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Physical Activity, Diet Quality, and Mortality among Community-Dwelling Prefrail and Frail Older Adults

Justin C. Brown¹, Michael O. Harhay¹, and Meera N. Harhay²

¹Center for Clinical Epidemiology & Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania

²Division of Nephrology, Department of Medicine, Drexel University College of Medicine, Philadelphia, Pennsylvania

Abstract

It is unknown if physical activity and diet quality are associated with the risk of poor outcomes, such as mortality, among prefrail and frail older adults. This was a population-based cohort study among 1,487 prefrail and frail older-adults from the Third National Health and Nutrition Survey. Compared to participants who were sedentary (0 bouts of physical activity per week), those who were physically inactive (1–4 bouts of physical activity per week) were 24% less likely to die [HR: 0.76 (95% CI: 0.58–0.98)], and those who were physically active (≥ 5 bouts of physical activity per week) were 34% less likely to die [HR: 0.66 (95% CI: 0.51–0.86); $P_{\text{trend}}=0.002$]. Compared to participants with poor diet quality, those with fair diet quality were 26% less likely to die [HR: 0.74 (95% CI: 0.52–0.98)], and those with good diet quality were 33% less likely to die [HR: 0.67 (95% CI: 0.55–1.00); $P_{\text{trend}}=0.050$]. There was a synergistic interaction between physical activity and diet quality on the risk of mortality ($P_{\text{interaction}}=0.058$). Participation in physical activity and consumption of a healthy diet is associated with a lower risk of mortality among prefrail and frail older adults.

Keywords

Exercise; lifestyle; population-based; energy balance; behavior

INTRODUCTION

Frailty is a syndrome of poor global health characterized by features of unintentional weight loss, impaired physical function, weakness, exhaustion, and low levels of ambulatory activity (1). Prefrailty represents an intermediate phase on frailty pathway, with 10–25% of prefrail older adults progressing to frailty within seven years (1–3). Prefrail and frail older adults are prone to higher rates of disability, falls, hospitalization, and premature mortality compared to their non-frail counterparts (1). Consequently, there exists a need to identify interventions that may improve outcomes among this vulnerable population of older adults.

Corresponding Author: Justin C. Brown, Center for Clinical Epidemiology & Biostatistics, University of Pennsylvania School of Medicine, 423 Guardian Drive, 8th Floor, Blockley Hall, Philadelphia, PA 19104, brownjus@mail.med.upenn.edu.

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Participation in physical activity and consumption of a healthy diet are modifiable health behaviors that may be associated with the delay or prevention of frailty. Physical activity, defined as any bodily movement produced by skeletal muscles that requires energy expenditure (4), is associated with a reduction in the risk of developing frailty and a reduction in the risk of progression of frailty (5). Among 2,964 older adults, expending 1,000 kilocalories per week participating in moderate or vigorous-intensity physical activity was independently associated with a 31% lower risk of developing frailty over five years (5). A high quality diet, defined as consuming an adequate amount of grains, fruits, vegetables, meats, and dairy products, with modest intake of total fat, saturated fat, cholesterol, and sodium, is also associated with a lower risk frailty (6, 7). For example, adherence to a diet rich in unrefined grains, fruits, vegetables, legumes, and fatty fish was associated with a 17–63% lower risk of developing prefrailty or frailty over 4.6 years (6). These data suggest the importance of physical activity and diet to prevent a frailty phenotype. However, it is unknown if participation in physical activity and consumption of a high quality diet delays or reduces the risk of poor outcomes, such as mortality, among older adults with existing features of frailty.

This study sought to determine if physical activity and diet quality influence the risk of mortality among a population-based sample of 1,487 prefrail and frail older-adults aged 65 years. We then aimed to determine if participation in physical activity and consumption of a healthy diet interact with one-another to jointly influence the risk of mortality.

METHODS

Study Population and Design

The Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III) was a stratified multistage study designed to provide health information on a nationally-representative sample of U.S. civilians (8). The NHANES III sample does not include persons residing in nursing homes, members of the armed forces, institutionalized persons, or U.S. nationals living abroad. Participants provided written informed consent prior to completing any study-related activities. Participants in this analysis included adults aged 65 years.

