Title

A Descriptive Analysis of the Association Between the Duration of Eating Interval Over the Course of the Day, Diet Quality, and Clinical Cardiometabolic Health in NHANES 2015-2016

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THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Epidemiology

by

Valeria Elahy

Thesis Committee:
Assistant Professor Andrew O. Odegaard, Chair
Professor Karen L. Edwards
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ABSTRACT OF THE THESIS

A Descriptive Analysis of the Association Between the Duration of Eating Interval Over the Course of the Day, Diet Quality, and Clinical Cardiometabolic Health in NHANES *2015-2016*

By

Valeria Elahy

Master of Science in Epidemiology

University of California, Irvine, 2019

Assistant Professor Andrew O. Odegaard, Chair

There is little population level descriptive evidence on the association between the duration of eating interval over the course of the day with diet quality and clinical cardiometabolic health measures. A cross-sectional analysis using data from The National Health and Nutrition Examination Survey 2015-2016 included 3848 adults (aged 20–79) who underwent medical examination and had two days of dietary data based on 24h dietary recall. Diet quality was measured using the Health Eating Index-2015 (HEI-2015). Clinical cardiometabolic measures included total cholesterol, HDL, LDL, triglycerides, TG/HDL-c ratio, fasting glucose, glycohemoglobin, insulin, OGTT, HOMA-IR, systolic and diastolic blood pressure, BMI and sagittal abdominal diameter. Eating duration was defined as the time period between the beginning of the first and the last eating episodes of the day and was divided into 6 intervals (<8hr, 8-9:59hr, 10-11:59hr, 12-13:59hr, 14-15:59hr, 16+hr). Analyses were carried out using multiple linear regression with adjustment for major confounders. Participants had higher diet quality with longer duration of eating over the course of the day from <8 hr to 15.59 hr and participants with a 16+ hr eating duration had lower diet quality. Duration of eating over the

course of the day and diet quality were influenced by breakfast habits, smoking habits, and family-income to poverty ratio. Additionally, clinical cardiometabolic risk measures also varied according to duration of eating over the course of the day, with particularly worse glycemic-related measures for people with diabetes with longer duration.

INTRODUCTION

Poor diet quality is linked to diabetes, cardiovascular disease, cancer and other chronic morbidities among Americans and around the world. Dietary guidelines are regularly updated with regards to recommended amounts of dietary macronutrients, micronutrients and energy density for adults and children, however, the recommendations lack clarity over what optimal time period all food is best to be consumed. Majority of American adults eat for 15 hr or longer every day, however there is a variation of eating intervals in the population (Gill & Panda, 2015).

The practice of intermittent fasting and time-restricted feeding has been increasing among some populations, due to the potential benefit time-restricted feeding has on health that has been shown in some animal studies. Particularly, eating for a limited number of hours a day has been associated with weight loss, longevity, and decreased risk of diabetes, metabolic syndrome and cardiovascular disease (Pedersen et al. 1999, Castello et al. 2010). Animal models have shown biological mechanisms that explain how fasting might impact health by optimizing energy metabolism and reducing inflammation, yet there are no studies in humans, that have confirmed these results (Longo & Mattson, 2014).

Although, duration of eating intervals affects total caloric intake, no studies have assessed how eating duration affects diet quality. Identifying an association between eating interval, diet quality and health risk could help to provide the population with the recommendations regarding optimal eating period that is associated with lower risk of developing chronic health disparities.

To answer the questions about how the duration of eating interval associates with the diet quality and health risks of adults in the U.S. a nation-wide cross-sectional study was conducted. The first aim of this study was to describe and compare how different eating intervals associate with overall diet quality. A second aim was to describe and compare how different eating intervals associate with clinical biomarkers of diabetes (fasting glucose, glycohemoglobin, insulin, two hour glucose (OGTT), HOMA-IR), cardiovascular disease (total cholesterol, HDL, LDL, triglycerides (TG), TG/HDL-c ratio, systolic and diastolic blood pressure,) and obesity (BMI and sagittal abdominal diameter) in adults. The null hypothesis was that eating duration had no association with measurements of diet quality and clinical biomarkers. The secondary aim of this study was to examine how diet quality modified the association between eating intervals and clinical cardiometabolic measures. Secondary null hypothesis was that diet quality had no association with the effect of eating duration on the measurements of clinical biomarkers.

METHODS

Study Design

The National Health and Nutrition Examination Survey (NHANES) is a cross-sectional survey that represents noninstitutionalized population of the United States. Data was collected during in-person interviews and standardized physical and medical examinations were performed in mobile examination centers, the methods of which were described elsewhere (Centers for Disease Control and Prevention, 2017). Survey protocols were approved by the National Center for Health Statistics Research Ethics Review Board. All participants provided written informed consent, and data are publicly available.

Setting and Subjects

Adults aged 20 to 79 years who had completed 2 days of dietary recall without missing data were eligible for this study (Figure 1). Restriction of subjects to adults was done because children and adolescents required a modified diet quality assessment tool different from the one used in this study (Feskanich, Rockett, & Colditz, 2004). Since NHANES 2015-2016 coded all responses of participants aged 80 years and older as '80', the subjects older than 79 years old were not included in this study. The analysis excluded individuals who were reported to be pregnant or lactating at the time of dietary recall (obtained from the reproductive health section of the questionnaire) because of concerns regarding the influence that pregnancy or lactation might have on dietary patterns (Verbeke, 2007). The subjects who had missing data on the primary exposure or outcome variables were excluded from the analysis. The socio-demographic and other characteristics of the study sample were detailed in Table 1.

Table 1. Participant Characteristics According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16

Duration of Eating Interval (hours)	<8h	8-9:59h	10-11:59h	12-13:59h	14-15:59h	16+h
n (%)	251 (6.5)	482 (12.5)	1209(31.4)	1269 (33)	488 (12.7)	149 (3.9)
Characteristics						
Sex, %						
Male	47.4	46.1	42.6	50.3	57.4	63.8
Female	52.6	53.9	57.4	49.7	42.6	36.2
Level of Education, %						
<12y	27.1	24.5	21.8	17.7	16.2	14.1
High school graduate	31.5	28.8	21.3	18.6	24.0	25.5
Some college or AA degree	27.9	28.0	30.2	30.7	30.9	30.9
College graduate or above	13.6	18.7	26.6	32.9	28.9	29.5
Race/Ethnicity, %						
Non-Hispanic White	20.3	26.6	32.1	37.4	41.4	34.9
Non-Hispanic Black	44.2	27.2	21.3	17.3	18.9	28.9
Hispanic	24.3	33.2	33.5	29.5	26.2	21.5
Other	11.2	13.1	13.2	15.8	13.5	14.8
Smoking Status, %						
current smoker	31.5	20.3	15.4	18.3	24.2	29.5
quitted 1-49y ago	14.3	15.8	23.4	24.0	27.3	26.9
never smoked	54.2	63.9	61.0	57.5	48.2	43.6
Marital Status, %						
married	50.2	51.5	61.6	66.8	63.3	52.4
not married	49.8	48.6	38.4	33.2	36.7	47.7
Physical Activity %						
>=150 mins	39.8	42.5	45.4	48.8	44.3	46.3
<150 mins	4.0	2.7	4.7	5.0	4.3	6.7
Missing	56.2	54.8	49.9	46.3	51.4	47.0
Sleep Duration, %						
<7h	25.1	22.0	19.7	20.9	33.0	42.3
7-9h	52.2	63.5	66.3	73.3	62.3	50.3
>9h	22.7	14.5	14.1	5.8	4.7	7.4
Ratio income-poverty, %						
<=1	47.4	34.9	28.5	24.3	23.8	26.2
>1 to 2.5	32.3	36.1	32.8	29.2	34.4	32.2
>2.5 to 4	11.2	14.3	16.6	17.4	19.7	15.4
>4	9.2	14.7	22.1	29.2	22.1	26.2
Health insurance, %						
Yes	71.2	74.6	83.7	86.0	86.9	84.6
No	28.8	25.4	16.3	14.0	13.1	15.4
Employment Status, %						
employed	54.2	52.3	53.8	65.1	71.1	66.4
unemployed	45.8	47.7	46.2	34.9	28.9	33.6
Age group, %						
20-30	28.7	25.9	15.8	15.3	12.9	20.8
31-40	21.1	19.7	17.5	16.4	15.0	13.4

41-50	17.5	12.9	17.1	20.1	19.1	17.4
51-60	14.3	16.2	16.2	19.2	26.2	22.1
61-70	11.6	17.0	21.2	18.2	17.8	22.8
71-79	6.8	8.3	12.2	10.8	9.0	3.4
Diabetes status, %						
Diabetes	12.4	13.3	18.1	13.6	17.4	11.4
No diabetes	87.6	86.7	81.9	86.4	82.6	88.6
Hypertension status, %						
Hypertension	31.5	30.7	30.5	27.5	29.3	31.5
No Hypertension	68.5	69.3	69.5	72.5	70.7	68.5

Measures

Diet quality was estimated using Healthy Eating Index-2015 (HEI-2015). HEI-2015 was released by the United States Department of Agriculture's (USDA) Center for Nutrition Policy and Promotion and designed to align with the 2015-2020 Dietary Guidelines for Americans (DGAs) (NIH National Cancer Institute Division of Cancer Control and Population Sciences, 2015). The HEI-2015 contains 13 components that sum to a total maximum score of 100 points. A higher score corresponds to a healthier diet. 9 HEI-2015 categories score the adequacy of total fruits (including 100% fruit juice), whole fruits (includes all forms of fruits except juice), total vegetables (including legumes), greens and beans, whole grains, dairy (all dairy products and fortified soy beverages), total protein (including legumes), seafood and plant protein (seafood, nuts, seeds, non-beverage soy products and legumes) and fatty acids (ratio of poly- and monounsaturated fatty acids to saturated fatty acids). Moderation of refined grains, sodium, added sugars and saturated fats intake is scored by other 4 HEI-2015 components.

