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RELATIONSHIP BETWEEN DIET QUALITY, PHYSICAL ACTIVITY AND HEALTH-RELATED QUALITY OF LIFE IN OLDER ADULTS: FINDINGS FROM 2007-2014 NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY

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Abstract: *Background:* A growing body of research shows that diet quality and physical activity (PA) are associated with health-related quality of life (HRQOL). However, no study to date has assessed this association using the Healthy Eating Index-2015 as a measure of diet quality. Furthermore, few studies have examined the association between PA dose and HRQOL among a nationally representative sample of older adults. *Objectives:* To investigate the relationship between diet quality, physical activity, and HRQOL. *Design:* A cross-sectional analysis was conducted using data obtained from 5,311 adults aged 60+ years who took part in the National Health and Nutrition Examination Survey between 2007 and 2014. *Measurements:* HRQOL was assessed by general health status, and number of physically unhealthy days, mentally unhealthy days, and inactive days in past 30 days. Diet quality was assessed by the Healthy Eating Index-2015 using data generated by two 24-hour dietary recalls. PA was measured by the Global Physical Activity Questionnaire. Multivariate logistic/or linear regression models were used to examine the association between diet quality, PA and HRQOL controlling for confounders and accounting for complex sampling. *Results:* Approximately half of the participants (55.2%) were women, 45.1% met current PA recommendations, 65% had less healthful diets according to the Healthy Eating Index-2015. Diet quality was associated with HROQL. For every 1-point diet quality score increase, the likelihood of respondents rating their general health as being excellent/good increased by 3% (OR=1.03, 95%CI: 1.02, 1.04), and number of inactive days (β =-0.03, 95%CI: -0.05, 0.00) and mental unhealthy days (β =-0.03, 95%CI: -0.05, -0.01) declined by 0.03 days. PA was associated with all HROQL measures and respondents with high PA levels reported better general health (OR=3.53, 95%CI: 2.69, 4.63), fewer inactive days (β =-1.53, 95%CI: -2.11, -0.95), fewer physical unhealthy days (β =-1.88, 95%CI: -2.74, -1.02) than individuals with low PA levels but not fewer mentally unhealthy days. *Conclusions:* Among older adults in this study, eating a healthier diet and being physically active were associated with better general health and reporting fewer physical unhealthy days and inactive days. Study results provide valuable information that could inform policies, programs and interventions designed to improve HRQOL in older adults and reduce potentially preventable health disparities.

Key words: Diet quality, physical activity, health-related quality of life, lifestyle behaviors.

Introduction

The population aged 60 and older is the fast-growing segment of the US population. As of 2015, there were 66.9 million people aged 60 and above, and this figure is expected to double by 2050 (1). The increasing population of older adults will likely be accompanied by an increase in chronic diseases that impact individuals' health-related quality of life (HRQOL) (1, 2, 3). HRQOL, a predictor of frequent hospitalization and mortality (4, 5), is not solely the absence of disease or infirmity but is an individual's perception of his/her overall health status, including physical, mental, and social health (6). Recent research indicates that approximately 30% of adults aged 65+ perceive their general health status (GHS) as being fair/poor compared to around 10% of adults 18-45 years of age. Similarly, adults aged 65+ report more physically unhealthy days than adults 18-45 (7). As perceived HRQOL predicts future adverse health events (4, 5), there is a critical need to examine factors that are potentially associated with HRQOL in older adults to aid health practitioners in promoting optimal HRQOL in this population.

Although overall diet quality has been found to be associated with HRQOL among older adults (8), research examining this relationship using a representative sample of older adults in the US is lacking. To our knowledge, no studies examining diet quality have used the recently released Healthy Eating Index-2015 (HEI-2015) although the US Department of Agriculture uses this measure to assess diet quality based on the 2015-2020 Dietary Guidelines for Americans (9). Additionally, despite evidence suggesting an association between physical activity (PA) and HRQOL among older adults (10-13), studies assessing this association in older adults using representative sample is lacking (10, 11, 13). Furthermore, the relationship between diet quality and PA levels with HRQOL in older

