Undiagnosed Prediabetes among Food Insecure Adults

Meng Ding, MS; Norbert L.W. Wilson, PhD; Kimberly B. Garza, PharmD, MBA, PhD; Claire A. Zizza, PhD, RD

***Objectives*: To identify sub-populations at risk for diabetes based on having prediabetes. Although food insecurity has been linked to diabetes, to our knowledge, no studies have examined whether food insecure individuals are more likely than fully food secure individuals to have undiagnosed prediabetes. *Methods*: This study was based on a cross-sectional analysis of 6577 adults in the 2005-08 National Health and Nutrition Examination Survey. USDA's Food Security Survey Module, self-reported prediabetes status and clinical measures were examined. *Results*: Whereas men who were food insecure were more likely than fully food secure men to have undiagnosed prediabetes, no association was observed among women. *Conclusion*: Prediabetes screening appears warranted for food insecure men.**

***Key words*: poverty, diabetes prevention, healthcare, hunger, sex difference**

***Am J Health Behav.* 2014;38(2):225-233**

DOI: http://dx.doi.org/10.5993/AJHB.38.2.8

Despite spending more on medical care than any other nation, the United States lags behind other high income countries in overall life expectancy and the incidence of preventable disease and injuries.[1] Non-communicable, preventable chronic conditions are contributing remarkable amounts to national spending on health.[2] Chronic medical conditions that have been linked to modifiable risk factors, such as dietary behaviors, smoking, weight, and physical activity, represent 6 of the 10 costliest medical conditions in the United States with a combined medical care expenditure of $338 billion in 2008.[3]

According to an Institute of Medicine (IOM) panel, an underlying cause of the imbalance between spending and outcomes is the nation's inadequate investment in strategies that promote health and prevent disease population-wide.[1] A growing body of evidence indicates that effective prevention strategies can substantially improve health with little additional lifetime medical spending. One study modeled various scenarios to estimate the potential benefits of effective interventions to reduce risk factors of adults in mid-life.[4] Results from these simulations showed those exposed to successful prevention interventions for obesity, hypertension, and diabetes experienced reduced lifetime medical spending and lived longer. As the population ages, diabetes prevalence is predicted to rise, peaking at about 34% at the age of 79 years. In the predicted scenarios where interventions had success rates of 10%, 20%, or 50%, the predicted diabetes prevalence was lowered to about 30%, 25%, and 16%, respectively.[4]

Families make decisions regarding their use of healthcare services within the context of their household budgets. Food insecurity, defined as not having access at all times to enough food for an active, healthful life, has been shown to be an indicator of financial strain that is severe enough to affect a families' ability to meet other basic needs.[5-7] Families may choose to prioritize meeting their needs for food over those for healthcare, particularly preventive types of care. Although, food insecure (FI) individuals have been shown to have higher rates of diabetes compared to their food secure counterparts,[8-13] to our knowledge, no studies have examined whether FI individuals are more likely than food secure individuals to have undiagnosed prediabetes (a condition in which individuals do not meet diagnostic criteria for diabetes, yet have an increased risk for diabetes). Identifying sub-groups predisposed to developing diabetes but not aware of their prediabetes is necessary for targeting effective preventive measures. Having a diagnosis of prediabetes allows individuals to seek interventions that can prevent or delay the progression of prediabetes to type 2 diabetes.[14-17] Ac-

Meng Ding, Graduate Research Assistant and Claire A. Zizza, Associate Professor, Department of Nutrition, Dietetics, and Hospitality Management, Auburn University, AL. Norbert L.W. Wilson, Associate Professor, Department of Agricultural Economics and Rural Sociology, Auburn University, AL. Kimberly B. Garza, Assistant Professor, Department of Pharmacy Care Systems, Auburn University, AL.
Correspondence Dr Zizza; Zizzaca@auburn.edu

Table 1
Characteristics among Male and Female Participants by Food Security Status: NHANES 2005-2008[a]