HEI-2015 components and total scores were calculated using a bivariate approach from the 24-hour dietary recall data of 2 days collected in NHANES 2015-2016.

Other primary outcome measures that included direct HDL-cholesterol (mg/dL), LDL-cholesterol (mg/dL), total cholesterol (mg/dL), triglyceride (mmol/L), fasting glucose (mg/dL), glycohemoglobin (%), insulin (µU/ml), two hour glucose (OGTT) (mg/dL) were obtained from NHANES 2015-2016 laboratory data. The subjects participating in the interview were invited to participate in the examination carried out in a mobile examination center including phlebotomy and body measurements. The procedures of blood serum collection, handling and blood serum analysis were described elsewhere (NIH National Cancer Institute Division of Cancer Control and Population Sciences, 2015). The participants who had data for LDL, triglycerides, insulin, and fasting plasma glucose were examined in the morning session and had completed at least a 9-hour fast. After the initial blood draw, the participants were asked to participate in an oral glucose tolerance test (OGTT) and drink 75 grams of dextrose (10 oz of glucose solution) within 10 minutes. Two hours later, a second blood sample for OGTT was collected.

The ratio of triglycerides to HDL-cholesterol (TG/HDL-c ratio) and HOMA-IR were calculated using the NHANES data. HOMA-IR was calculated using the formula: HOMA-IR = insulin (μU/ml) × glucose (mg/dL)/405, using fasting values (Matthews, 1985).

Systolic and diastolic blood pressure (mm Hg), body mass index (BMI) (kg/m^2) and average sagittal abdominal diameter (cm) measurements were obtained from NHANES physical examination data. Mean Systolic and diastolic blood pressure (mm Hg) and average sagittal abdominal diameter were calculated using four consecutive readings.

Eating duration was defined as the time interval between the reported time of the first eating episode of the day (>0 kcal) and the last eating episode (>0 kcal) in the 24-h dietary recall. A primary predictor variable was calculated as a mean of eating durations for 2 days for every subject. For a better visualization of the results, the eating duration was broken down into 6 intervals (<8hr, 8-9:59hr, 10-11:59hr, 12-13:59hr, 14-15:59hr, 16+hr). The threshold cut-off points of the intervals were influenced by the findings of previous studies (Sidhu et al. 2012, Wajngot et al. 2012, Chaix et al. 2014)

Sociodemographic characteristics, including gender, age, race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, including Mexican American and other Hispanic, and others), income to poverty ratio (ratio of reported total family income to the US Census Bureau's poverty threshold, which varies by size of family and age of family members), marital status, and education level were obtained from NHANES demographic data collected during the interview. 4 categories of income to poverty ratio were defined as <=1, >1 to 2.5, >2.5 to 4, >4 if the family income was below or at the poverty level, above poverty level up to 250% of the poverty level, greater than 250% to 400% of poverty level, greater than 400% of poverty level respectively. Marital status was recoded in two groups as married or living with a partner and not married or not living with a partner. Education level was recoded in 4 categories as <12 years of education, high school graduate, some college education without completion or AA degree, college graduate and above. Smoking status was defined in three categories as current smokers (smoked >100 cigarettes in a lifetime and current smokers), non-smokers or quitted smoking >50 years ago (did not smoke >100 cigarettes in a lifetime or quit >50 years ago) and quitted smoking 1-49 years ago (smoked >100 cigarettes in a lifetime and quitted 1-49 years ago). The data referring to smoking habits was obtained from the NHANES questionnaire. Physical activity was categorized in 2 groups with the cutoff point at 150 minutes of moderate or vigorous recreational physical activity a week. The measure of minutes of physical activity was calculated as a sum of moderate and vigorous recreational physical activity in a week which were self-reported in NHANES questionnaire (exact questions: "How much time do you spend doing vigorous-intensity/ moderate-intensity sports, fitness or recreational activities on a typical day?" and "In a typical week, on how many days do you do vigorous-intensity/moderate-intensity sports, fitness or recreational activities?"). Sleep duration was defined in sleep hours as three categories <7hr, 7-9hr and >9hr, based on the data reported to the question “How much sleep usually get at night on weekdays or workdays?”. Insurance coverage was defined as “yes/no” based on the response of the subjects to the question in the NHANES questionnaire: “Are you covered by health insurance or some other kind of health care plan?”. Employment status was defined as “employed” if the subject reported working at or having a job or business last week, and “unemployed” if the subject reported looking for work or not working at a job or business last week. Diabetes status was defined positive if the subject answered yes to the question: “Have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?”. Hypertension status was defined as positive if the subject answered yes to the question: “Have you ever been told by a doctor or other health professional that you had hypertension, also called high blood pressure?”. In each recall the respondents were asked to identify or name the eating occasion for each reported food and beverage. Breakfast consumption was determined based on whether the respondent mentioned any foods and beverages for breakfast, desayuno, or brunch. Then number of breakfast occasions was calculated for 2 days of 24-hour dietary recall. If the subjects did not recall having breakfast on both days, subject having breakfast once in 2 days or subject having breakfast on both days of recall, they were categorized as “never”, “occasional” and “always” respectively (Graubard et al. 2018).

Data Analysis

Directed acyclic graphs (DAGs) were constructed based on the questions of the study prior to the study analysis with all the variables of interest. The findings of the previous studies were used to determine the relationship of the variables to each other (references). Decisions of selection of potential confounders was based on the underlying confounding effect of the known covariate on the associating between exposure and outcome. Figure 2a presented DAG visualizing the relationship between primary exposure (eating duration), primary outcome (diet quality) and other covariates. Based on this graph, sex, race/ethnicity, age, sleep duration, breakfast habit, employment status, family income and education were potential confounders. Figure 2b presents DAG visualizing the relationship between primary exposure (eating duration), primary outcome (clinical biomarkers) and other covariates. Based on this graph, sex, race/ethnicity, age, sleep duration, breakfast habit, family income and education were potential confounders.

Pearson polyserial correlation coefficient was used to explore the relationship between education, family income to poverty ratio and employment status. Both education and employment status were moderately positively correlated with family income to poverty ratio ($r>0.5$, $p<0.05$). Due to a number of missing observations of employment status it was decided not to use this variable in the future model. Level of education and family income to poverty ratio were taken further for the analysis and only one of these two variables would be selected for adjustment based on the higher change of adjusted mean during the model selection process.

First, stratified analysis was performed to evaluate the association between primary exposure and outcomes while controlling for potential confounders one at a time. This method helped to visualize the distribution of subjects by outcome, exposure and the potential confounder.

Then, multivariable linear regression models were used to evaluate the association between eating duration and diet quality as well as eating duration and clinical biomarkers, while simultaneously controlling for multiple possible confounders (Rothman, 2012). Basic unadjusted models with a primary predictor (eating duration) and primary outcomes (diet quality for question 1 and clinical biomarkers for question 2) were set up. Then, using potential confounder selected through DAGs, models were built by introducing potential confounders as well as potential interaction terms, one at a time. The potential confounders were introduced to the model as single terms. As a result, two final adjusted models (Model 1.1 and Model 1.2) were created for examining the association between eating duration and diet quality and one adjusted model (Model 2.1) was created to examine the association between eating duration and clinical biomarkers. Models 1.1 and 2.1 adjusted for age, race, sex and family income to poverty ratio. Model 1.2 adjusted for all covariates of Model 1.1 and sleep duration. The mean unadjusted and adjusted estimates of diet quality and clinical outcomes associated with 6 intervals of eating duration were recorded in Tables 2 and 4.

Table 2: Diet Quality (HEI-2015 scores) According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16

Duration of Eating	***<8h***	***8-9:59h***	***10-11:59h***	***12-13:59h***	***14-15:59h***	***16+h***
HEI-2015 (Mean, SE)[1]	47.8 ±0.9	51.7 ±0.6	54.1 ±0.4	55.4 ±0.4	54.5 ±0.6	51.7 ±1.1
HEI-2015 (Mean, SE)[2]	49.8 ±0.9	52.8 ±0.6	54.2 ±0.4	55.1 ±0.4	55.1 ±0.6	52.3 ±1.1
HEI-2015 (Mean, SE)[3]	49.7 ±0.9	52.7 ±0.6	54.2 ±0.4	55.2 ±0.4	55.2 ±0.6	52.5 ±1.1

Maximum possible scores: HEI-2015 total score 100
[1]Crude
[2]Adjusted for age, sex, race and family income to poverty ratio
[3] Adjusted for age, sex, race, family income to poverty ratio, and sleep duration

Stratification was used to control for potential effect measure-modifiers as well as other confounders not included in the final models. For question 1, stratification of adjusted estimates of association between diet quality and eating duration by breakfast frequency habit, smoking status and family income to poverty ratio were performed and the results were reported below (Tables 3a, 3b, 3c). The stratification on physical activity level, employment status, marital status was performed during the sensitivity analysis, but the results were similar to unstratified model, thus the results are not reported below. For question 2, stratification of adjusted estimates of association between clinical biomarkers and eating duration by diet quality tertiles and diabetes status were performed, and the results were reported below (Tables 5a and 5b). The stratification on physical activity level, hypertension status and health insurance status were performed during the sensitivity analysis, but the results were similar to unstratified model, thus the results are not reported below.

