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Pathways between Food Insecurity and Diabetes, Observing the Mediating Effects of Depression.

Alpha-Isaac Eferighe

Abstract

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(NSCH 2020)

By

Alpha-Isaac Eferighe

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INTRODUCTION: Type 2 diabetes is the seventh leading cause of death in the U.S. and is significantly associated with morbidity, mortality, decreased quality of life, increased health-care utilization, and cost. Studies have shown adults suffering from food insecurity have a greater risk of having diabetes than those that do not. Although 11% of U.S. households suffer from food insecurity, the link between food insecurity and diabetes is not fully understood.

AIM: This study aims to determine the direct and indirect pathways through which food insecurity may lead to diabetes, observing the mediating effects of depression using nationally representative data.

METHODS: The 2005-2006 National Health and Nutrition Examination Survey (NHANES) data were used for this study. The mechanism through which food insecurity influences diabetes was determined using Structural Equation Modeling (SEM). The analysis also included an investigation of the direct and indirect effects of depression on diabetes.

Results: Food insecurity was found to have a negative direct effect on diabetes (β= -.018, p= .497). Depression was directly and significantly related to diabetes (β = 0.09, p = 0.009). Food insecurity was positively and significantly associated with depression (β = 0.329 , p > 0.01).

Conclusion: This study shows that depression is linked to diabetes, and food insecurity is linked to depression. While the total effect of food insecurity on diabetes was positive, the direct impact was negative. Food insecure individuals have heightened chances of being depressed, thus having diabetes, and may benefit from additional income supplements and education in proper food consumption.

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Alpha-Isaac Eferighe
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30303

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By

Alpha-Isaac Eferighe

Approved:

Dr. Ike S Okosun, PhD

Committee Chair

Dr. Katherine Masyn PhD

Committee Member

Dr. Therese Pigott PhD

Committee Member

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Chapter 1: Introduction

1.1 Introduction

Food insecurity is a significant public health issue.[1-3] In 2014, approximately 49 million Americans or 14 percent of the population were affected by food insecurity.[1] Food insecurity is a condition in which households lack access to adequate food because of limited income or other resources.[2] Food insecure individuals usually follow unhealthy eating behaviors such as consuming processed foods that are inexpensive and easily accessible. These cheap and easily accessible foods are associated with increased total energy intake, accumulation of visceral fat, and subsequent chronic disease outcomes.[3] Food insecurity is also associated with a number of adverse health outcomes. Among adults, food insecurity is associated with diabetes, hypertension, and hyperlipidemia.[4]

Data shows the prevalence rates of diabetes and food insecurity mirror each other. In 2005 the prevalence of food insecurity in Canada was 9.3% among individuals with diabetes, compared with 6.8% among those without diabetes. Additionally, each year, the earlier a person is diagnosed with diabetes, the likelihood of food insecurity increases by 4%.[5] In 1999-2004, the prevalence of diabetes in the U.S. was 10.2% in food-insecure households, compared with 7.4% in food-secure households.[6] Along with prevalence rates of diabetes and food insecurity mirroring each other, diabetes prevalence also rises with increasing severity of food insecurity (10% for mild food insecurity vs. 16.1% for severe).[6,7]

1.2 Study Purpose

Significant evidence supports a relationship between food insecurity, depression, and diabetes.[8] Food insecurity can induce feelings of worry and distress, and these feelings of uncertainty may contribute to diabetes-related distress, which is estimated to affect 33% of adults with diabetes.[9] Chronic emotional stress is an established risk factor for the development of depression.[14] Food insecure patients with diabetes report lower overall health status, lower satisfaction with life, and a higher prevalence of depression, diabetes distress, and self-perceived stress.[5,8,11,12,13]

Many studies have shown a positive association between depression and diabetes and a positive association between food insecurity and diabetes.[12,15] The relationship between food insecurity and depression is often examined within diabetes or low-income populations.[16] In many of the above studies, only a little attention has been paid to the direct effect of food insecurity and depression on the risk for diabetes. Hence, this study aims to understand the direct and indirect pathways through which food insecurity impacts diabetes and the mediating effects of depression.

1.3 Research Questions

This study is designed to answer the following questions:

1. What is the direct effect of food insecurity on diabetes?
2. What are the indirect pathways of food insecurity on diabetes through the mediating effect of depression?

Chapter 2: Literature Review

2.1 Diabetes

Diabetes affects an estimated 34.2 million Americans or 10.5% of the population, and is the 7th leading cause of death in the U.S. Approximately 1.5 million Americans are diagnosed with diabetes every year.[25]

There are many forms of diabetes; the three common types of diabetes are type 2 diabetes, type 1 diabetes, and gestational diabetes. High caloric intake is a major forerunner of type 2 diabetes and enhances insulin secretion but attenuates its metabolic actions in the liver, skeletal muscle, and adipose tissue and is mostly developed in adulthood.[45,47] Type 1 diabetes results from immune-mediated loss of pancreatic beta cells leading to insulin deficiency. It is the most common form of diabetes in children.[46,47] The third type of diabetes is gestational diabetes which is defined as any glucose intolerance with onset or first recognition during pregnancy. Underlying maternal defects characterize gestational diabetes in the β-cell response to insulin during pregnancy. Diabetes is dangerous because it affects the bodies' inability to process insulin. Insulin regulates blood sugar levels. After food is eaten, carbohydrates break down into glucose, which is the body's primary source of energy. Glucose then enters the bloodstream.

