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Lower Nutritional Status and Higher Food Insufficiency in Frail Older US Adults

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Abstract

Frailty is a state of decreased physical functioning and a significant complication of aging. We examine frailty, energy and macronutrient intake, biomarkers of nutritional status, and food insufficiency in US older adult (age ≥60 years) participants of the Third National Health and Nutrition Examination Survey (n=4731). Frailty was defined as meeting ≥2 and pre-frailty as meeting 1 of the following 4 item criteria: 1) slow walking; 2) muscular weakness; 3) exhaustion, and 4) low physical activity. Intake was assessed by 24-hour dietary recall. Food insufficiency was self-reported as “sometimes” or “often” not having enough food to eat. Analyses adjusted for gender, race, age, smoking, education, income, BMI, other comorbid conditions, and complex survey design. Prevalence of frailty was highest among people who were obese (20.8%), followed by overweight (18.4%), normal weight (16.1%), and lowest among people who were underweight (13.8%). Independent of BMI, daily energy intake was lowest in people who were frail, followed by pre-frail, and highest in people who were not frail (mean kJ ± SE: 6648±130, 6966±79, 7280±84, respectively, $p<0.01$). Energy adjusted macronutrient intakes were similar in people with and without frailty. Frail (adjusted odds ratio (AOR)= 4.7, 95% CI 1.7-12.7) and pre-frail (AOR=2.1, 95% CI 0.8-5.8) people were more likely to report being food insufficient than not frail people. Serum albumin, carotenoids, and selenium levels were lower in frail adults than not frail adults. Research is needed on targeted interventions to improve nutritional status and food insufficiency among frail older adults, while not necessarily increasing BMI.

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Keywords

Frailty; nutritional status; food insufficiency

Introduction

Geriatric syndromes are a loosely defined group of conditions highly prevalent in older adults but not considered discrete diseases; these include frailty, among others.[1] Frailty is a state of decreased physical functioning and a significant complication of aging that increases the risk for incident falls, fractures, disability, comorbidity, health care expenditure, and premature mortality.[2-4] In 2010, the proportion of US adults 65 years of age and older was 13%; however, by 2030 it is projected that about 20% of the population will be older than 65 years of age, a 54% increase. This shift in age demographics will have a substantial impact on the prevalence of frailty and highlights the need for identifying clinical and population-based strategies to decrease the prevalence and consequences of frailty.[5, 6]

Several studies have shown a potential association between nutrition and frailty. Specifically, low energy and protein intake and low serum nutrients have shown to be positively associated with frailty.[7, 8] Studies have either been relatively small or with women only. Food insufficiency occurs when persons sometimes or often do not have enough food to eat. Food insufficient older adults have been shown to have poorer dietary intake, nutritional status and health status than food sufficient older adults.[9] Although little is known about food insufficiency as it relates to frailty, conceivably if food insufficiency is associated with poorer nutritional status, it may also be associated with physical functioning[10]and frailty. Given the potential importance of nutrition on frailty and the amenability to intervention, we examine the association between nutritional status, food insufficiency, and prevalent frailty in a representative sample of the US older adult population.

Methods

Study Participants

The study population consists of adults aged 60 years and older who took part in the Third National Health and Nutrition Examination Survey (NHANES III). Briefly, the NHANES III is a nationally representative sample of the population that used a stratified random sample of the civilian non-institutionalized population, drawn from 50 states in the United States and the District of Columbia during 1988-1994.[11] The analytic sample for this study consists of older adults (60+ years) with complete data on each frailty criteria (n=4731). This particular survey period was chosen for the availability of frailty measures, which are not available in more recent survey years. The NHANES III was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the National Center for Health Statistics ethics committee. Written informed consent was obtained from all survey participants. The secondary data analysis for our study was deemed exempt by Oregon State University Institutional Review Board.