Definition of Frailty

We implemented a definition of frailty that has been operationalized previously in the NHANES III database (9). The five criteria for frailty included were low weight for height (body mass index (BMI) $< 18.5 \text{ kg/m}^2$), slow walking speed (slowest quintile adjusted for sex, in a timed 2.4-meter walk), weakness (self-report of having any level of difficulty or inability to lift or carry something as heavy as 4.5-kilograms), exhaustion (self-report of having any level of difficulty or inability to walk from one room to another on the same floor), and low levels of ambulatory activity including leisure time, occupational, household, and transportation-related activity (a single self-report question of being less active compared to men or women of a similar age). Participants who met 1–2 or 3 of the 5 above-described criteria were classified as prefrail or frail, respectively (9).

Assessment of Physical Activity

Participants were asked to report if they engaged in any of the following leisure-time physical activities during the past month: jogging or running (≥ 1 mile), riding a bicycle, swimming, aerobic or other dance, callisthenic or floor exercise, gardening or yard work, and weight lifting. For each affirmative response, participants were asked how frequently they engaged in the physical activity. Duration of each bout of physical activity was not collected. Participants who reported 0, 1–4, or ≥ 5 bouts per week of physical activity were classified as sedentary, physically inactive, and physically active, respectively (10).

Assessment of Diet Quality

The original Healthy Eating Index (HEI) was designed as a measure that integrates ten components of diet quality to assess conformance to the 1995 federal dietary recommendations (11). The ten dietary components include the number of servings of grains, fruits, vegetables, meats, and dairy products; intake of total fat, saturated fat, cholesterol, and sodium; and dietary variety. The HEI was derived from a single 24-hour dietary recall using an automated interview process (11, 12). The HEI score ranges from 0 to 100, with higher scores indicating better conformance to the 1995 federal dietary recommendations. Participants with HEI scores <51, 51–80, and >80 were classified as having a poor, fair, or good diet quality, respectively (13).

Ascertainment of Mortality Outcome

Vital status was identified using the National Death Index (NDI) database through December 31, 2011. Participants were linked to the NDI database using probabilistic matching that included 12 identifiers such as Social Security Number, sex, and date of birth (14). The National Center for Health Statistics found that 96.1% of deceased participants and 99.4% of living participants were correctly classified using the probabilistic matching algorithm (15). The National Center for Health Statistics removed select subject characteristics in the file to prevent re-identification of study participants. The publically-released survival data are nearly identical to the restricted-use NHANES III mortality-linked file (16).

Covariates

Demographic information including date of birth, sex, and race were self-reported with a standardized questionnaire (17). Height (meters) and body mass (kilograms) were measured by study technicians and used to calculate BMI (kg/m^2). Appendicular skeletal muscle mass (kilograms) was quantified with bioimpedance analysis (18), utilizing a validated algorithm for frail older adults (19). Cognitive function was quantified using the short portable version of the Mini Mental Status Exam to form a score that ranges from 0 to 17, with higher scores indicating better cognition (20). The presence of comorbid health conditions including hypertension, diabetes, hyperlipidemia, COPD, arthritis, myocardial infarction, stroke, congestive heart failure, and kidney disease were self-reported. Behavioral and clinical information including smoking status, hospitalization, falls, and self-rated health were reported with a standardized questionnaire (17). Albumin, c-reactive protein, glycated hemoglobin, insulin, glucose, and creatinine were quantified using standardized laboratory assay procedures that have been described in detail (21, 22). Gait speed was assessed using a

four-meter walk with a stopwatch (23). The missing-indicator method was used for absent covariate values (24); no covariate was missing 3% of values.

