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Food Insecurity and Age at Menarche in Tampa Bay, Florida

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ABSTRACT

The aim of this study was to assess whether household food insecurity is associated with delayed or early menarche among girls in the United States. Thirty-six dyadic household interviews were conducted with mothers and adolescent girls. The interviews included a socio-demographic survey, the USDA Six-Item Short Form Household Food Security Survey Module, anthropometric measurements, and the self-administered Youth-Adolescent Food Frequency Questionnaire. Using non-parametric quantitative analyses, we examined the associations among food insecurity, anthropometrics, diet, and age at menarche. Cox Proportional Hazards Models were used to evaluate the odds of menarche based on household food insecurity. Food insecurity significantly predicted earlier time to menarche. Food insecure girls were 4.38 times more likely to experience menarche at earlier ages when compared to food secure girls (HR = 4.38, p = .04). Furthermore, the hazard of menarche increased by 25% for each unit increase in food insecurity (OR = 1.253, p = .027). The findings suggest that household food insecurity is associated with earlier ages of menarche among girls in this sample. Early menarche has been associated with adult chronic disease risk. Thus, these findings propose that food security initiatives may be used to reduce the prevalence and health consequences of early-onset puberty.

KEYWORDS

Menarche; food insecurity; life history; puberty

Introduction

Adolescence is a critical life period consisting of accelerated growth, sexual maturation, and brain development (Bogin, Silva, and Rios 2007). Menarche, defined as the first menstruation, is often used to determine the start of adolescence and the timing of puberty among girls (Papadimitriou 2016). While heritability can play a role (Gluckman and Hanson 2006), environmental factors also account for variation in age at menarche within populations (Villamor and Jansen 2016). Currently, it is unknown how living in a food-insecure environment during childhood and adolescence influences the timing of menarche among girls in the U.S. Because early menarche is associated with chronic health

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risks in adulthood as well as with mental health conditions and risky behaviors in adolescence, it is important to understand how food insecurity influences the timing of this critical life history event.

Food insecurity is the context in which one has limited and inconsistent access to safe and nutritious foods (USDA n.d). Food-insecure households in developed countries such as the U.S. rely on cheap foods that are high in calories but low in nutritional value. Thus, food insecurity and poverty are often linked to over-nutrition and micronutrient deficiencies in high-income societies. In contrast, under-nutrition remains a substantial health risk among food-insecure households in developing areas of the world. Both very high infant mortality rates and under-nutrition in early life as well as during maturity associate with delayed menarche. Research in Ethiopia and Colombia found food insecurity delayed menarche, pointing to poor energetic availability as the key motivator (Belachew et al. 2011; Jansen, Herrán, and Villamor 2015). While the connection between food insecurity and menarche in the U.S. is unexamined, it is known that girls from low-income households and/or African American and Hispanic ethnicity reach menarche earlier than their more privileged counterparts (Amir, Jordan, and Bribiescas 2016; Belsky, Schlomer, and Ellis 2012; Biro et al. 2018; Chumlea et al. 2003; Deardorff et al. 2014; Forman et al. 2013; Kelly et al. 2017; Krieger et al. 2015; Reagan et al. 2012; Simpson et al. 2012; Wiley 2011). The variation in menarche ages between developed and developing regions likely stems from differences in energy availability and extrinsic mortality rates. Life history theory assumes that when food insecurity associates with under-nutrition and/or exists concurrently with high juvenile mortality risk, available energy is allocated for somatic needs rather than for reproduction and menarche is delayed. On the other hand, when food insecurity associates with over-nutrition and low extrinsic mortality risk, girls have enough energy to sustain somatic needs as well as reproductive maturation. So, menses can begin earlier or at the “average” time.

Like energetics, psychosocial stress during childhood is also associated with accelerated puberty (Belsky et al. 2007, 2010; Ellis and Garber 2000; Kelly et al. 2017; Richardson, La Guardia, and Klay 2018; Simpson et al. 2012). Cross-culturally, food insecurity is known to cause stress, worry, anxiety, and depression, and is connected to unstable and unpredictable food access (Connell et al. 2005; Ellis and Essex 2007; Leung et al. 2015). Therefore, food insecurity provides a unique opportunity for understanding the determinants of menarche because it involves both nutritional stress and psychosocial stress, which vary by context. The aim of this study was to evaluate how food insecurity influences the timing of menarche among girls in the Tampa Bay region of the U.S. Since food insecurity in the U.S. is connected to over-nutrition and mental stress, and juvenile mortality risks are low, we hypothesized that food insecurity would associate with earlier ages at menarche compared to the national average of 12.5 years.