Frailty

A clinical definition of the frailty phenotype has been developed by Fried and colleagues[3] for the general aging population and is widely used and validated by others.[4, 12-14] The definition is based on meeting 3 of following 5 criteria: unintentional weight loss, slowness, muscle weakness, exhaustion, and low physical activity. Given that our goal was to examine the association between energy intake and frailty, and because information on unintentional weight loss is not available in NHANES III, we excluded weight loss in our definition of frailty. This approach is similar to and modeled after the definition used by Bartali et al in the InCHIANTI study.[8] InCHIANTI (Invecchiare in Chianti, aging in the Chianti area) is a community-based study of risk factors for disability performed in 1299 participants ages 65 years or older in Italy. The definition of frailty in the InCHIANTI study follows four of the five domains of frailty by Fried et al.[3] Similarly, we defined frailty based on the four domains by Fried et al.[3] These are: 1) slow walking; 2) muscular weakness; 3) exhaustion, and 4) low physical activity. Participants were classified as frail if they met 2 of these 4 criteria. Participants who met 1 of the 4 criteria were classified as pre-frail, and participants meeting none of the criteria were classified as not frail.

The specific measurement tools for each of the four frailty criteria were selected based on similar measurements or similar questions to those used by Fried et al, and the measurement tools that have been operationalized by other studies on frailty in NHANES III.[3, 15-17] A timed 8 foot walk test was performed twice and the best time (seconds) for the 8 foot walk was used for each participant. A participant was classified as a slow walker if their best time for the 8 foot walk was within the slowest quintile adjusted for sex. Participants were asked whether they had no difficulty, some difficulty, much difficulty or were unable to lift or carry something as heavy as 10 pounds (like a sack of potatoes or rice) when they were by themselves and without the use of aids. Participants who responded to this question as having some or much difficulty or unable to lift or carry that amount were classified as having muscular weakness. Participants were also asked whether they had no difficulty, some difficulty, much difficulty, or were unable to walk from one room to another on the same level. Participants who responded to this question as having some or much difficulty or unable to walk from room to room were classified as having exhaustion. Participants who considered themselves as less active when compared with most (men/women) of the same age were classified as low physical activity.

Dietary intake and food insufficiency

One 24-hour recall was collected during the visit to the mobile examination center (MEC). Dietary intake may differ by weekday, especially weekend days. To capture intake on all days of the week, the 24 hour recalls were collected on every day of the week. The dietary interviewers used the Dietary Data Collection (DDC) system, which is an automated standardized interactive dietary interview and coding system. The system was specifically developed for NHANES III by the University of Minnesota Nutrition Coordinating Center.[18] Participants with 24 hour recalls that were noted as incomplete or as unreliable during the interview were excluded (n=178). All energy intake values from participants with reliable 24 hour recalls were included in the final analysis, after preliminary analysis showed similar results with and without excluding outlying intakes (data not shown).

Food insufficiency was determined by asking participants if the food eaten by them and/or their families was enough food to eat, sometimes not enough food to eat, or often not enough to eat. Respondents were considered to be food insufficient if they reported sometimes not enough food to eat, or often not enough to eat. This has been found to be a reliable measure of food insufficiency[19] and has been used by others.[20, 21]

Biochemical variables

Blood concentrations were determined on a specimen obtained by venipuncture during the visit to the MEC. Details of the laboratory procedures can be found in the Laboratory Procedures Used in NHANES III.[11] Albumin was measured with the Boehringer Manneheim Diagnostics (BMD, Indianapolis, IN, US) albumin system and the bromocresol purple binding agent. Folate was measured by using the Bio-Rad Laboratories "Quantaphase Folate" radioassay kit (Hercules, CA, US). Serum levels of vitamins (vitamins A, B_{12}, C, and E, carotenoids) were measured by isocratic high-performance liquid chromatography with detection at three different wavelengths. Serum selenium was measured using atomic absorption spectrophotometry.

Covariates

We selected covariates based on known factors associated with frailty and/or nutritional status, including age, BMI, race-ethnicity, gender, smoking, education, income, and presence of chronic diseases. Self-reported race and ethnicity were used to classify participants as non-Hispanic white, non-Hispanic black, or Mexican-American (i.e., persons of Mexican origin living in the United States). Age was defined as the age in years at the time of the household interview. Education was based on number of years the participant attended and completed school, and coded as less than high school, high school, and more than high school. During the medical examination, height was measured using a stadiometer and weight was measured on a balance beam scale. Height and weight data were then used to calculate BMI (weight (kg)/height^2 (m)). BMI was categorized into underweight (BMI<18.5), normal weight (BMI 18.5-24.9), overweight (BMI 25-29.9), and obese (BMI ≥30). Smoking history was assessed during the interview and classified into current, former, or never smokers. For this study presence of current or history of chronic diseases related to physical function was based on affirmative responses to the following physician diagnosed self-reported chronic conditions: lupus, osteoarthritis, rheumatoid arthritis, bronchitis, stroke, asthma, congestive heart failure, emphysema, heart attack, cancer, and chronic low back pain.