Least-squares means (mean) with standard error (SE) estimates of the HEI-2015 total scores and clinical biomarkers were used to present the relationship between primary predictor and outcomes in unadjusted and adjusted models.

To visualize multidimensional qualities of HEI-2015 scores radar plot was used (Figure 3b) (NIH National Cancer Institute: Division of Cancer Control and Population Sciences, 2018). Each spoke of the plot represents a separate component of the score. The lines of different color represent the estimates of HEI component by different eating durations.

Table 3a: Diet Quality (HEI-2015 scores) According to Duration of Eating Interval over the Course of the Day and Breakfast Frequency: NHANES 2015-16

Breakfast [3]	***Duration of Eating***	***<8h***	***8-9:59h***	***10-11:59h***	***12-13:59h***	***14-15:59h***	***16+h***
Always	HEI-2015 (Mean, SE)[1]	52.5±2.3	53.9±0.9	55.7±0.5	56.2±0.4	56.1±0.7	54.6±1.4
	HEI-2015 (Mean, SE)[2]	52.5±2.3	53.9±0.9	55.7±0.5	56.2±0.4	56.1±0.7	54.6±1.4
Occasionally	HEI-2015 (Mean, SE)[1]	50.6±1.3	51.1±1.1	48.9±0.9	50.3±1.1	50.8±2	48.3±2.3
	HEI-2015 (Mean, SE)[2]	50.6±1.3	51.1±1.1	48.9±0.9	50.3±1.1	50.8±2	48.3±2.3
Never	HEI-2015 (Mean, SE)[1]	44.7±1.3	49.2±1.5	49.6±1.9	45.4±2.3	47.1±3.1	45.8±3.3
	HEI-2015 (Mean, SE)[2]	44.7±1.3	49.2±1.5	49.6±1.9	45.4±2.3	47.1±3.1	45.8±3.3

[1]Adjusted for age, sex, race and family income to poverty ratio

[2] Adjusted for age, sex, race, family income to poverty ratio, and sleep duration

Table 3b: Diet Quality (HEI-2015 scores) According to Duration of Eating Interval over the Course of the Day and Smoking Status: NHANES 2015-16

Smoking	***Duration of Eating***	***<8h***	***8-9:59h***	***10-11:59h***	***12-13:59h***	***14-15:59h***	***16+h***
current smoker	HEI-2015 (Mean, SE)[1]	43.7±1.5	49±1.3	49±0.9	49.5±0.8	48.3±1.2	45.4±1.9
	HEI-2015 (Mean, SE)[2]	43.7±1.5	49±1.3	49±1	49.5±0.8	48.2±1.2	45±1.9
quitted 1-49y ago	HEI-2015 (Mean, SE)[1]	49.7±2.5	53.5±1.6	55.4±0.9	56.8±0.9	56.3±1.2	58.4±2.1
	HEI-2015 (Mean, SE)[2]	49.6±2.5	53.5±1.6	55.1±0.9	56.8±0.9	56.6±1.2	59±2.2
never smoked	HEI-2015 (Mean, SE)[1]	52.3±1.3	53.5±0.8	55±0.5	56.4±0.5	57.4±0.9	52.6±1.7
	HEI-2015 (Mean, SE)[2]	52.2±1.3	53.5±0.8	54.9±0.5	56.4±0.5	57.5±0.9	52.6±1.7
Maximum possible scores: HEI-2015 total score 100 [1]Adjusted for age, sex, race and family income to poverty ratio [2] Adjusted for age, sex, race, family income to poverty ratio, and sleep duration							

Table 3c: Diet Quality (HEI-2015 scores) According to Duration of Eating Interval over the Course of the Day and Family Income to Poverty Ratio: NHANES 2015-16

Income-Poverty	***Duration of Eating***	***<8h***	***8-9:59h***	***10-11:59h***	***12-13:59h***	***14-15:59h***	***16+h***
<=1	HEI-2015 (Mean, SE)[1]	47.8±1.5	52±1.2	52±0.9	52.8±0.9	51.4±1.6	47.8±2.4
	HEI-2015 (Mean, SE)[2]	47.7±1.5	52±1.2	52±0.9	52.8±0.9	51.6±1.6	47.7±2.5
>1 to 2.5	HEI-2015 (Mean, SE)[1]	48±1.5	51.7±1	52.1±0.7	53.2±0.7	53.5±1	52.4±1.9
	HEI-2015 (Mean, SE)[2]	47.9±1.5	51.6±1	52±0.7	53.3±0.7	53.6±1	52.6±1.9
>2.5 to 4	HEI-2015 (Mean, SE)[1]	51.7±2.5	49.5±1.6	55.7±1	56±0.9	55.1±1.4	55.5±2.8
	HEI-2015 (Mean, SE)[2]	51.7±2.5	49.5±1.6	55.7±1	56±0.9	55.2±1.4	55.3±2.9
>4	HEI-2015 (Mean, SE)[1]	52.4±2.8	56.5±1.6	57.6±0.8	58.8±0.7	59.9±1.3	54.1±2.1

	HEI-2015 (Mean, SE)[2]	52.6±2.8	56.3±1.6	57.5±0.8	58.8±0.7	60±1.3	54.6±2.1
Maximum possible scores: HEI-2015 total score 100 [1]Adjusted for age, sex, race [2] Adjusted for age, sex, race, and sleep duration							

Sensitivity analysis was performed to see if various definitions of the first eating episode affected the resulting estimates of diet quality and clinical biomarkers. First eating occasion of >0 kcal, >50kcal (equivalent to 8oz of coffee with 1 tbsp of cream and 2 sugars) and >100kcal (equivalent to 8oz of nonfat Greek yogurt). The resulting estimates of diet quality and clinical biomarkers did not change sufficiently (<7%), thus the decision was made to use >0 kcal meal as the definition of the first eating episode of the day.

Table 4: Clinical Measures According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16

Duration of Eating	**<8h**	**8-9:59h**	**10-11:59h**	**12-13:59h**	**14-15:59h**	**16+h**
	Mean, SE[1]					
Average Sagittal Abdominal Diameter (cm)	24±0.3	23.5±0.2	23.3±0.1	22.8±0.1	22.9±0.2	23.4±0.4
Body Mass Index (kg/m^2)	31.3±0.5	31±0.3	30.3±0.2	29.4±0.2	29.1±0.3	29.8±0.6
Diastolic Blood Pressure (mmHg)	70.7±0.8	70.8±0.6	70.3±0.4	69.9±0.3	70.5±0.6	72.3±1
Systolic Blood Pressure (mmHg)	126.3±1.1	125.9±0.8	125.4±0.5	123.9±0.5	124.8±0.8	125.4±1.5
Insulin (uU/mL)	14.6±1.9	17.1±1.5	15.5±0.9	14.3±0.9	12.4±1.4	12.9±2.7
Fasting Glucose (mg/dL)	105.1±3.9	113.1±2.9	115.6±1.8	112.5±1.7	120.1±2.7	118.3±5.4
Two Hour Glucose (OGTT) (mg/dL)	119.5±5.5	123.2±4.1	123±2.7	122.2±2.4	119.8±4.1	118.9±8.2
HOMA-IR	4±0.9	5.6±0.7	5±0.4	4.5±0.4	3.9±0.6	3.7±1.3
Glycohemoglobin (%)	5.7±0.1	5.8±0.1	5.9±0	5.8±0	5.9±0.1	5.8±0.1
Direct HDL-Cholesterol (mg/dL)	51.7±1.1	53.9±0.8	53.6±0.5	53.9±0.5	54.5±0.8	54.4±1.5
LDL-cholesterol (mg/dL)	119.2±3.5	108.4±2.6	113.3±1.6	114.7±1.5	113±2.4	105.9±4.9
Triglyceride (mg/dL)	117.6±9.7	117.3±7.2	121.3±4.5	109.5±4.3	117.7±6.8	104.5±13.7
Ratio of Triglycerides to HDL-Cholesterol	2.6±0.3	2.5±0.3	2.8±0.2	2.4±0.2	2.7±0.2	2.4±0.5
Total Cholesterol (mg/dL)	189±2.7	186.6±1.9	191.3±1.2	193.6±1.2	192.9±1.9	187.1±3.5

	Mean, SE[2]					
Average Sagittal Abdominal Diameter (cm)	24±0.3	23.5±0.2	23±0.1	22.7±0.1	22.5±0.2	23.1±0.4
Body Mass Index (kg/m^2)	30.7±0.5	30.5±0.4	29.8±0.2	29.2±0.2	29±0.3	29.8±0.6
Diastolic Blood Pressure (mmHg)	70.3±0.9	71.1±0.6	70.8±0.4	70.3±0.4	70.7±0.6	72±1.1
Systolic Blood Pressure (mmHg)	126.5±1.1	126.8±0.8	125±0.5	124±0.5	124.1±0.8	125.3±1.4
Insulin (uU/mL)	14.7±2	16.3±1.5	15.4±0.9	13.8±0.9	12.6±1.4	12.5±2.6
Fasting Glucose (mg/dL)	107.9±4.1	111.3±3	115.6±1.9	112.7±1.8	119.3±2.8	117.7±5.2
Two Hour Glucose (OGTT) (mg/dL)	123.8±5.7	125.2±4.2	122.1±2.7	121.6±2.5	118.2±4.1	120.1±7.8
HOMA-IR	4.3±1	5.4±0.7	5.1±0.4	4.4±0.4	4±0.7	3.5±1.2
Glycohemoglobin (%)	5.8±0.1	5.8±0.1	5.9±0	5.8±0	5.9±0.1	5.9±0.1
Direct HDL-Cholesterol (mg/dL)	52.5±1.2	54.8±0.8	53.3±0.5	53.7±0.5	55.2±0.8	55.2±1.4
LDL-cholesterol (mg/dL)	118.9±3.8	107.9±2.8	113.7±1.7	115.4±1.7	113.1±2.6	106.2±5
Triglyceride (mg/dL)	128.1±9.2	119.4±6.6	114.6±4.2	107.8±4	116.7±6.3	107.2±11.9
Ratio of Triglycerides to HDL-Cholesterol	2.8±0.3	2.5±0.2	2.6±0.1	2.4±0.1	2.7±0.2	2.5±0.4
Total Cholesterol (mg/dL)	192.6±3	187.3±2.1	190.4±1.3	193.4±1.3	192.6±2	188±3.6

[1] Crude
[2] Adjusted for age, sex, race and family income to poverty ratio

Data cleaning was performed prior to modeling and outliers were identified. After the final models were created, the analysis was performed with and without outliers. The resulting estimates were not significantly different, thus the decision to retain the outliers in the analysis was made.