Methods

This research (PRO #00028412) was conducted between March and October of 2017 and was approved by the University of South Florida Institutional Review Board. The data was obtained through cross-sectional household interviews with adolescent girls and their maternal guardians (mothers, grandmothers, and aunt) in three counties within Tampa Bay, Florida. Tampa Bay consists of urban and suburban areas and is home to a diverse population of more than three million residents (U.S. Census Bureau 2016). Hispanic and African American residents make up the largest minority groups, with approximately 18% of Tampa Bay's population self-identifying as Hispanic and 13% as African American (U.S. Census Bureau 2016). It is estimated that 14% of Tampa Bay households live in poverty, and 15% are food insecure (Feeding America, 2016; U.S. Census Bureau, 2016). In addition, 22.5% of households with children under the age of 18 are food insecure. Approximately 42% of Tampa Bay families struggle to meet basic needs but are ineligible for government-funded assistance due to the income and asset eligibility thresholds of U.S. food assistance programs (e.g., Supplement Nutrition Assistance Program [SNAP], The Emergency Food Assistance Program [TEFAP]) (United Way Florida 2017).

The large numbers of struggling households and the high prevalence of food insecurity among children make Tampa Bay an important research setting for understanding the influence of food insecurity on adolescent growth and development. Food insecurity research in this area has failed to assess adolescents as a separate group, despite their vulnerability (critical growth period, increased nutritional demands, and social awareness/fear). Part of this may be due to the difficulties in reaching this age group (Mathews et al. 2015; Sterzing, Gartner, and McGeough 2018). Furthermore, Tampa Bay's large minority population provides an opportunity to capture and compare variations within food insecurity realities and timing of menarche among different ethnic-racial groups.

Sampling and ethics

Girls were recruited using convenience sampling at local mobile pantries and youth organizations. Because teens are hard to reach and the study includes two sensitive topics, convenience sampling was necessary for the scope of this thesis project (Mathews et al. 2015). To be eligible for participation, households must have had at least one girl living in the home who had experienced menarche and was no older than 16 years. Since the aim of the study was to evaluate the association between food insecurity and age at menarche, households were recruited from mobile food pantries and low-income areas where the chance of food insecurity was high. Furthermore, purposive sampling was necessary to account for the difficulties of finding willing adolescent participants. At mobile pantries, adults were approached while waiting in line and asked if they had girls living in the household that had started menstruation. If they did, they were provided information about the study and had the option to schedule an interview or provide their contact information for future scheduling if they were a primary guardian. Girls were also recruited at youth summer programs in low-income areas. A researcher visited the summer camps and explained the research goals and methods to the girls in a group. Interested girls took home flyers and consent forms and were asked to have their parents call to schedule an interview after they gave permission. Lastly, flyers were posted in low-income areas. Interested families responded to the flyers via e-mail or phone call.

Before data collection, the interviewer read the consent, parental permission, and assent forms to each child and parent, and obtained written adult consent, child assent, and parental permission for participation before the interview began. A total of 40 girls and 36 maternal caretakers, which included 27 mothers, 8 grandmothers, and one aunt, participated in the study. Due to the small sample size, nonparametric statistical tests were used for the quantitative analyses.

Socio-demographics

Parents and girls were both asked to provide their age, age at menarche, ethnicity, highest level of education, current household annual income, income at girls' age of menarche, current and past health conditions, and whether they participated in government-provided food or income assistance. Parents were asked to describe their infant feeding practices and the birth weight(s) of the girl(s). Using a semi-structured interview format, girls and parents were also asked to describe food acquisition strategies and household food behaviors. Questions included where they received/obtained most of the food for the household, how often they ate outside the home and where, whether girls ate different foods than the adults (and if yes, when, why, and what they ate differently), the most important factors behind food choices (including cost, location, time/effort, healthiness, taste/desire, and family/friends preferences), whether the girls ate the food provided by their schools and/or summer program (if not, why), and what they did (as a family) to make sure they had enough food to eat.

