

RELATIONSHIP BETWEEN DIET QUALITY, BODY WEIGHT AND FOOD INSECURITY
AMONG LOW-INCOME WOMEN AT RISK OF TYPE 2 DIABETES AND THEIR
CHILDREN

by

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
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ABSTRACT

Food insecurity—the limited or uncertain availability of nutritionally adequate and safe food—affects one in six U.S. households. National data suggest disproportionately higher rates of food insecurity among those living in poverty, rurally, or who identify as racial/ethnic minorities. Food insecure individuals adopt coping strategies which favors the consumption of inexpensive, ultra-processed foods that are calorie-dense and nutrient-scarce, ultimately contributing to low diet quality. Low diet quality and food insecurity independently are associated with increased risk and prevalence of obesity and diet-related diseases, especially type 2 diabetes mellitus (T2DM). Understanding the direction, magnitude, and clinical significance of relationships between diet quality, food insecurity, and T2DM risk factors are critical to effectively intervening on dietary intake, and diet-sensitive disease. These relationships were characterized with baseline data from a study sample comprised of low-income women at risk of T2DM, and their children, 8-12-years-old, recruited from El Rio Community Health Center to participate in a randomized controlled trial (EPIC El Rio Families) testing the effects of a behavioral lifestyle intervention on type 2 diabetes risk factors. Results will be presented at the level of the household, and the individual (mothers and children), and the public health implications of this work discussed.

CHAPTER 1: LITERATURE REVIEW

1.1 Diabetes

Diabetes mellitus is a group of metabolic diseases characterized by impaired insulin action and/or insulin secretion, and associated dysglycemia.¹ Diabetes is a highly prevalent disease, affecting 10.5% of the total U.S. population, and 13% of adults.²

Diabetes mellitus can be broadly categorized as one of three types: Type 1 (T1D) an autoimmune disease resulting from the destruction of pancreatic β -cells, accounts for approximately 5-10% of all diabetes cases;¹⁻³ Type 2 (T2DM), which is associated with an insulin resistant phenotype due to a variety of causes (most commonly, obesity), accounting for 90-95% of all cases;¹⁻³ and, gestational diabetes mellitus (GDM), which is experienced in up to 10% of pregnancies, with resolution of GDM and associated symptoms immediately following delivery.⁴

T2DM is often preceded by prediabetes, a condition characterized by physiological abnormalities that indicate increased risk of future T2DM, including impaired fasting plasma glucose (100-125 mg/dL), impaired glucose tolerance (140 mg/dL and 199mg/dL two hours after the ingestion of 75g of oral glucose), and/or levels of glycated hemoglobin A1c (HbA1c) between 5.7 and 6.4%.⁵ Studies have explored the associations between GDM and prediabetes with the incidence of T2DM, with evidence suggesting that persons with a history of GDM have a higher risk to develop T2DM⁶ in the following 5-10 years after the resolution of the pregnancy, and a lifetime cumulative incidence of 60%.⁷⁻⁸ Annually, 5-10% of people convert from prediabetes to diabetes⁹ but similar to GDM, the conversion rates vary depending of the population, duration of follow up and diagnostic criteria.¹⁰ Given the increasing prevalence of T2DM and severity of associated complications, it is imperative to identify and intervene with

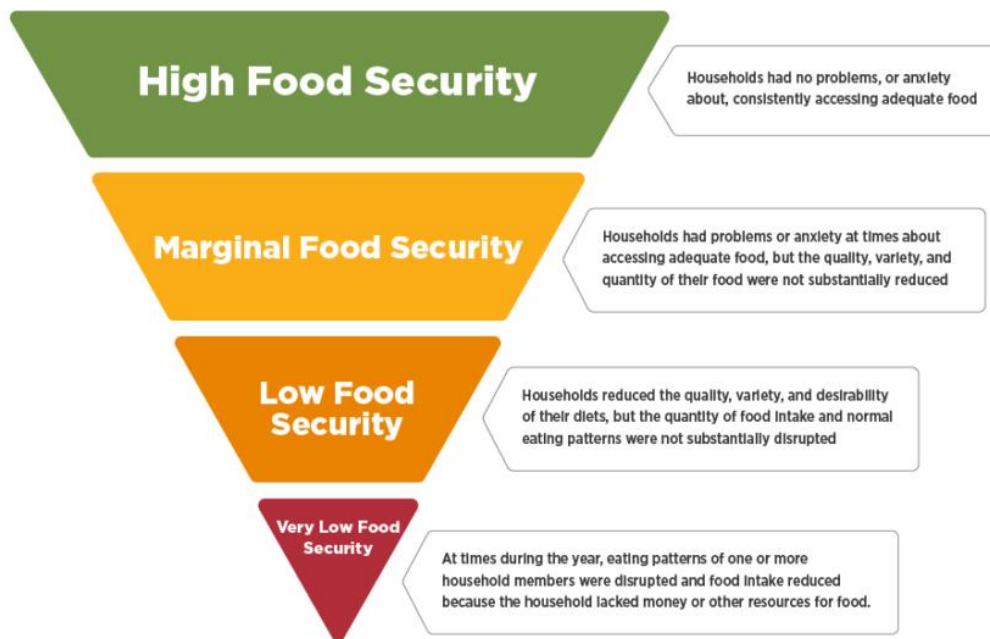
persons who have GDM and prediabetes in order to mitigate risk factors and slow or halt the onset of T2DM.

There are several common risk factors for T2D, GDM, and prediabetes. One risk factor is excess body weight, defined as a body mass index (BMI) of ≥ 25 -29.99 Kg/m² (overweight) and >30 Kg/m²(obese), a high body fat percentage relative to lean mass, and high central adiposity and/or high visceral fat storage relative to subcutaneous fat. Obesity, central adiposity, and high visceral fat are all associated with metabolic disruption created by free fatty acids circulating in plasma, impairing the effectiveness and sensitivity of insulin in the cell and creating an insulin resistant environment. This phenotype is shared across persons with T2DM, GDM and prediabetes, which is concerning when considering that the prevalence of overweight and obesity combined in the U.S. population was 73.6% (42.6% for obesity) in 2018.¹¹

1.2 Food Insecurity

Food insecurity is defined as “a household-level economic and social condition of limited or uncertain access to adequate food.”¹² The United States Department of Agriculture uses four levels to describe the extent to which food insecurity impacts food patterns and health, including High Food Security in which there are no reported indications of limitations or concerns while accessing food; Marginal Food Security which indicates that the household at times had concerns about accessing adequate food, however quantity and quality was not substantially reduced;¹²⁻¹³ Low Food Security wherein household members had to reduce the quality and variety of the food acquired, but quantity was not affected; and, Very Low Food Security, where in both quantity and quality for one or more household members was disrupted at times during the previous year due to lack of money or resources (**Figure 1**).¹²⁻¹³

Figure 1. Levels of food security.



Source: Adapted from the USDA Economic Research Service.

(Available on: *Hunger and Health, Feeding America*)

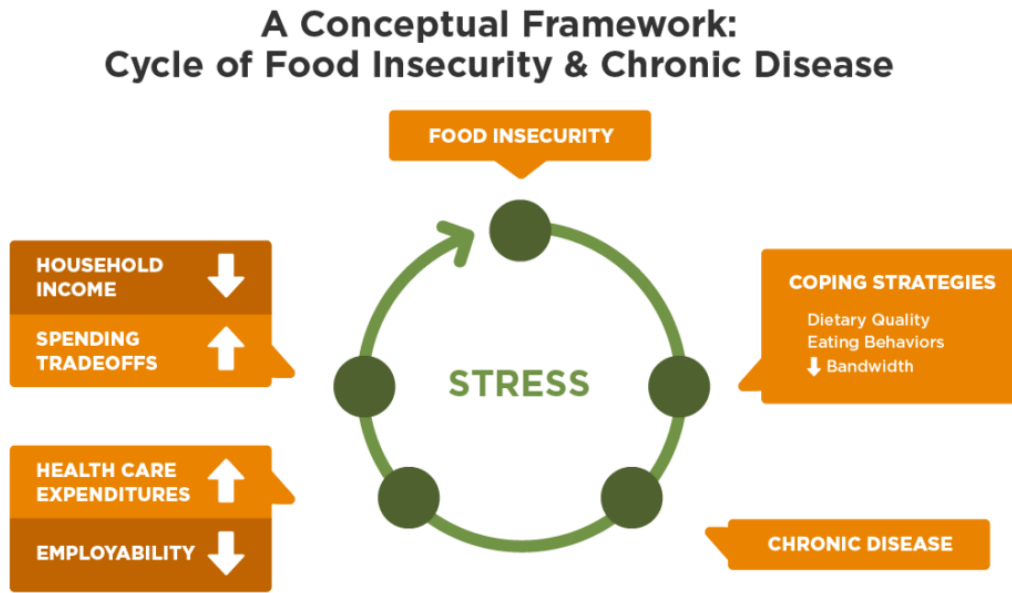
Although the prevalence of food insecurity decreased from 11.1% in 2018, in 2019, 10.5% of U.S. households reported some type of food insecurity; 6.4% of these food insecure households were considered low food security and 4.1% were very low food security.¹⁴ In 2020, the SARS-CoV-2 virus and resulting pandemic doubled the prevalence of food insecurity, with projections of up to 23% of households reporting shortages in quality and/or quantity.¹⁵ In the U.S., food insecurity disproportionately affects minority households (Black and Hispanic households experience food insecurity at a rate of 1.5 – 2.0 times that of non-Hispanic Whites), as well as those headed by single women with children.¹⁴ In 2019, households that reported an income below the Federal Poverty Line (FPL) had a 34.9% prevalence of food insecurity.¹⁴

