# Association of diet quality and physical function among overweight and obese primarily African American older adults with lower extremity osteoarthritis

Teresa Schering[a,b,c], Linda Schiffer[d], Andrew McLeod[d,e], Andrew DeMott[f], Susan Hughes[f,h], Marian L. Fitzgibbon[c,d,g] and Lisa Tussing-Humphreys[c,d,e,*]

[a]*Department of Medicine, Chicago, IL, USA*
[b]*Department of Epidemiology, School of Public Health, University of Illinois at Chicago, Chicago, IL, USA*
[c]*University of Illinois Cancer Center, University of Illinois at Chicago, Chicago, IL, USA*
[d]*Institute for Health Research and Policy, Chicago, IL, USA*
[e]*Department of Kinesiology and Nutrition, University of Illinois at Chicago, Chicago, IL, USA*
[f]*Center for Research on Health and Aging, Institute for Health Research Policy, University of Illinois at Chicago, Chicago, IL, USA*
[g]*Department of Pediatrics, University of Illinois at Chicago, Chicago, IL, USA*
[h]*Department of Community Health Sciences, School of Public Health, University of Illinois at Chicago, Chicago, IL, USA*

**Abstract**.

**BACKGROUND:** Strategies to reduce osteoarthritis (OA) symptoms and increase physical function in persons with lower extremity (LE) OA is a public health priority.

**OBJECTIVE:** To examine associations between diet quality and measures of physical function among overweight and obese older adults with self-reported LE OA.

**METHODS:** 413 overweight and obese primarily African American adults ≥60 years old with LE OA were assessed. Diet quality was quantified using the Healthy Eating Index-2010 (HEI-2010) and Alternative Healthy Eating Index-2010 (AHEI-2010). The six-minute walk, 30-second chair-stands, and timed up-and-go tests were used to assess physical function. Unadjusted and multivariable linear regressions were performed to assess associations between the diet quality and measures of physical function.

**RESULTS:** The mean age of the subjects was 67.8 (SD 5.9) years and mean BMI was 34.8 (SD 5.5) kg/m$^2$. Adjusting for total calories, AHEI-2010 total score was associated with superior performance on the six-minute walk test. However, the association was attenuated when also controlling for age, gender, BMI, waist circumference, self-reported pain, and physical activity. HEI-2010 was not associated with the physical function measures.

**CONCLUSION:** AHEI-2010 total score was positively associated with walking speed among older overweight and obese primarily AA older adults with LE OA. However, the association weakened when adjusting for subject covariates. The relationship between diet quality and physical function among health disparate populations should be further investigated in larger cohorts and using rigorous experimental study design.

Keywords: Diet quality, osteoarthritis, African Americans, older adults, obesity

## 1. Introduction

The United States (U.S.) population of adults 65 years and older is projected to double over the next

*Corresponding author: Lisa Tussing-Humphreys, University of Illinois at Chicago (MC 275), 1919 W Taylor St., Chicago, IL 60612, USA. Tel.: +1 312 355 5521; E-mail: ltussing@uic.edu.

three decades, increasing from 48 million to approximately 88 million individuals [1]. The aging of the U.S. population brings with it a rise in prevalence of chronic diseases and an increased burden on the healthcare system. According to the Centers for Disease Control and Prevention, three in four U.S. adults aged 65 and older have multiple chronic conditions [2]. One such condition is osteoarthritis (OA). OA is the most common joint disorder, and the most common type of arthritis. OA affects approximately 30 million U.S. adults [3] with 70% of those over the age of 65 affected by OA [4]. Common symptoms of OA include pain, stiffness, and decreased mobility and range of motion [4]. Given its likelihood of affecting knee and hip joints, OA accounts for more difficulty in stair climbing and general mobility than any other disease [5].

Risk factors for OA include age, sex, obesity and joint injury or overuse [6]. Moreover, African Americans (AA) are more likely to be affected in their large joints [7], with AA women experiencing physical impairment at almost twice the rate of non-Hispanic white women [8]. This health disparity may be attributed to a higher prevalence of obesity among AA women [9] given the fact that obesity is the most significant modifiable risk factor for OA [10]. Currently, persons with a body mass index (BMI) $\geq 30 \, \text{kg/m}^2$ are 6.8 times more likely to develop knee OA than normal weight individuals [10]. Obesity is linked to the development and chronicity of OA through both mechanical and pro-inflammatory pathways [11]. Behavioral lifestyle modification targeting calorie restriction for weight loss is an effective strategy to reduce inflammation and improve physical function and decrease pain in overweight and obese persons with OA [12–14]. Regardless of the evidence of its benefits, weight loss and weight loss maintenance through calorie restriction and physical activity is challenging [12]. Due to these limitations, the development of alternative strategies to reduce OA symptoms and increase physical function in persons with obesity and lower extremity (LE) OA is a public health priority.