Household food insecurity

Household food insecurity was measured using the United States Department of Agriculture (USDA) Six-Item Short Form Household Food Security Survey Module (Economic Research Service, 2012). The instrument was developed by the National Center for Health Statistics as a substitute for the 18-item U.S. Household Food Security Survey Module to reduce respondent burden (Economic Research Service 2012). The six-item module does not ask specifically about children or adult food insecurity, but rather, assesses food insecurity at the household level. It has been validated to "identify food-insecure households and households with very low food security with minimal bias" (Economic Research Service 2012). Since the topic of the research and the population (adolescents) are sensitive, a household assessment using the shortened questionnaire was chosen to limit participant stress.

The survey asks questions that pertain to the previous 12 months, including how often food did not last, the household could not afford to eat balanced meals, the household had to cut the size of meals or skip meals; and whether the respondent had to eat less or go hungry because there was not enough money for food (Economic Research Service 2012). Households with girls who had menarche more than one year prior to the interview were asked to answer food insecurity questions relative to the date of menarche. Affirmative answers were counted to provide a food insecurity score. Scores were translated into dichotomous categorical variables where households who answered affirmatively to two or more questions were considered food insecure and households who scored one or zero were considered food secure. Categorical food insecurity variables were used to obtain summary statistics, compare demographics between food insecure and food secure girls, and as a predictor variable in hazard regression analysis. Food insecurity scores were also translated into Rasch-based scale scores (Economic Research Service 2012), and used as continuous variables for interval-level statistical analyses including central tendency comparisons between various demographic groups, correlation analyses, and hazard regression analysis.

Anthropometry

Anthropometry is a powerful tool for understanding past and current nutritional status of individuals (Gibson 2005). Girls were measured for weight, height, iliac height, sitting height, waist circumference, and hip circumference using protocols from *Principles of Nutritional Assessment* (Gibson 2005) and the National Health and Nutrition Examination Survey (NHANES) III (National Center for Health and Statistics, 2007). Weight was measured to the nearest hundredth kilogram using a portable digital scale. Height was measured to the nearest millimeter with a portable stadiometer (Seca 216 n.d). Sitting height, iliac height, waist circumference, and hip circumference were measured to the nearest millimeter with a measuring tape. These measurements were used to calculate body mass index (BMI), sitting height ratio, and waist-hip ratio (Bogin and Varela-Silva 2010; Gibson 2005). Height, iliac height, and sitting height ratio were used to indicate linear growth. Linear growth measurements are the best physical indicator of early life malnutrition and have been validated among children (Bogin and Silva 2010; de Onis and Branca 2016; Frongillo, Leroy, and Lapping 2019). For example, height-for-age below −2 standard deviations of a population's mean is known as stunting and suggests long-term malnutrition and weight-for-age above +2 standard deviations is considered a risk factor for overweight and obesity among children (Bogin & Varela-Silvia, 2010; de Onis and Branca, 2016; Gibson, 2005).

Linear growth indicators were used to evaluate the associations between long-term nutritional status and menarche timing, as reductions in linear growth may be an adaptive life history response (Bogin and Silva 2012; Gibson 2005; Gluckman and Hanson 2006). To indicate whether overnutrition is playing a role within growth and development, BMI and waist-hip ratios were used to calculate current nutritional status (e.g., underweight, overweight, obese) and body fat composition (Gibson 2005). These variables were also used as controls when assessing the association between stressed bodies and menarche. Because BMI does not differentiate fat mass from muscle mass, waist and hip circumference were used to indicate body fat distribution using waist-hip ratio – a measure of risk for chronic disease like cardiovascular disease and hypertension (Gibson 2005; Lieberman 2017; Wiley 2017). In addition, it is debated as to whether central or lower adiposity is more influential in determining menarche timing. Thus, both were included to better understand whether overnutrition as indicated by large waist circumferences or skeletal maturation as indicated by lower body fat is more significant within the onset of menarche (Bhadra et al. 2013; Villamor and Jansen 2016; Ziomkiewicz and Kozieł 2015).