Statistical Analysis

Our study sample included adults of age ≥ 65 years ($n=4,492$), with the requisite measures necessary to determine frailty status ($n=3,748$), with physical activity and diet quality questionnaire data ($n=3,551$). The final analytic sample included 1,487 pre-frail and frail men and women. Continuous variables are presented as means (standard error) or medians (interquartile 25–75% range), and categorical variables are presented as percentages (%). We used Cox proportional hazards regression models to estimate the hazard ratio (HR) and 95% confidence interval (95% CI) between physical activity or diet quality and mortality. We tested for a dose-response effect using linear contrasts. To determine if participation in physical activity and consumption of a healthy diet interact with one-another to jointly influence the risk of mortality, we included a statistical interaction term in the Cox proportional hazards regression models. Due to limitations in statistical power the *a priori* threshold for statistical significance for interactions was $P<0.10$ (25), and the threshold for statistical significance for all other analyses was $P<0.05$. Sample weights were incorporated into the statistical analyses to account for nonresponse bias, and multistage sampling probabilities were used to provide estimates generalizable to the U.S. population (26). Stata/SE v.14.1 statistical software was used for all analyses.

RESULTS

Cohort Characteristics

The mean age of study participants was 74.9 years (range: 65–90), 67% were female, and 43.9% reported ≥ 3 comorbid health conditions (Table 1). Weakness was the most common individual frailty component (63.6%), followed by low ambulatory activity (38.4%), slow walking (33.4%), exhaustion (17.1%), and low weight for height (6.4%). The majority of study participants were prefrail (86.3%). Participants were at risk for physical disability, as reflected by a slow gait speed (76% with a gait speed <0.8 m/s), and high frequency of falls in the prior year (32.4% with ≥ 1 falls). During a median of 8.9 years of follow up [range: 0.25–22.0 years], 1,307 participants died (87.2%).

Physical Activity

The median frequency of physical activity among all participants was one bout per week [interquartile range: 0–6]; 44.1%, 24.4%, and 31.6% were classified as sedentary (0 bouts per week), physically inactive (1–4 bouts per week), and physically active (≥ 5 bouts per week), respectively. Various demographic, clinical, and behavioral characteristics were associated with physical activity classification at baseline (Supplementary Table 1). Pertinent to this analysis, participants who were more physically active were younger, female, had more muscle mass, better cognitive function, and a faster gait speed. Compared to participants who were sedentary, those who were physically inactive were 24% less likely to die [HR: 0.76 (95% CI: 0.58–0.98)], and those who were physically active were 34% less likely to die [HR: 0.66 (95% CI: 0.51–0.86); $P_{\text{trend}}=0.002$; Table 2; Figure 1]. This

relationship was independent of various demographic, clinical, and behavioral covariates. This relationship remained unchanged after adjustment for diet quality ($P_{\text{trend}}=0.004$).

Diet Quality

The median diet quality score among all participants was 67.1 [interquartile range: 56.3–75.3]; 11.2%, 66.4%, and 22.4% were classified with a poor (<51), fair (51–80), and good (>80) diet quality, respectively. Various demographic, clinical, and behavioral characteristics were associated with diet quality classification at baseline (Supplementary Table 1). Pertinent to this analysis, participants who consumed a good diet were older, female, and had less muscle mass. Compared to participants with poor diet quality, those with fair diet quality were 26% less likely to die [HR: 0.74 (95% CI: 0.52–0.98)], and those with good diet quality were 33% less likely to die [HR: 0.67 (95% CI: 0.55–1.00); $P_{\text{trend}}=0.050$; Figure 2]. This relationship was independent of various demographic, clinical, and behavioral covariates. This relationship was attenuated after adjustment for physical activity ($P_{\text{trend}}=0.077$).

Physical Activity and Diet Quality

There was a significant interaction between physical activity and diet quality on the risk of mortality ($P_{\text{interaction}}=0.058$; Table 3). Compared to sedentary participants with a poor diet quality, physically active participants with a good diet quality were 50% less likely to die [HR: 0.50 (95% CI: 0.29–0.87); $P=0.014$].