Historically, researchers have focused on individual nutrients and foods and their relation to disease prevention and progression. However, the human diet is complex. Therefore, it is becoming common practice to examine diet in a comprehensive manner. Diet quality is one such concept that focuses on the quality of foods included in a diet pattern versus specific individual foods or nutrients [15]. Recent studies show that higher diet quality is associated with less weight gain over the long-term independent of restricting calories [16]. Higher diet quality is also associated with lower OA prevalence [17], signifying a possible protective effect. In one study, higher diet quality in older adults was associated with superior physical function, specifically rising from a seated chair position [18]. Therefore, diet quality could be a useful intervention target for the prevention and management of OA. However, few studies have examined associations between diet quality and measures of physical function in older adults with OA, particularly AAs.

Diet quality can be operationalized by numerically scoring food patterns based on how well they align with national dietary recommendations [19]. One index used to measure diet quality is the Healthy Eating Index (HEI). HEI is a scoring system to evaluate an individual's adherence to a given set of Dietary Guidelines for Americans (DGAs) [19, 20]. The score ranges from 0 to 100, with a score of 100 reflecting full adherence. In older females, better diet quality, measured by HEI-2010, was associated with lower BMI, better physical function and fewer self-reported falls [21].

An additional index used to quantify diet quality is the Alternative Healthy Eating Index (AHEI) [22]. AHEI evaluates an individual's adherence to the Harvard Healthy Eating Plate (HHEP) [22]. HHEP was developed in response to the DGAs, citing a greater focus on foods and nutrients consistently associated with lower risk of major chronic diseases [21–23]. In one cohort of older women, greater AHEI-2010 was associated with lower risk of developing physical functional impairment over an 18-year follow up [24].

The primary aim of this study was to examine associations between diet quality, assessed using HEI-2010 and AHEI-2010, and objective measures of physical function among older overweight and obese primarily AA adults with self-reported LE OA. We hypothesized that higher adherence to both measures of diet quality would be associated with superior physical function. We also hypothesized that AHEI-2010 would exhibit the strongest positive association with measures of physical function given its greater focus on anti-inflammatory dietary components.

## 2. Materials and methods

### 2.1. Study design

This study is a cross-sectional analysis of data collected at baseline from the Fit & Strong! Plus Trial (R01AG039374; NCT03180008). The study

was designed to compare the impact of physical activity versus physical activity plus weight loss on body weight, diet quality, physical activity, and OA symptoms in overweight and obese older adults with self-reported LE OA [25]. Subjects were recruited throughout the city of Chicago. Main findings from the trial have been published [26]. The study was reviewed and approved by the University of Illinois at Chicago Institutional Review Board (#2012-0277). All subjects provided written informed consent prior to study participation.

Interested individuals were screened for eligibility through telephone interview.

Inclusion criteria stipulated that participants have LE OA determined by pain in or around at least one knee or hip most days in the past month, or pain or stiffness in or around hips, knees, ankles, feet, or lower back on most days of at least one month of the last six months; age 60 years and older; no current participation in a regular physical activity program and completing less than 150 min of combined moderate and vigorous physical activity per week; calculated BMI of 25–50 kg/m$^2$; and ability to attend class at specified times and to participate in measurement and intervention procedures. Exclusion criteria: a score of three or more on the 9-item Mental Status Questionnaire [27]; uncomplicated hip or knee surgery within the previous six months or surgery with complications within the past year; plans for hip or knee surgery within the next year; steroid injections in either knee or hip within the previous three months; diagnosis of rheumatoid arthritis; uncontrolled diabetes, or health conditions that might interfere with exercise. The Exercise and Screening for You (EASY) screener [28] was used to identify health contraindications to exercise. Participants who identified one or more high-risk conditions on the EASY screener are required to obtain a physician's approval before participating.