Dietary intake

Diet was assessed using the self-administered 2012 Youth-Adolescent Food Frequency Questionnaire (Rockett, Wolf, and Colditz 1995), which asked respondents to answer how often they consumed a specific food item over the previous year. The responses extend from *never/less than once a month* to multiple times per week or day depending on the item. The Youth-Adolescent Food Frequency Questionnaire has been validated for use among children (Rockett, Wolf, and Colditz 1995). It includes easy-to-understand directions and foods that U.S. children commonly consume (e.g., chicken nuggets, popsicles). Furthermore, it includes measurements for each food item (e.g., 1–3 cups; 12oz bottle), making it easier to quantify dietary intakes. The responses were quantified, calculated, and referenced against the International Dietary Quality Index (International Dietary Data Expansion Project 2015). Girls were also asked whether their diets had changed since menarche to ensure reliable data for analysis. If that was the case, girls were asked to answer the food frequency questionnaire based on their diets at the age of menarche. In addition, girls were asked to describe the foods they typically ate each day for breakfast, lunch, dinner, snacks, and dessert.

Analysis

The data were analyzed using IBM SPSS Statistics Version 24.0 (IBM 2016). Continuous variables included household food insecurity score, anthropometrics, age at menarche, and food frequencies. Categorical variables included food insecurity category, pre- and post-menarche, and BMI-for-age percentiles. Descriptive statistics, such as means and standard variation, were obtained for sociodemographic, anthropometric, food frequencies, and food insecurity variables. Dietary variety and adequacy were calculated by coding the frequencies of each food group consumed using the Dietary Quality Index-International scale (DQI-I). Codes were summed and averaged to achieve a mean DQI-I score for the total sample. Due to the small sample size, non-parametric statistical models were used for further analysis and data exploration. Mann-Whitney U tests evaluated differences in food insecurity and anthropometrics between post and pre-menarcheal girls. Spearman's Rank Correlation Coefficients assessed correlations between age at menarche, food insecurity score, food frequencies, and anthropometrics.

Because 10 girls in the sample had not achieved menarche, the relationship between age at menarche and food insecurity could not be tested using standard linear regression models, as these girls would have to be dropped from the analysis. Instead, a Cox Proportional Hazards model, a type of survival analysis, was used to test the hypothesis. Survival analyses are used to model the relationship between time to an event of interest and one or more predictor variables. The outcome of interest, the hazard ratio, can be interpreted as the risk of the event occurring, given a one-unit change in the predictor variable. Cox Proportional Hazard models (PH) require a "time" variable as well as a dichotomous "event" variable (denoted "uncensored" and coded as 1 if the event occurred at some point during the designated time period, or "censored" and coded as 0 if the event did not occur before the study concluded). In this model, time from birth until age at menarche or age at interview was modeled as the "time," and menarche was considered the "event." Using food insecurity as the predictor variable, a Cox PH model was fitted to evaluate the effect of food insecurity on the risk of reaching menarche. To control for covariates that significantly correlated with age at menarche, adjusted Cox PH models were tested using food insecurity score, waist-hip ratio, and iliac height as independent variables. A test of multicollinearity showed that waist-hip ratio and iliac height were multicollinear (VIF = 1.002), so these variables were included independently as covariates in the Cox PH models with food insecurity score (see Table 6, models 1 and 2).

Results

Table 1 presents the summary statistics for the sample demographics. The total sample included 36 households and 40 girls from ages 10 to 16 years. The majority of the girls self-identified as African American (65%), Hispanic

Table 1. Sample characteristics.

	Girls (n = 40)	Parents (n = 36)	Household (n = 36)
Age (y), mean ± SD	13.2 ± 2.21	45.14 ± 12.31	
Menarchael Age (y), mean ± SD	11.2 ± 1.36	12.19 ± 2.04	
Race/Ethnicity (%)			
Black	65.0%	63.9%	
Biracial	12.5%	2.8%	
Hispanic	17.5%	11.1%	
White	5.0%	11.1%	
Other		11.1%	
Household Income, mean ± SD			\$33,420.69 ± \$16,040.34
Households in poverty (%)			30.6%
Food secure (%)			47.2%
Food insecure (%)			52.8%
Low Food Security (%)			41.7%
Very Low Food Security (%)			11.1%

(17.5%), or biracial (12.5%). Thirty (75%) of the girls had experienced menarche, with an average age at menarche of 11.2 years. Approximately 55.6% of households were food insecure, with 19 (52.8%) households having low food security and 4 (11.1%) households having very low food security.