Persons with diabetes are 1.8 times more likely to die from all-cause compared to persons without diabetes. Persons with diabetes are also at a much greater risk of heart attack (1.8 times) than those without diabetes.[25] Diabetes is the leading cause of kidney failure accounting for 44% of new cases and leads to lower limb amputation and adult-onset blindness.[28] Diabetes can lead to extreme financial burden, with the cost of insulin consuming

half a family's average disposable income, making access to regular diabetes medication out of reach for many patients.[26] Proper management of diabetes includes standard treatment, maintaining a healthy lifestyle, blood glucose monitoring and continuous diabetes education. Maintaining healthy lifestyles such as losing weight, being physically active, and having a healthy diet is a sure way for diabetes prevention.[31] For this study, all types of diabetes diagnoses will be considered. Considering the final measure of consuming a healthy diet as an effective tertiary prevention method, coupled with the increasing number of individuals and families who face food insecurity, it is important to explore the relationship an insecure food diet has on diabetes.

2.2 Depression

Depression is two to three times higher in people with diabetes compared to those without diabetes.[29] As defined by the American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders (DSM-5), diabetes is a mood disorder that reunites several symptoms that alter an individual's functionality.[29] In 2017, 17.3 million American adults (approximately 7.1% of all adults) experienced significant depressive episodes.[30] Depression is a common and severe disease and the fourth cause of disability-adjusted life years in developed countries.[29] Depression disturbs emotions, cognition, and behaviors. Depression could be described as a first episode, a recurrent or chronic episode or could be mild, moderate, or severe, with or without psychotic features.[33]

Several studies show food insecurity is significantly associated with depressive symptoms in people with diabetes.[5,6,7,8,13,14] The close ties between food insecurity, depression, and diabetes leaves room to question the pathways that stem from the food insecurity and

connect to diabetes. The results from several studies highlight the need to determine the economic issues in conjunction with psychosocial issues related to comprehensive diabetes care.[32]

2.3 Food Insecurity

Food insecurity is defined as a lack of consistent access to enough food for an active, healthy life.[54] While hunger and food insecurity are related, they have an acute definition. Hunger refers to a physical feeling of discomfort, while food insecurity refers to a lack of available resources to access healthy foods. Food insecurity is a complex problem; not all individuals who live below the poverty experience food insecurity, and people living above the poverty experience food insecurity.

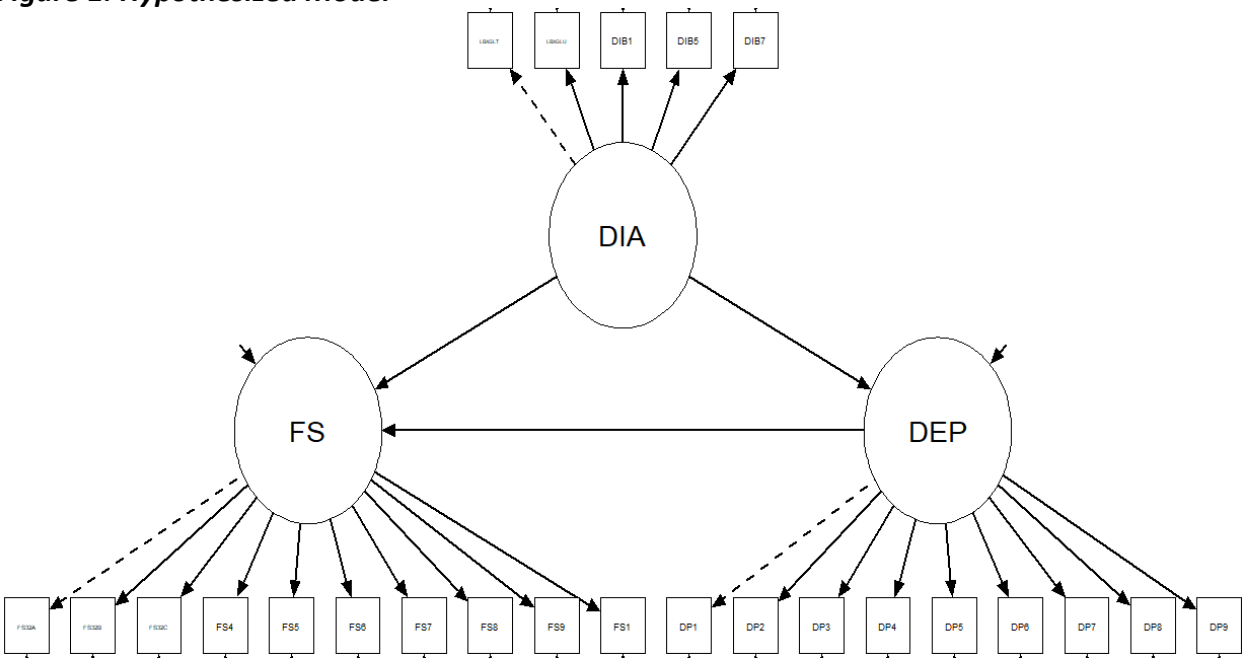
Food insecurity has been identified as a potentially modifiable risk factor associated with the development of type 2 diabetes and anxiety and depression.[30] Food insecurity refers to the lack of a dependable means of obtaining safe, sufficient, and nutritious food[34]. Food insecurity can induce feelings of worry and distress, particularly for individuals with diabetes, resulting from feeling powerless over their nutrition and self-management of their diabetes[7]. Interestingly enough, though food insecurity stems from limited financial resources, food insecurity is associated with overeating and excess weight. For single-parent households and Black and Hispanic households, food insecurity rates are substantially higher than those of whites.[30] Food insecurity increased from 10.5 percent in 2000 to 12 percent in 2004, to 14.6 in 2008. Food insecurity is significantly associated with self-care behaviors, including less adherence to a general diet, less physical activity, a greater occurrence of medication non-adherence, and calorie restriction.[6] Food insecurity is also associated with poor glycemic

control.[2] The rise in food insecurity rates, along with the knowledge of the influence food insecurity has on the occurrence of depression, exploring the added connection between diabetes is not too far of a reach.