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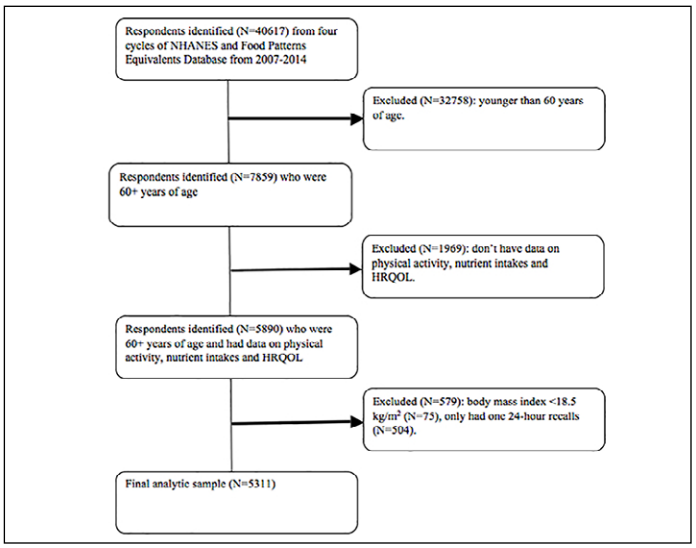
adults is not clear. We can gain insight into this relationship by examining the association between lifestyle groups that assess both PA and diet behavioral patterns, and HRQOL (14). This information is needed to better address quality of life in older adults and promote healthy aging. Therefore, the primary purpose of the current study was to examine the association between diet quality, PA, lifestyle groups and HRQOL in older adults. Also, given the possible differences between men and women regarding diet quality, physical activity and HRQOL (8, 10, 12), the secondary purpose of the current study was to examine this association in sex-specific subgroups.

Method

Study design & participants

This is a cross-sectional study analysis of data from two datasets: The National Center for Health Statistics' National Health and Nutrition Examination Survey (NHANES) (15) and the US Department of Agriculture's Food Patterns Equivalents database (15, 16). The two datasets were merged using participants' study identification numbers and days of recalled dietary data. We used four cycles of NHANES and Food Patterns Equivalents Database data gathered over eight years from 2007 to 2014 (n=40,617), which included 5,890 respondents who were 60+ years of age with data on PA, nutrient intakes, and HRQOL. Of 5,890 respondents 60+ years of age, 75 (1.1%) were excluded due to their body mass index (BMI) being < 18.5 kg/m2 and possible weight related psychological or physical pathology (17) and 504 (6.2%) were excluded as they did not complete two 24-hour recalls. The final analytical sample included 5,311 respondents (see Figure 1).

Figure 1
Study flow chart



Note: NHANES= National Health and Nutrition Examination Survey, HRQOL = health-related quality of life.

Health-related quality of life

HRQOL was assessed using four self-reported measures: 1) GHS, 2) physical unhealthy days in past 30 days, 3) mentally unhealthy days in past 30 days, and 4) inactive days in past 30 days due to physical or mental health (18). With the exception of GHS, all measures were only available from 2007-2012 (15). GHS was divided into three groups for analysis: 1) excellent/very good, 2) good, 3) fair/poor. Each of the four HROQL measures has its own indicators and there is no composite HRQOL score (18).

Diet quality

Dietary intake was assessed by two 24-hour dietary recalls completed on non-consecutive days. The first recall was completed in-person and the second one was done via telephone 3 to 10 days later (15). All data were coded and processed by the US Department of Agriculture's Food Surveys Research Group and made publicly available in the NHANES and Food Patterns Equivalents databases. Individuals' total diet quality scores were calculated using the simple HEI-2015 scoring algorithm that was recently developed by the US Department of Agriculture and the National Cancer Institute (9, 19). HEI-2015 scores 13 dietary components: Fatty acids, sodium, saturated fats, total vegetables, greens and beans, total fruit, whole fruit, whole grains, dairy, total protein foods, seafood and plant proteins, refined grains, and added sugars (19). Data needed to generate fatty acids, sodium, and saturated fats scores were obtained from the NHANES dataset and the data needed to score the other components were in the Food Patterns Equivalents dataset. The 13 component scores were summed to calculate the total diet quality score (range 0 to 100) with a higher score indicating better diet quality and greater consistency with the 2015-2020 Dietary Guidelines for Americans (19). Since HEI-2015 dietary cut points have not yet been published, participants were stratified into three groups based on tertiles from the distribution of diet quality scores (20): 1) lower quality diet (scores 0-52.3); 2) intermediate quality diet (scores 52.3-62.8); 3) healthier diet (scores >62.8). The first two tertiles (lower quality diet and intermediate quality diet) were considered to be indicative of eating a less healthful diet.