Food insecurity is not a condition that occurs in isolation, but rather, it overlaps and relates to a variety of social and health factors. These social aspects of health and disease – referred to as the social determinants of health (SDOH) – collectively influence the health of individuals across the lifespan and can explain some of the differences in rates of morbidity and mortality associated with non-communicable diseases. The SDOH is a concept first proposed in 2004 at the World Health Assembly in which it was observed that many of these determinants co-exist or exacerbate health problems associated with chronic illness.¹⁶ There are five key domains of SDOH: healthcare access and quality, education access and quality, social and community context, economic stability, and neighborhood and the built environment. Food insecurity is an influential SDOH component, as it can be viewed as a consequence of disrupted economic stability due to limited money, and/or limited by specific features of a neighborhood or built environment where lower availability of healthy food (e.g., the so-called “food desert”)¹⁷ in combination with concentrated fast- and convenience food locations (e.g., “food swamps”)¹⁷ contribute to poor nutrition and lower diet quality. These are also conditions associated with diet-sensitive chronic diseases and conditions, most notably obesity, prediabetes, and T2DM, as well as cardiovascular disease and hypertension.¹⁸

A conceptual framework describing a cycle in which SDOH (especially food insecurity) and chronic disease are interrelated was proposed by Seligman in 2010 (**Figure 2.**). Seligman et al. suggested that the presence of food insecurity prompts the use of coping strategies to avoid adverse consequences, including increased purchase and selection of cheap, calorie-dense, nutrient-poor foods. This shift can produce changes in diet quality that might contribute to the development (or worsening) of diet-sensitive diseases, such as obesity and type 2 diabetes.¹⁹⁻²¹ Seligman’s model goes on to frame consequences of the onset or worsening of a disease as

increased health care costs and expenditures, and further disrupting household income through underemployment and worsening food insecurity.¹⁹

Figure 2. A Conceptual Framework: Cycle of Food Insecurity & Chronic Disease.



Adapted: Seligman HK, Schilling D. N Engl J Med. 2010;363:6-9.

(Available on: *Hunger and Health, Feeding America*)

Limited cross-sectional research has suggested that food security might be an influential T2DM risk factor.²⁰⁻²² A cross-sectional study using the data from National Health and Nutrition Examination Survey (NHANES) from three different waves (1999–2000, 2001–2002, and 2003–2004) showed that adults in food insecure households had 1.5 times the diabetes risk of adults in food secure households; this same study also showed that individuals in food insecure households were two times more likely to have diabetes, and the association remained even after controlling for income, employment, education, and body mass index.^{20,21,24} In another cross-sectional study (n=22,596 low-income adults) examining the relationship of food insecurity with

T2DM, low food security was significantly correlated with T2DM in White men and women, and Latina women, but not Latino men, or African American or Black women and men.²⁵

Food insecure status is also associated with poorer management of prevalent T2DM. Cross-sectional studies have shown that food secure individuals report lower likelihood of engaging in recommended diabetes self-care behaviors such as following a general healthy diet, engagement in regular physical activity, and adherence to medication and management of glycemic control compared to food secure persons.^{24,26-27} In these studies, female and male adult participants with T2DM and with low or very low food security had significantly higher values in HbA1C (indicating poorer glucose control in the prior three months) compared to those who were food secure (≥ 8.5 mmol/mol versus ≥ 8 mmol/mol, $p=0.04$).²⁶⁻²⁷

There is also evidence that food insecurity is associated with excess body weight. Food insecurity has been associated with increased prevalence of overweight and obesity, referred to as the “food insecurity-obesity paradox”.²⁸ Systematic reviews have shown a strong association between food insecurity and excess body weight, predominantly in adult women (18 articles addressed within both reviews), with growing evidence in adolescents and mixed results in children (15 articles addressed within both reviews).²⁸⁻²⁹ The 2012 Behavioral Risk Factor Surveillance System study conducted in twelve states explored the relationship of food stress (a surrogate measurement for food insecurity) with obesity in adults, observing a higher prevalence of obesity in those individuals who were food insecure compared to food secure (35.1% vs 25.2% respectively); in this same study, those who were food insecure had 32% increased odds of being obese in contrast to their food secure counterparts. This association remained statistically significant after controlling for race, education, age, income, and if the participant had children.³⁰ Another cross-sectional study using data from the 2007-2008 NHANES added to

the evidence of this association; the study used data from adults within the ages of 24-64 years old and found through regression analyses that in women, food insecurity was associated with higher BMI of different races and ages ($p \leq 0.01$) and that the association remained significant after adjusting for key variables such as education, physical activity, dietary intake, smoking status, and budget designated for food purchases ($p \leq 0.05$).³¹ Nonetheless, these results agree with the heretofore mentioned studies and systematic reviews, suggesting a strong association of food insecurity and obesity in women.

1.3 Diet Quality

While there is no unified diet quality metric, it is generally accepted that the intent of a diet quality assessment is to compare how well an individual dietary pattern aligns with dietary recommendations, broadly defined.³² Diet quality can be considered as the assessment of the quality and variety of the entire diet including group foods rather than only nutrients. It is often used in nutrition epidemiology to evaluate the dietary behaviors of a population and the efficacy of dietary interventions.³² Diet quality has also been proposed as a risk assessment tool to predict diet-associated diseases and outcomes including T2DM, risk of cancer and cardiovascular disease.³² Due to the broad definition of diet quality, different assessment tools and approaches exist. The most common approach is to assess dietary compliance, in which a score is created that compares an individual's dietary intake with dietary recommendations within the major food groups – vegetables, fruits, grains, dairy, proteins, fats, as well as discretionary calories from added sugars and alcohol.³²⁻³³ Diet quality also often incorporates an assessment of nutrient density and energy density using a nutrient-to-calorie ratio, which characterizes foods as healthier if they contain higher levels of nutrients in comparison of the number of calories; this approach became common after the 2005 Dietary Guidelines for Americans.³²⁻³³ There are

additional metrics of diet quality used worldwide,³² and the “right” metric should be selected based on the research question or topic being studied.

Recent applications of diet quality include as a global indicator of dietary health (surveillance data), as a marker of health risk assessment (predictor of diet-related illness), as a tool for nutrition education, or as a multidimensional research variable allowing comparisons of an individual’s dietary intake with evidence-based recommendations.³¹

Diet quality scores have been related to a variety of health outcomes in the literature.³³ In a systematic review, there were inverse relationships between diet quality scores, where higher scores were protective by reducing prevalence of all-cause mortality by 17–42%, CVD mortality by 18–53%, CVD risk by 14–28%, cancer mortality by 13–30%, and all-cancer risk by 7–35%.³³ However, it was mentioned that these associations varied depending upon the dietary assessment approach, the diet quality index, and choice of covariates when performing analyses.³³

Diet quality has also been shown to differ across socioeconomic positions and sociodemographic characteristics;^{34,35} children and older adults have better diet quality scores than younger and middle-aged adults; women have better diet quality scores than men; people who identify as Hispanic have higher scores than African Americans or non-Hispanic Whites; and diet quality improves with higher incomes.³⁵ Thus, it is expected that diet quality is affected by food security. As previously mentioned, food insecurity is associated with a plethora of diet-sensitive chronic diseases in adults, including but not limited to cardiovascular diseases, type 2 diabetes, gestational diabetes and overweight/obesity. Some of the mechanisms explaining the observed relationships between food insecurity and diet quality are economic: nutrient-dense foods such as fruit and vegetables tend to be more expensive and less available than ultra-

processed convenience food. Palatability and convenience (time spent in preparation) also drive selection of ultra-processed foods over more nutrient dense options.³⁶