DISCUSSION

The major findings of this study are that prefrail and frail older adults who participated in physical activity and consumed a healthy diet had a lower risk of mortality than their counterparts. Compared to sedentary participants with a poor diet quality, physically active participants with a good diet quality had the lowest risk of mortality during the follow up period. Furthermore, our finding of an interaction between physical activity and diet on mortality risk are consistent with the hypothesis that older adults cannot compensate for poor adherence to one healthy behavior with more favorable adherence to another healthy behavior (i.e., “you cannot outrun a bad diet” (27)). These findings underscore the importance of promoting both participation in physical activity and consumption of a healthy diet among prefrail and frail older adults.

In this population-based sample of older adults, 31.6% were physically active (≥5 bouts per week), 24.4% were insufficiently physically active (1–4 bouts per week), and 44.1% participated in no physical activity (0 bouts per week). These data are consistent with prior reports of objectively-measured physical activity which indicate that the majority of prefrail and frail older adults do not regularly participate in the recommended levels of physical activity (28, 29), despite knowledge that physical activity and exercise are associated with a lower risk of developing frailty, and a lower risk of progression of frailty (5). Our data build upon these findings to show that participation in physical activity may continue to provide health benefits among older adults with existing features of frailty. Compared to those who were sedentary, physically inactive and physically active older adults were 24% and 34%

less likely to die, respectively. The observed dose-response relationship between physical activity and the risk of mortality suggests that replacing sedentary behavior with even modest levels of physical activity may provide substantive short and long term health benefits (30).

In this population-based sample of older adults, 22.4% consumed a diet that was of good quality when compared to federal dietary recommendations, 66.4% consumed a diet of fair quality, and 11.2% consumed a diet of poor quality. These data are consistent with prior reports that frail older adults consume a diet of poorer nutritional quality compared to non-frail persons (7). Several individual dietary components have been previously associated with frailty. Frail older adults often have lower intake of total calories, protein, and other important vitamins and minerals (31–33). Low serum micronutrient levels, including carotenoids, alpha-tocopherol, and vitamin D, predict the development of incident frailty over three years (34). Our data build upon these findings and indicate that consumption of a healthy diet may also provide health benefits among older adults who develop prefrailty or progress into frailty. Compared to those with a poor diet quality, older adults who consumed a diet of fair and good quality were 26% and 33% less likely to die, respectively. Similar to the patterns observed for physical activity, these data indicate that modest improvements in diet quality may help to improve long term health outcomes (35, 36).

We identified an interaction between physical activity and diet quality, such that older adults who were physically active and consumed a healthy diet were 50% less likely to die compared to those who were sedentary and consumed a poor diet. One physiologic mechanism that may explain this observed association is inflammation. Prefrail and frail older adults often have elevated inflammatory profiles (37), which is associated with premature mortality (38). Physical activity and diet are associated with significant reductions in systemic inflammation among older adults (39). However, the physiologic processes that underpin the frailty-mortality relationship are complex, likely to also include oxidative stress, coagulation, and other pathways (40). Furthermore, exercise and diet are known to elicit systemic physiologic effects (41), which has made identifying important individual mechanistic pathways challenging.

These findings may be useful in the design of randomized trials of lifestyle modification to improve health outcomes. A randomized trial is necessary to definitively prove that favorably altering lifestyle behaviors, such as increasing physical activity and improving diet quality, will improve distal health outcomes that are common among frail older adults, such as falls, hospitalization, and mortality. Efforts are underway to design pharmacological interventions for the treatment of frailty (42), however the use of lifestyle modification may be a promising complement to pharmacological intervention (43). Recently, a large randomized multicenter trial among 1,600 older adults at risk for disability demonstrated that regular physical activity, consisting of 150 minutes per week of walking, complemented with strength, flexibility, and balance training, was associated with an 18% reduction in the risk of developing major mobility disability, defined as the inability to walk a distance of 400 m within 15-minutes, over 2.6 years (44). The success of this trial provides a compelling rationale for future studies to examine benefits of lifestyle modification on distal health outcomes among older adults.