## 2.2. Dietary assessment

All study participants completed a Block 2005 Food Frequency Questionnaire (FFQ) at baseline [29, 30]. The FFQ was administered by trained research staff. The FFQ was designed to assess habitual intake of foods over the past year and current use of a variety of common dietary supplements (*e.g*., multivitamins, calcium, iron). Nutrient values were calculated from the FFQ by NutritionQuest (Berkeley, CA, USA) using a proprietary nutrient database developed from the USDA Food and Nutrient Database for Dietary

Studies [31] to obtain mean daily intake of macro- and micronutrients and HEI-2010 and AHEI-2010 total and component scores. Only plausible (*i.e*., consuming 500–5000 calories daily [32] and valid (*i.e*., <10 missing responses) [33] surveys were used for the analysis (*n* = 13 were excluded).

## 2.3. Diet quality

HEI-2010 is a commonly used measure of diet quality that assesses adherence to the 2010 DGAs [19]. HEI-2010 consists of 12 diet components that encourage adequacy (nine components) and moderation (three components) of foods and nutrients summing to 0–100 points. The nine adequacy components include total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids. The three moderation components include refined grains, sodium, and empty calories (calories from solid fats, alcoholic beverages, and added sugars) [34]. Higher scores in all components indicate closer conformance to the 2010 DGAs. Thus, higher intakes in the adequacy components receive higher scores and higher intakes in the moderation components receive lower scores. HEI-2010 uses an energy density approach to scoring (*i.e.,* per 1000 calories or as a percent of calories), making it unnecessary to control for mean energy intake during statistical analysis [34]. HEI-2010 total and component scores were calculated by NutritionQuest (Berkeley, CA, USA).

AHEI was created as an alternative to the HEI and assesses adherence to the HHEP [22]. AHEI consists of nine components, vegetables, fruits, whole grains, sugar-sweetened beverages and fruit juice, nuts and legumes, red/processed meat, trans fat, long chain fatty acids, polyunsaturated fatty acids (PUFA), sodium, and alcohol [35]. Each component is scored from 0 (worst) to 10 (best), with the total AHEI-2010 score ranging from 0 to 110 points [35]. AHEI does not employ a calorie density scoring approach. Thus, mean energy intake must be accounted for in statistical analysis examining AHEI. AHEI-2010 total and component scores were calculated by NutritionQuest.

## 2.4. Physical function measures

Subjects completed physical function tests in a fed state, at varied times throughout the day and year. Physical function was measured objectively using three different assessments: the six-minute walk test,

the timed up-and-go (TUG) test, and 30-second chair-stands test.

The six-minute walk test is a measure of aerobic capacity and endurance [36]. This test has been used in research interventions, specifically to measure changes in physical function in persons with OA [37]. For this test, subjects were instructed to walk for six minutes at a regular pace along a pre-measured indoor course.

The TUG test measures physical function with targeted focus on gait, gait-speed, and balance [38]. It has been used in research to evaluate balance and gait in older adults with and without OA [39]. The TUG test measures, in seconds, the time taken by an individual to stand up from a standard arm chair (approximate seat height of 46 cm, arm height 65 cm), walk a distance of 3 meters (approximately 10 feet), turn, walk back to the chair, and sit down. Subjects were asked to wear their regular footwear and use their customary walking aid (none, cane, walker). No physical assistance was given. They started with their back against the chair, their arms resting on the armrests, and their walking aid at hand. They are instructed that, on the word "go" they were to get up and walk at a comfortable and safe pace to a line on the floor 3 meters away, turn, return to the chair and sit down again. The subject walked through the test once before being timed in order to become familiar with the test.

Chair-stands are used in research as a tool to assess leg strength and endurance in older adults with and without OA [37]. For this test, subjects were asked to sit in a chair with their hands crossed to their opposite shoulder, and with feet flat on the floor and rise to a full standing position and sit back down again. The number of complete chair-stands completed in a 30-second time period was recorded.

## 2.5. Self-reported physical activity

Self-reported physical activity was measured using the Physical Activity Scale for the Elderly (PASE), which has been used previously among older adults with and without OA [40]. A higher PASE score indicates higher self-reported engagement in physical activity.

## 2.6. Sociodemographic characteristics

A sociodemographic survey was administered to examine subjects' self-reported sex, age, race/

ethnicity, educational attainment, relationship status, household income, and employment status.

## 2.7. Anthropometric measures

Body weight was measured twice using a digital scale (Tanita, Arlington Heights, IL, USA). Height was measured twice using a portable stadiometer (seca, Birmingham, UK). BMI was calculated from weight (kg) and height (m$^2$) and was used to classify subjects into the categories of overweight (25–29.9 kg/m$^2$), obesity class I (30–34.9 kg/m$^2$), obesity class II (35–39.9 kg/m$^2$), or obesity class III ($\geq$40 kg/m$^2$). Waist circumference was measured twice using a Gulick 150-centimeter anthropometric tape (Country Technology, Inc; Gays Mills, WI, USA).