There is a substantial body of evidence showing that adults in food insecure households tend to have lower scores for total diet quality, as well as lower consumption of fruits, vegetables, dairy products, whole grains, and a higher consumption of highly palatable, ultra-processed foods or food items with high concentrations of either sugar, fat or both.³⁶⁻³⁸ Similar relationships between food insecurity and diet quality are observed in children living in food insecure households, although to a lesser extent than adults. In youth, lower diet quality scores have been associated with decreased consumption of fruits, vegetables, greens and beans, and higher consumption of foods high in added sugars, specifically beverages.^{37,39-41} Discrepancies between diet quality of food insecure adults and children in the same household have been observed. Parents report lower diet quality scores compared to their children. This has led to the hypothesis that parents might be protecting their children from the negative effects of food insecurity by prioritizing their children's diet adequacy over their own.^{14,37,39-41}

It is generally accepted that diet quality can contribute to improvement or worsening of diet-related diseases; however, the mechanism of action is not entirely clear. Diet quality has also been associated with changes in anthropometric measurements. A systematic review explored the associations between diet quality and excess body weight, finding that in a majority of the studies, there was an inverse relationship between diet quality and obesity in adults, where lower total diet quality scores predicted obesity.⁴² However, the association between diet quality and body weight was not as consistent when the analyses performed tested specific components of diet quality rather than total scores; additionally, it was identified that confounders such as sex, race, or even study design could modify the impact of the association.⁴² A 15-year longitudinal

study conducted in Australia looked at BMI and waist circumference.⁴³ In this study, men with higher diet quality scores had the lowest gain in BMI, with no significant changes in waist circumference; diet quality was unrelated to anthropometric measurements among women.⁴³ A cross-sectional study in the U.S. assessed body fat percentages and diet quality in 407 young adults (27.6 ± 3.7 years old), but only found significant relationship between these variables in men with and without controlling for physical activity and other confounders.⁴⁴ In this same study, researchers also noted that high consumption of protein, sodium and ‘empty’ calories (calories that do not provide nutrients) increase the risk of overweight and obesity in men.⁴⁴

In children, a cross-sectional study in Ireland demonstrated that with decreasing scores (quintiles) for total diet quality, the percentage of children in the obesity category increased (4.2% of children were in obese category in the highest quintile of diet quality vs 8.8% in the lowest quintile), but when exploring associations between specific food items or groups, the significance of the association was lost;⁴⁵ similar behavior was previously mentioned in adults,⁴² where total scores had better relationships. Another study conducted with children in the United Kingdom found that higher diet quality was associated with lower BMI, waist circumference and body fat percentage in 1700 children (ages 9-10) and that this association remained after controlling for physical activity and energy intake.⁴⁶

1.4 Research Study Justification, Goal and Aims

Prior research – mostly observational – suggests that both food insecurity and body measurements are associated with diet quality.³⁷⁻⁴⁶ However, the body of literature is still rather scarce and it is notable to mention that there is significant variation in methods by which these outcomes have been measured, making it difficult to understand direction and magnitude of these relationships. Nonetheless, existing data suggest that food security status, diet quality, and

certain anthropometric measures – BMI, weight and waist circumference – have independent effects on risk of diet-sensitive disease, especially T2DM.

Typically, in community intervention programs targeting to reduction of diabetes risk, the most frequent recommendation is to adopt a healthy diet. However, this recommendation may not be attainable within the income and resources of the participants. Ironically, those at highest risk for T2DM – single women with children who identify as Hispanic or Black and are low-income – are among those least likely to be able to act on recommendations. Children in low-income households already often face non-modifiable or difficult-to-modify risks (genetic, epigenetic, environmental)⁴⁷ which makes it exceptionally important to understand more modifiable intra-household dynamics of dietary intake and diet quality, and the household food supply. The public health implications of this knowledge are significant, as diabetes prevention programs for low-income persons must be designed to consider influential SDOH, especially food insecurity, if they are to be successful in impacting diet quality and body weight to prevention T2DM and optimize health.

Due to scarcity of literature examining the relationships between food insecurity, diet quality and anthropometric measurements among low-income persons at risk of T2DM, we do not know the direction nor magnitude of these relationships, or whether and how these relationships are similar between parents and children in the same household. Therefore, the overall aim of this study was to characterize the relationships between diet quality, body weight and food insecurity among low-income women at risk of T2DM, and their children, 8-12-years-old. In pursuit of this goal, we proposed the following specific aims:

1. Characterize the relationship between household food security status and adequacy of mother and child diet quality (defined by the Healthy Eating Index-2015).
 - a. Hypothesis 1. Diet quality will be significantly lower in the food insecure individuals compared to their food secure counterparts, driven by consumption of lower nutrient dense foods and higher consumption of calorically-dense (nutrient scarce) foods.
2. Characterize the relationship between household food security status and anthropometric measurements among mothers and children.
 - a. Hypothesis 2. Those individuals in food insecure households will present higher body weight, BMI, and waist circumference compared to the food secure individuals.
3. Characterize the relationship between diet quality and the anthropometric measurements among mothers, and how this differs by household food security status.
 - a. Hypothesis 3. Lower diet quality, driven by the presence of a food insecure status, will predict increased waist circumference and BMI.

CHAPTER 2: METHODOLOGY

The sample in this study was drawn from a research study designed to develop and test (using a randomized controlled design) the effects of a behavioral lifestyle intervention on diabetes risk factors in low-income women with a history of gestational diabetes or prediabetes, and their 8-12-year-old children. The study – Encourage, Practice and Inspire Change in El Rio Families “EPIC El Rio” Study (NIH/NIDDK Grant 1 R34 DK118486-01) – was conducted with patients at a Federally Qualified Health Center (FQHC) in Tucson, Arizona.⁴⁸

2.1 Setting

Measurements and data collection were performed at El Rio Community Health Center, a Federally Qualified Health Center in the Southwestern United States. El Rio serves more than 110,000 underinsured and uninsured patients, a majority (85%) of whom identify as Hispanic or Latino, and live at or below the federal poverty level (90%).

2.2 Participants

Forty-six women were recruited from El Rio Community Health Center to participate in the EPIC El Rio Study with the following criteria:

Inclusion criteria:

Previous diagnosis of gestational diabetes mellitus (GDM) or who have confirmed pre-diabetes HbA1c (5.7-6.4%)

Child, ages 8-12-years-old, who is also willing to participate

Fluent in English or Spanish

Willing to participate in 13-week lifestyle change intervention at El Rio Community Health Center

Exclusion criteria:

Previous diagnosis of type 2 diabetes

2.3 Demographics

Participants completed the Protocol for Responding to and Assessing Patients' Assets, Risks, and Experiences (**PRAPARE** Questionnaire), a screening tool used by Federally Qualified Health Centers to better understand social determinants of health.⁴⁹ This questionnaire prompted participants to self-report basic demographic and socioeconomic data, including age, race, ethnicity, household size, governmental benefits received, health insurance, employment status, level of education, and number of household members.

2.4 Household food insecurity status

Food security status was assessed using the **Hunger Vital Sign™**, a validated 2-item survey wherein a positive answer to either of the following items indicated food insecurity:^{50,51} “Within the past 12 months we worried whether our food would run out before we got money to get more” and “Within the past 12 months the food we bought just didn’t last and we didn’t have money to get more.”.

2.5 Dietary intake

Adult participants’ (mothers) dietary intake was collected through the validated Southwest Food Frequency Questionnaire (SFFQ), which is a semi-quantitative self-administered 159-item questionnaire, where the mother had to report the frequency of consumption of specific food items and food groups in the past 3 months, with the portion size typically consumed.⁵² Children’s dietary intake was collected through two, nonconsecutive, interviewer-administered 24-hour dietary recalls (where they were asked about the food items

and portions consumed the day prior)⁵³ conducted via telephone by trained nutritionists and entered into the Nutrient Data System for Research.