Dagitty v2.3 was used to generate DAGs. Data cleaning and dataset merging were conducted using SAS, version 9.4 (SAS Institute), and the analysis of sociodemographic characteristics, testing the hypothesis, estimating adjusted means were done using SAS Studio. Graphic output was done using Microsoft Excel.

Table 5a. Clinical Measures According to Duration of Eating Interval over the Course of the Day and Diet Quality: NHANES 2015-16

HEI [2]	Duration of Eating Interval (hours)	<8h	8-9:59h	10-11:59h	12-13:59h	14-15:59h	16+h
		Mean, SE[1]					
1st Tertile	Average Sagittal Abdominal Diameter (cm)[3]	24.2±0.5	23.9±0.4	23.8±0.3	23.3±0.3	22.9±0.4	23.2±0.6
	Body Mass Index (kg/m^2)	31.3±0.8	31.3±0.6	30.9±0.4	30.4±0.5	29.7±0.7	30±1
	Systolic Blood Pressure (mmHg)	124.6±1.6	124.6±1.3	124.7±0.9	125.6±0.9	123.5±1.3	127.4±2.2
	Diastolic Blood Pressure (mmHg)	71.3±1.2	70.5±1	71.1±0.7	72±0.7	70.7±1	74.1±1.7
	Insulin (uU/mL)	14.4±3	20.9±2.4	15.9±1.8	15.1±1.8	13.4±2.6	12.8±4.4
	Fasting Glucose (mg/dL)	106.2±5.3	112.4±4.3	114.4±3.1	112.7±3.1	121.8±4.5	114.4±7.6
	Two Hour Glucose (OGTT) (mg/dL)	119.9±7.5	118.4±6	120.2±4.3	121.8±4.1	115.1±6.9	117.7±10.6
	HOMA-IR	3.9±1.3	7±1	5.4±0.7	4.6±0.7	4.1±1.1	3.6±1.9
	Glycohemoglobin (%)	5.7±0.1	5.9±0.1	5.9±0.1	5.8±0.1	6±0.1	5.9±0.2
	Direct HDL-Cholesterol (mg/dL)	51.7±1.5	53.2±1.2	50.2±0.8	51.4±0.9	52.9±1.3	52.5±2
	LDL-cholesterol (mg/dL)	112.9±5.6	105.5±4.3	112±3.2	113.8±3.2	107.2±4.8	108.6±7.9
	Triglyceride (mg/dL)	118.3±15.4	120.8±11.9	114.5±8.8	106.1±8.7	127.5±12.9	115.7±21.4
	Ratio of Triglycerides to HDL-Cholesterol	2.7±0.4	2.5±0.3	2.6±0.2	2.3±0.2	2.9±0.3	2.8±0.6
	Total Cholesterol (mg/dL)	186.4±4.4	185.8±3.4	186.3±2.4	194.9±2.5	191.6±3.6	188.8±5.8
2nd Tertile	Average Sagittal Abdominal Diameter (cm)[3]	24.5±0.6	23.9±0.4	23±0.2	22.5±0.2	22.4±0.4	24.2±0.7
	Body Mass Index (kg/m^2)	31.2±0.8	30.9±0.6	29.6±0.4	28.9±0.4	28.9±0.6	30.8±1.1
	Systolic Blood Pressure (mmHg)	129±2	128.3±1.3	126±0.9	124±0.9	124.3±1.4	123.3±2.5
	Diastolic Blood Pressure (mmHg)	68.7±1.5	72.2±1	71.3±0.7	69.5±0.6	71.7±1.1	70.4±1.9
	Insulin (uU/mL)	16.8±3.2	12.8±2.4	14.5±1.5	14.4±1.4	14.3±2.5	15±4.1
	Fasting Glucose (mg/dL)	107.8±7.5	114.1±5.4	119.5±3.5	112.6±3.2	121±5.6	121±9.5

	Two Hour Glucose (OGTT) (mg/dL)	132.8±11.4	136.6±9	128.6±6	123.8±5.1	116±9.3	138.2±16
	HOMA-IR	5.4±1.9	4±1.4	5±0.9	5.2±0.8	5.1±1.4	4.1±2.4
	Glycohemoglobin (%)	5.9±0.1	5.8±0.1	6±0.1	5.8±0.1	5.9±0.1	5.9±0.2
	Direct HDL-Cholesterol (mg/dL)	53.8±2.1	53.4±1.4	53.3±1	54.3±0.9	55.9±1.5	54.1±2.5
	LDL-cholesterol (mg/dL)	120.8±6.5	106.7±4.8	117±3.2	116.2±2.8	110±4.9	109.8±8.7
	Triglyceride (mg/dL)	137.2±13.5	121.3±10	113.6±6.6	99.8±5.8	119.4±10.2	112.3±18.2
	Ratio of Triglycerides to HDL-Cholesterol	2.9±0.5	2.7±0.4	2.6±0.3	2.1±0.2	3.1±0.4	2.8±0.7
	Total Cholesterol (mg/dL)	199.5±5.2	186.7±3.5	192.9±2.4	192.7±2.2	192.8±3.7	190.2±6.3
3rd Tertile	Average Sagittal Abdominal Diameter (cm)[3]	22.6±0.7	22.4±0.4	22.5±0.2	22.3±0.2	22.3±0.3	21.7±0.7
	Body Mass Index (kg/m^2)	29.1±1.1	29±0.6	29±0.3	28.7±0.3	28.7±0.5	28.4±1.1
	Systolic Blood Pressure (mmHg)	125.6±2.6	127.7±1.5	124.4±0.8	122.7±0.8	124.6±1.2	124.6±2.5
	Diastolic Blood Pressure (mmHg)	70.3±2	70.4±1.2	70±0.6	69.4±0.6	69.6±1	71.3±2
	Insulin (uU/mL)	11.8±5.4	13.5±3	15.7±1.6	12.1±1.6	10.5±2.3	9±5.4
	Fasting Glucose (mg/dL)	118.6±10.9	104.4±6	114.2±3.2	114.1±3.1	116.8±4.7	120.6±10.7
	Two Hour Glucose (OGTT) (mg/dL)	117.3±12.6	122±6.4	119.2±3.7	119.2±3.5	123.7±5.2	90.5±14.9
	HOMA-IR	3.8±2.3	4.4±1.3	5.2±0.7	3.5±0.7	3.2±1	2.8±2.3
	Glycohemoglobin (%)	5.9±0.2	5.6±0.1	5.9±0.1	5.9±0.1	5.9±0.1	5.8±0.2
	Direct HDL-Cholesterol (mg/dL)	49.3±2.9	58.6±1.6	56.3±0.9	54.6±0.8	56.3±1.3	60.5±2.9
	LDL-cholesterol (mg/dL)	128.6±9.5	111.8±5.5	112±2.8	116.6±2.8	119.3±4.1	96.6±9.8
	Triglyceride (mg/dL)	133±21.5	112.4±12.1	112.9±6.3	115.3±6.3	100.9±9.3	82.9±22.1
	Ratio of Triglycerides to HDL-Cholesterol	3.1±0.7	2.3±0.4	2.5±0.2	2.6±0.2	2±0.3	1.6±0.7
	Total Cholesterol (mg/dL)	193.3±7.1	189.3±3.9	191.6±2.1	192.6±2	192.8±3.2	183.2±7

[1] Adjusted for age, sex, race and family income to poverty ratio

[2] 1st Tertile of HEI-2015 score has a range between 10 and 47, 2nd Tertile of HEI-2015 score has a range between 47 and 60, 3nd Tertile of HEI-2015 score has a range between 60 and 100 Number of subjects in each category by HEI Tertile, clinical measure (identified with a "number") and eating duration (from <8hr to 16+hr): 1st Tertile[3] n= 117, 168, 374, 344, 153, 58; 2nd Tertile[3] n=77, 164, 371, 424, 146, 45;3rd Tertile[3] 42, 122, 406, 455, 171, 40

Table 5b. Clinical Measures According to Duration of Eating Interval over the Course of the Day and Diabetes Status: NHANES 2015-16