## 2.8. Osteoarthritis severity

The Western Ontario McMaster Universities Osteoarthritis Index (WOMAC) was used to evaluate self-reported symptoms of pain (five items; score range 0–20). A higher score reflects greater self-reported pain related to OA [41]. The validity of the WOMAC in patients with hip or knee OA has been demonstrated [41].

## 2.9. Depression and anxiety

Depression and anxiety were measured using GERI-AIMS, a version of the Arthritis Impact Measurement Scale [42]. This version was adapted for an older adult population. Three questionnaires were used to measure anxiety and three were used to measure depression. The total score was created on a 0–10 scale, with higher scores reflecting higher depression/anxiety.

## 2.10. Statistical analysis

Independent group $t$-tests, chi-square, and Wilcoxon rank sum test were performed to determine if sociodemographic and health characteristics differed by gender. Independent group $t$-tests for HEI-2010 and linear regression controlling for total calories for AHEI-2010 total and components scores were used to examine differences by gender. In simple linear models, total HEI-2010 and AHEI-2010 score were tested separately as independent predictors of the objective physical function measures. The variable total kcal was added to all linear models

Table 1
Characteristics of overweight and obese primarily African American older adults with self-reported lower extremity osteoarthritis

| Variable | Overall (n = 400) | | Men (n = 57) | | Women (n = 343) | | p |
|---|---|---|---|---|---|---|---|
| | Mean, Median or % | SD, n, or IQR | Mean, Median or % | SD, n, or IQR | Mean, Median or % | SD, n, or IQR | |
| Age, years | 67.8 | 5.9 | 67.8 | 5.4 | 67.8 | 6.0 | 0.98 |
| 60–69 | 70% | 279 | 72% | 41 | 69% | 238 | 0.70 |
| >= 70 | 30% | 121 | 28% | 16 | 31% | 105 | |
| Race | | | | | | | 0.50 |
| Black or African American | 92% | 367 | 89% | 51 | 92% | 316 | |
| White, not Hispanic | 4% | 17 | 11% | 6 | 8% | 11 | |
| Education, years | 14.2 | 1.9 | 13.6 | 1.7 | 14.3 | 1.9 | 0.01 |
| Not high school graduate, n % | 6% | 22 | 10% | 6 | 4% | 16 | 0.007 |
| Some college or tech school | 43% | 170 | 54% | 31 | 41% | 139 | |
| College graduate | 37% | 147 | 18% | 10 | 40% | 137 | |
| Employment Status | | | | | | | 0.81 |
| Employed full or part time | 13% | 53 | 12% | 7 | 13% | 46 | |
| Retired/Not employed | 87% | 347 | 88% | 50 | 87% | 297 | |
| Marital Status | | | | | | | 0.01 |
| Married or member of couple | 26% | 104 | 40% | 23 | 24% | 81 | |
| Divorced or separated | 36% | 145 | 26% | 15 | 38% | 130 | |
| Widowed | 22% | 88 | 12% | 7 | 24% | 81 | |
| Never married | 16% | 63 | 21% | 12 | 14% | 51 | |
| Anxiety/Depression (0–10) | 3.0 | 2.0 | 2.1 | 1.4 | 2.6 | 1.7 | 0.08 |
| Income, median (n = 338) | 25,000 | IQR 40,000 | 25,000 | IQR 40,000 | 25,000 | IQR 40,000 | 0.78 |
| WOMAC pain subscale (0–20) | 5.6 | 4.0 | 5.1 | 3.4 | 5.7 | 4.1 | 0.34 |
| PASE total score (n = 396) | 98.2 | 61.8 | 105.3 | 55.7 | 97.0 | 62.7 | 0.35 |
| BMI, kg/m$^2$ | 34.8 | 5.5 | 35.1 | 5.6 | 32.7 | 4.8 | 0.002 |
| Overweight (25 –29.9 kg/m$^2$) | 20% | 78 | 26% | 15 | 18% | 63 | 0.06 |
| Obesity class I (30.34.9 kg/m$^2$) | 35% | 144 | 46% | 26 | 35% | 118 | |
| Obesity class II (35–39.9 kg/m$^2$) | 25% | 100 | 18% | 10 | 26% | 90 | |
| Obesity class III (>= 40 kg/m$^2$) | 20% | 78 | 10% | 6 | 21% | 72 | |
| Waist circumference, cm (n = 398) | 113.0 | 13.8 | 114.1 | 12.2 | 113.0 | 13.8 | 0.58 |