2.6 Diet quality

Using the dietary intake data collected for each participant, a Healthy Eating Index (HEI-2015) score was created according to the “simple” HEI scoring method developed by the National Cancer Institute. The HEI-2015 is a diet quality measure used to assess compliance to the 2015 Dietary Guidelines for Americans, with total score ranging from 0 to 100, wherein higher values represented higher compliance to the guidelines or better dietary intake. Thirteen dietary components comprise the total: nine “adequacy” **components** (foods to promote or eat more of, including: total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein, seafood and plant proteins, and fatty acids) which are proportionally scored, where higher consumption equals higher scores; and four “moderation” **components** (foods for which consumption is suggested to be limited, including: refined grains, sodium, added sugars and saturated fats) which are inversely scored, where low consumption equals a high score. Total fruits, whole fruits, total vegetables, total protein foods, and seafood and plant proteins have maximum scores of five. Whole grains, dairy, refined grains, sodium, added sugars and saturated fats have maximum scores of 10.^{54,55}

2.7 Anthropometrics/ Blood pressure/Glucose levels

Blood pressure, body weight, height, waist circumference and hemoglobin A1c (HbA1c) were measured by trained staff. Body weight was measured using a calibrated, digital scale while height was measured with a mechanical height rod and a stadiometer. Waist circumference was measured at the umbilicus in both populations. All measurements were completed in duplicate and an average of the two measures was used. Body mass index was calculated using the

formula weight (kg) / height² (m) for mothers and the body mass index classification was generated according to the World Health Organization cut-points (normal, 18.5 – 24.9 kg/m²; overweight, 25 – 29.9 kg/m²; obesity class I, 30 – 34.9 kg/m²; obesity class II, 35 – 39.9 kg/m²; obesity class III, ≥ 40 kg/m²).⁵⁶ In children, body mass index z-scores [standard deviation (SD) scores] were generated using the age- and sex- specific growth chart found in the CDC;⁵⁷ body mass index classification was generated according to the cut-offs for Z-scores from the World Health Organization (normal, -2SD - +0.99 SD; overweight, $\geq +1$ SD; Obesity, $\geq +2$ SD).⁵⁸ Blood pressure was measured twice and HbA1c once, using portable, CLIA approved technologies.

2.8 Analyses

All statistical analyses were performed using the statistical software package STATA, version 16.

2.8.1 Analyses for aim 1: Characterize the relationship between household food security status and adequacy of mother and child diet quality.

Demographic differences between food secure and food insecure households were assessed by performing two-sided two-sample T-tests for continuous, normally distributed variables including waist circumference, systolic blood pressure, diastolic blood pressure and BMI. For non-parametric continuous variables (age, household size, and HbA1c), Wilcoxon Rank Sum Tests were performed. For categorical variables (ethnicity, race, income, household benefits, insurance employment and education), Chi²/ Fisher's Test were performed.

Differences in diet quality (HEI 2015 scores) between food secure and food insecure households for mothers and children were assessed using two-sided two-sample T-tests. Seven

mother-child pairs were excluded from diet quality analyses due to missing dietary intake information, resulting in a total of 39 pairs.

Diet quality adequacy (meeting or not meeting minimum threshold for adequate diet quality) was defined using cut points proposed by Kirkpatrick wherein an HEI score of 60 or above indicated “adequate” diet quality and a score of below 60 indicated “low” diet quality.⁵⁹ Independence of proportions for diet quality adequacy of mothers and children was tested through 2x2 tables for the overall sample (n=39 pairs) and stratified by food security status using McNemar’s Tests. Concordance for diet quality adequacy of mothers and children (how well diet quality agrees among child/mother pairs, corrected for chance) was tested with Kappa tests for the overall sample (n=39) and stratified by food security status.

2.8.2 Analyses for aim 2: Characterize the relationship between household food security status and anthropometric measurements among mothers and children.

Anthropometric measurements (Weight, BMI, and waist circumference) differences between food secure and food insecure households for mothers and children were assessed using two-sided two-sample T-tests with the total sample (n=46 pairs).

2.8.3 Analyses for aim 3: Characterize the relationship between the anthropometric measurements and diet quality among mothers, and how this differs by household food security status.

Linear regression analysis tested whether the association of mother’s BMI and waist circumference with diet quality was impacted by household food security status. For the BMI regression, the total sample for mothers was used (n=46). For the waist circumference regression, two mothers were excluded from the analyses due to an incorrect value and to a participant disclosing a pregnancy (n=44). Two models were used for each anthropometric measurement.

Model one included diet quality and the anthropometric measurement of interest, and Model 2 included diet quality and the anthropometric measurement of interest adjusting/controlling by food security. Assumptions of linearity, normality of residuals, constant variance, and independence were assessed for each linear regression.

CHAPTER 3: RESULTS

3.1 Participant Characteristics

Forty-six women were recruited from El Rio Community Health Center (“El Rio”), a Federally Qualified Health Center in Tucson, Arizona. (**Table 1.**) The mean age of adult participants was 41 ± 6.1 years-old. Average household size was five. A majority of participants self-identified their race as White ($n=37$, 80%), followed by Native American (13%) and Black or African American (7%). Thirty-eight participants (83%) identified their ethnicity as Hispanic or Latino. Almost half of participants ($n=22$, 48%) reported an annual household income below \$25,000; of those reporting an income above \$25,000, only 3 households reported $> \$75,000$. Twenty-six participants (57%) indicated receiving some form of household benefits, the most common being SNAP/food stamps ($n=14$) followed by The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) ($n=6$) and then a combination of both services ($n=3$). Thirty participants (65%) reported having health insurance from Arizona Health Care Cost Containment System (AHCCS), Medicaid or KidsCare, five (11%) had private insurance, and eleven (24%) indicated being uninsured. Sixty-three percent of participants reported that they were employed (63%); twenty of these participants held full-time jobs, and nine were working part-time. Eight participants reported that they were unemployed but seeking a job, while nine were unemployed but not in the process of seeking a job. Thirty-nine percent ($n=18$) reported an education level higher than high school, 35% ($n=16$) had an education of less than high school, and 26% ($n=18$) had a high school/GED degree.

Adults had a mean weight of 87 ± 16.3 kg, mean BMI of 34.3 ± 5.6 Kg/m², and a mean waist circumference of 110.8 ± 15.6 cm. Just over eighty percent (80.4%, $n=37$) of adult participants were obese (BMI ≥ 30 Kg/m²), 17.4% ($n=8$) were overweight (BMI 25 – 29.99

Kg/m²), and only one person (2.2%) was in the normal weight category (BMI 18.5-24.99 Kg/m²). Average HbA1c was 5.9 mmol/mol which indicates prediabetes (prediabetes range is 5.7% to 6.4%), and average systolic blood pressure was 118.4±12.7 mmHg while average diastolic blood pressure was 71.3±8.2 mmHg. (**Table 1.**)

Forty-six children were recruited to participate in the study along with their mothers. Child participants were on average 10.3±1.5 years old, and exactly half of the sample were female. Similar to their mothers, a large proportion identified as White (85%), while the remaining participants identified as Native American (13%) or Black or African American (2%). Eighty-nine percent identified their ethnicity as Hispanic or Latino. Child mean body weight was 40.1±13.2 kg, with mean BMI z-scores of 1.3 ± 0.8; 30% had a normal BMI for age and gender, 48% were classified in the overweight category, and 22% were classified with obesity. Mean waist circumference was 79.6 centimeters. Children’s mean HbA1c was 5.3 mmol/mol, their average systolic blood pressure was 105.5±10.3 mmHg, and their average diastolic blood pressure was 58.7±7.4 mmHg. (**Table 1.**)

Table 1. Participant baseline characteristics (n=46 women, n=46 children)

Characteristic	Total	
	Mean or Freq.	SD or %
<i>Parent / Household (n=46)</i>		
Age (years)	40.6	6.1
Household Size	5.08	1.3
Ethnicity		
<i>Hispanic</i>	38	83%
<i>Non-Hispanic</i>	7	16%
Race		
<i>White</i>	37	80%
<i>Black/African American</i>	3	7%
<i>Native American</i>	6	13%
Household Income		

	<\$25, 000	22	48%
	>\$25, 000	24	52%
Household Benefits~			
	<i>Any benefit*</i>	26	57%
	<i>None</i>	20	43%
Health Insurance			
	<i>AHCCS/Medicaid/KidsCare</i>	30	65%
	<i>Private insurance</i>	5	11%
	<i>Uninsured</i>	11	24%
Employment			
	<i>Employed (Full time)</i>	20	43%
	<i>Employed (Part-time)</i>	9	20%
	<i>Unemployed (Seeking work)</i>	8	17%
	<i>Unemployed (Not seeking work)</i>	9	20%
Education			
	<i>Less than High School</i>	16	35%
	<i>High School/ GED</i>	12	26%
	<i>More than High School</i>	18	39%
Household Food Security Status			
	<i>Food Secure</i>	25	54.4%
	<i>Food Insecure</i>	21	45.6%
Weight (kg)		87.4	16.3
Body Mass Index (kg/m²)		34.3	5.6
Body Mass Index (WHO categories)			
	<i>Normal (18.5-24.99)</i>	1	2.2%
	<i>Overweight (25-29.99)</i>	8	17.4%
	<i>Obesity Class I (30-34.99)</i>	20	43.5%
	<i>Obesity Class II (35-39.99)</i>	10	21.7%
	<i>Obesity Class III (≥40)</i>	7	15.2%
Hemoglobin A1c (mmol/mol)		5.9	1.0
Waist Circumference (cm)		110.8	15.6
Systolic Blood Pressure (mmHg)		118.4	12.7
Diastolic Blood Pressure (mmHg)		71.3	8.2
<i>Children n=46</i>			
Age (years)		10.3	1.5
Sex			
	<i>Female</i>	23	50%
	<i>Male</i>	23	50%
Ethnicity			
	<i>Hispanic</i>	41	89%
	<i>Non-Hispanic</i>	5	11%
Race			
	<i>White</i>	26	85%
	<i>Black/African American</i>	1	2%
	<i>Native American</i>	6	13%