Diabetes	**Duration of Eating Interval (hours)**	**<8h**	**8-9:59h**	**10-11:59h**	**12-13:59h**	**14-15:59h**	**16+h**
		Mean, SE[1]					
Diabetes	Average Sagittal Abdominal Diameter (cm)[3]	24.9±0.9	26.8±0.7	25.7±0.4	25.6±0.4	25±0.6	27±1.2
	Body Mass Index (kg/m^2)	31.1±1.5	35.2±1	32.8±0.6	32.7±0.6	31.8±0.9	33.9±1.9
	Systolic Blood Pressure (mmHg)	137.4±3.8	133±2.6	132.1±1.4	129.5±1.6	130.3±2.2	137.7±4.7
	Diastolic Blood Pressure (mmHg)	65.4±2.5	67.8±1.7	70.1±1	69.2±1.1	67.3±1.5	73±3.1
	Insulin (uU/mL)	17.6±16.5	41.3±8.2	28.2±4.6	26.6±5.5	17.9±6.8	18.5±13.7
	Fasting Glucose (mg/dL)	148.3±28.1	151±13.7	166.1±7.7	162.9±9.1	174.8±11.5	176.6±23
	Two Hour Glucose (OGTT) (mg/dL)		144±150.9	179.3±52	150.7±53.3	255±112.1	
	HOMA-IR	7.8±8.3	17.8±4.1	13.1±2.3	12.6±2.8	7.9±3.4	6.5±6.9
	Glycohemoglobin (%)	7.4±0.4	7.2±0.3	7.6±0.2	7.5±0.2	7.7±0.2	7.5±0.5
	Direct HDL-Cholesterol (mg/dL)	48.2±3.1	46.2±2	48.6±1.1	48.8±1.3	48.3±1.7	47.2±3.6
	LDL-cholesterol (mg/dL)	121.6±14	97.7±7.1	101.7±4	106±4.8	104.7±6	102.2±12.4
	Triglyceride (mg/dL)	171.6±50.8	188.1±25.2	133.3±14	123.6±17.4	145.5±21.1	137.5±42.2
	Ratio of Triglycerides to HDL-Cholesterol	4.4±1.2	4.3±0.6	3.2±0.3	2.7±0.4	3.3±0.5	3.6±1
	Total Cholesterol (mg/dL)	173.9±9.3	173.2±6	183.5±3	181±3.8	179.8±5.1	182.5±10.8

No Diabetes	Average Sagittal Abdominal Diameter (cm)[3]	23.8±0.3	23±0.2	22.5±0.2	22.3±0.1	22±0.2	22.6±0.4
	Body Mass Index (kg/m^2)	30.7±0.5	29.8±0.4	29.2±0.2	28.7±0.2	28.4±0.4	29.2±0.6
	Systolic Blood Pressure (mmHg)	124.8±1.1	125.8±0.8	123.8±0.5	123±0.5	123.1±0.8	123.4±1.4
	Diastolic Blood Pressure	71±0.9	71.8±0.6	70.9±0.4	70.5±0.4	71.2±0.6	71.9±1.1
	Insulin (uU/mL)	14±1.1	12±0.8	12.4±0.5	12.1±0.5	11.4±0.8	11.3±1.5
	Fasting Glucose (mg/dL)	103.2±2	103.4±1.5	102.2±1	104.8±0.9	102.9±1.5	106.8±2.7
	Two Hour Glucose (OGTT) (mg/dL)	123.5±5.5	125.1±4	120±2.6	120.7±2.4	116±4	119.5±7.5
	HOMA-IR	3.8±0.4	3.2±0.3	3.3±0.2	3.3±0.2	3±0.3	2.9±0.5
	Glycohemoglobin (%)	5.5±0	5.6±0	5.5±0	5.6±0	5.5±0	5.6±0.1
	Direct HDL-Cholesterol (mg/dL)	53.1±1.2	56.1±0.9	54.2±0.6	54.2±0.5	56.8±0.9	56.3±1.5
	LDL-cholesterol (mg/dL)	119.7±3.9	110.3±2.9	117.1±1	116.7±1.7	114.3±2.9	107±5.3
	Triglyceride (mg/dL)	124.7±8.1	107.9±6.1	110.5±4	105.8±3.6	107.6±6	101±11.2
	Ratio of Triglycerides to HDL-Cholesterol	2.7±0.3	2.2±0.2	2.4±0.1	2.3±0.1	2.5±0.2	2.2±0.4
	Total Cholesterol (mg/dL)	195.3±3.1	190.2±2.1	192.1±1	195.4±1.3	194.9±2.2	188.7±3.7

[1] Adjusted for age, sex, race and family income to poverty ratio
Number of subjects in each category by diabetes status, clinical measure (identified with a “[number]”) and eating duration (from <8hr to 16+hr):
Diabetes[3] n= 28, 54, 200, 156, 77, 15; No Diabetes[3] n=208, 400, 951, 1067, 393, 128;

RESULTS

In 2015-2016, a total of 15,327 persons were identified, of which 61% (9,971) were interviewed and 59% (9,544) completed the health examination component of the survey (National Health and Nutrition Examination Survey, 2017). Figure 1 shows, after restricting the study sample to adults aged 20-79 with completed 24h dietary recall for 2 days, 3935 individuals were included in the study. 3848 subjects were included in the analysis of the association between eating duration and diet quality. Due to the missing data on some of the clinical biomarkers, the number of subjects who were included in the analysis of the association between eating duration and diet quality ranged between 1663 and 3810.

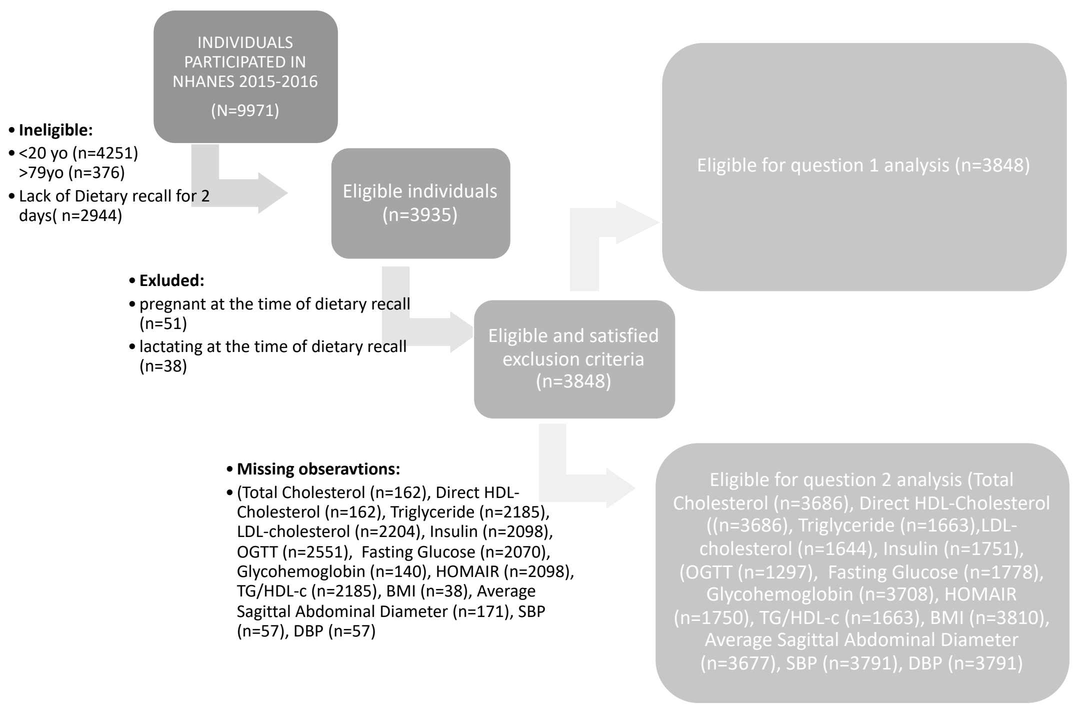

Figure 1. Flow chart describing inclusion and exclusion criteria

Participant characteristics according to duration of eating interval throughout the day were presented in Table 1. Out of 1869 males and 1979 females, 34% males and 35% females had eating interval of 12-13:59hr and 10-11:59hr, respectively. 33% (1296/3848) were Non-

Hispanic White. 32% (1237/3848) of the study sample had family income between the poverty level and 250% of the poverty level. 47% (119/ 251) of those who consumed food for less than 8 were below or at the poverty level of family income.

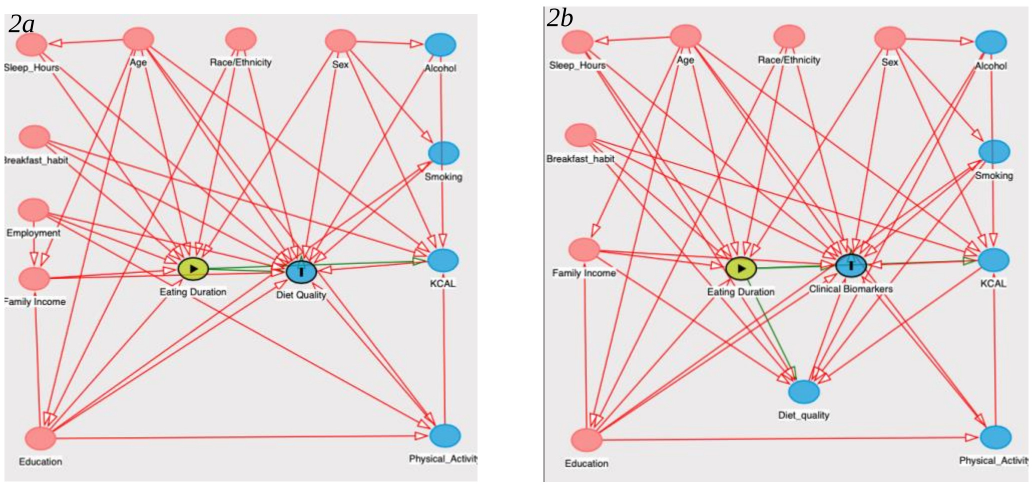

Figure 2. Directed acyclic graphs (DAGs) were constructed for selection of potential confounders. 2a. For study question 1, the relationship between primary exposure (eating duration), primary outcome (diet quality) and other covariates. Based on this graph, sex, race/ethnicity, age, sleep duration, breakfast habit, employment status, family income and education are potential confounders. 2b. For study question 2, the relationship between primary exposure (eating duration), primary outcome (clinical biomarkers) and other covariates. Based on this graph, sex, race/ethnicity, age, sleep duration, breakfast habit, family income and education are potential confounders.