2.4 Food Insecurity, Diabetes, & Depression

Food insecurity includes indulging in low-food quality, highly processed foods, and less consumption of healthier foods such as whole grains, fresh fruits and vegetables, and lean proteins.[38] In a study by J. Silverman et al. (2015), examining differences in sociodemographic and health characteristics between individuals with and without food insecurity, the prevalence of depression was significantly higher in the group with food insecurity. While several studies have shown that food insecurity is associated with diabetes and depression, most studies are limited to evaluating the relations using the logistic regression models. Few studies have used structural equation modeling to analyze how food insecurity and depression directly affect diabetes.[39,40,41] Research has shown that depression is linked to less optimal diabetes control, causing a less optimal glycemic outcome.[43] However, only a few studies have been done to test the direct relationship between food insecurity and diabetes using nationally representative data. A hypothesized model was created linking food insecurity, depression, and diabetes (Figure 1) using pre-specified theoretical assumption.

Figure 1: Hypothesized Model



Chapter 3 Research Design and Method

3.1 Study Design

The 2005–2006 data from the United States National Health and Nutritional Examination Surveys (NHANES) was used in this study. These surveys are based on cross-sectional sampling designs that collect health-related information from noninstitutionalized American adults. NHANES participants were interviewed in their homes and subsequently received physical and laboratory examinations in mobile examination centers. A detailed description of the NHANES methodologies is available at the National Center for Health Statistics (NCHS) website. The surveys were based on a stratified, multistage probability sampling technique. The stages of sample selection were as follows: (i) Primary Sampling Units were counties or small groups of contiguous counties; (ii) segments within Primary Sampling Units (a block or group of blocks containing a cluster of households); (iii) households within

segments; and (iv) one or more participants within households.[18] The institutional review board of NCHS approved the protocol for the NHANES. For this study, the total size of adults from the 2005-2006 assessments was n=2174. This study's analytic sample was limited to adults aged ≥20 and took either the Two Hour Glucose or Fasting Glucose test.

3.2 Measures

Food Insecurity: In NHANES, food Insecurity was assessed by self-report using a questionnaire based on the U.S. Food Security Survey Module developed by the U.S. Department of Agriculture.[18] This scale consists of 18 items, 10 of which refer to adults in the household and eight refer to children. Because the sample size was limited to adults, only the relevant ten items were used. In this study, each item was recoded in an ordinal manner (1- never true, 2- sometimes true, and 3- often true), and a range of experiences was assessed in the past 12 months, including; scarcity of food in the household, worry due to food running out, affordability of eating nutritiously balanced meals, hunger, and reduced food intake.[17,18] These ten items (Table 1) were treated as manifest variables used to observe food insecurity in our structural equation model.

Table 1 Adult Food Security Screener Questionnaire

1	H.H. worried run out of food
2	H.H. Food didn't last
3	H.H. Couldn't afford balanced meals
4	H.H. Adults cut size or skip meals
5	H.H. How often adults cut size/skip meals
6	H.H. Eat less than should
7	H.H. hungry, but didn't eat
8	H.H. Lost weight, no money for food
9	H.H. Adults not eat whole day
10	H.H. How often adults not eat for day

Depression: In NHANES, depressive symptoms were measured using the Patient Health Questionnaire (PHQ), a version of the Prime-MD diagnostic instrument.[19] These symptoms are self-reported based on nine PHQ-9 signs and symptoms of depression, referred to as the Depression Screener Questionnaire (DPQ) in NHNAES. Previous studies have shown that the unidimensional factor model of the PHQ-9 can be used to assess more detail of depression.[55] In this study, the nine symptom questions were recoded to "1" (not at all), "2" (nearly every day), "3" (more than half the days) and "4" (several days). These nine questions were used as manifest variables for the latent variable depression.

Table 2 Depression Screener Questionnaire

1	Little interest in doing things
2	Feeling down, depressed, or hopeless
3	Trouble sleeping or sleeping too much
4	Feeling tired or having little energy
5	Poor appetite or overeating
6	Feeling bad about yourself
7	Trouble concentrating on things
8	Moving or speaking slowly or too fast
9	Thought you would be better off dead

Diabetes: In this study, diabetes status was assessed using (1) self-reported diabetes or (2) reported taking diabetic medication or (3) fasting plasma glucose (FPG) based on American Diabetes Association (ADA) guidelines (FPG ≥ 126 mg/dl) and (4) oral glucose (≥200 mg/dL) or (5) history of a previous diabetes diagnosis. All five questions were coded as dichotomous "1" - no diabetes and "2"– diabetes. To fully capture those who had diabetes and those who were not these five questions were used to observe diabetes as a latent variable.

Table 3 Diabetes Screener

1	LBXGLT -Two Hour Glucose (OGTT) (mg/dL)
2	LBXGLU – Fasting Glucose (mg/dL)
3	Doctor told you have diabetes

4	Taking Insulin now
5	Taking diabetic pills to lower sugar

Covariates: Demographic covariates included in this study were: age, gender, race/ethnicity, marital status, and household income.