Weight (kg)	40.1	13.2
BMI (Z-score)	1.3	0.8
BMI (Z-score categories)		
Normal (-1.99 – 0.99)	14	30.4%
Overweight (1 – 1.99)	22	47.9%
Obesity (>2)	10	21.7%
Hemoglobin A1c (mmol/mol)	5.3	0.2
Waist Circumference (cm)	79.6	12.1
Systolic Blood Pressure (mmHg)	105.5	10.3
Diastolic Blood Pressure (mmHg)	58.7	7.4

*Benefits including: Social Security, SNAP- Supplemental Nutrition Assistance Program, WIC- The Special Supplemental Nutrition Program for Women, Infants, and Children, Veterans Affairs or the combination of some of the services. AHCCCS- Arizona Health Care Cost Containment System.

3.2 Relationship between household food security status and diet quality

Twenty-one (46%) participants (households) identified as food insecure (**Supplemental Table 1**). There were no statistically significant differences in any of the reported sociodemographic characteristics between food secure and insecure households. There were also no statistically significant differences in the measurements of HbA1c, systolic and diastolic blood pressure for food secure versus food insecure adult or child participants.

3.3 Aim 1: Household food security status influences diet quality adequacy (defined by the Healthy Eating Index-2015) in mother and child.

Mean HEI score for the overall sample of adults (mothers) was 58.3 (SD ±10) out of the maximum possible score of 100 (**Table 2**). The average HEI score was significantly higher among food secure versus food insecure households (61.8±9.9 versus 54± 8.5, respectively, $p=0.007$). Assessing the components comprising the total score, mothers in food secure households also had significantly higher scores in three of the adequacy components compared to mothers in food insecure households, including total fruit (3.9±1.5 versus 3.1± 1.6, $p=0.04$), total vegetables (3.4±1.4 versus 2.8± 1.4, $p=0.04$), and greens and beans (4.6±0.9 versus 3.4±

1.4, $p=0.008$). There were no significant differences between food secure and insecure households in any of the moderation components, inclusive of refined grains, sodium, added sugars and saturated fat.

Table 2. Overall and Component Diet Quality Scores for Mothers (n=46)

		Overall (n=46)		Food secure (n=25)		Food insecure (n=21)		
HEI Component	Score range	Mean	SD	Mean	SD	Mean	SD	p-value
Total Diet Quality	0–100	58.3	10	61.8	9.9	54	8.5	0.007*
Adequacy Components								
Total Fruit ^a	0–5	3.6	1.6	3.9	1.5	3.1	1.6	0.04*
Whole Fruit ^b	0–5	4.2	1.3	4.4	1.2	4	1.5	0.21
Total Vegetables ^c	0–5	3.3	1.4	3.6	1.4	2.8	1.4	0.04*
Greens and Beans ^c	0–5	4.1	1.3	4.6	0.9	3.4	1.4	0.008*
Whole Grains	0–10	2.4	1.9	2.4	1.7	2.5	2.2	0.77
Dairy ^d	0–10	6.2	2.7	6.3	2.7	6	2.7	0.74
Total Protein ^e	0–5	4.9	0.5	4.8	0.6	4.9	0.4	0.89
Seafood and Plant Protein ^e	0–5	4.7	0.6	4.9	0.3	4.5	0.8	0.06
Fatty Acids ^f	0–10	4.8	2.4	5.1	2.4	4.5	2.4	0.37
Moderation Components								
Refined Grains	0–10	5.2	3.6	5.6	3.4	4.7	3.9	0.49
Sodium	0–10	0.8	2.4	1.1	2.9	0.5	1.4	0.65
Added Sugars	0–10	8.7	2.4	9	2.2	8.3	2.5	0.18
Saturated Fats	0–10	5.4	2.9	6	2.8	4.7	3.1	0.18

^aIncludes 100% fruit juice; ^bIncludes all forms except juice; ^cIncludes legumes (beans and peas); ^dIncludes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages; ^eIncludes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas); ^fRatio of poly- and monounsaturated fatty acids to saturated fatty acids. ***p-value** <0.05

Thirty-nine (out of 46) children completed the two 24-hour dietary recall interviews needed to calculate an HEI score. Mean HEI score for the child sample was 56.1 ± 10 out of the

maximum possible score of 100 (**Table 3.**). There were no significant differences in total HEI scores by household food security status. However, when looking at the components comprising the total score, children from food secure households had significantly higher HEI scores for whole fruit when compared to children from food insecure households (3.4±1.9 versus 1.3± 1.9, p=0.001). Similar to the mothers, there was no significant differences between moderation component scores for food secure versus food insecure households.

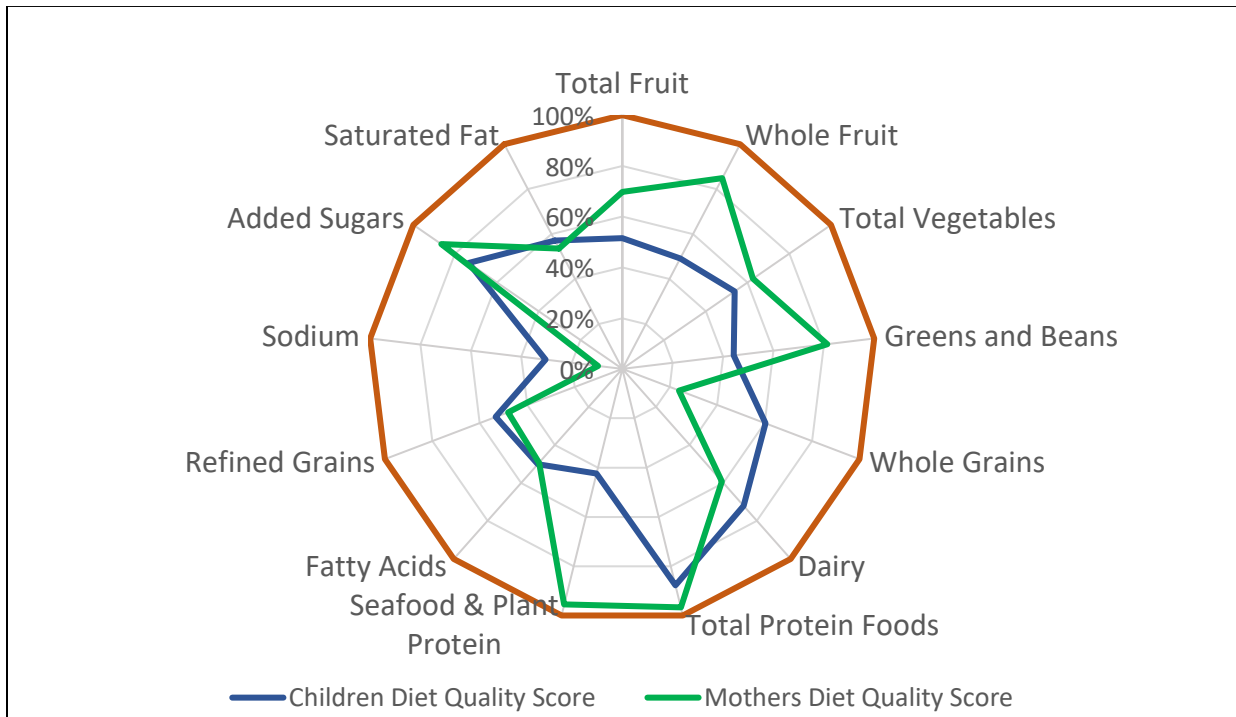
Table 3. Overall and Component Diet Quality Scores for Children (n=39)