Physical activity

Total PA time for a typical week was reported using the Global PA Questionnaire which encompasses PA in work, travel, and recreational domains. Participants completed the survey at homes using NHANES's Computer-Assisted Personal Interview program (15). Total PA time was converted to metabolic equivalent of task (MET) minutes of moderate to vigorous PA per week (moderate PA = 4 MET, vigorous PA = 8 MET) (21, 22) and used to create three levels of PA based on the US Department of Health and Human Services guidelines: low PA (< 600 MET-minutes/week), medium PA (600-1200 MET-minutes/week), and high PA (> 1200 MET-

Table 1
Subjects characteristics by three health-related quality life general health levels, NHANES 2007-2014 (N=5311)

Demographic characteristics	**Total**	**Males**	**Females**
	n=5311	**n=2551**	**n=2760**
Sex, n (weighted %)			
Males	2551 (44.8)	-	-
Females	2760 (55.2)	-	-
Age	69.4 ± 0.1	69.1 ± 0.2	69.7 ± 0.2
Race/Ethnicity, n (weighted %)			
Non-Hispanic White	2883 (81.4)	1415 (82.6)	1468 (80.4)
Non-Hispanic Black	1119 (8.3)	539 (7.3)	580 (9.2)
Mexican American	576 (3.6)	273 (3.7)	303 (3.5)
Other (including other Hispanic)	733 (6.8)	324 (6.4)	409 (7.0)
Education level, n (weighted %)			
High school or less	2803 (42.9)	1299 (39.6)	1504 (45.6)
College or above	2501 (57.1)	1250 (60.4)	1251 (54.4)
Poverty to income ratio, n (weighted %)			
Below poverty (<1.0)	731 (8.2)	286 (5.9)	445 (10.0)
Above poverty (≥ 1.0)	4145 (91.8)	2070 (94.1)	2075 (90.0)
Smoking status, n (weighted %)			
Never smokers	2612 (49.2)	905 (37.0)	1707 (59.1)
Former smokers	2114 (41.1)	1308 (52.1)	806 (32.2)
Current smokers	584 (9.7)	338 (10.9)	246 (8.7)
BMI (kg/m2)	29.4 ± 0.1	29.2 ± 0.2	29.5 ± 0.2
BMI classification, n (weighted %)			
Normal (18.5≤ BMI ≤ 24.9), n (weighted %)	1220 (24.0)	562 (20.8)	658 (26.5)
Overweight (25≤BMI≤29.9), n (weighted %)	1930 (36.5)	1046 (41.2)	884 (32.7)
Obese (BMI ≥30), n (weighted %)	2161 (39.5)	943 (38.0)	1218 (40.8)
Physical activity (MET-minutes/week)			
Total	1469.7 ± 70.0	1967.8 ± 123.4	1065.2 ± 59.8
Met recommendation, n (weighted %)	2165 (45.1)	1220 (53.2)	945 (38.6)
Low physical activity	3146 (54.9)	1331 (46.8)	1815 (61.4)
Medium physical activity	750 (15.4)	374 (15.5)	376 (15.2)
High physical activity	1415 (29.8)	846 (37.7)	569 (23.4)
Diet quality (HEI-2015)			
Total diet quality score	57.9 ± 0.4	56.1±0.3	59.3 ± 0.4
First tertile (<52.3), n (weighted %)	1913 (34.6)	1036 (40.7)	877 (29.6)
Second tertile (52.3 - 62.8), n (weighted %)	1592 (30.4)	766 (29.6)	826 (31.1)
Third tertile (>62.8), n (weighted %)	1806 (35.0)	749 (29.7)	1057 (39.3)
HRQOL			
General health status, n (weighted %)			
Excellent, very good	1765 (41.7)	856 (40.5)	909 (42.7)
Good	2046 (38.1)	988 (39.3)	1058 (37.2)
Fair, poor	1500 (20.2)	707 (20.2)	793 (20.2)
Physical unhealthy days	4.3 ± 0.2	3.7 ± 0.2	4.8 ± 0.3
Mental unhealthy days	2.8 ± 0.1	1.9 ± 0.2	3.6 ± 0.2
Inactive days	2.0 ± 0.1	1.9 ± 0.2	2.0 ± 0.2

Note: Data are presented as weighted Mean ± Standard Error unless otherwise specified; BMI =body mass index, MET= metabolic equivalent, HEI=healthy eating index, Low PA: <600 MET-minutes/week, medium PA: 600 -1200 MET-minutes/week, high PA: > 1200 MET-minutes/week.

minutes/week). The medium and high PA levels are equivalent to meeting or exceeding the current PA recommendations of 150+ minutes of moderate to vigorous PA per week (23) and participants in these two groups were considered physically active.