The anthropometric characteristics of the girls are presented in Table 2. More than half the girls were considered overweight or obese using BMI-for-age percentiles. Hip circumference, weight, BMI, and iliac height were all above the mean percentile-for-age for the total sample. Girls who were post-menarcheal (n = 30) weighed more, were taller, had larger hips, and had more severe food insecurity (p = .01) when compared to pre-menarcheal girls.

Table 2. Anthropometric characteristics of girls.

	Total Sample	Menarche		
	Mean ± SD	Pre-Menarchael	Post-Menarchael	p
Weight (kg)	57.6 ± 17.7	47.0 ± 8.7	60.5 ± 18.5	.031*
Weight-for-age percentile	69.5 ± 31.3	87.1 ± 12.8	64.7 ± 33.2	.195
Height (cm)	155.8 ± 0.12	148.5 ± 8.6	158.2 ± 12.9	.011*
Height-for-age percentile	55.3 ± 35.5	81.3 ± 20.0	46.7 ± 35.5	.005**
Iliac Height (cm)	93.8 ± 7.5	89.9 ± 7.2	94.9 ± 7.3	.07
Sitting Height (cm)	76.7 ± 8.1	75.2 ± 6.6	77.2 ± 8.6	.496
Sitting Height-for-age percentile	29.2 ± 33.3	44.38 ± 35.8	24.4 ± 31.7	.117
Waist circumference (cm)	78.4 ± 12.6	76.0 ± 9.9	79.1 ± 13.4	.726
Waist percentile	42.9 ± 32.8	53.1 ± 30.5	39.6 ± 33.4	.29
Hip circumference (cm)	93.5 ± 10.9	86.2 ± 6.9	95.9 ± 11.0	.015*
Hip percentile	62 ± 26.6	68.8 ± 21.0	59.8 ± 28.2	.496
Waist-hip ratio	0.84 ± 7.3	0.88 ± 0.06	0.82 ± 0.07	.061
Waist-hip percentile	50.2 ± 33.1	61.9 ± 33.8	46.4 ± 32.7	.254
BMI	23.6 ± 6.7	21.5 ± 4.5	24.2 ± 7.1	.562
BMI-for-age percentiles, no. (%)				
Underweight	2 (5.3%)	0 (0%)	2 (6.7%)	
Normal weight	16 (42.1%)	3 (37.5%)	13 (43.3%)	
Overweight	8 (21.1%)	1 (12.5%)	7 (23.3%)	
Obese	12 (31.6%)	4 (50%)	8 (26.7%)	
Wasted, no (%)	0 (0%)	0 (0%)	0 (%)	
Stunted, no (%)	1 (2.5%)	0 (0%)	1 (3.3%)	

Furthermore, there was a positive correlation between age at menarche and iliac height (p = .032, r_s = 0.407), and an inverse correlation between age at menarche and waist-hip ratio (p < .008, r_s = .518). There were no significant associations between food insecurity and any anthropometric measurements.

On average, the girls' diets were moderate in dietary adequacy **($\tilde{x}$ = 12.3) and variety ($\tilde{x}$ = 7.1)** as referenced against the International Dietary Quality Index. According to the I DQI, approximately 72% of girls met their daily recommendations for protein, 64% for grains, 56% for fruits, 28% for dairy, and 26% for vegetables. The most common food items consumed included (in descending order) chicken, eggs, peanut butter and jelly, pasta, pizza, white cow's milk, cheese, cereal, and sugary drinks. Menarche timing was not significantly associated with diet (Tables 3 and 4). Food insecurity, however, was significantly correlated with grain and starch intake (p = .028, r_s = 0.443) as well as with snack consumption (p < .001, r_s = 0.834).