		Overall (n=39)		Food secure (n=21)		Food insecure (n=18)		
HEI Component	Score range	Mean	SD	Mean	SD	Mean	SD	p-value
Total Diet Quality	0–100	56.1	13.5	55.5	16.9	53.5	14.7	0.52
<i>Adequacy Components</i>								
Total Fruit ^a	0–5	2.6	1.9	3	1.7	2	2	0.11
Whole Fruit ^b	0–5	2.5	2.2	3.4	1.9	1.3	1.9	0.001*
Total Vegetables ^c	0–5	2.7	1.6	2.6	1.8	2.8	1.4	0.73
Greens and Beans ^c	0–5	2.2	2.2	2	2.2	2.4	2.1	0.54
Whole Grains	0–10	6	3.9	6	3.6	6.1	4.2	0.91
Dairy ^d	0–10	7.2	2.8	6.9	3.1	7.5	2.6	0.5
Total Protein ^c	0–5	4.4	1.1	4.4	1.2	4.3	1	0.75
Seafood and Plant Protein ^e	0–5	2.1	2.2	2.1	2.2	2.1	2.3	0.98
Fatty Acids ^f	0–10	5	3.5	5.4	3.5	4.6	3.7	0.48
<i>Moderation Components</i>								
Refined Grains	0–10	5.3	3.4	5.8	3.3	4.7	3.5	0.31
Sodium	0–10	3	4	2.9	4.3	3.2	3.7	0.8
Added Sugars	0–10	7.3	2.3	7.3	2.6	7.4	2	0.88
Saturated Fats	0–0	5.7	3.5	6.3	3.4	5.1	3.6	0.31

^aIncludes 100% fruit juice; ^bIncludes all forms except juice; ^cIncludes legumes (beans and peas); ^dIncludes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages; ^eIncludes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas); ^fRatio of poly- and monounsaturated fatty acids to saturated fatty acids. ***p-value** <0.05

A visual comparison of component scores for thirty-nine matched pairs of mothers and children (**Figure 3.**) confirmed that mothers have higher scores in six of the adequacy components (total fruit, whole fruit, total vegetables, greens and beans, total protein, seafood and plant protein) and one of the moderation components (added sugars), while children appeared to have higher scores in two adequacy components (whole grains and dairy), and three moderation components (refined grains, sodium and saturated fats). When we examined the component scores of mothers and children by food security status, we observed consistent trends within both subgroups, where mothers tended to possess better consumption for total fruit, whole fruit, total vegetables, greens and beans, total protein, seafood & plant protein, and score for added sugars; while children in both subgroups had better consumption of whole grains, dairy, fatty acids, and better scores for refined grains, sodium and saturated fats (**Figure 4.**).

Figure 3. Visual comparison of HEI-2015 component scores for n=39 matched pairs of mothers and children



Diet quality component scores stratified by mothers (green line) and children (blue line). Each component score is scaled as a percentage of the maximum score of that component (orange line), with moderation components (Refined grains, Sodium, Added sugars and Saturated fat) reversed coded in the scoring process, meaning a high percentage in moderation indicates a low intake of that component relative to recommendations.

Figure 4. Visual comparison of HEI-2015 component scores for matched pairs of mothers and children from food secure and food insecure households



Diet quality component scores stratified by household food security status (Food secure- top half, food insecure-bottom half) and by mothers (green line) and children (blue line). Each component score is scaled as a percentage of the maximum score of that component (orange line), with moderation components (Refined grains, Sodium, Added sugars and Saturated fat) reversed coded in the scoring process, meaning a high percentage in moderation indicates a low intake of that component relative to recommendations.

3.4 Dietary adequacy scores of mother and child participants, and concordance between mother-child pairs

We evaluated the overall diet quality scores of mothers and children with regard to dietary adequacy, where an HEI score of 60 or above indicated “adequate” diet quality and a score of below 60 indicated a “low” diet quality.⁵⁹ The only subgroup with a mean meeting the “adequate” diet quality score threshold were mothers from food secure households (HEI score mean of 67.8 ± 9.9), while children from food secure households (HEI score mean of 55.5 ± 16.9), and mothers and children from food insecure households fell below the “adequate” threshold (Mothers’ HEI score mean of 54 ± 8.5 ; Children’s HEI score mean of 53.5 ± 14.7).

We assessed concordance of diet quality scores between mothers and their children using 2 x 2 tables. (**Tables 4-6.**) Across the total sample (n=39), sixteen mothers had adequate diet quality and twenty-three had low diet quality; twelve children had adequate diet quality while twenty-seven had low diet quality. Mother and child proportions for adequacy were dependent on each other (p=0.03) (**Table 4.**). Across the food security group (n=21), thirteen food secure moms had an adequate diet quality and eight had low; only eight food secure children had adequate diet quality score, while thirteen had low. Mother and child proportions for adequacy in food secure households were independent from each other (p=0.9) (**Table 5.**). Within the food insecure group (n=18), only three food insecure moms had adequate diet quality and fifteen had low; only four food insecure children had adequate diet quality, while fourteen had low diet quality. Mother and child proportions for adequacy in food insecure households were independent from each other (p=1.0) (**Table 6.**).

Table 4. Adequacy of score between mother and child (n=39)

Child's HEI	Mother's HEI		Total
	Adequate	Low	
Adequate	7	5	12
Low	9	18	27
Total	16	23	39

McNemar Chi2=

1.14

p=0.28

Exact p= 0.42

Table 5. Adequacy of score between mother and child in food secure households (n=21)

Child's HEI	Mother's HEI		Total
	Adequate	Low	
Adequate	6	2	8
Low	7	6	13
Total	13	8	21

McNemar Chi2=

2.78

p=0.10

Exact p=0.18

Table 6. Adequacy of score between mother and child in food insecure households (n=18)

Child's HEI	Mother's HEI		Total
	Adequate	Low	
Adequate	1	3	4
Low	2	12	14
Total	3	15	18

McNemar Chi2=

0.20

p=0.65

Exact p=1.0

We evaluated concordance of diet quality adequacy among mother and child pairs in our total sample (n=39); twenty-five pairs agreed (64%) (considered “fair” agreement, kappa 0.23 as

it was slightly higher than by chance (53.2%), however, this difference was not statistically significant ($p=0.07$, 95% CI -0.077 – 0.534). Less than 50% of children and mothers in our sample had adequate diet quality (12 children, 16 mothers); however, mothers were more likely to have good diet quality compared to children. Our hypothesis that mothers have poorer diet quality than children was not supported by the data. There was 72% agreement between food insecure mother-child pairs (kappa 0.12), but this difference was not statistically significant ($p=0.3$, 95% CI -0.385 - 0.621). Again, our hypothesis that mothers have poorer diet quality than children was not supported by the data. Among food secure pairs ($n=21$), there was a 57% agreement between mother and child pairs (considered “fair” agreement, kappa 0.19), but this difference was not significant ($p=0.17$, 95% CI -0.179 - 0.556). Our hypothesis that mothers have poorer diet quality than children was not supported by the data. (**Table 7.**)

Table 7. Concordance between diet quality adequacy in mother-child pairs.

Mother-child pairs	Agreement (%)	Expected agreement (%)	Kappa	95% CI	p-value
Overall sample (n=39)	64.10	53.45	0.229	-0.077 - 0.534	0.07
Food secure sample (n=21)	57.14	47.17	0.189	-0.179 - 0.556	0.17
Food insecure sample (n=18)	72.22	68.52	0.117	-0.385 - 0.621	0.31

3.5 Relationship between household food security status and mother and child body measurements

There were significant differences in weight, BMI and waist circumference between mothers from food secure versus food insecure households (**Table 8.**) Body weight was significantly lower in mothers from food secure compared to food insecure households

(82.7±15.1 kg and 93.0± 16.2 kg, p=0.03). We also compared BMI, a surrogate adiposity measure, wherein mothers from food secure households had significantly lower BMI than those from food insecure households (32.4±4.6 kg/m² versus 36.4± 6 kg/m², p=0.01). Waist circumference was also significantly lower in mothers from food secure households relative to mothers from food insecure households (104.7±10.1 cm versus 117.7± 18 cm, p=0.01). There was furthermore a significant difference in the categories for BMI in mothers (p=0.02), where mother in food insecure households had a higher frequency in the obese category (class I, Class II, and Class III combined) compared to food secure (72% versus 90.5%), particularly in obesity Class II and obesity Class III. There was no significant difference in weight and waist circumference for children when stratified by household food security status. However, mean BMI for age and gender (z-scores) was significantly higher in children in food secure households compared to food insecure (1.5±0.8 versus 1± 0.7, p=<0.04); similarly, in BMI categories using z-scores, children in food secure households had higher frequency of overweight and obesity statuses compared to food insecure children, who had higher prevalence of normal BMI for age and gender (**Table 8**).

