Preventive Medicine Reports 3 (2016) 58–61

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Association between accelerometer-determined physical activity and flavonoid-rich fruit and vegetable consumption among a national sample of U.S. adults

Paul D. Loprinzi *

Center for Health Behavior Research, Department of Health, Exercise Science, and Recreation Management, The University of Mississippi, 229 Turner Center, University, MS 38677, USA

ARTICLE INFO

Available online 11 December 2015

Keywords:
Accelerometry
Epidemiology
Flavonoids
Fruits
NHANES
Vegetables

ABSTRACT

Few population studies have examined the association between accelerometer-assessed physical activity and dietary behavior. Further, no studies have systematically examined the association between accelerometer-assessed physical activity and flavonoid rich fruits and vegetables in a national sample. As a result, the purpose of this study was to examine the association between objectively measured physical activity and consumption of flavonoid rich fruits and vegetables among a national sample of U.S. adults. Data from the 2003–2006 National Health and Nutrition Examination Survey (NHANES) were used (N = 2949). Physical activity was measured via accelerometry and fruit and vegetable consumption was measured from the NHANES Food Frequency Questionnaire. After adjustments, moderate-to-vigorous physical activity was positively associated ($p < 0.05$) with apples ($\beta = 0.30$), grapes ($\beta = 0.27$), strawberries ($\beta = 0.32$), oranges ($\beta = 0.35$), raw greens ($\beta = 0.19$), carrots ($\beta = 0.23$), peppers ($\beta = 0.29$) and an overall flavonoid index variable ($\beta = 2.34$). Future studies employing a longitudinal design are needed to better understand the direction of the observed associations. If future studies do indeed support the possibility that physical activity may help to foster changes in dietary behavior, then this will have strong implications for health behavior interventions, particularly among individuals finding it difficult to change multiple health behaviors concurrently.

Introduction

Emerging research demonstrates that consuming foods rich in flavonoids, such as oranges, grapes, and apples, is associated with improved health, including lower inflammation and reduced incidence of diabetes (Holt et al., 2009; Chun et al., 2008; Zamora-Ros et al., 2013). There is also some encouraging work showing that individuals engaging in higher levels of physical activity tend to eat an 'overall' healthier diet than their less active counterparts (Loprinzi et al., 2014; Gillman et al., 2001; Emmons et al., 1994; Eaton et al., 1995; French et al., 1996; Blair et al., 1996; Matthews et al., 1997). However, unlike studies in children and adolescents (Vissers et al., 2013; Jago et al., 2010), these adult studies are limited in the extent that they have exclusively used self-reported physical activity methodology, which is prone to considerable measurement error (Shephard, 2003). Validation studies examining the association between self-report physical activity and some gold-standard (e.g., accelerometry, indirect calorimetry, and doubly labeled water) typically show a poor correlation in the range of 0.3–0.5 (van Poppel et al., 2010; Helmerhorst et al., 2012). Thus, these 'validated' self-report questionnaires only account for 9–25% of the variance in the explanatory parameter and are therefore likely to result in considerable misclassification. Further, the few previous studies on this topic did not systematically examine the association between physical activity and foods rich in flavonoids.

As a result, the purpose of this brief study was to examine the association between objectively-measured (accelerometry) physical activity and 15 different food items rich in flavonoids, as identified from the USDA database for the flavonoid content of selected foods. To improve generalizability, data from the 2003–2006 National Health and Nutrition Examination Survey (NHANES) was used. I hypothesize that adults who are more active will consume more food items rich in flavonoids.

Study design and participants

Data from the 2003–2006 National Health and Nutrition Examination Survey (NHANES) were used (only available cycles with accelerometry data at the time of this writing). All procedures for data collection were approved by the National Center for Health Statistics ethics review board, and all participants provided written informed consent prior to data collection. For the present analyses,

* Fax: +1 662 915 5525.
E-mail address: pdloprin@olemiss.edu.

http://dx.doi.org/10.1016/j.pmedr.2015.12.001

2949 adult participants (20–85 yrs) provided data for all study variables.

Assessment of physical activity

2003–2006 NHANES participants were asked to wear an ActiGraph 7164 accelerometer during all activities, except water-based activities and while sleeping. Prior to the participant's examination, accelerometers were initialized to collect data in one minute time periods. The output of an accelerometer is *activity counts*, which are proportional to measured acceleration. The ActiGraph 7164 accelerometer measures accelerations in the vertical axis using a piezoelectric plate. The accelerometer output is digitized using an analog-to-digital converter, and once digitized, the signal passes through a digital filter that detects accelerations ranging from 0.05 to 2.00 g in magnitude with frequency responses ranging from 0.25 to 2.5 Hz to filter motion outside normal human movement. The filtered signal is then rectified and summed over a pre-determined epoch period. After the activity count is sorted into an epoch, it is stored in the internal memory and then the integrator is reset to zero.

Activity counts per minute of ≥2020 were used to denote moderate-to-vigorous physical activity (MVPA) intensity (Troiano et al., 2008). Nonwear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1–2 min of activity counts between 0 and 100 (Troiano et al., 2008). For the analyses described here, only those participants with at least 4 days with 10 or more hours per day of monitoring data were included in the analyses (Troiano et al., 2008).