Lifestyle groups

Participants were categorized as being in one of four lifestyle groups based on their diet quality and PA level (20). The lifestyle groups were: Group 1: healthier lifestyle group (a healthier diet and physically active); Group 2: healthier diet only (low PA + healthier diet); Group 3: physically active only (physically active + less healthful diet); and Group 4: less healthful lifestyle group (less healthful diet + low PA).

Body Mass Index (BMI)

Respondents' BMI was calculated using their measured height (meters) and weight (kilograms) in the Mobile Examination Center by trained health technicians (15) and then used to determine weight status: 1) normal weight (18.5 kg/m2 ≤ BMI ≤ 24.9 kg/m2, 2) overweight (25 kg/m2 ≤BMI <30 kg/m2), and 3) obese (BMI≥30 kg/m2) (24).

Demographics

Demographic data from NHANES were collected by trained staff members at participants' homes using Computer-Assisted Personal Interview program including sex, age, race/ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, other), educational attainment (high school graduate or less, some college or more) and smoking status (never, former, current), as well as information (family income, family size) used to calculate poverty to income ratio (15, 25). The poverty to income ratio was divided into two categories based on the poverty guidelines: at or above (≥1) and below the poverty level (<1) (25).

Statistical analysis

All data analyses used the Mobile Examination Center exam 2-year weights as the sample weight (26). The general distributions of continuous variables were presented using weighted means ± standard errors and categorical variables were presented using count and weighted percentages for all sample characteristics. Multivariable logistic regression models were performed with the use of PROC SURVEYLOGISTIC with GLOGIT link (multinomial logistic model) for GHS to examine the association between PA, diet quality and GHS. Multivariate linear regression models using PROC SURVEYREG were used to evaluate the associations between PA, diet quality and the continuous HRQOL measures (physical unhealthy days, mental unhealthy days, or inactive days). PA and diet quality both were analyzed as continuous variable but PA levels and diet quality tertile were analyzed as category variables. All models were adjusted for age, sex, race/ethnicity, education, poverty level, smoking status, and BMI.

A secondary analysis was performed to examine the association of lifestyle groups and HRQOL using the multivariable logistic/or linear regression models described above, depending on the HRQOL measures being examined. In addition, a sensitivity analysis was conducted using the previously established cut points for the original HEI in the late 1990s: 1) a good diet (scores >80), 2) needs improvement (scores 51-80), 3) a poor diet (scores <51) to determine if results of the current study tertile categorization were supported using this HEI categorization (27). All analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA), and p-values <0.05 were considered statistically significant.

Results

Of the 5,311 participants (mean age 69.4±0.1 years), 72.8% (n=3,710) were aged 60-75, 27.2% (n=1,601) were aged 75-85, approximately half (55.2%) were women, 18.6% were racial/ethnic minorities, 42.9% had a high school education or less, 8.2% lived below the poverty line, and 20.2% reported their GHS as being fair/poor. About one-third (39.5%) of respondents had obesity, 54.9% had low PA levels, 34.6 % had diets that were classified as being lower quality, and 9.7% were current smokers. See Table 1 for sample characteristics stratified by sex.

The adjusted logistic regression models determined that diet quality, PA, and GHS were associated (see Table 2). For every 1-point increase in diet quality score, the likelihood for respondents rating GHS as excellent/very good increased by 3% (OR=1.03, 95%CI: 1.02, 1.04). Respondents with a healthier quality diet were 2.01 times as likely to rate their GHS as excellent/very good than individuals with lower diet quality (OR=2.01, 95% CI:1.48, 2.73). For every 100 MET-minutes/week PA time increase, the likelihood of the individuals rating their GHS as excellent/very good increased by 1% (OR=1.01, 95%CI: 1.00, 1.02). Respondents with high PA levels were 3.53 times as likely to rate their GHS as excellent/very good compared to individuals with low PA levels (OR=3.53, 95%CI: 2.69, 4.63). In general, similar patterns were observed for the other HRQOL measures (inactive days, physical unhealthy days, mental unhealthy days); however, diet quality was not associated with number of physical unhealthy days. Although diet quality was associated with number of inactive days (β =-0.03, 95%CI: -0.05, 0.00), there was no significant difference in number of inactive days between individuals with a healthier or intermediate diet quality and those with a lower quality diet. Also, PA time was inversely associated with number of mentally unhealthy days (β =-0.01, 95%CI: -0.02, 0.00), but there was no difference in number of mental unhealthy days between medium or high PA levels and low PA levels. The dietary sensitivity analysis results were consistent with the results of primary analysis except respondents with intermediate diet quality and healthier diet quality was associated with fewer inactive days than individuals with lower quality diet using the