Food insecurity and menarche

The results of the unadjusted Cox Proportional Hazards regression analyses are displayed in Table 5. The hazard ratio indicates the "risk" of reaching menarche by the time of the interview. A hazard ratio greater than one paired with

Table 3. Dietary characteristics of girl.

	Total Sample	Menarche		
	Mean ± SD	Pre-Menarchael	Post-Menarchael	p
Dairy Total	7.1 ± 5.3	7.9 ± 6.1	6.9 ± 5.1	.638
Dairy Adequacy, no (%)	11 (28.2%)	3 (30%)	8 (27.6%)	
Protein Total	20.1 ± 10.7	23.5 ± 12.1	19 ± 10.3	.308
Protein Adequacy, no (%)	28 (71.8%)	7 (70%)	21 (72.4%)	
Grains/Starch Total	15.3 ± 6.2	16.3 ± 6.1	14.9 ± 6.3	.561
Grains/Starch Adequacy, no (%)	25 (64.1%)	7 (70%)	18 (62.1%)	
Fruit Total	20.2 ± 13	22.9 ± 14.2	19.3 ± 12.7	.491
Fruit Adequacy, no (%)	22 (56.4%)	6 (60%)	16 (55.2%)	
Vegetable Total	13.4 ± 9.5	13.5 ± 8.2	13.4 ± 10	.967
Vegetable Adequacy, no (%)	10 (26.3%)	2 (20%)	8 (29%)	
Sugary Drinks Total	6.9 ± 3.8	6.6 ± 2.9	7.0 ± 4.12	.719
Snack Total	25.7 ± 14	29 ± 17.5	24.6 ± 12.8	.478

Table 4. Linear regression of age at menarche and diet.

				95% CI for B	
Covariates	B	t	Sig	Lower	Upper
Dairy	0.36	0.545	0.590	−0.985	1.705
Protein	−0.601	−1.75	0.090	−1.301	0.099
Grains/Starch	−0.266	−0.498	0.622	−1.356	0.832
Fruit	−0.097	−0.394	0.696	−0.598	0.404
Vegetable	0.298	0.903	0.373	−0.374	0.969
Sugary Drinks	−0.057	−0.072	0.943	−1.677	1.562
Snacks	0.348	1.6	0.119	−0.095	0.792

Table 5. Unadjusted and adjusted Cox proportional hazards models with time to menarche as the response variable.

Covariates	B	Hazard Ratio	Sig.	95% CI for HR	
				Lower	Upper
Unadjusted Model 1					
Food secure					
Low food security	1.478*	4.385	0.040	1.067	18.013
Very low food security	0.211	1.235	0.599	0.562	2.712
Unadjusted Model 2					
Food Insecurity Score	0.225*	1.253	0.027	1.026	1.529
Adjusted Model 1					
Food Insecurity Score	0.193	1.213	0.085	0.974	1.511
Iliac Height (cm)	−0.034	0.967	0.116	0.895	1.012
Adjusted Model 2					
Food Insecurity Score	0.136	1.146	0.19	0.934	1.405
Waist-Hip Ratio	0.054	1.055	0.093	0.991	1.124

Adjusting for iliac height and waist-hip ratio.

a positive beta coefficient indicates a greater risk of menarche compared to the control group – food secure girls. The hazard of menarche for girls with low food security (food insecure) was 4.38 times greater than the hazard of menarche for food secure girls (p = .04). However, having *very* low food insecurity did not significantly influence the risk of reaching menarche. This is likely due to the small sample size of households with very low food security. Using food insecurity scores as a continuous variable, the hazard of menarche increased by 25% for every one-unit increase in food insecurity (p = .027). Thus, food insecurity, specifically low food security, significantly predicted earlier time to menarche when assessed with no other covariates in the model.

Since waist-hip ratio and iliac height significantly correlated with age at menarche, adjusted Cox PH models including these variables along with food insecurity were tested to control for their influence. The default "enter" method was used, which enters all independent variables into the equation in one step. The results are presented in Table 6. Model 1 found neither food insecurity score nor waist-hip ratio significantly influenced the hazard of menarche when tested together. Similarly, neither food insecurity nor iliac height significantly predicted the risk of menarche in model 2. Measurements of confounding showed that both iliac height and waist-hip ratio confound the relationship between food insecurity and age at menarche in the Cox PH models (14.22% and 39.56% confounding, respectively.)