Analysis

Total and adjusted means, variances and prevalences were calculated using multivariate linear and multinomial logistic regression models. Sample weights, provided by the National Center for Health Statistics, were used to correct for differential selection probabilities and to adjust for non-coverage and non-response. Logistic regression models with frailty as the outcome were used to obtain adjusted odds ratios. Covariates that were significantly ($p<0.05$) associated with frailty in the univariate models were included in the multivariate models, namely age, BMI, race-ethnicity, gender, smoking, education, income, and presence of chronic diseases. Additional models related to the macronutrients also adjusted for energy

intake where appropriate. All analyses were completed using STATA (version 10.0, College Station, TX, US).

Results

The prevalence of frailty in US adults aged 60 years and older was 21.7%, and the prevalence of pre-frailty was 27.4%. Characteristics of frail, pre-frail, and not frail older adults are shown in table 1. Among frail people, weakness was the most common criteria met, followed by slow walking, low physical activity, and exhaustion (85, 74, 62 and 30%, respectively). Frail people were older, less educated, at lower income levels, more likely to be female and current smokers, and less likely to be white than adults who were not frail. Frail people were more likely to be underweight or obese than people who were not frail. In addition, frail people were more likely to report being food insufficient. In fact, people who were frail were 4.69 (95% CI 1.73-12.67) times more likely to report food insufficiency than people who were not frail, after adjusting for age, gender, race-ethnicity, smoking status, education, BMI and co-morbidity (data not shown). Pre-frail people were 2.14 (95% CI 0.79-5.76) times more likely to report food insufficiency than people who were not frail. In general, pre-frail older adults had values for demographics, BMI and food insufficiency in between the values for frail and not frail adults. For example, the prevalence of obesity was 32% among frail people, 26% among pre-frail people, and 21% among not frail people.

Energy intake was lowest in people who were frail, followed by pre-frail, and highest in people who were not frail, independent of BMI (see table 2). Crude dietary intake of grams of total fat, monounsaturated fat, carbohydrates, and protein were lower in people who were frail (57.9± 1.7, 21.7± 0.6, 201±4.1, 64.0±1.2, respectively) than people who were not frail (63.6±1.1, 24.4±0.4, 223±3.0, 68.9±0.7, respectively)(data not shown). However, after adjusting for differences in energy intake, intake of all macronutrients was similar among frail and not frail people (see table 2). For example, protein intake, either as a percent of total energy intake or as grams adjusted for energy intake, was similar for frail, pre-frail, and not frail people. Plant and animal protein intake were also similar. Biomarkers of nutritional status are shown in table 3. Serum albumin, carotenoids, and selenium levels were significantly lower in people who were frail than people who were not frail.

To examine if one particular criterion for frailty accounts for most of the lower energy intake, we evaluated average energy intake between people that met or did not meet each of the 4 frailty criteria (see table 4). Energy intake was lower in people who met each of the criteria than people who did not meet each of the respective criteria. For example, energy intake was lower in people who reported exhaustion than people who reported no exhaustion. Similarly, underweight, obesity and food insufficiency were consistently higher in people who met each individual criterion than people who did not meet that particular criterion.

We examined frailty by BMI categories, and found that the prevalence of frailty was highest among people who were obese (20.8%), followed by overweight (18.4%), normal weight (16.1%), and lowest among people who were underweight (13.8%)($p<0.01$). We also compared energy intake levels for people who are frail and not frail by BMI categories. For

each BMI category, energy intake was consistently lower in people who were frail than people who were not frail ($p<0.01$). The difference in energy intake between people who were frail and not frail was highest among people who were obese (1367 kJ), followed by overweight (1294 kJ), normal weight (1220 kJ), and lowest among people who were underweight (1148 kJ). Energy intakes by BMI category among pre-frail older adults were in between the values for frail and not frail adults (data not shown).