Table 8. Association Between Household Food Security status and Anthropometric Measurements among mothers (n=46) and children (n=46)

Characteristic	Total (n=46)		Food secure (n=25)		Food insecure (n=21)		p-value
	Mean or Freq.	SD or %	Mean or Freq.	SD or %	Mean or Freq.	SD or %	
Mother, n=46							
Weight (kg)	87.4	16.3	82.7	15.1	93.0	16.2	0.03*
BMI (kg/m ²)	34.3	5.6	32.4	4.6	36.4	6	0.01*
BMI (WHO categories)							
<i>Normal (18.5-24.99)</i>	1	2.2%	1	4%	0	0.0%	0.02*

<i>Overweight (25-29.99)</i>	8	17.4%	6	24%	2	9.5%	
<i>Obesity Class I (30-34.99)</i>	20	43.5%	14	56%	6	28.6%	
<i>Obesity Class II (35-39.99)</i>	10	21.7%	2	8%	8	38.1%	
<i>Obesity Class III (≥ 40)</i>	7	15.2%	2	8%	5	23.8%	
Waist circumference (cm)	110.8	15.6	104.7	10.1	117.7	18	0.00*
Child, n=46							
Weight (kg)	40.1	13.2	46.5	11.9	45.5	14.8	0.8
BMI (Z-score)	1.3	0.8	1.5	0.9	1.0	0.7	0.04*
BMI (Z-score categories)							
Normal (-1.99 – 0.99)	14	30.4%	2	8%	12	57.1%	0.001*
Overweight (1 – 1.99)	22	47.9%	16	64%	6	28.6%	
Obesity (>2)	10	21.7%	7	28%	3	14.3%	
Waist circumference (cm)	79.6	12.1	81.8	11.1	77.1	13.3	0.19

*p-value <0.05

3.5 Relationship between diet quality score and mother body measurements adjusted for food security status

Unadjusted linear regression (Model 1) showed an inverse relationship between HEI score and BMI (p= 0.03); for every unit increase in HEI, BMI decreased by 0.17; however, after controlling for household food security status (Model 2) there was no significant effect of diet quality score on BMI (**Table 9**).

Unadjusted linear regression showed an inverse relationship between HEI score and waist circumference (p= 0.02); for every unit increase in HEI, waist circumference measurement decreased by 0.49 cm. There was no significant effect of HEI on waist circumference after adjusting for food security status; however, food insecurity was a positive predictor of waist circumference (p=0.04) – those who were from food insecure households had a higher WC (**Table 10**).

Table 9. Associations Between Diet Quality Score (HEI-2015) and BMI in mothers, n=46

Predictors		β	SE	p-value	Adjusted R ²
<i>Model 1</i>					0.09
	Mother's HEI-2015	-0.17	0.08	0.037~	
<i>Model 2*</i>					0.16
	Mother's HEI-2015	-0.11	0.09	0.202	
	Food insecurity	3.19	1.69	0.066	

* Adjusted for food insecurity status. ~ p-value<0.05

Table 10. Associations Between Diet Quality Score (HEI-2015) and Waist circumference in mothers, n=44

Predictors		β	SE	p-value	Adjusted R ²
<i>Model 1</i>					0.12
	Mother's HEI-2015	-0.49	0.20	0.017~	
<i>Model 2*</i>					0.21
	Mother's HEI-2015	-0.33	0.20	0.110	
	Food insecurity	8.17	3.83	0.039~	

* Adjusted for food insecurity status. ~ p-value<0.05

CHAPTER 4: DISCUSSION/CONCLUSION

4.1 Discussion

The purpose of this study was to obtain a better understanding of the relationships between food insecurity, diet quality and anthropometric measurements among low-income persons at risk of T2DM in order to characterize the direction and magnitude of these relationships and explore whether and how these relationships are similar between parents and children in the same household. Across the forty-six mother-child pairs that were studied, 45.6% reported household food insecurity. This alone could suggest that a high proportion of the patients at El Rio Community Health Center with health-related concerns are at risk of suffering the negative consequences of food insecurity.¹⁹⁻²² A high proportion of households with food insecurity in our sample self-identified as Hispanic (83% in adults and 89% in children), an ethnic minority known to be disproportionately burdened by food insecurity (1.5-2.0 times more likely than non-Hispanic whites).¹⁴ Food insecurity is also highly likely to be present among those living in poverty, a demographic characteristic present in almost half of our sample, with 48% reporting a household income of below \$25,000 a year – the U.S. federal poverty level for a single person household.¹⁴ While there were no significant differences in demographic characteristics between food secure and food insecure households in our sample, it is worth noting that most participants had low diet quality, and had a BMI that fell into the overweight or obese categories.

Total diet quality score (HEI-2015 scores) for mothers in our sample was 58.3, which was identical to the HEI score for adults between the ages of 18-64 of 58.3 participating in 2015-2016 NHANES.⁶⁰ A similarly close score was also observed for total diet score of our child sample (n=39, HEI-2015=56.1) and the HEI national average of 53.9 for children 2-17 years old

in the same NHANES study year.⁶⁰ Those similarities were not present when looking at the thirteen HEI component scores in adults or children.⁶⁰ When stratified by household food security status, our result that food insecure mothers had significantly lower HEI scores compared to food secure aligns with prior results reported through cross-sectional studies and systematic review also observing lower HEI scores among food insecure individuals.^{38-40,61} Our results also are comparable with the evidence that indicate that food insecure adults have lower consumptions of fruits and vegetables^{36-38,61}; moreover, our adult sample also reported lower consumption of greens and beans. In child participants in our sample, there were no significant differences between total diet quality when stratified by food secure status, however, there was a difference in one of the HEI components – total fruits – a food group whose intake was previously reported to be lower among food insecure youth compared to food secure.^{37, 39-41}

However, it is notable that in our overall study sample, both mothers and children had diet quality that is considered “low” when using generally accepted cut points (values below 60 are considered to carry a “F” grade or “Low”).⁵⁹ Among food secure / food insecure subgroups in our sample, mothers from food secure households were the only participants with a mean diet quality score slightly above the cut point of 60 (mean score of 61); mothers from food insecure households and all children in our sample had mean HEI scores lower than 60. These results are concerning, particularly when considering that low diet quality in childhood has been associated with negative psychosocial and health outcomes later in life including body composition, risk of metabolic syndrome, blood pressure, HbA1c, health related quality of life, and premenopausal breast cancer.⁶²

Very little research has investigated relationships between parent and child diet quality in the presence of food insecurity. However, more information is available about the association

without considering household food security status. A 2009 cross-sectional study investigated the relationship between diet quality in both parents and their children using data from the USDA Continuous Survey of Food Intakes by Individual (CSFII) 1994-1996.⁶³ Correlations were conducted within gender subgroups (mother-daughter, mother-son, father-daughter, father-son), stratified by ethnicity. The results showed weak to moderate parent-child correlations, with a stronger association observed between children with mothers compared to fathers, and among Hispanics compared to Non-Hispanic White and Black families. They also evaluated the agreement within the diet qualities for parent-child dyads (Kappa test), finding overall weak agreement (61%, kappa=0.22) in HEI scores; however, the agreement between mother-daughter and mother-son were higher than father-daughter and father-son. When stratified by ethnicity, there was a slightly higher agreement in Hispanics dyads (64.7%, kappa= 0.28) compared to non-Hispanic white and black.⁶³ In our sample, we found similar kappa values in our overall sample (64%, kappa=0.22) indicating fair agreement in parent-child diet quality adequacy. However, the proposed hypothesis that mothers have poorer diet quality than children was not supported by our overall data, or when we stratified by food security status.

In our sample, we tested the relationship of food insecurity with anthropometric measurements in both mothers and in children. Our results are similar to prior evidence from cross-sectional and observational studies, which observed that food insecure status was associated with higher body weight, BMI (especially prevalence of obesity), and waist circumference in adults.²⁸⁻³⁰ In our sample, all of our food insecure participants were considered obese by WHO standards, while several food secure participants were normal weight and overweight. In contrast to the adults in our sample, child anthropometric data were not similar to cross-sectional representative data suggesting that food insecure children had higher

anthropometric measurements and higher odds (up to 5 times more likely) of obesity compared to their food secure counterparts.^{28, 64}

We further explored whether diet quality score could serve as a predictor of BMI and waist circumference in the presence of household food insecurity. Prior work investigating this specific association is extremely scarce, thus our data contribute important, albeit very preliminary, insight as to whether or not food insecurity has the potential to moderate the interactions of HEI with BMI and waist circumference. In a cross-sectional study in 2014, Drenowatz et al. explored the relationship of diet quality (HEI-2010) with body fat in 407 young adults (age 27.6 ± 3.7 years old) using dual X-ray absorptiometry while adjusting for physical activity. Classifying the diet quality score as “good” if higher than 80 and “poor” if below 51, a significant correlation of HEI and energy intake with body fat was observed after controlling for sex and age.⁴² However, a moderate to vigorous level of physical activity posed a stronger correlation with body fat, and after controlling for physical activity, the association between diet quality and body fat only remained in men but not in women.⁴² This suggests that in adults (or relatively young adults), physical activity might influence the association of diet quality with body fat in men.