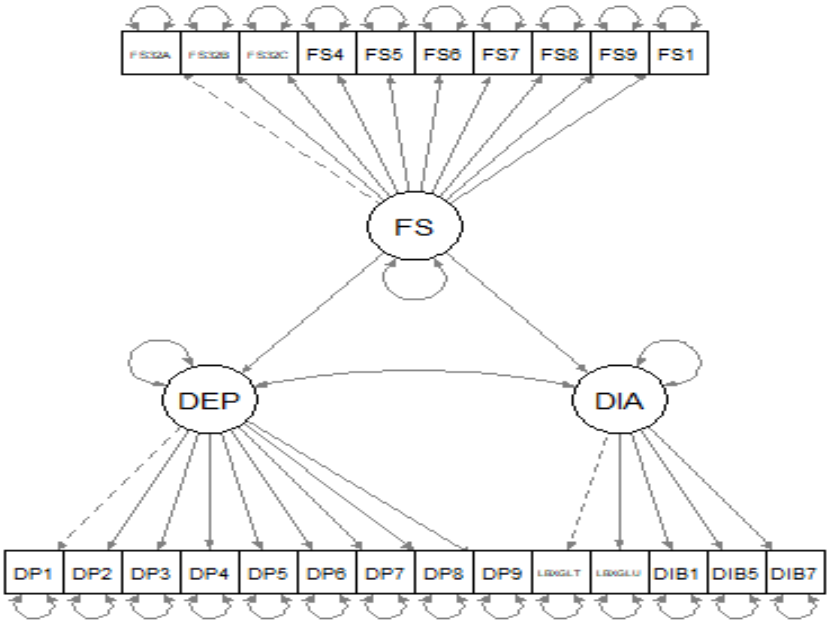
3.3 Statistical Analysis

First preliminary analyses were conducted to determine the pattern of missing responses using Statistics Package for Social Science (SPSS) version 25.0. The SPSS Missing Values Analysis (MVA) option supports Little's MCAR test, a chi-square test for missing completely at random (MCAR). Little's test is useful for testing the assumption of missing completely at random for multivariate, partially observed quantitative data.[52] After evaluating the missing response, the multiple imputation (MI) method was used to populate responses. Then frequencies and means were run to summarize demographics and exogenous variables of depression, food insecurity, and diabetes.

In this study, the latent variable diabetes was tested using exploratory factor analysis (EFA) to determine the extent to which shared variance exists between variables within the item pool developing measure. This is a unique step, food insecurity and depression latent models were developed using previous models that had been explored using factor analysis in previous studies. However, the diabetes latent model was developed to ensure diabetes could be fully captured and produce a parsimonious model for analysis. Eigen values were used to test for total factors. To test where the model fitted observed data the X^2 test was used, where nonsignificant p values ($p > 0.05$) represent a good fit.

Then confirmatory factor analysis (CFA) was used to verify the factor structure observed variables (Figure 2). After that, the direct and indirect links between diabetes, depression, and food insecurity were examined using structural equation modeling (SEM). SEM is a powerful analytical technique allowing testing of complex, theoretical models using clinical and environmental data. Briefly, in an SEM model, it is possible to depict multiple causal pathways between measured and latent factors and to estimate their relative effect towards one or more outcome variables. Moreover, it is possible to estimate if one or more factors may act as mediators of such assumed causal associations/chains. Also, SEM allows researchers to assess if other variables that are not implicated in a model (moderators) can influence the magnitude or direction of the associations between each factor in the model. Although SEM analysis of cross-sectional data cannot directly establish causation, it provides important cues to a causal relationship.[51] Direct, indirect, and total effects were estimated using the maximum likelihood estimation procedure and standardized coefficients. The WLSMV option in R was used, allowing full-information maximum likelihood and retaining variables rather than using listwise deletion. To test for adequate fit for all models (EFA, CFA, SEM), the Root Means Square Error of Approximation (RMSEA), the (Standardized) Root Mean Square Residual (RSMR), the Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were implored. An RMSEA value less than 0.05, an RMSR less than 0.08, with CFI and TLI values more than .9 indicates an acceptable model fit. Analysis were performed using R version 3.3.0 with Rstudio version 1.2.5019 and the packages lavaan (version 0.6-7), psych (version 2.0.8), GPArotation (version 2), and semPlot (version 1.1.2).

Figure 2: Confirmatory Factor Analysis



Chapter 4 Results

Missing values

Little's Missing Completely at Random (MCAR) test was performed to determine the missing data pattern using the expectation-maximization (E.M.) technique. With Chi-Square = 97.022; DF = 4, Sig. < 0.01; the null hypothesis for Little's MCAR test was rejected. Consequently, it was concluded that missing at random (MAR) or missing not at random (MNAR) was evident in the dataset, and the multiple imputation (MI) method of handling missing data was used in this study. This procedure analyzes patterns of missing data geared toward eventual multiple imputations of missing values. Numerous versions of the dataset are produced, each containing its own set of imputed values. Maximum likelihood was during analysis.

Table 4: Little Missing Completely as Random

Chi-Square	DF	Sig
97.022	4	.000

4.1 Descriptive Statistics

The final cross sectional analytic sample included responses from 1967 individuals. After using multiple imputation some variables still had missing data, all records that had missing data were dropped. Demographics of the sample were measured using previously validated questions from the National Health and Nutrition Examination Survey, and include gender (Men 48.5%; Women 51.5%), age (48.3 ± 18.9), race/ethnicity (Non-Hispanic White 50.8%; Non-Hispanic Black 22.4%; Mexican American 19.2%; Mixed Race 7.7%), marital status (Married 49.5%; Never Married 32.2%; Separated/Divorced/Widow 18.3%), years of education(Less than 9^{th} Grade 10.6%; 9^{th}-11^{th} Grade 17.1%; High School Graduate 26.1%; Some College 28.5%; College Graduate 17.6%), and household income (<$10,000 5.9%; $10,000- $19,999 14.2%; $20,000- $34,999 22.9%; $35,000- $54,999 19.1%; $55,000 or more 34.8%). (Table 5)

Table 5 Demographic Data

	Mean ± Standard Deviation or %
Age	48.33 ± 18.9
Race	
Non-Hispanic White	50.8
Non-Hispanic Black	22.4
Mexican American	19.2
Mixed Race	7.7
Gender	
Men	48.5
Women	51.5
Education	
Less Than 9th Grade	11.4
9th-11th Grade	15.5
High School Graduate	24.1
Some College	29.3
College Graduate	19.5
Marital Status	
Married	55
Never Married	20.4

Separated/Divorced/Widow	24.6
Annual Household Income	
<$10,000	5.9
$10,000- $19,999	14.2
$20,000- $34,999	22.9
$35,000- $54,999	19.1
$55,000 or more	34.8

Table 6 Descriptive Statistics for Measures Included in Structural Equation Model