examining AHEI-2010. Following the simple linear modeling, Pearson correlations were used to examine the relationships between the diet quality indices, the objective measures of physical function, and potential covariates (age, gender, BMI, education, race, marital status, self-reported pain from WOMAC, PASE, anxiety/depression, employment, income, and waist circumference). The correlation analyses informed which variables would be included in the multivariable models. Backward selection was used to build a parsimonious multivariable model with total diet quality score as the main independent variable and the physical function test as the dependent variable. In the backward selection model, the covariates BMI, waist circumference, self-reported OA pain from WOMAC, self-reported physical activity, anxiety/depression from GERI-AIMs, race, age, income and gender were tested. All analyses were conducted using SAS version 9.4. Statistical significance was set at $p < 0.05$.

## 3. Results

Four hundred and thirteen participants were recruited, of whom four hundred had plausible and valid FFQs and were included in the analysis. The sociodemographic and health characteristics of the participants are reported in Table 1. The sample was majority female (86%) and AA (92%). The mean age was 67.8 years (SD 5.9). Eighty percent of all subjects reported having completed some college or held a college degree with a median household income of $25,000 (IQR $40,000). Approximately 25% of study participants reported being a member of an unmarried or married couple. The majority (87%) reported being retired or not employed. The mean WOMAC pain score was 5.6 (SD 4.0), indicating a relatively low degree of pain at the time of assessment. The mean PASE score was 98.2 (SD 61.8) indicating low to modest engagement in physical activities. Mean BMI was 34.8 kg/m$^2$ with 20% of participants classified as

Table 2

Physical function measures in overweight and obese primarily African American older adults with self-reported lower extremity osteoarthritis

| Variable | Overall ($n = 400$) | | Men ($n = 57$) | | Women ($n = 343$) | | $p$ |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | |
| Six-minute walk test, feet ($n = 396$) | 1171.4 | 318.7 | 1223.6 | 372.4 | 1162.6 | 308.6 | 0.25 |
| Chair-stands test, (# in 30 seconds) ($n = 399$) | 8.7 | 3.6 | 9.6 | 4.5 | 8.6 | 3.4 | 0.09 |
| Timed up and go test, seconds ($n = 395$) | 11.7 | 3.9 | 11.4 | 3.9 | 11.8 | 3.9 | 0.54 |

Table 3

Healthy Eating Index 2010 (HEI-2010) and Alternative Healthy Eating Index-2010 (AHEI-2010) in overweight and obese primarily African American older adults with self-reported lower extremity osteoarthritis