Characteristics	Men (20-64years) (N = 3332)[b]			Women (20-64years) (N = 3245)[b]		
	FFS (N = 2452)	MFS (N = 366)	FI (N = 514)	FFS (N = 2334)	MFS (N = 407)	FI (N = 504)
	% (95% CI)					
Age (years)						
20–34	30.8 (27.9– 33.8)	45.9 (38.8– 53.1)	45.0 (40.1– 49.9)	28.7 (26.8– 30.5)	43.6 (37.2– 50.1)	36.6 (31.3– 42.0)
35–44	22.8 (20.5– 25.0)	26.8 (20.9– 32.7)	27.8 (23.2– 32.3)	24.8 (22.2– 27.4)	22.4 (17.1– 27.7)	28.1 (22.7– 33.5)
45–54	29.2 (26.8– 31.6)	17.9 (11.7– 24.1)	17.9 (14.1– 21.7)	27.0 (24.7– 29.4)	22.4 (17.2– 27.5)	24.2 (18.8– 29.3)
55–64	17.2 (14.9– 19.4)	9.4 (6.1– 12.7)	9.3 (6.3– 12.3)	19.5 (17.0– 21.9)	11.6 (8.3– 14.9)	11.1 (8.3– 14.0)
BMI (kg/m²)[c]						
≤24.9	26.3 (23.6– 28.9)	30.9 (25.7– 36.2)	36.6 (31.3– 41.9)	40.0 (36.5– 43.4)	24.1 (19.7– 28.5)	28.9 (22.7– 35.1)
25–29.9	39.4 (37.2– 41.6)	34.4 (27.5– 41.2)	36.2 (31.1– 41.8)	25.6 (23.4– 27.8)	27.4 (21.8– 33.1)	22.8 (18.6– 27.1)
≥30	34.3 (30.7– 37.9)	34.7 (27.5– 41.9)	27.0 (22.2– 31.8)	34.5 (31.8– 37.1)	48.5 (42.9– 54.1)	48.2 (41.8– 54.7)
Smoking status						
Non-smoker	49.5 (46.3– 52.6)	42.8 (35.8– 49.7)	35.5 (30.4– 40.6)	59.9 (57.0– 62.9)	52.0 (45.3– 58.7)	49.4 (41.7– 57.0)
Former smoker	24.3 (22.2– 26.4)	19.4 (12.9– 26.0)	15.2 (10.2– 20.2)	19.8 (18.0– 21.6)	17.2 (12.7– 21.7)	11.4 (7.8– 15.0)
Current smoker	26.3 (23.6– 28.9)	37.8 (32.1– 43.5)	49.3 (43.8– 54.8)	20.2 (17.6– 22.9)	30.8 (25.4– 36.2)	39.2 (32.1– 46.4)
Race/ethnicity						
Non-Hispanic White	74.6 (70.8– 78.3)	46.2 (33.5– 59.0)	46.9 (37.8– 56.0)	74.2 (70.0– 78.4)	42.7 (32.0– 53.4)	51.1 (41.8– 60.4)
Non-Hispanic Black	9.6 (7.4– 11.7)	14.3 (8.5– 20.1)	18.7 (13.8– 23.6)	10.7 (8.0– 13.5)	24.3 (15.8– 32.8)	20.4 (14.4– 26.4)
Mexican American	6.7 (5.2– 8.2)	23.7 (18.1– 29.4)	20.9 (14.8– 27.0)	5.3 (4.2– 6.5)	18.8 (12.4– 25.2)	14.2 (9.4– 19.0)
Other races[d]	9.2 (7.2– 11.1)	15.7 (4.6– 26.9)	13.6 (9.2– 17.9)	9.7 (7.4– 12.0)	14.2 (7.6– 20.7)	14.3 (8.5– 20.1)
Education						
≥High school	86.0 (83.1– 89.0)	64.6 (57.1– 72.0)	57.3 (50.8– 63.9)	88.6 (86.2– 90.9)	71.7 (65.8– 77.6)	70.0 (65.9– 74.0)
< High school	14.0 (11.0– 16.9)	35.5 (28.0– 42.9)	42.7 (36.1– 49.2)	11.5 (9.1– 13.8)	28.3 (22.4– 34.2)	30.0 (26.0– 34.0)
PIR (%)[e]						
>185	82.3 (79.9– 84.7)	40.9 (32.4– 49.5)	33.6 (26.8– 40.4)	80.6 (78.5– 82.7)	36.7 (29.6– 43.9)	26.0 (20.1– 31.8)
≤185	17.7 (15.3– 20.1)	59.1 (50.5– 67.6)	66.4 (59.6– 73.2)	19.4 (17.3– 21.5)	63.3 (56.1– 70.4)	74.0 (68.2– 79.9)

(continued on next page)

cordingly, the purpose of this study was to examine the relationship between food security status and undiagnosed prediabetes among adults in the US. The association between food security status and health and lifestyle behaviors has been shown to vary by sex.[8,18] For example, FI has been linked to obesity and overweight among adult women but not among men. Therefore, the possible effect modification of sex in the relationship between food security status and undiagnosed prediabetes was also examined. The data used for this study were from NHANES 2005-08 because this is the

Table 1 (continued)
Characteristics among Male and Female Participants by Food Security Status: NHANES 2005-2008[a]