There are several limitations to this study. Our sample did not include persons residing in nursing homes, where it may be assumed that there would be a large number of prefrail and frail individuals (45). Consequently, our analyses may only be applicable to community-dwelling older adults with prefrailty or frailty. The physical activity questionnaire did not quantify duration of physical activity. Consequently, we were unable to examine if the duration or volume of physical activity influenced the risk of mortality. We were not able to examine the specific benefits of weight lifting or muscle strengthening exercise, as a minority of older adults in this sample (<5%) reported regular recent participation in these types of activities. We were unable to examine specific dietary constituents that may be associated with frailty. In our interaction analyses of participation in physical activity and adherence to a healthy dietary pattern, our statistical power was limited, which warrants conservative interpretation. Comorbidities in this sample were self-reported. Many of the comorbidities in this sample are consistent with population-based normative values (46). However, several comorbidities such as cancer, arthritis, and chronic kidney disease were higher than normative values. This is expected, as each of these chronic conditions is associated with an increased risk of frailty (47–49). Because physical activity and diet quality were measured only once at baseline, it is unknown if increasing physical activity or improving diet quality would improve distal health outcomes among prefrail and frail older adults. A randomized clinical trial is necessary to definitively confirm this hypothesis.

There are several strengths to this study. The main strength of this study is the large sample size that, based on the sampling design, is representative of the U.S. population of community-dwelling older adults (8). Our sample included participants with a wide age range, from 65 to 90 years. The cohort had an extensive length of follow up (median 8.9 years) which allowed us to observe mortality events in 87.2% of participants. In prior studies that have examined the relationship between frailty and mortality among older adults with 5 years of follow-up, event rates ranged between 22 and 54% (50). Our multivariable-adjusted regression analysis accounted for variables that are known to influence the relationship between physical activity or diet quality and mortality.

In conclusion, among older adults who are prefrail or frail, participation in physical activity and consumption of a healthy diet is associated with a lower risk of mortality. Many prefrail or frail older adults do not achieve recommended levels of physical activity and/or do not consume a healthy diet, as defined by conformance to federal dietary recommendations. Lifestyle modification is positioned as a potentially efficacious intervention for prefrail and frail older adults. A randomized controlled trial is necessary to demonstrate the feasibility and efficacy of lifestyle modification to improve important clinical outcomes in this vulnerable population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TAKE AWAY POINTS

- Participation in physical activity is associated with a lower risk of mortality among prefrail and frail older adults.
- Consumption of a healthy diet activity is associated with a lower risk of mortality among prefrail and frail older adults.
- Physical activity is not associated with a lower risk of mortality when diet quality is poor; and conversely, consumption of a healthy diet is not associated with a lower risk of mortality when participation in physical activity is poor (i.e., sedentary).

Figure 1.
Survival of study participants, stratified by physical activity

Figure 2.
Survival of study participants, stratified by diet quality

Table 1Characteristics of study participants^a

Characteristic	Overall (N=1,487) [mean (SE) or (%)]
Age, yrs	74.9 (0.25)
Sex, %	
Male	33.3%
Female	66.7%
Race, %	
White	85.6%
Black	11.6%
Other	2.9%
Body Mass Index, kg/m ²	26.6 (0.21)
Appendicular Skeletal Muscle Mass, kg	18.9 (0.15)
Smoking Status, %	
Never	48.9%
Former	36.7%
Current	14.3%
Cognitive Function, sp-MMSE score	12.2 (0.14)
Comorbid Health Conditions, %	
Hypertension	50.1%
Diabetes	16.4%
Hyperlipidemia	35.5%
COPD	18.2%
Cancer	11.9%
Arthritis	57.5%
Myocardial Infarction	15.6%
Stroke	10.7%
Heart Failure	11.8%
Kidney Disease	29.0%
Self-Rated Health, %	
Excellent	15.4%
Very Good	30.5%
Good	31.3%
Fair	17.5%
Poor	5.3%
Hospitalization (1/year), %	23.1%
Falls (1/year), %	32.4%
Hemoglobin, g/dL	13.7 (0.05)
Albumin, g/dL	3.9 (0.01)
C-Reactive Protein, mg/dL	0.6 (0.04)
Glycated Hemoglobin, %	5.9 (0.05)

