamin supplements included multivitamin/mineral, B vitamins, or single oral supplements of vitamin B12.
[4]Total food score ranged from 0 to 5 and one point was given for meeting each recommended serving from five food groups as follows: two or more servings of meat, poultry, or fish daily, two or more servings of dairy foods daily, four or more servings of green vegetables weekly, three or more servings of orange or yellow vegetables weekly, and three or more servings of fruit daily (16).
[5]Information obtained from participant or a proxy by self-report.
[6]Based on laboratory values and defined as hemoglobin <12 g/dL for females or <13 g/dL for males (20).

Table 3: Associations of dietary intake patterns with underweight or overweight/obesity in Georgia centenarians.

Independent Variable	BMI ≤20[a] Odds ratio (95% CI)	P	BMI ≥ 25[b] Odds ratio (95% CI)	P
Meat, <2 servings/day	0.83 (0.40–1.70)	.608	1.17 (0.54–2.53)	.685
Dairy, <2 serving/day	0.93 (0.48–1.78)	.819	1.18 (0.57–2.42)	.660
Fruit & vegetables, <3 servings/day	0.75 (0.35–1.59)	.450	2.12 (1.04–4.32)	.039
Orange/yellow vegetables, <4 servings/week	1.17 (0.56–2.44)	.684	2.27 (1.11–4.65)	.025
Citrus fruit, <1 serving/day	0.77 (0.40–1.50)	.445	2.40 (1.20–4.76)	.013
Noncitrus fruit, <1 serving/day	0.73 (0.36–1.45)	.362	2.18 (1.09–4.38)	.028

[a]Determined by a series of logistic regression analyses with BMI ≤20 versus BMI ≥20 as the dependent variable, controlled for gender, race, and residence.
[b]Determined by a series of logistic regression analyses with BMI ≥25 versus BMI <25 as the dependent variable, controlled for gender, race, and residence.

centenarians was approximately 25%, which was considerably below the prevalence for these conditions in the overall population of older adults, aged 60 and above, in the USA at the time of data collection (~69%; [22]). In analyses controlled for gender, race, and place of residence, several parameters indicative of a low frequency of fruit and vegetable intake were associated with overweight/obesity (BMI ≥25), whereas there were no associations between frequency of intake of meat, dairy, and fruits and vegetables and being underweight (BMI ≤20). Other findings include strong associations of underweight with anemia and of overweight/obesity with diabetes and high blood pressure, extending knowledge of such associations to the very old.

The present research was part of a large, multidisciplinary study across a range of cognitive, mental, physical, and health-associated domains exploring the role of various factors pertinent to the survival and functioning of centenarians. To decrease testing burden for participants, dietary intake data focused on frequency of intake of specific food groups selected based on the Dietary Guidelines for Americans and age-related associations with nutritional deficiencies and chronic diseases [16, 17]. Notably, we observed that based on frequency of intake and regardless of BMI classification, a large percentage of centenarians were not meeting the dietary guidelines for many food groups, with the exception of green and orange/yellow vegetables. This later finding is consistent with an apparent preference for sweet potatoes and green vegetables reported for an earlier convenience sampling of Georgia centenarians [23, 24]. Such preferences likely are reflective of the traditional diet of the Southeastern USA, rather than longevity-related differences in dietary patterns, and may not be replicable in other regions and cultures.

Our initial analysis indicated a greater intake of meat and total fruits in the underweight centenarians, suggesting that they were eating better than those in the normal weight and

Table 4: Associations of underweight or overweight/obesity with health conditions or indicators in Georgia centenarians.

	BMI ≤20[a]		BMI ≥ 25[b]	
Dependent variable	Odds ratio (95% CI)	P	Odds ratio (95% CI)	P
Diabetes				
Model 1	0.91 (0.30–2.69)	.858	2.86 (1.02–7.99)	.045
Model 2	0.89 (0.30–2.64)	.837	3.11 (1.11–8.75)	.031
Anemia				
Model 1	2.47 (1.32–4.62)	.004	0.72 (0.38–1.36)	.309
Model 2	2.47 (1.32–4.62)	.005	0.72 (0.38–1.37)	.318
Systolic BP ≥140 mmHg				
Model 1	0.72 (0.32–1.61)	.425	2.09 (1.02–4.27)	.043
Model 2	0.70 (0.31–1.57)	.385	2.26 (1.09–4.69)	.029
Diastolic BP ≥90 mmHg				
Model 1	0.81 (0.25–3.18)	.760	2.96 (0.98–9.01)	.055
Model 2	0.71 (0.18–2.79)	.621	3.81 (1.21–12.05)	.022
CVD				
Model 1	0.54 (0.29–1.01)	.053	1.85 (0.94–3.64)	.074
Model 2	0.53 (0.28–1.00)	.048	1.95 (0.98–3.88)	.058
History of cancer				
Model 1	1.09 (0.58–2.07)	.791	0.82 (0.40–1.66)	.575
Model 2	1.08 (0.57–2.05)	.818	0.87 (0.42–1.77)	.694
Stroke				
Model 1	0.91 (0.46–1.82)	.791	1.18 (0.57–2.47)	.655
Model 2	0.91 (0.46–1.83)	.794	1.18 (0.56–2.47)	.667
Depression				
Model 1	1.12 (0.49–2.57)	.782	0.89 (0.32–2.50)	.829
Model 2	1.22 (0.53–2.80)	.640	0.91 (0.32–2.58)	.854