Characteristics	Men (20-64years) (N = 3332)[b]			Women (20-64years) (N = 3245)[b]		
	FFS (N = 2452)	MFS (N = 366)	FI (N = 514)	FFS (N = 2334)	MFS (N = 407)	FI (N = 504)
	% (95% CI)					
Self-reported health condition						
Excellent to good	88.4 (85.9– 90.8)	75.4 (70.6– 80.2)	69.1 (64.6– 73.6)	87.3 (85.6– 89.0)	74.1 (69.7– 78.4)	63.3 (58.5– 68.1)
Fair to poor	11.6 (9.2– 14.1)	24.6 (19.8– 29.4)	30.9 (26.4– 35.4)	12.7 (11.0– 14.4)	25.9 (21.6– 30.3)	36.7 (31.9– 41.6)
Health insurance						
Covered	80.7 (78.2– 83.2)	49.4 (41.1– 57.8)	49.7 (43.6– 55.7)	86.2 (83.7– 88.6)	62.0 (56.0– 68.4)	63.8 (57.8– 69.9)
Not covered	19.3 (16.8– 21.8)	50.6 (42.2– 59.0)	50.3 (44.3– 56.4)	13.8 (11.4– 16.3)	38.0 (31.6– 44.4)	36.2 (30.1– 42.2)
Routine place for healthcare						
Doctor's office	63.8 (60.4– 67.2)	37.3 (28.0– 46.6)	36.7 (31.1– 42.4)	76.4 (73.1– 79.7)	54.3 (47.9– 60.6)	54.7 (48.0– 61.4)
Outpatient, clinic or health center	14.5 (12.8– 16.1)	16.0 (11.7– 20.3)	18.5 (14.3– 22.6)	13.8 (10.7– 16.9)	22.7 (16.7– 28.6)	23.5 (15.9– 31.0)
Hospital emergency room	2.2 (1.6– 2.9)	6.3 (3.6– 8.9)	8.0 (3.9– 12.2)	1.2 (0.6– 1.8)	4.0 (1.6– 6.3)	3.5 (1.4– 5.6)
No routine place	19.6 (16.9– 22.2)	40.4 (32.4– 48.4)	36.8 (31.6– 42.0)	8.6 (7.4– 9.9)	19.1 (14.0– 24.2)	18.3 (13.8– 22.8)
Receiving healthcare over past year (times)						
≥ 4	26.9 (24.3– 29.5)	21.4 (15.6– 27.2)	25.6 (21.2– 30.0)	39.4 (37.1– 41.7)	40.0 (32.9– 47.1)	41.2 (36.9– 45.6)
1-3	48.0 (45.0– 51.0)	46.0 (39.2– 52.8)	38.7 (33.7– 43.6)	51.0 (48.8– 53.2)	42.1 (35.7– 48.5)	44.9 (39.2– 50.6)
None	25.1 (22.9– 27.2)	32.6 (26.0– 39.2)	35.7 (30.2– 41.1)	9.6 (8.1– 11.1)	17.9 (13.4– 22.5)	13.9 (10.3– 17.5)

Note.

FFS = fully food secure
FI = food insecure
MFS = marginally food secure
NHANES = National Health and Nutritional Examination Survey
PIR = poverty income ratio

a Data were estimated % (95% CI). All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics. Column percentages do not always add up to 100% because of rounding. Food security status was significantly different for every characteristic among both men and women by χ^2-tests of independence. Significant p value < .05.
b Includes participants with complete data for age, BMI, sex, smoking status, race/ethnicity, education levels, poverty income ratio, self-reported health condition, health insurance status, routine place for healthcare, times receiving healthcare over past year, and self-reported diabetes and prediabetes status, as well as clinical tests for diabetes and prediabetes.
c Adults' BMI cut-off points were provided by National Institutes of Health.[35]
d Other race includes other Hispanic and multi-racial.
e PIR was calculated by dividing family income by the annual poverty threshold provided by U.S. Census Bureau.[20,21]

only US national survey that captures information on food security status as well as information on diabetes and prediabetes from both self-reported items and clinical measures.

METHODS

Survey Design and Participants

The NHANES 2005-08 are cross-sectional nationally representative health and nutrition surveys of the civilian noninstitutionalized US population. The National Center for Health Statistics (NCHS) conducts the NHANES, using a stratified, multistage probability cluster design. Sampling and survey design information are described elsewhere in more detail.[19] The NHANES surveys consist of personal interviews, standardized physical examinations, and laboratory tests. Participants for this study included adults aged 20-64 years

who participated in the 2005-08 rounds. Older adults (≥ 65 years) were not included, because the sample sizes for marginally food secure (MFS) (N = 86) and FI (N = 98) older adults were inadequate to analyze. Women who were pregnant or breastfeeding were excluded. Based on results from interaction models the sample was stratified by sex. Details regarding NHANES participants' consent have been published elsewhere.[20,21]

Food Security Status

The NHANES 2005–08 contains the Food Security Survey Module (FSSM), which has been shown to be a stable, robust, and reliable measurement tool.[22] According to Life Sciences Research Organization, FI occurs whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain.[22,23] During the household interview, one adult was prompted to consider his or her situation over the past 12 months for all household members. Based on the responses to 10 adult-specific items, adults were classified as: fully food secure (FFS) meaning no problems or anxieties regarding food, MFS indicating members are anxious about food or perceive problems in attaining food, but food quality, variety, and quantity are not reduced, and FI. Low and very low food security classifications were grouped together and referred to as FI.[23] Low food security refers to a condition in which the quality, variety, and desirability of food are reduced yet quantity remains adequate. Very low food security occurs when eating patterns are disrupted and food quantity is reduced due to inadequate resources.