Table 2
The association between weight status, physical activity, diet quality and HRQOL measures (N=5311)

	Excellent/very good vs. Fair/poor		Inactive days		Physical unhealthy days		Mental unhealthy days	
Overall	**Adjusted ORs (95% CI)**	**P value**	**Adjusted β (95% CI)**	**P value**	**Adjusted β (95% CI)**	**P value**	**Adjusted β (95% CI)**	**P value**
Physical activity								
Total physical activity time per increased 100 MET-minutes/week	1.01 (1.00, 1.02)	0.002*	-0.02 (-0.02, -0.01)	<0.001*	-0.01 (-0.02, 0)	0.016*	-0.01 (-0.02, 0.00)	0.006*
Low physical activity	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Medium physical activity	2.58 (1.85, 3.59)	<0.001*	-1.13 (-1.67, -0.58)	<0.001*	-1.64 (-3.09, -0.18)	0.028*	-0.54 (-1.38, 0.30)	0.201
High physical activity	3.53 (2.69, 4.63)	<0.001*	-1.53 (-2.11, -0.95)	<0.001*	-1.88 (-2.74, -1.02)	<0.001*	-0.08 (-0.89, 0.74)	0.853
Diet quality (HEI-2015)								
Diet quality score per increased 1 point	1.03 (1.02, 1.04)	<0.001*	-0.03 (-0.05, 0.00)	0.019*	-0.03 (-0.06, 0.01)	0.111	-0.03 (-0.05, -0.01)	0.006*
First tertile (<52.3), n (weighted %)	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Second tertile (52.3 - 62.8), n (weighted %)	1.54 (1.14, 2.08)	0.005*	-0.73 (-1.46, 0.01)	0.052	-0.06 (-1.18, 1.05)	0.91	-1.05 (-1.79, -0.31)	0.006*
Third tertile (>62.8), n (weighted %)	2.01 (1.48, 2.73)	<0.001*	-0.50 (-1.24, 0.23)	0.177	-0.1 (-1.2, 0.99)	0.854	-0.51 (-1.15, 0.13)	0.117
Men								
Physical activity								
Total physical activity time per increased 100 MET-minutes/week	1.01 (1.00, 1.02)	0.026*	-0.02 (-0.02, -0.01)	<0.001*	-0.01 (-0.02, 0.00)	0.054	-0.01 (-0.01, 0.00)	<0.001*
Low physical activity	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Medium physical activity	1.99 (1.35, 2.93)	<0.001*	-1.4 (-2.47, -0.32)	0.011*	-1.07 (-2.71, 0.58)	0.201	-0.47 (-1.30, 0.35)	0.254
High physical activity	3.72 (2.75, 5.02)	<0.001*	-1.58 (-2.49, -0.67)	<0.001*	-1.71 (-2.80, -0.62)	0.003*	0.19 (-0.65, 1.04)	0.65
Diet quality (HEI-2015)								
Diet quality score per increased 1 point	1.03 (1.02, 1.05)	<0.001*	-0.03 (-0.06, 0.01)	0.105	-0.03 (-0.07, 0.01)	0.112	0 (-0.02, 0.02)	0.947
First tertile (<52.3), n (weighted %)	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Second tertile (52.3 - 62.8), n (weighted %)	1.67 (1.14, 2.45)	0.008*	-0.43 (-1.54, 0.68)	0.438	-0.04 (-1.31, 1.22)	0.948	-0.17 (-1.05, 0.70)	0.693
Third tertile (>62.8), n (weighted %)	2.24 (1.51, 3.32)	<0.001*	-0.28 (-1.23, 0.66)	0.551	-0.30 (-1.51, 0.91)	0.621	0.42 (-0.27, 1.10)	0.232
Women								
Physical activity								
Total physical activity time per increased 100 MET-minutes/week	1.02 (1.01, 1.03)	0.001*	-0.02 (-0.03, -0.01)	0.001*	-0.02 (-0.05, 0.00)	0.092	-0.01 (-0.03, 0.01)	0.206
Low physical activity	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Medium physical activity	3.11 (1.87, 5.17)	<0.001*	-0.98 (-1.79, -0.17)	0.018*	-2.00 (-3.98, -0.02)	0.048*	-0.57 (-1.88, 0.73)	0.384
High physical activity	3.18 (2.12, 4.76)	<0.001*	-1.47 (-2.14, -0.80)	<0.001*	-2.04 (-3.56, -0.53)	0.009*	-0.37 (-1.75, 1.00)	0.589
Diet quality (HEI-2015)								
Diet quality score per increased 1 point	1.03 (1.01, 1.04)	<0.001*	-0.03 (-0.06, 0.00)	0.064	-0.02 (-0.06, 0.02)	0.304	-0.05 (-0.09, -0.01)	0.009*
First tertile (<52.3), n (weighted %)	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Second tertile (52.3 - 62.8), n (weighted %)	1.43 (0.95, 2.15)	0.081	-1.01 (-1.97, -0.05)	0.039*	-0.10 (-1.58, 1.39)	0.896	-1.93 (-3.19, -0.67)	0.003*
Third tertile (>62.8), n (weighted %)	1.87 (1.28, 2.75)	0.001*	-0.70 (-1.83, 0.44)	0.224	0.05 (-1.34, 1.43)	0.948	-1.28 (-2.48, -0.08)	0.036*