In another cross-sectional study, Lopez-Olmedo et al. evaluated the association of two measures of diet quality (Mexican Diet Quality Index- MxDQI, and Mexican Alternate Healthy Eating Index- MxAHEI) with BMI and waist circumference overall, and further stratified by education level, using data from 954 men and 1356 women in the Mexican National Health and Nutrition Survey 2012.⁶⁵ They concluded that there was no association of total diet quality with BMI for both men and women for either of the diet quality measurements. However, in men, a one unit increase in both MxDQI and MxAHEI scores resulted in a decrease of waist circumference

of 0.10 cm and 0.15 cm, respectively. Women diet quality had no association with BMI nor waist circumference neither in the total sample or by level of education.⁶⁵ Our study sample of women was similar in that when adjusted by education level, there was no longer an association of diet quality with any anthropometric measurements (data not shown).

In a secondary data analysis using data from 15658 adults over the age of 20 in NHANES III, Tande et al. investigated the association of HEI (HEI-1995) and its components with abdominal obesity using waist circumference as a surrogate measurement (categorized as obese and non-obese using sex-specific cut points).⁶⁶ In women, for every unit increase in total HEI score, waist circumference decreased by 0.8% ($p=0.014$); when examining HEI components and waist circumference, every one unit increase in fruit intake significantly decreased the risk of abdominal obesity ($p=0.007$).⁶⁶ Regressions were controlled for sociodemographic factors (age, sex, ethnicity, urban or rural, income, education, and marital status) and health risk factors (smoking and alcohol), which improved the validity of their analyses.⁶⁶

In our study sample, a one unit increase in total diet quality score significantly decreased both BMI and waist circumference values in adult women participants, but when we controlled for food insecurity, this association only remained for waist circumference. However, we did not control for physical activity, which as Drenowatz et al⁴⁴. demonstrated, might have a significant effect on anthropometric measurements in women. Additionally, analyzing the association of anthropometric measurements with the specific components that were significantly different between food secure and food insecure mothers (such as total fruits, total vegetables, and greens and beans) might provide some insight into the components which are key drivers of the association in a positive or negative manner, as seen with Tande et al⁶⁶, where an increase in the fruits score decreased values for waist circumference.

Keenan et al. tested whether the relationships between food security, diet quality, and obesity could be explained by levels of distress and unhealthy coping behaviors among 604 adults from the United Kingdom.⁶⁷ Their findings showed that food insecurity was associated with higher values for BMI due to greater distress and eating to cope; this was not true for the association of food security with diet quality in his study population.⁶⁷ These results suggest that considering other factors, such as psychological mechanisms, might provide additional explanations of the relationships between food security status, diet quality and body weight.

4.2 Limitations

Although this research had many strengths, there were also several limitations. Our sample size was relatively small with only forty-six pairs total, and only thirty-nine pairs with complete diet data. Since this sample was drawn from a pilot study focused on diabetes outcomes, we were not statistically powered to detect associations between food security, diet quality and health outcomes. Future appropriately powered research should examine intra- and inter- household differences in food security, food choices and behaviors among persons at risk for diabetes who also are food insecure. There are innate limitations associated with dietary assessment methodologies – food frequency questionnaires and 24-hr dietary recalls. Both tools utilize a self-report approach, thus relying heavily on participants’ memories and ability to communicate portion sizes with accuracy, leading to possible recall bias. Because we used two different dietary intake tools (mothers completed the Southwest Food Frequency Questionnaire, while children completed 24-hour dietary recalls), we also had to utilize two different methodologies for coding the Healthy Eating Index scores. These differences could have resulted in small inconsistencies in the scoring, reducing our confidence in our comparisons of diet quality between adults and children. In our analysis of anthropometric measurements, diet

quality, and food insecurity, we did not control for physical activity, a factor that could independently affect BMI and waist circumference. Therefore cautious interpretation is warranted. Finally, this was a cross-sectional analysis using baseline data only, limiting any inferences to that one point in time.

4.3 Conclusions and Public Health Implications

There is a scarcity of literature exploring the associations between diet quality and food insecurity in persons at risk of type 2 diabetes. Our findings suggested that diet quality, BMI, and waist circumference were negatively affected by food insecurity. Our data also suggest that total diet quality score and its component parts served as predictors of waist circumference among individuals at risk of T2DM and food insecurity. Finally, our data did not support the ongoing hypothesis of parents having a lower diet quality than their children as a tactic to protect them from the negatives effects of food insecurity.

Given the relatively high prevalence of both food insecurity and T2DM in the general U.S. population, dietary interventions designed to support persons with T2DM should also screen for household food security status (and ideally, take steps to address this issue) given the potential for food insecurity to reduce individual's abilities to act on most nutrition recommendations. Lastly, with the onset of the SARS-Cov-2 pandemic in 2020, the prevalence of food insecurity was estimated to increase by 2-3 times that of 2019 (with estimated projections of >57 million households affected). At the same time, limited surveillance data suggest that weight gain among adults and children attributed to pandemic lockdowns is common.^{68,69} Both of these trends have the potential to exacerbate risk of diet-related disease, while the collateral effects of the pandemic on employment, housing stability, and access to

medical care for underserved populations provide additional challenges to public health professionals seeking to intervene on diet quality among low-income persons at risk of T2DM.

APPENDIX A- SUPPLEMENTARY INFORMATION

Supplemental Table 1. Participants' baseline characteristics by household food security status.

Characteristic	Food secure (n= 25, 54.4%)		Food insecure (n=21, 45.6%)		p-value
	Mean or Freq.	SD or %	Mean or Freq.	SD or %	
Parent / Household					
Age (years)	41.4	6.1	39.6	6.1	0.42
Household Size (median)	5.0	1.4	5.2	1.2	
Ethnicity					0.68
<i>Hispanic</i>	22	88%	16	80%	
<i>Non-Hispanic</i>	3	12%	4	20%	
Race					0.09
<i>White</i>	23	92%	14	67%	
<i>Black/African American</i>	1	4%	2	10%	
<i>Native American</i>	1	4%	5	24%	
Household Income					0.25
<\$25, 000	14	56%	8	38%	
>\$25, 000	11	44%	13	61%	
Household Benefits*					0.08
<i>Any benefits</i>	11	44%	15	71%	
<i>None</i>	14	56%	6	29%	
Health Insurance					0.9
<i>AHCCS/Medicaid/Kidsicare</i>	17	68%	13	62%	
<i>Private insurance</i>	2	8%	3	14%	
<i>Uninsured</i>	6	24%	5	24%	
Employment					0.25
<i>Employed (Full time)</i>	9	36%	11	52%	
<i>Employed (Part-time)</i>	6	24%	3	14%	
<i>Unemployed (Seeking work)</i>	3	12%	5	24%	
<i>Unemployed (Not seeking work)</i>	7	28%	2	10%	
Education					0.17
<i>Less than High School</i>	11	44%	5	24%	
<i>High School/ GED</i>	4	16%	8	38%	
<i>More than High School</i>	10	40%	8	38%	

Hemoglobin A1c (mmol/mol)	6.0	1.3	5.8	0.4	0.57
Systolic Blood Pressure (mmHg)	121.0	12.8	115.3	12.2	0.12
Diastolic Blood Pressure (mmHg)	73.6	9.0	68.5	6.3	0.03
Child					
Age (years)	0.1	1.1	10.7	1.8	0.11
Sex					
<i>Female</i>	8	32%	15	71%	0.17
<i>Male</i>	17	68%	6	26%	
Ethnicity					
<i>Hispanic</i>	23	92%	18	86%	0.65
<i>Non-Hispanic</i>	2	8%	3	14%	
Race					
<i>White</i>	23	92%	16	76%	0.08
<i>Black/African American</i>	1	4%	0	0%	
<i>Native American</i>	1	4%	5	24%	
HbA1c (mmol/mol)	5.3	0.3	5.4	0.2	0.13
Systolic Blood Pressure (mmHg)	106.3	10.1	104.5	10.6	0.55
Diastolic Blood Pressure (mmHg)	59.6	6.3	57.7	8.5	0.38

*Benefits including: Social Security, SNAP- Supplemental Nutrition Assistance Program, WIC- The Special Supplemental Nutrition Program for Women, Infants, and Children, Veterans Affairs or the combination of some of the services. AHCCCS- Arizona Health Care Cost Containment System; T-test for normally distributed continuous variables (Systolic blood pressure, diastolic blood pressure), Wilcoxon Rank-Sum test for non-parametric continuous variables (Age, Household size, HbA1c), and Chi²/ Fisher's test for categorical variables (Ethnicity, Race, Income, Benefits, Insurance, Employment, Education).

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