Discussion

The girls in this sample had high rates of food insecurity (53%) compared to the national average of 11.8% (Coleman-Jensen et al. 2018). While food insecure households were targeted for this study, the exceptionally high prevalence of food insecurity lends support to the vulnerability of adolescents and their

Table 6. Adjusted multivariate analyses from Cox proportional hazards models with time to menarche as the response variable.

Covariates	B	Hazard Ratio	Sig	95% CI for HR Lower	95% CI for HR Upper
Model 1					
Food Insecurity Score	0.193	1.213	0.085	0.974	1.511
Iliac Height (cm)	−0.034	0.967	0.116	0.895	1.012
Model 2					
Food Insecurity Score	0.136	1.146	0.19	0.934	1.405
Waist-Hip Ratio	0.054	1.055	0.093	0.991	1.124

Adjusting for iliac height and waist-hip ratio.

households, particularly those of minority ethnic-racial background. National studies published by the USDA show household with children over the age of nine make up 70% of food-insecure households with children (Coleman-Jensen et al. 2012, 2016). Adolescents have increased nutritional demands because of the pubertal growth spurt (Christian and Smith 2018), and they are vulnerable to social stigmas as they become more socially aware (Hamersa and Kim 2016; Popkin, Scott, and Galvez 2016; Poppendieck 2010;). These biological and social needs can put more strain on a household's resources. Furthermore, Black and Hispanic households in the U.S. make up the largest percentage of food-insecure homes (USDA 2017). This study provides further support indicating that food insecurity disproportionately affects minority groups and households with older children in the Tampa Bay region of the U.S.

The average age at menarche in this sample was more than one year earlier than the national mean age of 12.5 years (CDC n.d). There has been recent debate as to whether the secular decline in menarche age has leveled off (Finer and Philbin 2014; Herman-Giddens 2007; Papadimitriou 2016). This study shows current below-average ages at menarche among minority and food insecurity groups in urban areas of the U.S., matching previous research findings. Non-Hispanic Blacks and Hispanic girls consistently have earlier ages at menarche compared to Non-Hispanic Whites (Biro et al. 2018; Chumlea et al. 2003; Forman et al. 2013; Reagan et al. 2012; Wiley 2011). In the U.S., minority groups are more likely to have low birth weights (Caudell and Quinlan 2012; Creanga et al. 2012; Reagan et al. 2012), live in cities (Caldwell et al. 2016), and have lower socioeconomic status (Semega, Fontenot, and Kollar 2017). In this sample, approximately 30% of families were in poverty based on their household size and income. Using life history theory, these circumstances along with racism and marginalization can indicate "risk" in early life (Belsky, Schlomer, and Ellis 2012). As a response to risk, an individual may accelerate sexual maturation with the goal of "beating the odds" and reproducing before the risk becomes reality. Studies show that low birth weight may be a response to stressors in utero and can be a signal for high juvenile mortality risk (Gravlee 2009; Worthman,2003). Others document that urban residency in the

U.S. associates with earlier menarche (Amir, Jordan, and Bribiescas 2016; Odongkara et al. 2014; Song et al. 2014), which is likely due to lower socio-economics and more exposure to pollutants and crime. The fact that Blacks and Hispanics are more likely to be exposed to stressors such as food insecurity might explain why they start menarche earlier than the majority white population.

Menarche and body size/composition

The finding that iliac height positively correlated with age at menarche was expected. It has long been understood that height and leg length are reliable measures for long-term nutritional status and energetic trade-offs in childhood (Bogin 1999; Gluckman and Hanson 2006; Villamor and Jansen 2016). When sexual development begins, energy is taken away from linear growth and instead used for reproductive efforts (Worthman 2003). Thus, earlier ages at menarche are associated with shorter legs and height (Forman et al. 2013; Jansen, Herrán, and Villamor 2015; Papadimitriou 2016; Said-Mohamed et al. 2018). Although iliac height did not predict the hazard of menarche in the Cox PH model, this is likely due to the small sample size and confounding between the variables: food insecurity, iliac height, and menarche. The significant correlation between iliac height and age at menarche supports the literature indicating that stature and menarche are related.