	Mean ±
Food Security	
HH Worried run out of food (FS32A)	1.26 ± .556
HH Food didn't last (FS032B)	1.20 ± .486
HH Couldn't afford balanced meals (FS32C)	1.18 ± .471
HH Adults cut size or skip meals (FS41)	1.06 ± .232
HH How often adults cut size/skip meals (FS52)	1.11 ± .490
HH Eat less than should (FS61)	1.06 ± .244
HH Hungry, but didn't eat (FS71)	1.04 ± .200
HH Lost weight, no money for food (FS81)	1.02 ± .133
HH Adults not eat while day (FS92)	1.02 ± .136
HH How often adults not eat for day (FS102)	1.04 ± .300
Depression	
Little interest in doing things (DP1)	1.27 ± .640
Feeling down, depressed, or hopeless (DP2)	1.29 ± .646
Trouble sleeping or sleeping too much (DP3)	1.53 ± .871
Feeling tired or having little energy (DP4)	1.73 ± .882
Poor appetite or overeating (DP5)	1.30 ± .694
Feeling bad about yourself (DP6)	1.20 ± .551
Trouble concentrating on things (DP7)	1.21 ± .581
Moving or speaking slowly or too fast (DP8)	1.12 ± .423
Thought you would be better off dead (DP9)	1.05 ± .282
Diabetes	
Two Hour Glucose (LBXGLT)	1.11 ± .317
Plasma fasting Glucose & insulin (LBXGLU)	1.10 ± .306
Doctor told you have diabetes (DIB1)	1.12 ± .325
Taking insulin now (DIB5)	1.03 ± .175
Take diabetic pills to lower blood sugar (DIB7)	1.08 ± .268

Table 7: Pairwise Correlation of all the variables included in Structural Equation Model

	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	FS32A	FS32B	FS32C	FS41	FS52	FS61	FS71	FS81	FS92	FS102	LBXGLT	LBXGLU	DIB1	DIB5
DP1	1																						
DP2	0.4750152	1																					
DP3	0.2949627	0.3098287	1																				
DP4	0.3541918	0.3436354	0.4139924	1																			
DP5	0.3425651	0.3144909	0.3071987	0.3358581	1																		
DP6	0.3843545	0.5484848	0.2748528	0.2850474	0.3313744	1																	
DP7	0.3464699	0.3923688	0.2863957	0.3135979	0.2970153	0.3671852	1																
DP8	0.2702261	0.2969903	0.2337659	0.2263958	0.2656297	0.3162971	0.3255768	1															
DP9	0.2712147	0.3273252	0.208334	0.1688691	0.2005393	0.3687017	0.2844918	0.3035928	1														
FS32A	0.1300507	0.1722438	0.1083534	0.0914298	0.1660645	0.1597197	0.1149965	0.1251116	0.0955263	1													
FS32B	0.1128896	0.1668973	0.1087101	0.0863177	0.1349061	0.161968	0.0956275	0.1212525	0.0805581	0.8190494	1												
FS32C	0.1277974	0.1916863	0.1000735	0.0970942	0.1238269	0.1883491	0.126814	0.1143421	0.0841994	0.6364062	0.6929015	1											
FS41	0.141558	0.1736621	0.1228135	0.1216884	0.1551466	0.1804609	0.1694577	0.151895	0.081497	0.4710199	0.5139966	0.4538882	1										
FS52	0.1405191	0.174057	0.1225072	0.1207389	0.1538646	0.179698	0.1682011	0.1513721	0.0823269	0.4702364	0.5140117	0.4547017	0.9903586	1									
FS61	0.1462837	0.1776529	0.1142125	0.1240385	0.1502593	0.1873232	0.1651261	0.1569482	0.093862	0.5131093	0.5625413	0.4881128	0.7904649	0.7851402	1								
FS71	0.1047066	0.1227792	0.0891924	0.1085033	0.1313414	0.1520308	0.0905568	0.1139973	0.1091034	0.3889937	0.4417861	0.4275668	0.5976983	0.596825	0.642161	1							
FS81	0.1163737	0.1336872	0.1099887	0.1180209	0.1014036	0.1299498	0.1416269	0.0960599	0.1100249	0.2618551	0.3001862	0.303809	0.4956638	0.4947961	0.5098085	0.49648	1						
FS92	0.1031471	0.0947289	0.0846234	0.0955847	0.0885742	0.1105482	0.1194898	0.089537	0.1322737	0.2687814	0.3087832	0.2864151	0.4081447	0.4073911	0.4424891	0.5036021	0.4836395	1					
FS102	0.1024206	0.0946222	0.0845759	0.0951834	0.0879617	0.1101925	0.1189072	0.0893862	0.1320094	0.2685368	0.3086014	0.2866369	0.4067176	0.4073675	0.4408785	0.5017817	0.4833564	0.9969651	1				
LBXGLT	0.0038207	-0.0064037	0.0165081	0.0342218	0.0169745	0.0083968	-0.0014599	-0.0102365	0.0260646	0.0136292	0.0081073	-0.0124723	0.0014558	0.001307	0.0041564	-0.0138194	-0.0271658	-0.0262142	-0.0261807	1			
LBXGLU	0.0306349	0.0354215	0.0392513	0.0634132	0.0185772	0.0381388	0.0003505	0.0141349	0.0668317	0.0147604	0.0064168	0.006404	0.0004628	0.0005972	0.0106608	-0.0138087	-0.0245624	-0.0236268	-0.0236026	0.6937319	1		
DIB1	0.0632443	0.0302013	0.0714051	0.0641161	0.0155831	0.0487895	0.029238	0.0384918	0.0637987	0.0178948	0.0110834	0.0342657	0.0297948	0.031046	0.0177462	0.0089213	0.0153285	0.0055583	0.0054515	0.4460392	0.6147519	1	
DIB5	0.0431802	0.016452	0.0650766	0.0733759	0.0459545	0.026808	0.0331042	0.0322534	0.0109927	0.0468378	0.047909	0.0725552	0.0512929	0.0519188	0.0547541	0.0458743	0.0145095	0.0153699	0.0155474	0.2443993	0.3385795	0.4940749	1
DIB7	0.0734235	0.0407908	0.023375	0.055572	-0.0035363	0.0360576	0.0282704	0.0292205	0.0671278	0.0114136	-0.0024296	0.0306458	0.0186991	0.0199606	0.0018234	-0.0125469	0.0003458	-0.0261523	-0.0261003	0.3739844	0.5458735	0.7657547	0.2628606