Undiagnosed Prediabetes

Undiagnosed prediabetes was defined by comparing clinical HbA1c examination results to self-reported information.[24,25] During the household interview, NHANES participants were asked whether a doctor or healthcare professional had ever told them they had any of the following diagnoses: *prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes or blood sugar is higher than normal but not high enough to be called diabetes or sugar diabetes*. Based on the American Diabetes Association guidelines, participants were classified as having prediabetes if they had HbA1c from 5.7% to 6.4%.[26] The blood collection techniques and the HbA1c assay method information are described elsewhere.[27,28]

In the logistical regression analyses, participants with undiagnosed prediabetes (that is the participants with HbA1c from 5.7% to 6.4% but did not report that they had been informed by a doctor or healthcare professional of their prediabetes status) were included. Participants who did not have diabetes or prediabetes were also included. Participants who had diabetes, based on either self-reported diabetes or clinical evidence of diabetes (plasma glucose concentration ≥ 11.1 mmol/l; or fasting plasma glucose (FPG) ≥ 7.0 mmol/l; or oral glucose tolerance tests (OGTT) ≥ 11.1 mmol/l; or HbA1c ≥ 6.5%)[29] as well as those with diagnosed prediabetes were excluded.

Statistical Analysis

As indicated by NCHS,[19] the sampling weights and sample design variables from the 2 survey rounds were accounted for in the analyses. Data were analyzed using Statistical Analysis Systems statistical software package version 9.2 (SAS Institute, Cary, NC, USA). Descriptive statistics (χ^2-tests of independence) were used to characterize participants according to their food security status. Logistic regression models were used to examine the relationship between food security status and undiagnosed prediabetes. In the logistic models, the FFS groups were the referent groups. Because the relationship between FI and health outcomes has been shown to vary by sex, the possible effect modification by sex was investigated. To reduce the possibility of residual confounding of income, additional analyses that restricted the sample to those participants with poverty income ratio (PIR) < 185% were also conducted. Statistical significance was assigned at $p < .05$ level.

Selection of confounding variables was based on theoretical models,[30,31] as well as empirical results from previous literature.[32,33] Multiple logistic regression models were used to estimate the associations between food security status and undiagnosed prediabetes, and 3 model specifications were used. In the first set of models only age and BMI were included as confounding variables. The confounding variables in the second set of models included age, BMI, smoking status, race/ethnicity, education levels, PIR, and self-reported health condition. The third or full model included age, BMI, smoking status, race/ethnicity, education levels, PIR, self-reported health condition, health insurance status, routine place for healthcare, and times receiving healthcare over the past year.

All confounding variables were examined as indicator variables. Age at the time of the screening interview was classified as 20-34, 35-44, 45-54, and 55-64 years for analysis. BMI was divided into 3 categories: < 25, 25 to 29.9, and ≥ 30 kg/m^2.[34,35] Smoking status was categorized as non-smoker, former smoker, and current smoker. Race/ethnicity was grouped as non-Hispanic White, non-Hispanic Black, Mexican-American and other races, including other Hispanic and multi-racial. Education levels were collapsed into 2 categories: < high school and ≥ high school degree (or equivalent). PIR was classified as < 185% and ≥185%.[20,21] Self-reported health status was divided into 2 categories: excellent to good and fair to poor. Participants were categorized as having or not having insurance. Routine places for healthcare were doctor's office, outpatient, clinic or health center, hospital emergency room, and no routine place. Visits to a healthcare professional (overnight hospitalizations

Table 2
Diagnosis Status of Prediabetes among Male and Female Participants by Food Security Status: NHANES 2005-2008[a]

	Men (20-64years) (N = 3332)[b]			Women (20-64years) (N = 3245)[b]		
	FFS (N = 2452)	MFS (N = 366)	FI (N = 514)	FFS (N = 2334)	MFS (N = 407)	FI (N = 504)
	% (95% CI)					
Diagnosed prediabetes[c]	1.3 (0.7– 1.8)	0.2 (0.0– 0.5)	0.7 (0.0– 1.4)	1.1 (0.5– 1.8)	1.2 (0.5– 1.9)	1.9 (0.3– 3.5)
Undiagnosed prediabetes[c]	11.2 (9.6– 12.7)	14.1 (11.0– 17.3)	17.7 (12.8– 22.6)	11.0 (9.7– 12.3)	14.3 (10.0– 18.6)	10.5 (7.0– 14.0)
Diagnosed diabetes[d]	5.5 (4.4– 6.5)	4.5 (1.7– 7.4)	6.0 (4.0– 8.0)	4.6 (3.4– 5.8)	5.6 (3.9– 7.4)	9.5 (6.0– 13.1)
Undiagnosed diabetes[d]	3.6 (2.8– 4.4)	7.0 (4.0– 10.1)	3.1 (1.6– 4.5)	2.6 (1.9– 3.4)	2.3 (1.1– 3.6)	3.1 (1.7– 4.6)
No diabetes or prediabetes	78.5 (76.4– 80.6)	74.1 (68.5– 79.8)	72.5 (66.7– 78.3)	80.6 (78.7– 82.6)	76.6 (72.0– 81.2)	74.8 (69.9– 80.0)