[a] Determined by a series of logistic regression analyses with BMI ≤20 versus BMI >20 as an independent variable, controlled for gender, race, and residence (Model 1) or for gender, race, residence, and total fruit and vegetable intake (<3 servings/day = 1; >3 servings/day = 0) (Model 2).
[b] Determined by a series of logistic regression analyses with BMI ≥25 versus BMI <25 as an independent variable, controlled for gender, race, and residence (Model 1) or for gender, race, residence, and total fruit and vegetable intake (<3 servings/day = 1; >3 servings/day = 0) (Model 2).

overweight/obese classifications. The underweight centenarians also had the highest total food scores, suggesting that they were meeting more of the recommended servings for specific food groups [17]. However, almost twice as many underweight centenarians lived in skilled nursing facilities as compared to the community, and there was no association between low BMI and dietary groups after controlling for race, residence, and gender. In a specific comparison between centenarians residing in skilled nursing facilities and in the community, Johnson et al. [16] reported that those in skilled nursing facilities were more likely to eat three or more meals a day and to have a higher frequency of intake of most food groups. They suggested that such differences may be due to (1) the requirement that skilled nursing facilities serve meals that meet dietary guidelines and other federal nutrition policies [25, 26], (2) the inability of the methodology used to distinguish between food that was served and food that was eaten, and (3) barriers faced by community dwelling centenarians or their caregivers in purchasing, preparing, or consuming appropriate food to meet their nutritional needs. Thus, associations in centenarians between low BMI and dietary status may be quite complex and influenced considerably by place of residence.

In the present study, there was an increase in the relative risk for being overweight/obese in centenarians reporting the lowest frequency of intake of some nutrient dense foods including orange/yellow vegetables and citrus and noncitrus fruits. These observations are consistent with previous studies finding associations between lower reported or inferred consumption of fruits and/or vegetables and increased prevalence of overweight/obesity in children [27] and young to middle-age adults [5, 28–30]. Interestingly, other studies in adults have indicated that increased consumption of fruits and vegetables may be an effective strategy for decreasing energy consumption and for increasing and maintaining weight loss [29, 31, 32]. In addition to potential beneficial effects on body weight, there is considerable evidence in other age groups that high consumption of fruits and vegetables may offer protective effects against and/or to reduce the relative risk of cardiovascular disease, hypertension, diabetes, and certain cancers [33–40]. We observed that centenarians in the highest weight category (BMI ≥25) reported eating lower amounts of certain types of fruits and vegetables than their nonoverweight/nonobese counterparts and also appeared to be at greater risk for diabetes, high blood pressure, and cardiovascular disease.

This suggests that a high intake of fruits and vegetables may be beneficial for maintaining optimal weight, and perhaps decreasing risk of chronic disease, even at very advanced age. However, additional, ideally longitudinal, research collecting more detailed food intake data is needed to support this contention. In addition, as social isolation, missing teeth, digestion difficulties, poor self-reported health, cost and preparation issues have been identified as barriers to fruit and vegetable intake in older adults [41–43], research is needed to determine if and to what degree these or other potential barriers may be influencing the intake of fruit, vegetables, and other low energy, high nutrient dense foods in the very old.

Clinically defined anemia was present in greater than 60% of the centenarians in the lowest BMI grouping. After controlling for demographic covariates, a strong association remained between low BMI and anemia but not with other health conditions and indicators. Accordingly, low BMI had been identified as an independent correlate or risk factor for anemia in some previous studies in older adults and clinical populations [44–46], but not in others [47]. Although older adults with a low BMI are considered to be at nutritional risk [47, 48], it cannot be assumed that the anemia observed in underweight older adults is primarily of dietary or nutritional etiology. Indeed, our previous studies indicate a similar prevalence of anemia in vitamin B12-deficient and vitamin B12-adequate in Georgia centenarians [7] and a high prevalence of inflammatory anemia, either alone or in combination with nutritional deficiencies, in this population [49]. Nonetheless, as anemia is associated with increased mortality in acute and chronic disease states, particularly in those underweight [50, 51], it is important to monitor and treat this condition, as appropriate, in the very old.

In summary, this secondary analysis provides evidence of an inverse association between fruit and vegetable intake and body weight status in a population-based study of centenarians. In addition, both underweight and overweight emerged as potential risk factors for various chronic diseases, emphasizing the importance of monitoring weight and of maintaining a healthy weight, even at very advanced ages. A major strength of the study is the inclusion of a population-based sampling of centenarians with greater diversity in race, place of residence, and functional status than would be typically obtained with a convenience sample. Limitations of the study include the relatively small sample size, lack of information regarding physical activity, and reliance on data of frequency of intake for only a few food groupings rather than the use of a more extensive food frequency questionnaire including individual foods and serving sizes as per our earlier convenience study of centenarians [23, 24]. Absence of intake data on key dietary components including grains/cereals and sweets/desserts necessitated the use a series of nonindependent binary logistic regression models instead of a more complex, single multinomial logistic regression to explore potential associations between BMI and dietary intake patterns. Thus, specifically designed studies including more detailed information of dietary intake, physical activity data, and additional chronic disease indicators are needed to verify associations, or lack thereof, between dietary intake patterns, weight status, and chronic health conditions in the very old. Furthermore, as dietary habits and other characteristics of this sample from Georgia likely differ from those of centenarians from other countries and cultures, our findings need replication in other population groups.

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