57% (2212/3848) of the sample were non-smokers or quitted smoking >50 years ago. Majority on non-smokers eat for 10-11:59hr (738/2212). 31% (232/757) of current smokers and 35% (305/873) of those who quitted smoking less than 49 years ago had eating duration of 12-13:59hr.

Majority of the subjects (66%) slept 7-9hr on a regular workday or weekend. 30% the subjects who slept less than 7hr (265/896) and 42% of the subjects who slept >9hr (170/405) consumed food for 12-13:59hr and 10-11:59hr respectively.

After adjusting for age, sex, race/ethnicity, family income to poverty ratio and sleep duration, mean HEI-2015 total score ranged from 49.7 ± 0.9 to 55.2 ±0.6 with the highest mean score when subjects consumed food for 14-15:59hr and lowest mean score when subjects consumed food for <8hr a day (Figure 3).

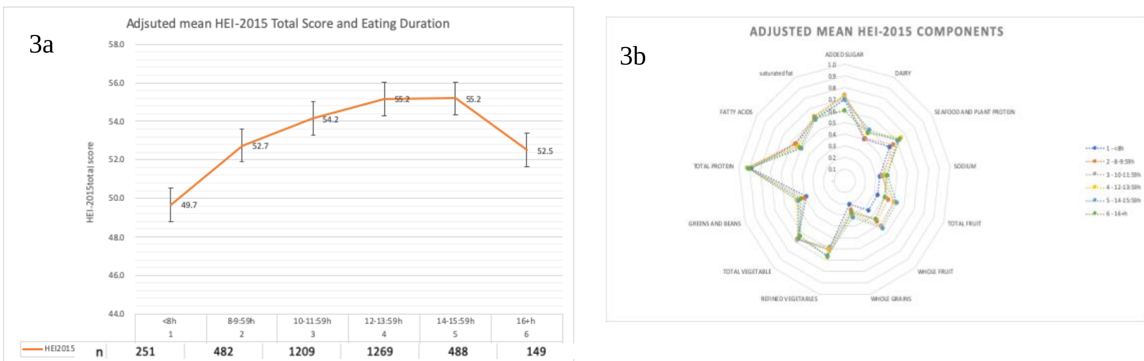

Figure 3a.Diet Quality (HEI-2015 total score, adjusted for age, sex, race/ethnicity, family income to poverty ratio and sleep duration) According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16. Figure 3b: A radar plot, which represents the contribution of each HEI-2015 component to the total score. The outer edge of the radar plot represents a maximum HEI-2015 total score that is 100%.

After stratification on breakfast frequency and adjustment for age, sex, race/ethnicity, family income to poverty ratio and sleep duration, the mean HEI totals score of the subjects who always consumed breakfast was higher than those who did not eat breakfast regularly, ranging from 52.5 ± 2.3 to 56.2 ± 0.4 at eating duration of <8hr and 12-13:59hr, respectively (Figure 4). The subjects who never had breakfast had lower mean adjusted HEI total score than those who ate breakfast, ranging from 44.7 ± 1.3 to 49.6 ± 1.9 at eating duration of <8hr and 10-11:59hr, respectively.

After stratification on smoking status and adjustment for age, sex, race/ethnicity, family income to poverty ratio and sleep duration, the mean HEI-2015 totals score of the subjects who were current smokers was lower than those who did not smoke, ranging from 43.7 ± 1.5 to 49.5 ± 0.8 at eating duration of <8hr and 12-13:59hr, respectively (Figure 5).

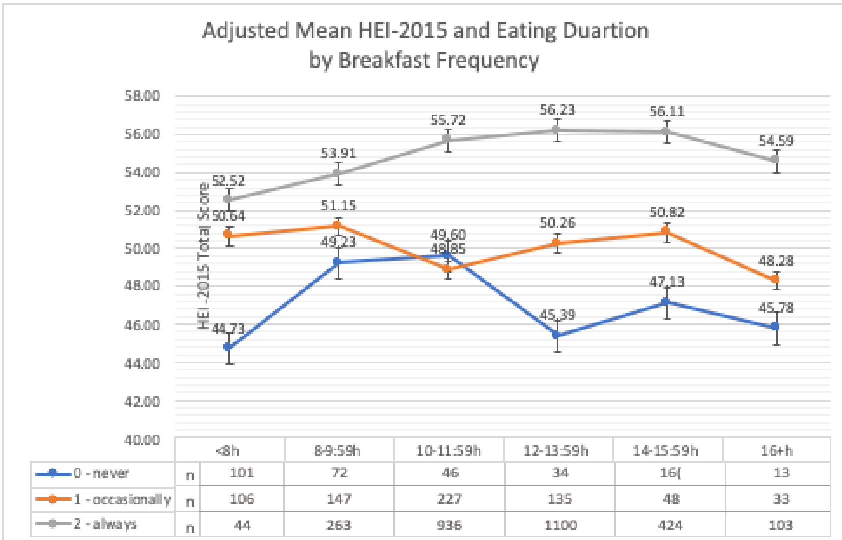

Figure 4. Diet Quality (HEI-2015 total scores, adjusted for age, sex, race/ethnicity, family income to poverty ratio and sleep duration) According to Duration of Eating Interval over the Course of the Day: and Breakfast Frequency: NHANES 2015-16. Breakfast frequency is defined as "always" if participants had breakfast 2 times over the course of the 2 days of dietary recall, "occasionally" if participants had breakfast 1 time over the course of the 2 days of dietary recall, "never" if participants had no breakfast over the course of the 2 days of dietary recall

After stratification on family income to poverty ratio and adjustment for age, sex, race/ethnicity, and sleep duration, the mean HEI totals score of the subjects who had family income above poverty but below 250% of the poverty level was lower than those who had higher family income, ranging from (47.9 ± 1.5) to (53.6 ± 1) at eating duration of <8hr and 14-15:59hr respectively (Figure 6). The highest adjusted mean HEI total scores of the subjects who had family income below or at the poverty level (52.8 ± 0.9), above poverty level up to 250% of the poverty level (53.6 ± 1) and greater than 250% to 400% of poverty level (56 ± 0.9) and greater than 400% of poverty level (60 ± 1.3), at eating duration of 12-13:59hr, 14-15:59hr, 12-13:59hr and 14-15:59hr respectively.

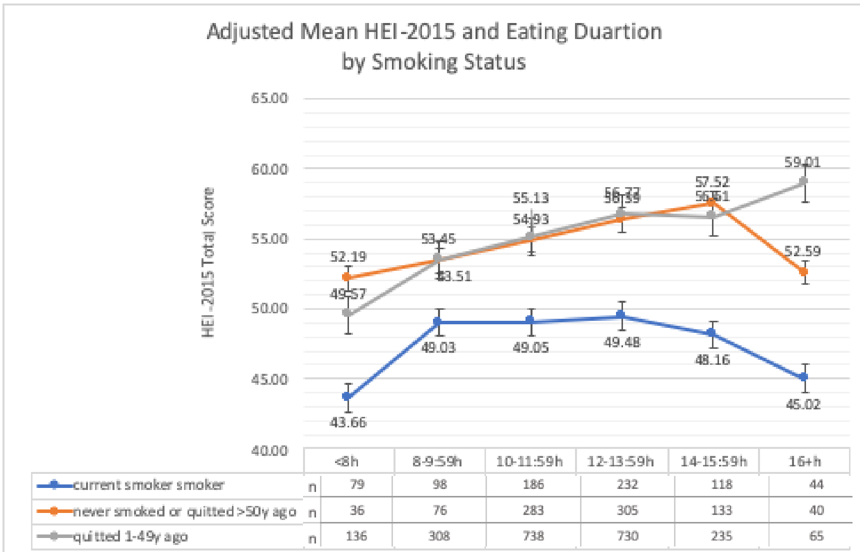

Figure 5. Diet Quality (HEI-2015 total scores, adjusted for age, sex, race/ethnicity, family income to poverty ratio and sleep duration) According to Duration of Eating Interval over the Course of the Day and Smoking Status: NHANES 2015-16.

Sagittal abdominal diameter and BMI decreased as the eating interval became longer and increased at 16+hr of eating duration, with the highest mean adjusted BMI of 30.7 and sagittal abdominal diameter of 24 cm at eating duration of <8hr and lowest mean adjusted BMI of 29 and average sagittal abdominal diameter of 22.5 cm at eating duration of 14-15.59hr (Figure 7). Figure 8 illustrates that there was a variability in adjusted mean measurements of systolic and diastolic blood pressure, LDL- and HDL-cholesterol and total cholesterol. Adjusted mean triglycerides decreased from 121.1 to 107.2 mg/dL as eating duration increased from <8hr to 16+hr, however the ratio of triglycerides to HDL-cholesterol was not affected by the duration of eating. Fasting glucose increased from 107.9 to 119.3 as eating interval increased from <8hr to

15:59hr. HOMA-IR and insulin decreased as eating interval increased from 5.37 to 3.48 and from 16.34 to 12.54 microU/mL for HOMA-IR and insulin respectively (Figure 9).