Assessment of flavonoid-rich fruits and vegetables

Based on the National Cancer Institute Diet History Questionnaire (DHQ) that is widely used in nutritional epidemiology research (Subar et al., 2001), participants completed the NHANES Food Frequency Questionnaire (FFQ) (Subar et al., 2006). Briefly, participants were asked to report the proportion of time certain types of foods were eaten. For the present study, which is consistent with other studies (Loprinzi and Mahoney, 2015; Mahoney and Loprinzi, 2014), 15 [solid] fruits and vegetables rich in flavonoids (i.e., apples, grapes, strawberries, oranges, cooked greens, raw greens, carrots, string beans, peas, broccoli, onions, peppers, cucumbers, tomatoes, and lettuce) were identified by using the USDA flavonoid content of foods (USDA, 2007). For each of the 15 food items, response options ranged from 1 to 11, and included never (1), 1–6 times/yr (2), 7–11 times/yr (3), 1 time/month (4), 2–3 times/month (5), 1 time/wk (6), 2 times/wk (7), 3–4 times/wk (8), 5–6 times/wk (9), 1 time/day (10), and 2 or more times/day (11). To create a flavonoid index variable, responses were summed, with higher values indicating more frequent consumption of flavonoid-rich fruits and vegetables. With 15 items, the possible range for the flavonoid index variable is 15–165.

Covariates

Covariates included age (yrs; continuous), gender, race-ethnicity (Mexican American, non-Hispanic white, non-Hispanic black, other), cotinine (ng/dL; continuous), poverty level (range: 0–5), BMI (kg/m^2; continuous), and comorbidity index (0–1 + comorbidities). Information about age, gender, and race-ethnicity were obtained from a questionnaire. As a measure of socioeconomic status, poverty-to-income ratio (PIR) was assessed, with a PIR value below 1 considered below the poverty threshold. The PIR is calculated by dividing the family income by the poverty guidelines, which is specific to the family size, year assessed, and state of residence. Serum cotinine was measured as a marker of active smoking status or environmental exposure to tobacco (i.e., passive smoking). Serum cotinine was measured by an isotope dilution-high performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. BMI was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). With regard to chronic disease, participants were classified as having 0 or 1 + comorbidities based on self-report of the following chronic diseases/events: arthritis, coronary heart disease, stroke, congestive heart failure, cancer, heart attack, emphysema, chronic bronchitis, asthma, or hypertension.

Data analysis

All statistical analyses (STATA, version 12.0, College Station, TX) accounted for the complex survey design used in NHANES by using survey sample weights, clustering, and primary sampling units. Means and standard errors were calculated for continuous variables and proportions were calculated for categorical variables. To examine the association between MVPA and flavonoid-rich fruits and vegetables (outcome variable), multivariable linear regression analysis was employed. Separate models were computed for each of the fruit and vegetable items. A model using the index variable was also computed. In total, 16 regression models (15 fruit and vegetable items plus the index variable) were computed. Models controlled for age, gender, race-ethnicity, cotinine, poverty level, BMI, and comorbidity index. A $p < 0.05$ denoted statistical significance for all analyses.

Results

Weighted characteristics of the analyzed sample are shown in Table 1. Participants were, on average, 50 years of age, 56% were female,

Table 1
Weighted characteristics of the analyzed sample, NHANES 2003–2006 (n = 2949).

Variable	Mean/proportion	(95% CI)
Demographics		
Age, yr	49.9	48.9–50.9
% Female	56.1	54.2–58.0
Race-ethnicity, %		
Mexican American	7.8	5.7–9.9
Other Hispanic	1.9	1.2–2.6
Non-Hispanic White	75.7	71.3–80.1
Non-Hispanic Black	8.3	6.0–10.7
Other Race	6.0	4.3–7.8
Cotinine, ng/mL	47.6	41.4–53.7
Poverty-to-Income Ratio	3.3	3.1–3.4
Body Mass Index, kg/m^2	28.1	27.7–28.5
Comorbidity Index, %		
0 Comorbidities	44.7	42.4–46.9
1 + Comorbidities	55.2	53.0–57.5
Physical activity		
MVPA, min/day	22.3	21.0–23.5
Diet [a]		
Apples	4.9	4.7–5.0
Grapes	4.3	4.2–4.4
Strawberries	4.5	4.4–4.7
Oranges	4.8	4.7–5.0
Cooked Greens	3.5	3.4–3.7
Raw Greens	2.9	2.8–3.1
Carrots	4.9	4.8–5.1
String Beans	5.1	4.9–5.3
Peas	4.1	4.0–4.2
Broccoli	4.6	4.4–4.7
Onions	6.6	6.5–6.8
Peppers	4.6	4.5–4.8
Cucumbers	4.3	4.1–4.4
Tomatoes	6.9	6.8–7.1
Lettuce	6.4	6.2–6.5
Index Variable (sum of each item)	73.1	72.0–74.2

MVPA = Moderate-to-vigorous physical activity.
[a] For each of the 15 food items, response options ranged from 1 to 11, and included never (1), 1–6 times/yr (2), 7–11 times/yr (3), 1 time/month (4), 2–3 times/month (5), 1 time/wk (6), 2 times/wk (7), 3–4 times/wk (8), 5–6 times/wk (9), 1 time/day (10), and 2 or more times/day (11).