Note: Adjusted ORs were obtained by PROC SURVEYLOGISTIC using the generalized logit model with the LINK=GLOGIT option, adjusted for age, sex, race/ethnicity, education level, household income, smoking status, and another independent variable; HRQOL = health-related quality of life, MET= metabolic equivalent, HEI=healthy eating index, Low PA: <600 MET-minutes/week, medium PA: 600 -1200 MET-minutes/week, high PA: > 1200 MET-minutes/week.

previous HEI cut points.

The analytic sample was then stratified by sex and the significant associations between diet quality, PA and GHS seen in the overall sample were evident in the stratified analysis for both men and women (see Table 2), although there were differences in terms of magnitude of the association by sex. Women, respondents with a healthier diet (β =-1.28, 95%CI: -2.48, -0.08) or intermediate quality diet (β =-1.93, 95%CI: -3.19, -0.67) were more likely to have less mental unhealthy days compared to those with a lower quality diet. For men, diet quality was not associated with number of inactive days, physical unhealthy days, or mental unhealthy days.

Table 3
The association between lifestyle groups and HRQOL measures, NHANES 2007-2014 (N=5311)

	General health status[a]		Inactive days[b]		Physical unhealthy days[b]		Mental unhealthy days[b]	
	Excellent, very good vs. Fair, poor							
	Adjusted ORs (95% CI)	P value	Adjusted β (95% CI)	P value	Adjusted β (95% CI)	P value	Adjusted β (95% CI)	P value
Overall								
Group4: less healthful	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Group1: healthier	4.78 (3.33, 6.87)	<0.001*	-1.50 (-2.16, -0.83)	<0.001*	-1.65 (-2.76, -0.55)	0.004*	-0.13 (-1.04, 0.79)	0.784
Group2: healthier diet only	1.73 (1.28, 2.34)	<0.001*	-0.25 (-1.12, 0.63)	0.577	-0.24 (-1.49, 1.00)	0.697	-0.43 (-1.27, 0.41)	0.309
Group3: physically active only	3.30 (2.43, 4.48)	<0.001*	-1.53 (-2.13, -0.94)	<0.001*	-1.87 (-3.02, -0.71)	0.002*	-0.64 (-1.57, 0.29)	0.176
Males								
Group4: less healthful	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Group1: healthier	4.20 (2.58, 6.84)	<0.001*	-1.57 (-2.81, -0.33)	0.014*	-1.62 (-2.98, -0.26)	0.02*	0.45 (-0.61, 1.51)	0.404
Group2: healthier diet only	2.56 (1.57, 4.19)	<0.001*	-0.97 (-2.07, 0.12)	0.08	-1.22 (-2.66, 0.22)	0.095	0.13 (-0.86, 1.11)	0.798
Group3: physically active only	3.67 (2.65, 5.08)	<0.001*	-2.06 (-3.10, -1.03)	<0.001*	-2.01 (-3.22, -0.80)	0.001*	-0.24 (-1.25, 0.77)	0.639
Females								
Group4: less healthful	1.0 (Ref)		0.0 (Ref)		0.0 (Ref)		0.0 (Ref)	
Group1: healthier	5.39 (3.35, 8.67)	<0.001*	-1.51 (-2.38, -0.63)	<0.001*	-1.76 (-3.27, -0.26)	0.023*	-0.53 (-2.17, 1.11)	0.52
Group2: healthier diet only	1.44 (0.96, 2.16)	0.075	0.14 (-0.95, 1.23)	0.805	0.17 (-1.36, 1.70)	0.826	-0.75 (-2.10, 0.60)	0.27
Group3: physically active only	2.88 (1.71, 4.85)	<0.001*	-1.02 (-1.87, -0.18)	0.018*	-1.94 (-3.96, 0.08)	0.059	-1.03 (-2.60, 0.55)	0.197