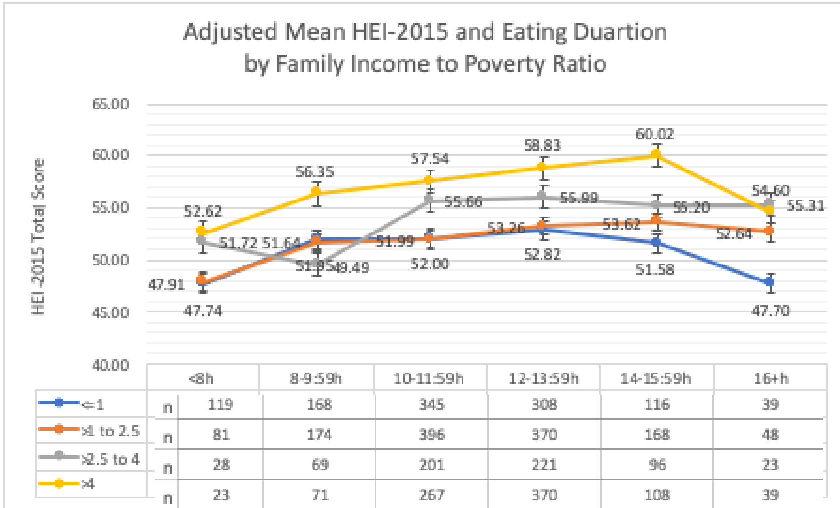

Figure 6. Diet Quality (HEI-2015 total scores, adjusted for age, sex, race/ethnicity and sleep duration) According to Duration of Eating Interval over the Course of the Day and Family Income to Poverty Ratio: NHANES 2015-16.

Figure 10a presents that the subjects with lower diet quality (HEI below 33 percentile) had higher average sagittal abdominal diameter during all intervals of eating duration in comparison to those who had higher diet quality (HEI above 66 percentile). On the other hand, subjects with higher diet quality (HEI above 66 percentile) had higher HDL-cholesterol during all intervals of eating duration (except <8hr) in comparison to those who had lower diet quality (HEI above 66 percentile) (Figure 10b).

Figure 11 shows that there was a steady increase from 148.3 to 176.6 mg/dL of adjusted mean fasting glucose as subjects with diabetes had longer eating period.

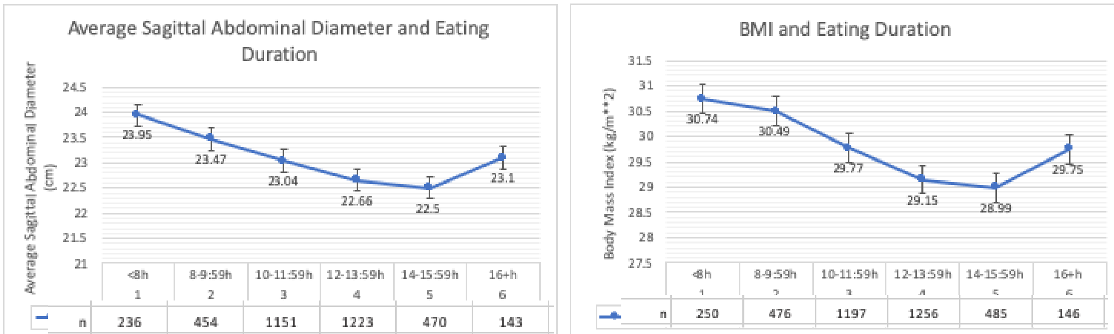

Figure 7. Clinical measures (means adjusted for age, sex, race/ethnicity and family income to poverty ratio) According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16.

DISCUSSION

Overall, there was enough evidence to reject the null hypothesis and conclude that diet quality and clinical cardiometabolic biomarkers varied with the change of the interval of eating. In addition, diet quality had the effect on how clinical biomarkers were affected by the intervals of food intake.

The results of this study showed that diet quality was lowest when the subjects consumed all meals within <8hr period, increased as subjects ate until 15:59 hr, and then decreased with 16+hr eating interval.

Clinically, BMI and sagittal abdominal diameter were the highest when the subjects consumed all meals within <8hr period and lowest when the subjects consumed all meals between 14 and 15:59 hr. All clinical biomarkers of cardiovascular diseases also varied with different intervals of eating duration, with a steady decrease of TG/HDL-c ratio as the subjects consumed food for a longer period of time. HOMA-IR, fasting insulin, and two-hour glucose decreased as subjects ate longer.

Finally, diet quality altered the magnitude of association between eating duration and sagittal abdominal diameter, HDL and HOMA-IR, with higher measurements of HOMA-IR, sagittal abdominal diameter and lower measurements of HDL for those who had poorer diet quality. While diet quality had no effect on the association between eating duration and TG/HDL-c ratio for those who eat less than 14 hr, eating diet of poor quality for longer eating period was associated with higher TG/HDL-c ratio.

Figure 8. Clinical measures (means adjusted for age, sex, race/ethnicity and family income to poverty ratio) According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16.

Previous studies have demonstrated that a 6-point increase in HEI-2010 score was associated with 9-12% decrease in all-cause mortality risk and 10% risk of cardiovascular disease mortality risk in women and 10-11% risk of cancer mortality (Reedy et al. 2014). Based on the results of this study, increasing eating duration from <8hr to 14-15:59hr was associated with the increase in HEI-2015 by more than 6 points, and decrease in BMI by almost 2 points, systolic blood pressure by more than 2 mm Hg, in triglycerides by more than 12 mg/dL. This might suggest that longer eating duration could be associated with lower risk of obesity, and cardiovascular disease. Contrariwise, the comparison of the association between eating duration interval and clinical biomarkers between diabetic and non-diabetic subjects showed, that fasting glucose and OGTT increased, while HOMA-IR decreased as subjects had longer eating interval.

A study about time-restricted feeding in mice suggested that though daily fast of <12 hr may not be sufficient to protect against obesity in mice, mice with confined food access to 9–12 hr were protected against insulin resistance and had better regulation of serum levels of cholesterol (Chaix et al. 2014). These findings appeared consistent with the results of this study, particularly with the change of glucose biomarkers in subjects with diabetes and HOMA-IR over the duration of eating in the entire sample.

The finding of the association between eating duration interval and clinical biomarkers may be considered in the future recommendations of identifying subjects with higher risk of cardiometabolic disorders. For example, erratic and elongated eating duration among shift workers could be addressed as a modifiable risk factors of diabetes, metabolic syndrome and cardiovascular diseases (Sulli et al. 2018).

Particularly, this study highlighted the necessity to pay attention to subjects with low quality diet. The subjects who had low diet quality had overall increased measures of sagittal abdominal diameter, HOMA-IR and decreased TG-HDL-c ratio than the subjects with higher diet quality. Modifying eating duration could help to reduce risk of developing chronic cardiometabolic disorders.

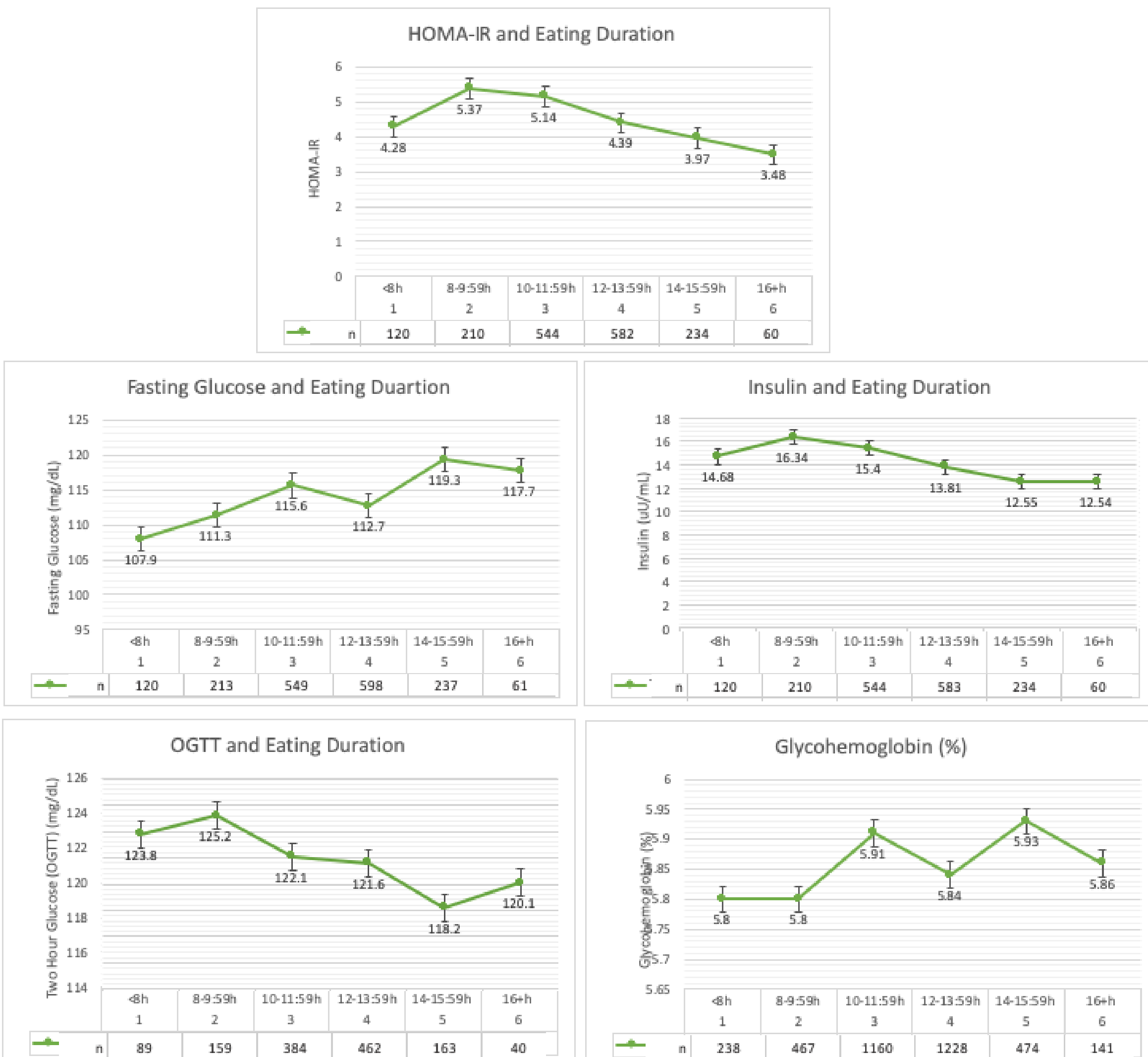

Figure 9. Clinical measures (means adjusted for age, sex, race/ethnicity and family income to poverty ratio) According to Duration of Eating Interval over the Course of the Day: NHANES 2015-16.