Note.
FFS = fully food secure
FI = food insecure
MFS = marginally food secure
NHANES = National Health and Nutritional Examination Survey

a All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics.
b Includes participants with complete data for age, BMI, sex, smoking status, race/ethnicity, education levels, poverty income ratio, self-reported health condition, health insurance status, routine place for healthcare, times receiving healthcare over past year, and self-reported diabetes and prediabetes status, as well as clinical tests for diabetes and prediabetes.
c Prediabetes was based on HbA1c from 5.7% to 6.4%.[26]
d Diabetes was based on plasma glucose concentration ≥ 200 mg/dl; or FPG ≥ 126 mg/dl; or OGTT ≥ 200 mg/dl; or HbA1c ≥ 6.5%.[29]

were not included) during the past 12 months were categorized as 0, 1-3, and ≥ 4 times.

RESULTS

Characteristics, including age, BMI, smoking status, race/ethnicity, PIR, education level, self-reported health condition, health insurance coverage and routine place for seeking and visits to a healthcare professional over the past year, are presented in Table 1 by food security status for men (N = 3332) and women (N = 3245). Differences across levels of food security for men and women were found for every characteristic: age, BMI, smoking status, race/ethnicity, education levels, PIR, self-reported health condition, health insurance status, routine place for healthcare, and times receiving healthcare over the past year.

The prevalence of diagnosed diabetes ranged from 4.5% (95% CI 1.7– 7.4) in MFS men to 9.5% (95% CI 6.0– 13.1) in FI women. The range for undiagnosed diabetes was 2.3% (95% CI 1.1– 3.6) in MFS women to 7.0% (95% CI 4.0– 10.1) in MFS men. For diagnosed prediabetes, it ranged from less than a percentage in MFS men to 1.9% (95% CI 0.3– 3.5) in FI women (Table 2). Undiagnosed prediabetes ranged from 10.5% (95% CI 7.0– 14.0) in FI women to 17.7% (95% CI 12.8– 22.6) in FI men.

The interaction terms used to investigate effect measure modification by sex were statistically significant (p = .0044) and accordingly, all analyses were stratified by sex (men N = 2939 and women N = 2875). Regardless of model specification, the odds of undiagnosed prediabetes were higher among MFS and FI men when compared to FFS men (Table 3). Among women, food security status was not associated with undiagnosed prediabetes in any of the 3 models. When the sample was restricted to those with PIR < 185%, similar results were also found. In the full model, MFS (odds ratio 1.76, 95% CI 1.10– 2.82) and FI (odds ratio 2.18, 95% CI 1.28– 3.70) men had higher odds of undiagnosed prediabetes than FFS men and no association was observed among women.

DISCUSSION

To our knowledge, this study is the first one to

Table 3
Associations between Food Insecurity and Undiagnosed Prediabetes in Male and Female Participants from the NHANES 2005-2008[a]

	Men (20-64years)[b] (N = 2939)			Women (20-64years)[b] (N = 2875)		
	Model 1[c]	Model 2[d]	Model 3[e]	Model 1[c]	Model 2[d]	Model 3[e]
Fully food secure	1.00	1.00	1.00	1.00	1.00	1.00
Marginally food secure	2.04 (1.45– 2.86)	1.57 (1.08– 2.27)	1.64 (1.12– 2.38)	1.19 (0.90– 1.57)	1.14 (0.74– 1.76)	1.13 (0.72–1.78)
Food insecure	2.81 (1.96– 4.03)	2.00 (1.23– 3.24)	2.12 (1.28– 3.49)	1.24 (0.85– 1.81)	0.89 (0.60– 1.31)	0.90 (0.60– 1.34)

Note.
NHANES = National Health and Nutritional Examination Survey

a Data were estimated OR (95% CI). Prediabetes was based on HbA1c from 5.7% to 6.4%. Analysis excludes participants who had diabetes and diagnosed prediabetes. All values were weighted and design corrections were applied to the analysis as directed by the National Center for Health Statistics.
b Includes participants with complete data for age, BMI, sex, smoking status, race/ethnicity, education levels, poverty income ratio, self-reported health condition, health insurance status, routine place for healthcare, times receiving healthcare over past year, and self-reported prediabetes status, as well as clinical tests for prediabetes.
c Model 1 was adjusted for age and BMI.
d Model 2 was adjusted for age, BMI, smoking status, race/ethnicity, education levels, poverty income ratio, and self-reported health condition.
e Model 3 was adjusted for age, BMI, smoking status, race/ethnicity, education levels, poverty income ratio, self-reported health condition, health insurance status, and routine place for healthcare, as well as times receiving healthcare over past year.

examine the relationship between FI and undiagnosed prediabetes and whether this relationship is modified by sex. Adult men with MFS and FI were found to be more likely to have undiagnosed prediabetes than FFS men. These results indicate that men, who worry about obtaining enough food as well as those who do not have consistent access to a health promoting diet, may lack awareness of their diabetes risk.