| | | | | Scores | | | |
|---|---|---|---|---|---|---|---|
| Variable | Overall ($n = 400$) | | Men ($n = 57$) | | Women ($n = 343$) | | $p$ |
| | Mean | SD | Mean | SD | Mean | SD | |
| HEI- 2010 Total Score, (0–100) | 66.3 | 10.5 | 64.0 | 11.0 | 67.0 | 10.0 | 0.13 |
| HEI-2010 Component Scores | | | | | | | |
| Total Vegetables (0–5) | 4.0 | 1.2 | 3.4 | 1.3 | 4.1 | 1.1 | <0.0001 |
| Greens and Beans (0–5) | 4.2 | 1.3 | 3.8 | 1.5 | 4.3 | 1.3 | 0.01 |
| Total Fruit (0–5) | 3.7 | 1.5 | 3.5 | 1.5 | 3.7 | 1.7 | 0.37 |
| Whole Fruit (0–5) | 3.9 | 1.4 | 3.6 | 1.5 | 3.9 | 1.4 | 0.11 |
| Whole Grains (0–10) | 4.4 | 2.9 | 4.4 | 3.0 | 4.4 | 2.9 | 0.98 |
| Dairy (0–10) | 3.9 | 2.3 | 4.0 | 2.1 | 3.9 | 1.4 | 0.11 |
| Total Protein Foods (0–5) | 4.7 | 0.6 | 4.9 | 0.4 | 4.7 | 0.7 | 0.01 |
| Seafood & Plant Proteins (0–5) | 4.2 | 1.2 | 4.1 | 1.3 | 4.2 | 1.2 | 0.47 |
| Fatty Acids, ($M + P/S$) (0–10)[a] | 7.5 | 2.4 | 7.3 | 2.5 | 7.5 | 2.4 | 0.51 |
| Sodium (0–10) | 4.4 | 3.0 | 4.8 | 2.8 | 4.4 | 3.0 | 0.34 |
| Refined grains (0–10) | 9.0 | 1.6 | 9.1 | 1.3 | 9.0 | 1.6 | 0.66 |
| Empty Calories (0–20)[b] | 12.2 | 4.7 | 11.4 | 5.3 | 12.4 | 4.5 | 0.14 |
| AHEI-2010 Total Score, (0–110)[c] | 57.3 | 10.5 | 54.0 | 11.0 | 58.0 | 10.0 | 0.02 |
| AHEI-2010 Component Scores, (0–10) | | | | | | | |
| Vegetables (not potato) | 5.4 | 2.9 | 4.2 | 2.6 | 5.5 | 2.9 | <0.0001 |
| Fruit (not juice) | 3.9 | 3.0 | 3.3 | 2.6 | 4.0 | 3.0 | 0.05 |
| Whole grains | 2.1 | 1.7 | 2.0 | 1.7 | 2.1 | 1.7 | 0.30 |
| Sugar sweetened beverages (and juice) | 3.1 | 3.7 | 2.5 | 3.6 | 3.2 | 3.7 | 0.31 |
| Nuts and legumes | 5.0 | 3.5 | 5.8 | 3.6 | 4.9 | 3.5 | 0.15 |
| Red/processed meat | 6.1 | 2.9 | 4.6 | 3.3 | 6.4 | 2.8 | <0.0001 |
| Trans-fat | 8.2 | 1.3 | 8.0 | 1.5 | 8.2 | 1.2 | 0.27 |
| Long-chain fats (EPA + DHA)[d] | 3.9 | 2.7 | 3.9 | 2.7 | 3.9 | 2.7 | 0.36 |
| Polyunsaturated fat | 8.4 | 1.8 | 8.2 | 1.6 | 8.5 | 1.8 | 0.26 |
| Sodium | 6.6 | 3.4 | 7.2 | 3.1 | 6.5 | 3.4 | <0.0001 |
| Alcohol | 4.6 | 2.4 | 4.6 | 2.6 | 4.5 | 2.3 | 0.84 |

[a]Monounsaturated Fatty Acids + Polyunsaturated Fatty Acids/ Saturated Fatty Acids. [b]Calories from solid fats, alcoholic beverages, and added sugars. [c]Linear model controlling for total calories. [d]Fatty acids from fish (Eicosapentaenoic acid and Docosahexaenoic acid).

overweight, and 80% as obese. When characteristics were examined by gender, women were significantly more likely to report their race as white, have higher educational attainment, and have lower BMI ($p < 0.05$ for all comparisons).

Table 2 reports the results from the tests of physical function. Men averaged 1223.6 (SD 372.4) feet and women averaged 1162.6 feet (SD 308.6) in six minutes. The amount of time on average it took to complete the TUG was 11.4 (SD 3.9) seconds for

men and 11.8 (SD 3.9) for women. The number of chair-stands completed in 30 seconds was on average 9.6 (SD 4.5) for men and 8.6 (SD 3.4) for women. The physical function tests were not significantly different by gender.

HEI-2010 and AHEI-2010 total and component scores are reported in Table 3. Mean HEI-2010 total scores were similar for men and women, respectively (64.0 (SD 11.0) vs. 67.0 (SD 10.0); $p = 0.13$). Men demonstrated significantly higher mean score for the

Table 4

Simple linear models examining Healthy Eating Index 2010 (HEI-2010) and Alternative Healthy Eating Index (AHEI-2010) as predictors of physical function in overweight and obese primarily African American older adults with self-reported lower extremity osteoarthritis

|  | HEI-2010 | | | AHEI-2010[a] | | |
|---|---|---|---|---|---|---|
|  | β | SE | P | B | SE | P |
| Six minute walk test ($n = 397$) | 1.50 | 1.53 | 0.33 | 3.17 | 1.53 | 0.04 |
| 30 second Chair-stands test ($n = 399$) | –0.01 | 0.02 | 0.75 | 0.013 | 0.02 | 0.43 |
| Timed up and Go test ($n = 395$) | –0.01 | 0.02 | 0.79 | –0.03 | 0.02 | 0.15 |

[a]Total calories included as a covariate in simple linear models with AHEI-2010 as the independent variable