Discussion

We examined dietary intake and markers of nutritional status in relation to frailty in a population of US adults aged 60 years and older. Energy intake was lowest in frail, intermediate in pre-frail, and highest in people who were not frail, independent of BMI. Our findings are in agreement with Bartali et al. who, using a similar definition of frailty as our study, examined frailty in 802 persons 65 years of age and older in the InCHIANTI study. They reported energy intake to be lower in frail adults independent of BMI.[8]

In contrast to other studies, we found that protein intake, either as energy adjusted grams of protein or as a percent of energy intake from protein, did not differ between people who were frail or not frail. The Women's Health Initiative (WHI) observed that protein intake as a percentage of energy intake, but not absolute protein intake, was positively associated with the incidence of frailty in 24,417 women aged 65 to 79 years of age.[7] The InCHIANTI study reported that low protein intake, defined as the lowest quintile of intake in grams per day, was positively associated with frailty.[8] Differences in our findings may in part be due to differences in study design, study geographical location, and analysis, where the WHI study examined the association of protein intake with the incidence of frailty in US women only and the InCHIANTI study reported prevalence of low protein (lowest quintile) intake by frailty status in Italy. NHANES III includes a single 24-hour recall, which provides reasonable group means, but less reliably classifies people in to low intakes of nutrients. Differences may also in part be due to differences in the frailty definition: the WHI study used the 5 domains of frailty including unintentional weight loss, while our study and the InCHIANTY study used 4 domains excluding weight loss. We analyzed our results by including a fifth domain to reflect low BMI (BMI <18.5) in our definition of frailty as done by others[15, 16], and results did not change substantially (data not shown).

Along with lower energy intake, frail people were more likely to be food insufficient than not frail people. Food insufficiency reflects an inadequate amount of food due to lack of resources and to our knowledge has not been examined in relation to frailty by others. The lower energy intake and higher food insufficiency among people with frailty suggests that food sufficiency and energy intake may be important in the assessment and treatment of frailty. Further, our findings of a higher prevalence of both underweight and obesity among people who are frail are also in agreement with other studies.[22-24] Hubbard et al. in the English Longitudinal Study on Aging showed a U shaped association between BMI and frailty.[22] Similarly, Blaum et al. in the Women's Health and Aging Study showed a positive association between obesity and frailty.[23] Thus, obesity does not preclude frailty, and the lower energy intake and higher food insufficiency in frail people occur across all categories of BMI.

Our findings of lower serum selenium and carotenoids and borderline lower levels of serum vitamins C and E are also in support of others.[25-27] Semba et al using data from the Women's Health and Aging Study, found that women who were frail had lower serum selenium and vitamin E.[25] Similarly, lower serum albumin has been shown to be associated with greater loss of muscle mass.[26] The lower serum albumin among frail people in our study may be an early indicator of impending muscle strength decline as suggested by the results by Schalk et al.[27] Thus, the lower energy intake, lower serum albumin and lower serum nutrients indicate a lower nutritional status in people who are frail compared to people who are not frail. Energy balance may be present in persons who have both lower energy intake and lower physical activity. Low physical activity is one of the criteria of frailty, and energy intake was lower among people who were frail, suggesting potential energy balance in people who are frail. Regardless of the possible energy balance, frail people experienced lower serum nutrients and higher food insufficiency.

Strengths of our study include dietary intake, serum nutrients, and frailty measures on a representative sample of the civilian, non-institutionalized older U.S. adult population, and detailed data on important covariates. Limitations include the use of cross-sectional data which limits our ability to assess cause and affect relationships. Nevertheless, these data are very useful in estimating frailty and describing nutritional status in the US population. Frailty measures were available for NHANES III (1988-1994) and were not available for more recent survey year. Given the aging population and the importance of physical function and nutrition in older adults, what we learn from NHANES III can be applicable today. The 24-hour recall does not reflect usual or individual intake, yet it does provide reasonable group estimates of dietary intake[28] for comparison of intake between frail, pre-frail and not frail people. Our estimates of food insufficiency are based on a single question and compared to more comprehensive measures may underestimate the prevalence of food insufficiency.[29] Pilot testing of the NHANES food insufficiency measure has shown it to be reliable[19], and others have published results using these data.[20, 21]

The definition of frailty was based on a modification of the Fried et al[3] criteria to fit the available NHANES data, excluding unintentional weight loss. The criteria "weakness" was based on interview data since measured grip strength was not available in NHANES. Other criteria were based on interview questions in both Fried et al and this study, with questions varying slightly. The definition of frailty used in this study is consistent with the definition of frailty used by others [15, 16] and has strong face validity. Moreover, our study focused on energy intake and serum nutrients as a measure of nutritional status rather than weight loss. This approach allowed us to take a close look at the association between BMI and frailty.