According to the concept of competing priorities, individuals with limited resources have to make choices among subsistence needs and healthcare needs.[30,31] Our results suggest men with limited resources may be forced to pay for food rather than preventive healthcare services.

Efforts to control and reduce the prevalence of diabetes may be more effective when they are initiated early during the progression of this chronic disease. Knowing their prediabetes status may motivate these men to pursue either lifestyle changes or to be treated with medications that can help prevent the onset of type 2 diabetes. Several professional organizations involved in diabetes surveillance and care have issued recommendations for screening for diabetes in the general population.[36] These recommendations range from screening only those individuals with elevated blood pressure to screening every person older than a specific age. Under the Affordable Care Act, type 2 diabetes screening will be covered for adults with high blood pressure.[37] A health service factor that might increase the screening options for FI men would be point-of-care testing. Point-of-care testing (as opposed to diagnostic laboratory testing) has been asserted as having transformative effects on healthcare in low resource settings.[38] Point-of-care testing has been shown to reduce emergency room (ER) crowding and associated patient length of stay in the ER.[39]

Some work has shown that inflammation may be a biological mechanism by which FI has been shown to predispose individuals to chronic disease, such as diabetes.[40] Stress and shifts in dietary patterns that characterize FI may promote an inflammatory state and alter immune function in FI individuals. Researchers have found that FI individuals had almost 40% higher odds of having high white blood cell counts, an indicator of infection and immune system activation.

An unexpected finding was that adult men with MFS and FI were more likely to have undiagnosed prediabetes whereas no relationship was observed among women. A relationship between FI and undiagnosed disease was expected among MFS women because they are more likely to be obese. Obesity particularly in women may act as a barrier to health seeking behavior, particularly preventive healthcare services.[41] Then again, previous work has shown that determinants of each type of healthcare use can vary considerably.[42]

European and US studies suggest that men respond differently to poverty than women by embracing poor coping strategies such as alcohol consumption and smoking, contributing to substance-related conditions that lead to high mortality rates.[43] Another poor coping strategy may be less use of healthcare services. A considerable percentage of MFS and FI men reported not having a routine place to go for healthcare and approximately one third of both MFS and FI men had not seen a healthcare provider in the past year. Researchers who study differences between men's and women's health have proposed that men have a lack of symptom recognition and delay seeking medical help because they perceive less vulnerability than women.[44] In addition, sex-role socialization has influenced schema regarding the typically feminine and culturally influenced role of "caretaker." Women, who are more likely to play the caretaker role, have more frequent contacts with the medical system, receive more physician time, and get more detailed answers to their medical questions.[45] Women's use of healthcare services and subsequent awareness of their health risk also may be attributable to the existence in the US of national nutrition assistance programs that target pregnant, postpartum and/or breastfeeding women who meet income, residency and nutritional status eligibility requirements. The Special Supplemental Nutrition Program for Women, Infants and Children not only provides food assistance but acts as a conduit to the healthcare system.

The depth of the information in the NHANES data allowed an analysis that incorporated several predisposing factors (age, sex, ethnicity and education), enabling factors (regular source of care, health insurance, income), perceived health status, and use of health services in the past year. Accounting for these factors is important because individuals without insurance and without routine healthcare have been linked to undiagnosed diabetes.[46] Also the frequency of healthcare use in the past year has been associated with undiagnosed diabetes.[32] Lastly, obese individuals were more likely than normal weight individuals to have undiagnosed diabetes.[47] However, the NHANES data did not allow us to account for community resources such as residence and proximity of health services resources. This study is also limited by the relatively small sample size of older adult participants, which prevents analyzing a relationship among this group. Another limitation is that all measures of assessing prediabetes were not available for all participants. Clinical evidence of prediabetes was based on HbA1c values in this study for a number of reasons. First, because the HbA1c test does not require fasting, a greater sample size was available. Second, HbA1c values do not fluctuate with recent eating or acute illness.[48] HbA1c tests assess glycemic trends over several months[49] and correspond with the FFSM measurements that encompass experiences over the past 12 months. Finally, previous studies have shown differences between men and women in the prevalence of prediabetes when using a fasting glucose test.[50] Because the objective of this study was to examine the role of sex, any differences related to sex should not be an artifact of the methods used.