The results of this study could also translate into new recommendations for patients who were diagnosed with diabetes. Based on the results of this analysis, eating for longer period of time associated with higher OGTT and fasting glucose in subjects with diabetes, thus altering eating duration interval could aid in disease management. However, future research should consider the potential effects of self-reported diabetes status more carefully and use diabetes biomarkers for defining diabetes status.

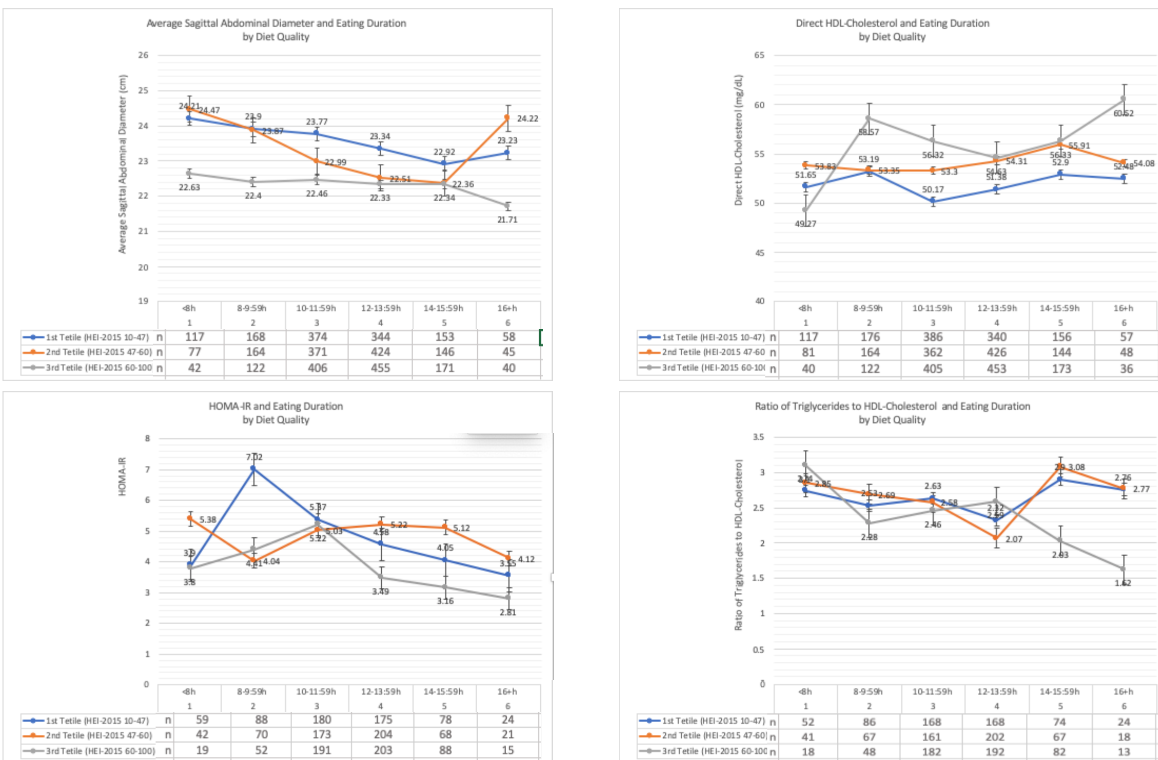

Figure 10. Clinical measures (means adjusted for age, sex, race/ethnicity and family income to poverty ratio) According to Duration of Eating Interval over the Course of the Day and Diet Quality: NHANES 2015-16.

This study had several limitations, including potential bias introduced by self-reported data. Time-stamps of eating episodes, which determined eating duration intervals in this study, were reported by the subjects during 24-h dietary recall. Other studies have shown that subjects with higher BMI tend to underreport caloric intake, which could be also true for duration of eating episodes (Kretsch et al. 1999). This study found that higher BMI was associated with shorter eating duration, which could be due to underreporting of eating duration.

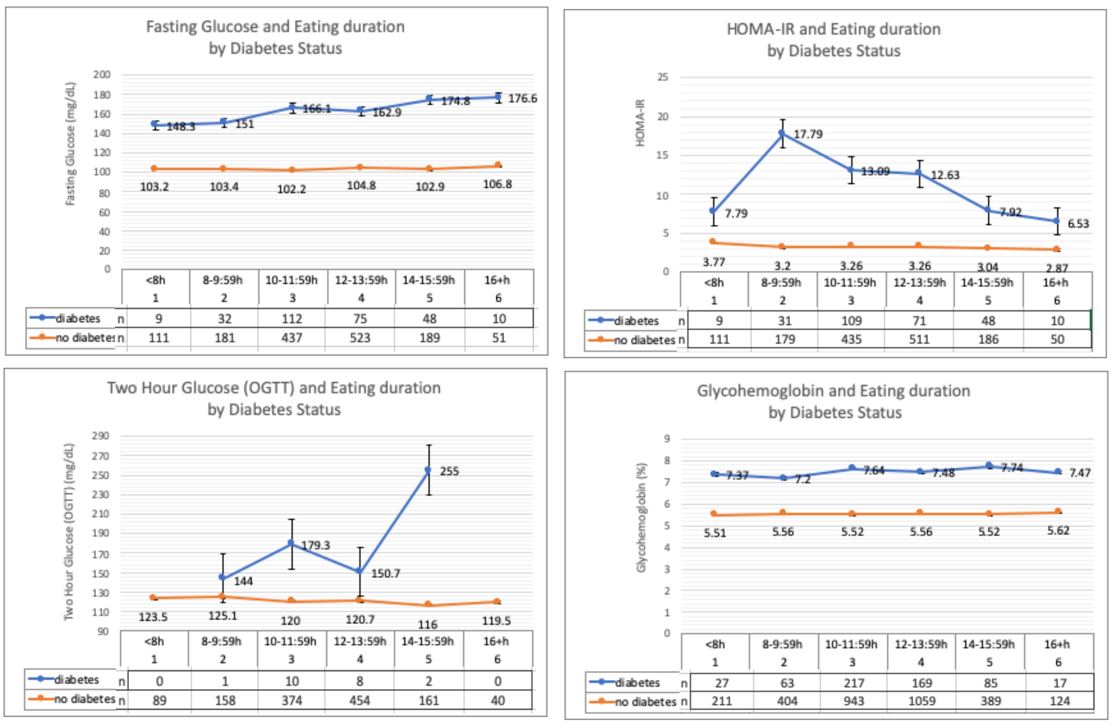

Figure 11. Clinical measures (means adjusted for age, sex, race/ethnicity and family income to poverty ratio) According to Duration of Eating Interval over the Course of the Day and Diabetes: NHANES 2015-16.

Although, caloric density of meals was taken into account for calculations of HEI-2015, the measure of total daily energy intake for not used in the analysis. It has been established that 24-hour dietary recalls do not yield accurate measure of energy intake (Bingham, 1991) Future research should consider a more accurate measure of energy intake, which would allow preforming stratified analysis based on total energy intake to see if eating duration had similar effect on diet quality as well as clinical biomarkers among the subject who had similar energy density diets.

Finally, due to the limitations of a cross-sectional study design, it is impossible to establish whether there is a causal association between eating duration and clinical biomarkers. However, there are no prospective studies up to date that have analyzed the association between eating duration, diet quality and clinical biomarkers of chronic diseases in humans. Thus, the novel findings of this study can serve as foundation for hypotheses related to further investigation how eating duration is associated with risk of morbidities. In a retrospective NHANES study, Marinac et al. found that a prolonged overnight fast of >13 hr correlated with reduced breast cancer risk (2015). In the future studies it would be interesting to examine the association of eating duration intervals with inflammatory and cancer biomarkers.

In a post-hoc exploratory analysis diet quality was highly associated with mean caloric density of the last eating episode. This increases interest in the quality of the last meal. Another NHANES study demonstrated that more than 60% of US adult consume evening snack after dinner (Kant & Graubard 2015). Future studies could fruitfully explore this issue further by analyzing how skipping after dinner snack would affect the HEI and clinical biomarkers.

CONCLUSION

In the 2015-16 NHANES study, participants had higher diet quality with longer duration of eating over the course of the day from <8 to 15.59 hr and participants with a 16+ hr eating duration had lower diet quality. Duration of eating over the course of the day and diet quality are influenced by breakfast habits, smoking habits, and family-income to poverty ratio. Additionally, clinical cardiometabolic risk factors also varied according to duration of eating over the course of the day, with particularly worse glycemic-related measures for people with diabetes with longer duration.

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