Conclusions

In summary, we found that the prevalence of frailty increases with increasing BMI and that energy intake is consistently lower among frail than not frail older adults. Further, frail older adults are more likely to be food insufficient and have lower serum selenium, carotenoids and albumin levels than older adults who are not frail. More research is needed on the energy balance of frailty, and on interventions that allow simultaneously improving nutritional status and food insufficiency among frail older adults, while not necessarily

increasing BMI. In the meantime, our results suggest that targeted interventions should focus on promoting availability and access to nutritious foods among older adults with frailty.

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Table 1

Characteristics of NHANES III adults ages 60 years and older by frailty; weighted means or percentages and SE.

	Frail n = 1,028		Pre-frail n = 1,294		Not frail n = 2,409		p-value
	Mean	SE	Mean	SE	Mean	SE	
Age, yrs	73.1	0.5	71.8	0.4	69.4	0.3	< 0.001
Gender, %							< 0.001
Male	35.7	2.0	36.7	1.9	46.1	1.0	
Female	64.3	2.0	63.3	1.9	53.9	1.0	
Race-ethnicity, %							< 0.001
White	74.5	2.6	82.7	1.9	87.8	1.2	
Black	14.3	1.8	10.0	1.2	6.0	0.7	
Mexican	4.1	0.4	2.6	0.3	1.7	0.1	
Other	7.2	2.1	4.7	1.4	4.5	0.9	
Education, %							< 0.001
Less than high school	59.3	3.1	44.1	2.9	35.6	1.9	
High school	24.7	2.0	32.1	1.5	31.7	1.4	
More than high school	16.0	2.5	23.8	2.4	32.7	1.7	
Income, %							< 0.001
Less than $20,000	54.2	2.9	47.1	2.8	36.3	1.7	
$20,000-34,999	17.9	2.0	21.7	2.0	28.7	1.3	
$35,000 or more	27.8	2.7	31.2	2.4	35.0	1.9	
BMI status, %							< 0.001
Underweight	3.3	0.9	2.3	0.7	1.7	0.3	
Normal weight	32.3	1.9	35.8	2.1	35.6	1.7	
Overweight	32.3	2.0	36.0	1.9	41.6	1.4	
Obese	32.1	2.5	25.8	1.5	21.1	1.2	
Employment, %							0.02
Working	1.5	0.8	0.8	0.4	2.9	0.6	
Retired	67.3	2.3	68.8	2.3	71.1	1.3	
Keeping house	26.0	2.4	27.6	2.3	23.6	1.3	
School or laid off	5.2	1.3	2.7	0.8	2.4	0.4	
Smoking, %							< 0.01
Current Smoker	19.2	2.4	16.0	1.6	14.0	1.0	
Previous Smoker	34.4	2.6	36.7	2.2	43.1	1.4	
Never Smoked	46.4	2.2	47.2	2.2	42.9	1.4	
Food insufficiency, %							< 0.001
Secure	94.9	1.2	98.1	0.5	99.2	0.2	
Insecure	5.1	1.2	1.9	0.5	0.8	0.2	
Frailty Criteria							n/a
Slow Walking, % yes	74.1	2.3	35.7	1.9	0.0		
Weakness, % yes	84.6	1.5	35.3	1.7	0.0		

	Frail n = 1,028		Pre-frail n = 1,294		Not frail n = 2,409		p-value
	Mean	SE	Mean	SE	Mean	SE	
Exhaustion, % yes	29.9	2.2	29.2	1.0	0.0		
Low Physical Activity, % yes	61.9	2.4	26.1	1.9	0.0		

Table 2

Dietary intake of macronutrients in NHANES III adults ages 60 years and older by frailty; weighted means SE †