According to an IOM report, the health system in the US needs to focus on population-based preventive efforts to improve life expectancy and major health outcomes.[1] This study found an association between FI as well as MFS and undiagnosed prediabetes among men. These results indicate that FI and MFS men may not know their risk for diabetes based on having prediabetes. Preventive efforts, especially prediabetes screening, among FI and MSF men appear to be warranted.

Human Subjects Statement

The protocol for this study was given exempt status by the Institutional Review Board, Office of Human Subjects Research, Auburn University.

Conflict of Interest

None of the authors had a conflict of interest.

Acknowledgements

This study was supported in part by the Alabama Agricultural Experiment Station (ALA043). The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; or preparation, review, and approval of the paper.

REFERENCES

1. Committee on Public Health Strategies to Improve Health. Board on Population Health and Public Health Practices; Institute of Medicine. For the public's health: investing in a healthier future (on-line). Available at: http://books.nap.edu/catalog.php?record_id=13268. Accessed June 15, 2012.
2. Centers for Disease Control and Prevention. Chronic Disease Prevention and Health Promotion. Preventive Health and Health Services Block Grant. A critical public health resource at a glance 2011 (on-line). Available at: http://www.cdc.gov/chronicdisease/resources/publications/AAG/blockgrant.htm. Accessed January 3, 2012.
3. Soni A. *Top Ten Most Costly Conditions among Men and Women, 2008: Estimates for the US Civilian Noninstitutionalized Adult Population, Age 18 and Older*. Washington, DC: Agency for Healthcare Research and Quality; 2011.
4. Goldman DP, Zheng Y, Girosi F, et al. The benefits of risk factor prevention in Americans aged 51 years and older. *Am J Public Health*. 2009;99(11):2096-2101.
5. Anderson SA. Core indicators of nutritional state for difficult-to-sample populations. *J Nutr*. 1990;120(Suppl 11):1559-1600.
6. Gelberg L, Andersen RM, Leake BD. The behavioral model for vulnerable populations: application to medical care use and outcomes for homeless people. *Health Serv Res*. 2000;34(6):1273-1302.
7. Reid KW, Vittinghoff E, Kushel MB. Association between the level of housing instability, economic standing and health care access: a meta-regression. *J Health Care Poor Underserved*. 2008;19(4):1212-1228.
8. Tayie FA, Zizza CA. Food insecurity and dyslipid-