Table 5

Multivariable model examining Alternative Healthy Eating Index 2010 (AHEI-2010) as a predictor of performance on the six-minute walk test in overweight and obese primarily African American older adults with self-reported lower extremity osteoarthritis ($n = 391$)

|  | AHEI-2010 β | AHEI-2010 SE | AHEI-2010 p | $R^2$ Model |
|---|---|---|---|---|
| Model adjusted for total calories only[a] | 3.17 | 1.53 | 0.04 | 0.01 |
| Full Model[b] | 2.36 | 1.42 | 0.10 | 0.26 |
| Final Model[c] | 2.40 | 1.40 | 0.08 | 0.25 |

[a]Total calories included as a covariate in simple linear models with AHEI-2010 as the independent variable. [b]Adjusted for covariates found to be significant in univariate models including age, BMI, gender, race, income, waist circumference, symptoms of pain, self-reported physical activity, anxiety/depression, total kilocalories. [c]Final model from backward selection adjusted for age, BMI, gender, waist circumference, symptoms of pain, self-reported physical activity, total kilocalories

total protein foods component (4.9 (SD 0.4) vs. 4.7 (SD 0.7), $p = 0.01$) while women scored significantly higher mean scores for the total vegetables (3.4 (SD 1.3) vs. 4.1 (SD 1.1); $p < 0.0001$) and greens and beans (3.8 (SD 1.5) vs. 4.3 (SD 1.3); $p = 0.01$) components. Men and women scored similarly in regards to the other HEI-2010 components. In regards to AHEI-2010, mean total score was significantly higher among women compared to men (58.0 (SD 10.0) vs. 54.0 (SD11.0); $p = 0.02$) when controlling for total kcal. Women scored significantly higher on the vegetables (5.5 (SD 2.9) vs. 4.2 (SD 2.6); $p < 0.0001$) and red and processed meats (6.4 (SD 2.8) vs. 4.6 (SD 3.3); $p < 0.0001$), and men for the sodium (7.2 (SD 3.1) vs. 6.5 (SD 3.4); $p < 0.0001$) AHEI-2010 component scores.

HEI-2010 and AHEI-2010 total scores were tested separately as independent predictors of performance on the physical function tests in linear models (Table 4). HEI-2010 was not a statistically significant predictor of any of the three physical function measures in unadjusted simple linear models. In the models examining AHEI-2010, controlling for total calories, AHEI-2010 total score was a significant predictor of number of steps walked on the six-minute walk test ($p = 0.04$) but was not a significant predictor of the other physical function measures.

Lastly, a multivariable linear regression model was tested with AHEI-2010 as the main independent variable and the six-minute walk test as the dependent variable (Table 5). Age, BMI, gender, race, income, waist circumference, self-reported OA pain from the WOMAC, PASE score, and anxiety/depression were tested in a backward selection (full model) based on their significant correlations with six-minute walk test in Pearson correlation analysis (data not shown). The final model included AHEI-2010 as the main independent variable and performance on the six-minute walk test as the dependent variable, adjusting for age, gender, BMI, race, self-reported pain, total calories, and PASE score. The association between AHEI-2010 and the six-minute walk test was no longer significant after adjusting for the covariates. The covariates age (β $= -12.1$, $p = < 0.0001$), waist circumference (β $= -4.54$, $p = 0.03$), self-reported pain (β $= -14.01$, $p = 0.0001$), and self-reported physical activity (β $= 1.13$, $p = < 0.0001$), were each significant independent predictors of performance on the six-minute walk test when controlling for AHEI-2010, total calories, and the other variables.

## 4. Discussion

While weight loss through calorie restriction can reduce inflammation and improve OA symptoms and physical function [13, 14], weight loss and weight

loss maintenance are challenging, especially among AAs [43]. In this analysis, we used baseline data from the Fit & Strong! Plus Trial to examine associations between diet quality, measured by HEI-2010 and AHEI-2010, and objective measures of physical function. Shifting a person's dietary pattern to affect physical function may be an appealing alternative to weight loss since it does not require calorie restriction, but instead focuses on changing food choices and improving diet quality. Thus, interventions targeting diet quality may be more attractive and translatable to a greater number of overweight and obese individuals. We found that in a model adjusting for total calories, higher diet quality, measured by AHEI-2010, was associated with superior performance on the six-minute walk test, in older overweight and obese AA adults with LE OA. However, the association was attenuated when also controlling for age, gender, BMI, waist circumference, self-reported pain, and self-reported physical activity. To our knowledge, this is the first study to examine associations between AHEI-2010 and objective measures of physical function among overweight and obese AA older adults with LE OA.