4.2 Factor Analysis

Eigenvalues were used along with scree plot to determine number of factors for analysis of diabetes, any values over 1 and any values over .7 were recorded (table 8). The model was first tested for one factor, ignoring the scree plot and the total amount of factors calculated with eigenvalues, 2 (figure 3). The test for fit for one factor includes the Root Mean Square Residual (RMSR) = .12, Root Mean Square Error of Approximation (RMSEA) = .254, Tucker Lewis Index = .61, and Comparative Fit Index (CFI)= .81 (Table). The model fit for two factors showed a better fit. All variables showed a positive correlation. The fit analysis for two factor showed Root Mean Square Residual (RMSR) = .01, Root Mean Square Error of Approximation (RMSEA) = .07, Tucker Lewis Index = .97, and Comparative fir index (CFI)= .99 (Table 8). The fit values for the 2-factor model showed that the model was appropriate, which provided confidence in moving on to CFA.

Table 8: EigenValues

2.1680034806	0.3526420998	-0.0002329453	-0.0586393995	-0.3334651086

Figure 3: Parallel Analysis Scree Plots

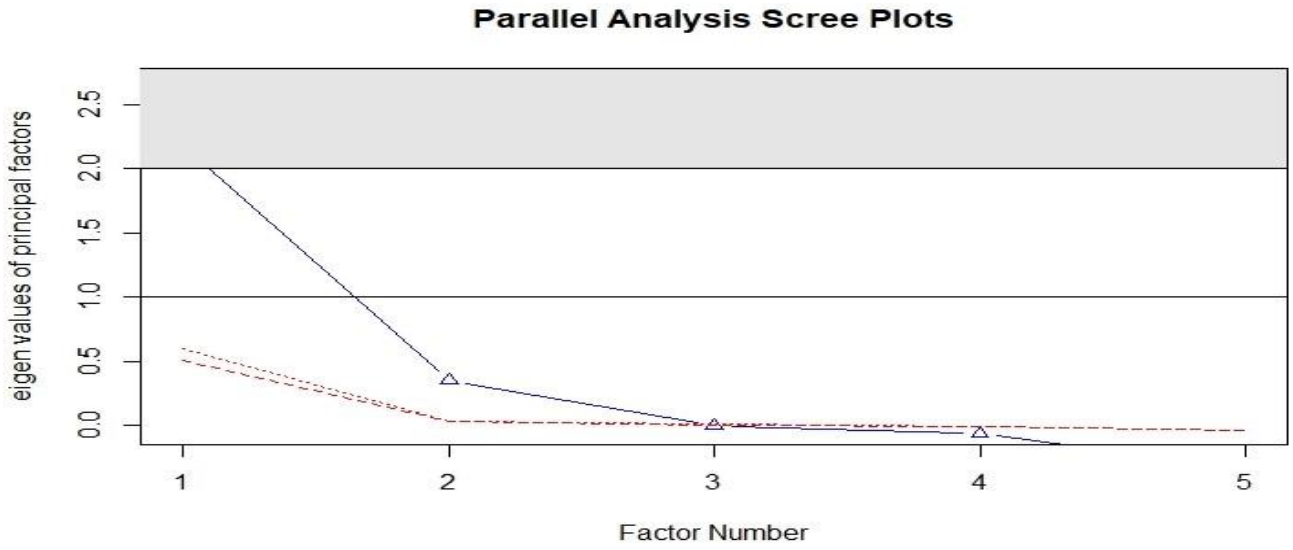


Table 9: Fit Values

	1 Factor	2 Factor
RMSR	.12	.01
RMSEA	.254	.07
TLI	.61	.97
CFI	.81	.99

Figure 4: One factor analysis

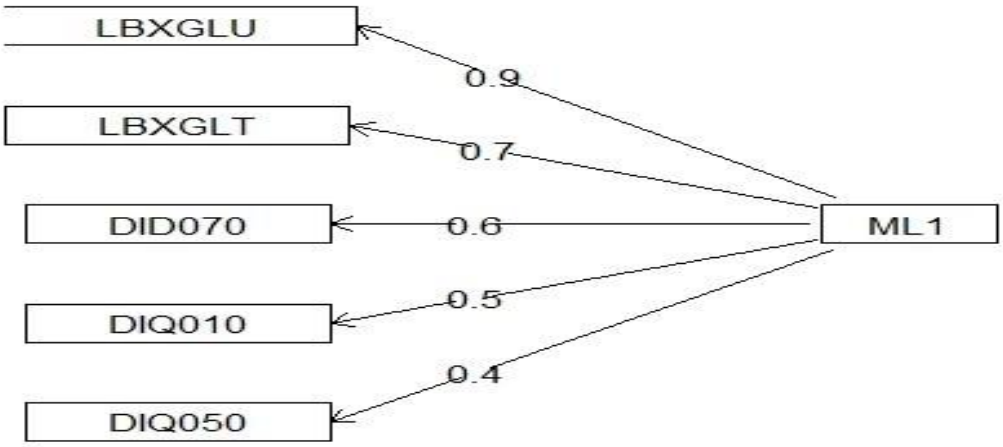
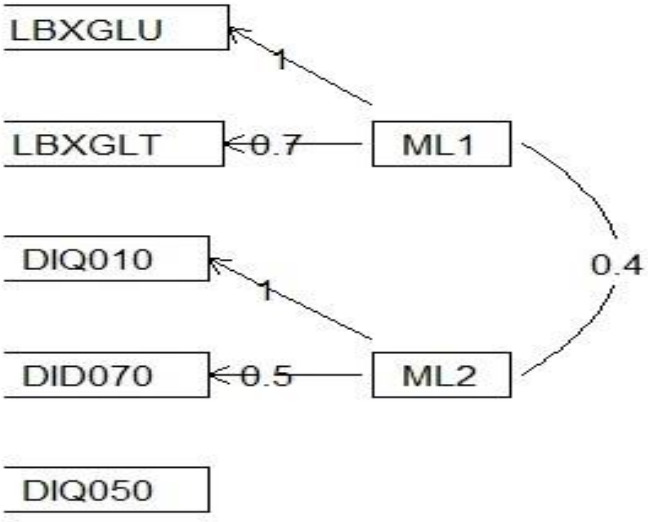