Note: HRQOL = health-related quality of life, Group1: healthier (physically active + healthier diet), Group 2: healthier diet only (low physical activity + healthier diet), Group 3: physically active only (physically active + less healthful diet), Group 4: less healthful (low physical activity and less healthful diet). a. Adjusted ORs were obtained by PROC SURVEYLOGISTIC using the generalized logit model with the LINK=GLOGIT option (multinomial logistic model), adjusted for age, sex, race/ethnicity, education level, household income, smoking status, and BMI. b. Adjusted β were obtained by PROC SURVEYREG, the same adjusted as above.

Additionally, while overall diet quality was not associated with number of inactive day among women, women with intermediate quality diet were likely to have fewer inactive days than those with a lower quality diet (β=-1.01, 95%CI: -1.97, -0.05). Although overall PA was inversely associated with mental unhealthy days in men (β =-0.01, 95%CI: -0.01, 0.00), there were no significant differences in mental unhealthy days between medium or high PA levels and low PA levels observed. In men, only respondents with high PA levels was associated with less physical unhealthy days than individuals with lower PA levels; however, among women, medium and high PA levels were associated with less physical unhealthy days compared to individuals with low PA levels. The results of the sensitivity analysis were generally consistent with the main findings of the primary analysis. The only exception was that men with a healthier quality diet had fewer inactive days compared to men with lower quality diet in the sensitivity analysis, whereas the association was not significant in the primary analysis.

Further analyses examined the association between lifestyle groups and the HRQOL measures (see Table 3). Individuals in Group 1 (healthier lifestyle group), Group 2 (healthier diet only group), and Group 3 (physically active only group) were more likely to rate their GHS at excellent/very good than the reference Group 4 (less healthful group). There were notable differences between Group 1 and Group 4 (β=4.78, 95%CI: 3.33, 6.87). Respondents in Group 1 had less physical unhealthy days (β=-1.65, 95%CI: -2.76, -0.55) and inactive days (β =-1.5, 95%CI: -2.16, -0.83) than individuals in Group 4. Respondents in Group 3 also had less physical unhealthy days (β =-1.87, 95%CI: -3.02, -0.71) and inactive days (β =-1.53, 95%CI: -2.13, -0.94) than individuals in Group 4. There were no differences between lifestyle groups regarding mental unhealthy days. For the subsequent analyses stratified by sex, similar patterns were observed. The only exception was that there was no difference in physical unhealthy days observed in women between Group 3 and Group 4. The results of the sensitivity analysis were consistent with the primary analysis results for lifestyle groups except men in Group 2 and women in Group 3 had less physical unhealthy days than men and women in Group 4.

Discussion

This is the first study to examine the association between diet quality as assessed by HEI-2015, dose of PA and HRQOL in older adults in a nationally representative sample. Study results determined that healthy dietary and PA behaviors were associated with HRQOL in older adults, which suggest that addressing these lifestyle behaviors may help older adults improve or maintain a better HRQOL.

The current study examined individuals' overall diet quality

using HEI-2015 while prior studies have used other diet quality measures such as a Mediterranean diet score (8, 28), the Dietary Screening Tool (29) or a dietary guideline index following Australian optimal eating pattern guidelines (8). It is likely that many of the differences observed in this study are due to the different assessment instruments (8, 28, 29). Although the HEI-2015 includes different components than previous versions, the mean score in the current sample of 57.9 is relatively similar to the HEI-2005 mean score of 63 found in 65-74 years old adults from the 2003-2004 NHANES, and the differences in these scores might reflect both dietary and scoring changes (30). A longitudinal study of older Europeans found that diet quality was not related to better GHS (28) whereas the results of Milte and colleagues' longitudinal study in Australia found that having a better diet quality was associated with better GHS, which is consistent with the finding of the current study (8). A cross-sectional study of rural Americans found that HRQOL as measured by a health and activity limitation index was significantly lower among participants whose dietary intakes categorized was unhealthy by the Dietary Screening Tool (29). Although Milte and colleagues (2015) found diet quality was associated with better physical functioning, better mental health overall, and better physical functioning in both men and women (8), the current study only found that a healthier diet was associated with fewer mental unhealthy days and inactive days. This difference may due to difference in HRQOL (the RAND 36-item general health survey vs. the four self-reported measures) and diet quality measures (8, 18).