Hagan and colleagues reported in a large cohort of U.S. nurses that greater adherence to the HHEP and higher AHEI-2010 score was associated with lower risk of developing self-reported physical impairment over an 18-year period [24]. We also showed in a subsample of our cohort that higher AHEI-2010 score is associated with lower peripheral inflammation [44]. Consistent with our previous finding, others have shown that higher adherence to the HHEP is associated with more favorable inflammatory and cardiovascular profiles [45]. Physical functioning is associated with these biologic parameters providing mechanistic support for our findings [24].

We were surprised that HEI-2010 was not associated with performance on the physical function tests given a prior study found that HEI-2010 total score was associated with superior physical function and fewer self-reported falls in older women [21]. Another study found a positive association between HEI-2005 total score and both gait speed and knee extensor power among an older representative sample of U.S. adults [46]. Two other studies examining associations between diet quality and OA symptoms concluded that adhering to a higher quality diet was associated with decreased OA symptoms (i.e., joint stiffness and pain with movement) and improved physical function. Specifically, Dyer et al. investigated associations between a Mediterranean type diet (MedDiet) and inflammatory and cartilage degradation in patients with OA. Their study found greater knee flexion and hip rotation, and decreased levels of pro-inflammatory cytokines in those adhering more closely to a MedDiet pattern [47]. Additionally, among adults in the Korean National Health and Nutrition Examination Survey, there was a significant inverse association between dietary glycemic index and symptomatic knee OA in women [48]. Despite these promising findings from ours and other cross-sectional and longitudinal studies, additional research is needed; specifically in the form of randomized controlled trials, to test the effect of diet quality on physical function in adults with OA and the related biological underpinnings.

There is room for improvement in diet quality for both men and women in our cohort. HEI-2010 total score was slightly lower than that reported for a representative U.S. population sample of adults aged 65 and older (69.3 (SD 1.8) vs. 64.0 (SD11.0) for men and 67.0 (SD 10.0) for women in our study, respectively) [20]. Moreover, our cohort demonstrated low HEI-2010 and AHEI-2010 component scores for whole grains, whole fruits and vegetables, and dairy. According to some studies, low fruit and vegetable intake may be associated with functional limitations and disability among older adults, particularly AA women [49]. Fruits and vegetables are an important source of antioxidants, and studies suggest a relationship between high concentrations of antioxidants and increased skeletal muscle repair, that translates to improved physical function [50]. Additionally, consuming five or more servings a day of fruits and vegetables is associated with lower circulating pro-inflammatory markers [51]. Moreover, higher intake of fruits and vegetables is linked with weight loss and weight loss maintenance which may positively affect OA symptoms [52].

## 4.1. Strengths and limitations

A strength of our study is the assessment of diet quality using both HEI-2010 and AHEI-2010, and objective measures of physical function in a majority AA sample of overweight and obese older adults with self-reported LE OA. However, our study is not without limitations. First, an FFQ is a self-reported method to assess dietary intake. As a result, it is prone to bias including poor participant recall, desirable responses, and underreporting of intake [53]. Second, other factors affecting physical function in those with OA including medications, dietary supplements,

and occupation were not examined. Another factor to consider is that this primarily urban AA cohort may not be representative of other older AAs inside or outside the city of Chicago. Other limitations include the facts that subjects who elect to enroll in a lifestyle intervention study may not be representative of the general population of older adults, the unbalanced number of women versus men in our analytic cohort, and the cross-sectional nature of the study design. Lastly, physical function tests were administered at different times of day convenient to the subject and across different seasons which may have introduced bias in our measurement approach.

## 5. Conclusion

To conclude, our study adds to the limited literature examining associations between diet quality and physical function in persons with self-reported LE OA. Our findings suggest that greater adherence to the HHEP and higher AHEI-2010 scores may translate to better physical function in older overweight and obese adults with LE OA. Future randomized trials should be conducted to understand if adopting the HHEP is an effective intervention to improve physical function among the growing population of older adults with LE OA.

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### Author contributions

T.S. and L.TH conceptualized the analysis. T.S. conducted the statistical analysis. T.S., L.TH., L.S., A.M. A.D. M.L.F. and S.H. wrote the paper, L.TH. had primary responsibility for final content. All authors read and approved the final manuscript.

### Conflict of Interest

The authors declare no conflict of interest.

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