Figure 5: Two-factor analysis

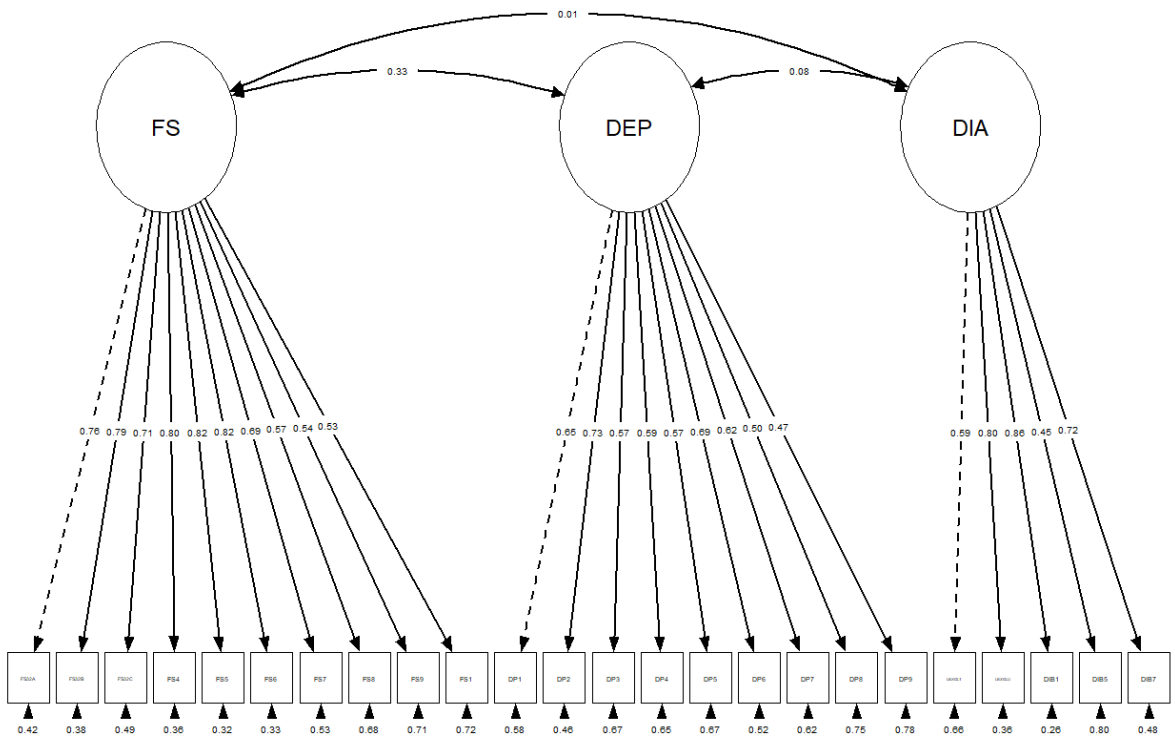


4.3 CFA

Figure 6 presents the CFA model of food insecurity, depression, and diabetes. There were no Heywood Cases. All variances were positive. Heywood cases may indicate a sample that is too

small to adequately estimate the parameters, data that does not have a normal distribution or contain outliers, a misspecified model that is not appropriate for the data, or a parameter whose true value is so close to a boundary. The R- square values were all below 1 and predicated latent variables. The standard errors were small and roughly the same. The model showed great fit, with Root Mean Square Residual (RMSR) = .063, Root Mean Square Error of Approximation (RMSEA) = .01, Tucker Lewis Index = .98, and Comparative fit index (CFI)= .99 (Table).

Figure 6: CFA of Food insecurity, Depression & Diabetes



4.4 SEM

Figure 7 shows the structural equation model. The standardized regression coefficient of depression on diabetes was statistically significant ($\beta = 0.09$, $p = 0.009$). The standardized

regression coefficient of food insecurity on depression was significant (β = 0.329 , p > 0.01). The standardized regression coefficient of food insecurity on diabetes was not statistically significant (β= -.018, p= .497). Thus, depression was directly related to diabetes and food insecurity, while food insecurity did not influence diabetes. The structural model was saturated; in the measurement model were 24 variance and covariance parameters of the latent variables, so the latent variance-covariance matrix was complete and unrestricted. There were also 24 parameters in the structural model. The parameters of the structural model are estimable and thus can check postulated effects, but the overall model is *just identified* and thus does not contribute to the model fit of the overall model. In other words, the structural model cannot check the fits with data well. Only the fit of the measurement model can be tested. The standardized effects of food security on diabetes, diabetes as a standalone factor, and the standardized effects of depression on diabetes can be seen in the table below. (table 10).