Characteristic	Overall (N=1,487) [mean (SE) or (%)]
Insulin, pmol/L	89.8 (3.94)
Glucose, mmol/L	6.3 (0.10)
Creatinine, mg/dL	1.2 (0.01)
Gait Speed, meters/second	0.58 (0.009)
Frailty Components, %	
Low Weight-For-Height	6.4%
Slow Walking	33.4%
Weakness	63.6%
Exhaustion	17.1%
Low Ambulatory Activity	38.4%
Frailty Classification, %	
Pre frail (1–2 Frailty Components)	86.3%
Frail (≥ 3 Frailty Components)	13.7%
Physical Activity, %	
Sedentary (0 bouts/week)	44.1%
Inactive (1–4 bouts/week)	24.4%
Active (≥ 5 bouts/week)	31.6%
Diet Quality, %	
Poor (<51)	11.2%
Fair (51–80)	66.4%
Good (>80)	22.4%
Died, %	87.2%
Follow-Up, Years ^b	8.9 [4.6–14.6]

Note:

^aValues are means (standard error) or percentages (%), except where noted.

^bMedian [Interquartile: 25–75% Range]. sp-MMSE: short portable version of the Mini Mental Status Exam.

Table 2

Association between physical activity, diet quality, and mortality

		Model 1 ^a	Model 2 ^b	Model 3 ^c
	Median Survival	HR (95% CI)	HR (95% CI)	HR (95% CI)
Physical Activity				
Sedentary	7.1 [3.7–13.2]	1.00 -- Reference	1.00 -- Reference	1.00 -- Reference
Inactive	10.2 [4.8–16.1]	0.74 (0.60–0.91)	0.76 (0.58–0.98)	0.76 (0.58–0.98)
Active	10.3 [6.2–16.3]	0.73 (0.60–0.89)	0.66 (0.51–0.86)	0.67 (0.51–0.88)
	<i>P</i> _{log-rank} =0.001	<i>P</i> _{trend} =0.002	<i>P</i> _{trend} =0.002	<i>P</i> _{trend} =0.004
Diet Quality				
Poor	7.6 [3.7–10.9]	1.00 -- Reference	1.00 -- Reference	1.00 -- Reference
Fair	9.2 [4.8–14.8]	0.69 (0.55–0.86)	0.74 (0.52–1.05)	0.74 (0.52–1.04)
Good	9.5 [4.8–16.3]	0.67 (0.52–0.87)	0.67 (0.44–1.00)	0.70 (0.47–1.04)
	<i>P</i> _{log-rank} =0.002	<i>P</i> _{trend} =0.002	<i>P</i> _{trend} =0.050	<i>P</i> _{trend} =0.077

Note:

^aModel 1 is adjusted for age and sex.^bModel 2 is adjusted for the covariates in model 1, and race, body mass index, smoking status, cognitive function, hypertension, hyperlipidemia, COPD, cancer, arthritis, myocardial infarction, stroke, heart failure, kidney disease, self-rated health, hospitalization, falls, hemoglobin, c-reactive protein, glyated hemoglobin, insulin, glucose, creatinine, frailty classification (frail v prefrail), appendicular skeletal muscle mass and gait speed.^cModel 3 is adjusted for the covariates in model 2, and either health eating index classification (for physical activity model) or physical activity classification (for healthy eating index model).

Table 3

Interaction between physical activity and diet quality

	Hazard Ratio (95% Confidence Interval)		
	Diet Quality		
Physical Activity	Poor	Fair	Good
Sedentary	1.00 – Reference <i>n</i> = 113	0.71 (0.51–0.97) <i>n</i> = 475	0.77 (0.55–1.07) <i>n</i> = 145
Inactive	0.62 (0.40–0.97) <i>n</i> = 61	1.22 (0.72–2.04) <i>n</i> = 235	1.18 (0.65–2.14) <i>n</i> = 64
Active	1.20 (0.78–1.85) <i>n</i> = 46	0.63 (0.39–1.03) <i>n</i> = 263	0.50 (0.29–0.87) <i>n</i> = 85
	<i>P</i> _{interaction} =0.058		

Note: Adjusted for age and sex.