Our study is among the first to examine the association between the dose of PA and HRQOL among older adults in the US. The finding of the current study complements and adds to previous research examining the relationship between overall PA and HRQOL (10, 11, 12, 13). Available studies were either conducted in the Netherlands or Korea (12, 13) or with adults of all ages (10, 11). One study with adults of all ages determined that level of PA was associated with HRQOL in older adults used different PA categories (no PA, some PA but not met PA recommendations, met PA recommendations) than employed in the current study (10). The current study extends this research by employing the US Department of Health and Human Services' PA guidelines and found that respondents who met and exceeded PA recommendations had better GHS, fewer inactive days, and less physical unhealthy days, although there was no difference in mentally unhealthy days by PA levels. Moreover, gender differences were observed in the current study. PA was inversely associated with number of mental unhealthy days in men but not in women. In addition, meeting or exceeding PA recommendations was associated with less physical unhealthy days in women and only exceeding PA recommendations was associated with less physical unhealthy days in men.

Additionally, we found that respondents in the healthier lifestyle groups had better GHS, fewer inactive days, and less physical unhealthy days than individuals who were in the less healthful lifestyle group. A similar pattern also was observed for people in the physically active only lifestyle group whereas the healthier diet only lifestyle group had better in GHS but there were no differences in number of inactive days, physical unhealthy days or mental unhealthy day. Gender specific results show the same pattern as the whole group. Examining the relationship between lifestyle behaviors and HRQOL in older adults is an important extension of previous studies given the relationship between GHS, inactive days, physical unhealthy and mortality that were identified (5). Overall, the findings of the current study emphasize the importance of being physically active and having a healthier diet for better HRQOL in older adults.

Strength and limitations

The main strength of the current study is the first, to our knowledge, to use the HEI-2015 to calculate diet quality which is the newest version of the index and align with current dietary guideline for Americans (9, 19). Second, the current study is the first study, to our knowledge, to examine the association between lifestyle groups based on diet quality and PA and HRQOL among older adults. Third, the current study used a nationally representative US sample that increased the statistical power of the study to detect association between diet quality, PA and HRQOL in older adults. Fourth, sensitivity analysis conducted using original cut points for HEI and found primary results were unchanged, supporting the robustness of study findings.

Nonetheless, this study is not without limitations. The cross-sectional study design not allow for conclusion to be drawn regarding casualty of the association between PA and diet quality with HRQOL. It is also possible that if respondents have a lower HRQOL, they may be less likely to want to eat a healthy diet and exercise. Moreover, the current study used tertile distribution for diet quality classification rather than actual cut points for diet quality thus cannot be used to define a healthful diet (27). PA and HRQOL information were collected via self-reported instrument that may reflect personal biases. However, both are widely used and validated instruments (18, 21).

Conclusion

The current study demonstrated that a healthier diet and higher PA levels was associated with better GHS, and less inactive days, physical unhealthy days and mental unhealthy days. The findings from the current study indicates that the importance of having healthier lifestyle behaviors pattern in complying with current dietary guideline and meeting or exceeding PA recommendations for better HRQOL promotion and healthy aging. The findings can also be used to inform policies, programs and interventions designed to improve HRQOL in older adults and reduce health disparities.

Statement of Authorship: Furong Xu, Steven A. Cohen, Ingrid E. Lofgren, Geoffrey W. Greene, Matthew J. Delmonico, and Mary L. Greaney were involved in the design of the current study. Furong Xu performed all analyses with assistance from Steven A. Cohen, Ingrid E. Lofgren and Geoffrey W. Greene. Furong Xu, Steven A. Cohen and Mary L. Greaney wrote the first draft of the paper. All authors made comments and edits on the drafts of the paper and approved the final version of the paper.

Ethics Standards: The University of Rhode Island Institutional Review Board has determined this study does not meet the definition of human subject research under the purview of federal regulation 45 CFR 46 regarding human subject research since data used for the current study are de-identified and publicly accessible.

Conflict of Interest: Furong Xu, Steven A. Cohen, Ingrid E. Lofgren, Geoffrey W. Greene, Matthew J. Delmonico, and Mary L. Greaney declare that they have no conflicting interests related to this study.

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