Figure 7

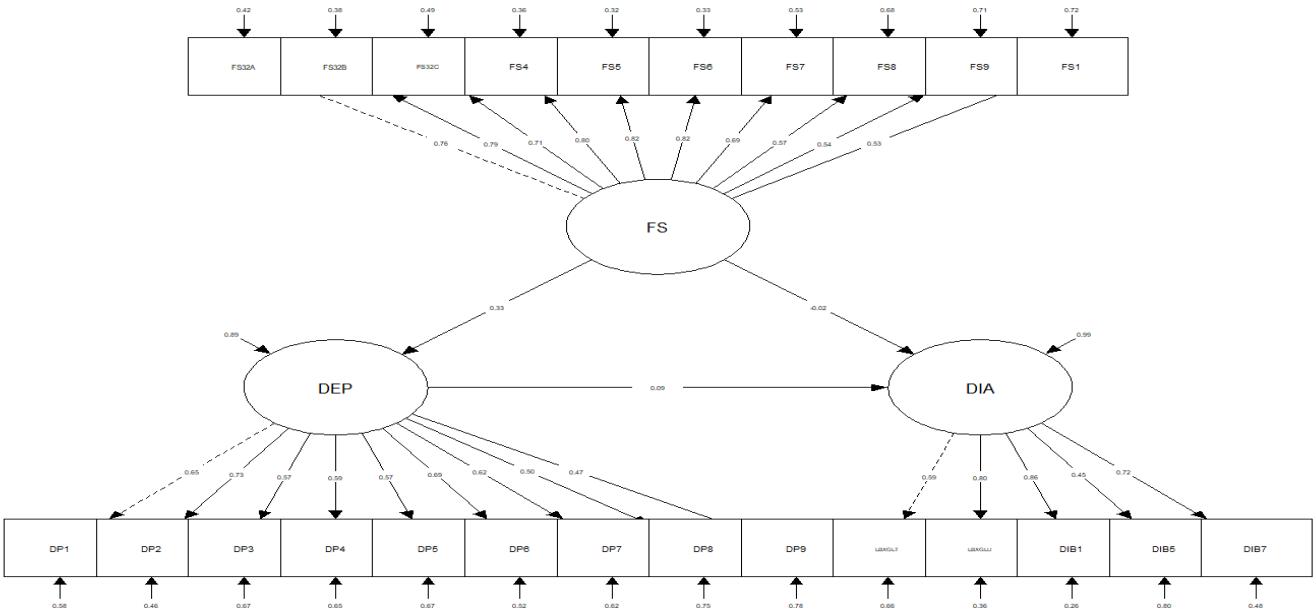


Table 10: Standardized Effects

	Direct effects	indirect effects	Total effects
Diabetes			
Depression	0.09		0.09
Food insecurity	-0.018	0.029	0.01161
Depression			
Food insecurity	0.329	-0.00592	0.323
Diabetes			

Chapter 5 Discussion

5.1 Overall findings

Although food insecurity in the U.S. has declined since the last 2000s and early 2010s, an estimated 15.6 million households continue to have difficulty affording enough food to support regular, balanced meals.[35] The current study demonstrated that depression is directly significantly related to diabetes; while food insecurity does not have a positive direct effect on diabetes, it does influence depression. This study's primary reason was to address the lack of studies that evaluated the relationship between food insecurity, diabetes, and depression with a national scope. A majority of the studies analyzed the relationship in diabetic populations.[7,13,16,29,]

This study's primary finding is that food insecurity has a negative direct effect on diabetes and that depression is directly significantly related to diabetes. In light of findings, it was interesting to see that food security did positively influence depression. Depression was found to have a meditating effect when evaluating the standardized indirect effect of food security on diabetes.

Other studies support food security relating to diabetes; a large-scale longitudinal survey conducted in the U.S. revealed that diabetes risk was approximately 50% higher among adults in food-insecure households than in food-secure households[6]. Even while controlling for income, employment status, physical measures, and lifestyle factors, food-insecure adults are two to three times more likely to have diabetes than food-secure adults.[7,36] My findings of depression being directly significantly related to diabetes are supported by Seligman et al. (2011), who found that difficulty following a diet and emotional distress met formal criteria as a mediator of the relationship.[12] Currently, most interventions in food-insecure populations have focused on improving the nutritional quality of food available.[37] Programs such as Supplemental Nutrition Assistance Program (SNAP) can increase food availability though some individuals may not be eligible.[11] Not many studies examine the relationship between food insecurity, depression, and diabetes using SEM. This present study suggests that a focus on the diabetic population alone will not help understand the connection. This study recommends additional pathways to be targeted with future interventions.

5.2 Strength and Weaknesses

While a key strength to this thesis is the nationally representative nature of the NHANES sample, a consequence of this design is that this sample included only limited numbers of some racial/ethnic minorities (e.g., American Indians, Asians, Native Hawaiians), which impacted my ability to generalize the results to these specific groups. Not using weights in the analysis is one of the limitations of this study. Established best practice suggests that weights be used in the analysis.[20] When evaluating missing data, multiple imputations were used; while justified by the Little's Missing Completely at Random test, the p values were not pooled to

ensure the correct variables were used for my model. This was not done due to Rstudio limitations, and the package psfmi could not be employed. The data was cross-sectional, thus finding cannot speak to causality. SEM is appropriate for non-experimental designs. Its interpretation is linked to the method of data collection.[21] My data was limited by the sensitivity of a self-reported diagnosis of diabetes for some NHANES participants. When performing EFA and CFA, I chose to keep all variables. However, all exogenous variables were significant, and the model was no over-fitted, not all variables were as strongly correlated with latent variable. While adding elevated fasting plasma glucose and self-reported consumption of diabetic medicine helped address this problem. Only a subset of my sample had fasting glucose measured or indicated a diabetic medication was taken. This bias conservatively influences my results.

5.3 Public Health Implications

This study examined the pathways in which food insecurity may lead to diabetes. This study will add to the literature that suggests food insecurity affects diabetes. These findings emphasize food insecurity as a pressing public health issue with the potential to impart physical and psychiatric harm among Americans. This study helps provide valuable insights to public health professionals developing upstream health promotion approaches to address food insecurity before it advances into diabetes disease.

5.4 Conclusion

In summary, food insecurity is found to have a significant relation to depression and a negative effect on diabetes. Depression does significantly impact the relationship between food insecurity and diabetes. Future studies should examine other possible pathways between food insecurity, such as diet, nutrition education, and neighborhood environment.

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