	Frail n = 1,028		Pre-frail n = 1,294		Not frail n = 2,409	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
Energy, kJ*	6648	128	6966	81	7286	84
Fat, g ††	61.8	0.7	61.3	0.4	60.8	0.6
% of energy	31.8	0.4	31.8	0.2	31.9	0.4
Saturated fatty acids, g ††	20.9	0.4	20.4	0.2	19.9	0.3
% of energy	10.7	0.2	10.6	0.1	10.5	0.1
Monounsaturated fatty acids, g ††	23.3	0.3	23.3	0.1	23.3	0.3
% of energy	11.9	0.2	12.0	0.1	12.2	0.2
Polyunsaturated fatty acids, g ††	12.8	0.4	12.8	0.2	12.8	0.2
% of energy	6.6	0.2	6.6	0.1	6.7	0.1
Carbohydrates, g ††	211.0	2.1	213.3	1.3	215.5	1.6
% of energy	51.7	0.5	51.9	0.3	52.0	0.4
Protein, g ††	67.0	0.8	66.9	0.5	66.9	0.6
% of energy	16.5	0.2	16.4	0.1	16.3	0.2
Animal protein, g ††	64.5	0.8	64.1	0.5	63.6	0.5
% of energy	10.8	0.2	10.7	0.2	10.6	0.2
Plant protein, g ††	35.5	0.8	35.9	0.5	36.4	0.5
% of energy	5.2	0.1	5.3	0.1	5.4	0.0

† Adjusted for age, gender, race-ethnicity, smoking, education, income, BMI, and co-morbidity

†† Also adjusted for energy intake

* $p<0.001$

Table 3

Biomarkers of nutritional status serum in NHANES III adults ages 60 years and older by frailty; weighted means and SE †

	Frail		Pre-frail		Not frail		p-value
Albumin, g/dL							0.002
(3.4-5.4 g/dL) ††	3.98	0.0	4.02	0.0	4.06	0.0	
Folate, ng/mL							0.84
(2.7-17.0 ng/mL)††	9.3	0.6	9.1	0.3	8.9	0.3	
Selenium, ng/mL							0.004
(70-150 ng/mL)††	122.6	1.0	124.2	0.8	125.8	0.8	
Total Carotenoids,* ug/dL							0.01
(48-200 ug/dL)††	75.1	1.8	78.8	1.1	82.5	1.5	
Vitamin A, ug/dL							0.43
(32.5-78.0 ug/dL)††	63.7	1.1	63.7	0.7	63.6	0.6	
Vitamin B12, pg/mL							0.57
(200-900 pg/mL)††	471.1	19.2	487.5	11.7	503.9	20.9	
Vitamin C, mg/dL							0.07
(0.2-2.0 mg/dL)††	0.77	0.0	0.81	0.0	0.85	0.0	
Vitamin E, ug/dL							0.07
(550-1700 ug/dL)††	1352.1	31.1	1383.2	19.6	1414.2	24.9	

† Adjusted for age, gender, race-ethnicity, smoking, education, income, BMI, and co-morbidity

†† Normal reference range

* Sum of beta carotene, beta cryptoxanthin, lutein/zeaxanthin, and lycopene

Table 4

Energy intake, underweight and obesity, and food insufficiency for each of the frailty criteria in NHANES III adults ages 60 years and older; weighted means and SE, or percent.*

	Energy Intake†		Food Insufficient †, %	Underweight, %	Obese, %
	Mean	SE			
Slow Walking					
Yes	6770	121	37.0	2.5	29.2
No	7201	84	19.3	2.0	22.5
Weakness					
Yes	6837	121	50.2	3.6	22.5
No	7163	80	20.4	1.7	28.4
Exhaustion					
Yes	6489	293	16.1	4.3	33.7
No	7125	75	4.8	2.0	23.3
Low Physical Activity					
Yes	6569	172	37.7	2.9	33.3
No	7184	71	15.1	2.0	22.1

† Adjusted for age, gender, race-ethnicity, smoking status, education, income, BMI, and comorbidity

* All p-values for differences by frailty criteria were significant at $p<0.01$. P values were obtained using linear regression for continuous variables and chi-square tests for categoricalvariables.