emia among adults in the United States. *Prev Med*. 2009;48(5):480-485.
9. Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr*. 2010;140(2):304-310.
10. Vozoris NT, Tarasuk VS. Household food insufficiency is associated with poorer health. *J Nutr*. 2003;133(1):120-126.
11. Holben DH, Pheley AM. Diabetes risk and obesity in food-insecure households in rural Appalachian Ohio. *Prev Chronic Dis*. 2006;3(3):A82.
12. Biros MH, Hoffman PL, Resch K. The prevalence and perceived health consequences of hunger in emergency department patient populations. *Acad Emerg Med*. 2005;12(4):310-317.
13. Marjerrison S, Cummings EA, Glanville NT, et al. Prevalence and associations of food insecurity in children with diabetes mellitus. *J Pediatr*. 2011;158(4):607-611.
14. Diabetes Prevention Program Research Group, Knowler WC, Fowler SE, et al. 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. *Lancet* 2009;374(9702),1677-1686.
15. Pan XR, Li GW, Hu YH, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care*. 1997;20(4):537-544.
16. Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344(18):1343-1350.
17. Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6):393-403.
18. Zizza CA, Duffy PA, Gerrior SA. Food insecurity is not associated with lower energy intakes. *Obesity*. 2008;16(8):1908-1913.
19. National Center for Health Statistics. Survey design factors course: sample design, weighting and variance estimation (on-line). Available at: http://www.cdc.gov/nchs/tutorials/NHANES/SurveyDesign/intro.htm. Accessed June 15, 2012
20. National Center for Health Statistics. 2005-2006 National Health and Nutrition Examination Survey: survey operations manuals, brochures, consent documents (on-line). Available at: http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/current_nhanes_05_06.htm. Accessed June 15, 2012.
21. National Center for Health Statistics. 2007-2008 National Health and Nutrition Examination Survey: survey operations manuals, brochures, consent documents (on-line). Available at: http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/current_nhanes_07_08.htm. Accessed June 15, 2012.
22. Bickel G, Nord M, Price C, et al. *Guide to measuring household food security, revised 2000*. Washington, DC: US Department of Agriculture, Food and Nutrition Service, Office of Analysis, Nutrition, and Evaluation. 2000.
23. Committee on National Statistics. Wunderlich GS, Norwood JL, eds. *Food insecurity and hunger in the United States: An assessment of the measure*. Washington, DC: The National Academies Press; 2006.
24. Centers for Disease Control and Prevention. National diabetes fact sheet, data sources, methods, and references for estimates of diabetes and prediabetes (on-line). Available at: http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011_pdf. Accessed June 15, 2012.
25. Hadaegh F, Bozorgmanesh MR, Ghasemi A, et al. High prevalence of undiagnosed diabetes and abnormal glucose tolerance in the Iranian urban population: Tehran Lipid and Glucose Study. *BMC Public Health*. 2008;8:176.
26. American Diabetes Association. Summary of revisions for the 2010 Clinical Practice Recommendations. *Diabetes Care*. 2010;33(Suppl 1):S3.
27. National Center for Health Statistics. National Health and Nutrition Examination Survey: 2005 - 2006 data documentation, codebook, and frequencies: glycohemoglobin (GHB_D) (on-line). Available at: http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/GHB_D.htm. Accessed June 15, 2012.
28. National Center for Health Statistics. National Health and Nutrition Examination Survey: 2007 – 2008 data documentation, codebook, and frequencies: glycohemoglobin (GHB_E) (on-line). Available at: http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/GHB_E.htm. Accessed June 15, 2012.
29. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2007;30(Suppl 1):S42-S47.
30. Lim YW, Andersen R, Leake B, et al. How accessible is medical care for homeless women? *Med Care*. 2002;40(6):510-520.
31. Reid KW, Vittinghoff E, Kushel MB. Association between the level of housing instability, economic standing and health care access: a meta-regression. *J Health Care Poor Underserved*. 2008;19(4):1212-1228.
32. Zhang X, Geiss LS, Cheng YJ, et al. The missed patient with diabetes: how access to health care affects the detection of diabetes. *Diabetes Care*. 2008;31(9):1748-1753.
33. Franse LV, Di Bari M, Shorr RI, et al. Type 2 diabetes in older well-functioning people: who is undiagnosed? data from the Health, Aging, and Body Composition study. *Diabetes Care*. 2001;24(12):2065-2070.
34. Crandall JP, Knowler WC, Kahn SE, et al. The prevention of type 2 diabetes. *Nat Clin Pract Endocrinol Metab*. 2008;4(7):382-393.
35. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res*. 1998;6(Suppl 2):S51-S209.
36. Murphy PA, Winmill DB. Screening for prediabetes and diabetes in non-pregnant adults. *J Midwifery Womens Health*. 2013;58(1):98-102.
37. National Conference of State Legislatures. Federal health reform provisions related to diabetes (on-line). Available at: http://www.ncsl.org/portals/1/documents/health/DiabetesinHR511.pdf. Accessed June 18, 2013.
38. Jani IV, Peter TF. How point-of-care testing could drive innovation in global health. *N Engl J Med*. 2013;368(24):2319-2324.
39. Lee-Lewandrowski E, Corboy D, Lewandrowski K, et al. Implementation of a point-of-care satellite laboratory in the emergency department of an academic medical center: impact on test turnaround time and patient emergency department length of stay. *Arch Pathol Lab Med*. 2003;127(4):456-460.
40. Gowda C, Hadley C, Aiello AE. The Association between food insecurity and inflammation in the US adult population. *Am J Public Health*. 2012;102(8):1579-1586.
41. Fontaine KR, Bartlett SJ. Access and use of medical care among obese persons. *Obes Res*. 2000;8(5):403-406.
42. Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the United States. *Milbank Mem Fund Q Health Soc*. 1973;95-124.
43. Spitzer DL. Engendering health disparities. *C J Public Health*. 2005;96:S78-S96.
44. Nicholas DR. Men, masculinity, and cancer: risk-factor behaviors, early detection, and psychosocial adaptation. *J Am Coll Health*. 2000;49(1):27-33.
45. Courtenay WH. Behavioral factors associated with disease, injury, and death among men: Evidence and implications for prevention. *The Journal of Men's Studies*.

2000;9(1):81-142.
46. Zhang X, Beckles GL, Bullard KM, et al. Access to health care and undiagnosed diabetes along the United States-Mexico border. *Rev Panam Salud Publica*. 2010;28(3):182-189.
47. Wilder RP, Majumdar SR, Klarenbach SW, et al. Socioeconomic status and undiagnosed diabetes. *Diabetes Res Clin Pract*. 2005;70(1):26-30.
48. Silverman RA, Thakker U, Ellman T, et al. Hemoglobin A1c as a screen for previously undiagnosed prediabetes and diabetes in an acute-care setting. *Diabetes Care*. 2011;34(9):1908-1912.
49. Olson DE, Rhee MK, Herrick K, et al. Screening for diabetes and pre-diabetes with proposed A1C-based diagnostic criteria. *Diabetes Care*. 2010;33(10):2184-2189.
50. James C, Bullard KM, Rolka DB, et al. Implications of alternative definitions of prediabetes for prevalence in U.S. adults. *Diabetes Care*. 2011;34(2):387-391