Waist-hip ratio negatively correlated with age at menarche in this sample, indicating that larger waists compared to hips are associated with earlier menarche ages. Higher waist-hip ratios indicate more abdominal fat compared to the lower trunk region and are connected to over-nutrition and higher risk for cardiovascular disease in adulthood (Gibson 2005). Using energetics life history theory, it makes sense that excess fat would associate with earlier menarche as an individual with an abundance of energy can sustain both somatic needs as well as reproductive efforts (Ellison 2008). Kelly et al. and Barcellos Gemelli et al. documented associations between total body fat and earlier puberty among girls in the UK and Brazil (Barcellos Gemelli et al. 2016; Kelly et al. 2017). Others have found connections between earlier menarche and higher waist circumferences in Nigeria (Nwankwo, Danborno, and Hamman 2016) and upper trunk fat in Bengali (Bhadra et al. 2013). In contrast, hip circumference and lower trunk fat has also been found to correlate with earlier menarche (Bhadra et al. 2013; Nwankwo, Danborno, and Hamman 2016; Ziomkiewicz and Kozieł 2015).

Food insecurity and nutritional status

Food insecurity correlated with higher intakes of energy-dense food groups including starches, grains, and snack foods. It is well documented that food insecurity during childhood and adolescence is associated with poor nutritional status. In higher-income countries, food insecurity is connected to over-nutrition and micronutrient deficiencies from consuming high amounts of macronutrients and food with low nutritional value (Hadley and Crooks 2012). As a result, food insecurity is associated with overweight, obesity, and higher risks for adult-onset diseases (Hadley and Crooks 2012; Hanson and Connor 2014). A review by Larson and Story found 42 documentations of the co-existence of food insecurity and obesity among U.S. children (Larson and Story 2011). A study by Schlussel and colleagues found food insecure adolescents were twice as likely to be overweight when compared to food secure girls (Himmelgreen 2013). On the other hand, food insecurity has resulted in under-nutrition, growth stunting, and wasting among children in low- and middle-income countries (Cordeiro et al. 2012; Mahmudiono et al. 2018; Shamah-Levy et al. 2017). Despite its connection to energy-dense foods, food insecurity was not associated with body size or body composition in this sample. The lack of association was likely due to the small sample size and lack of variance within the data. However, it may also be that food insecurity is a more recent, rather than long-term, experience for the households in this study. As mentioned, adolescence comes with increased energetic demands in which teens need more food than younger children and adults. Therefore, household food costs may increase, or foods may run out quicker. If household food insecurity is a recent phenomenon, the girls' body size and composition may have yet to be impacted. Another proposition made by Himmelgreen (2013) is that the adolescent growth spurt may protect girls from storing as much fat compared to adults or younger children (Himmelgreen 2013). Lastly, the lack of effect on linear growth due to food insecurity could also point to recent food insecurity or to the fact that the girls might have been buffered from under-nutrition in early life by older family members or programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children. Studies demonstrate that adults, particularly female caretakers, and older siblings will often protect younger children from hunger and food insecurity (Fram et al. 2011; Frank 2015; Hadley et al. 2008).

Food insecurity and menarche

When tested alone, food insecurity significantly predicted a greater hazard of reaching menarche earlier compared to food security. While very low food security did not significantly influence the hazard of menarche, this is most likely due to the small number of participants within that category (n = 4). When including iliac height and waist-hip ratio as covariates in the multiple Cox PH models (Model 1 and Model 2), both iliac height and waist-hip ratio significantly modified the effect that food insecurity had on the risk of menarche due to confounding. Thus, future analysis is needed to control for confounding to better understanding the interrelationships of these variables within the timing of menarche.

The finding that food insecurity increases the hazard of earlier menarche contradicts those of Belachew and Jansen, which are the only other evaluations of food insecurity and menarche we are aware of. Belachew and colleagues documented a positive relationship between food insecurity and age at menarche in Ethiopia, where girls who were food insecure reached menarche one year later than their food-secure counterparts (Belachew et al. 2011). Food insecure girls in the study also had higher rates of stunting indicating long-term nutritional stress, had lower socioeconomic status, and lived in rural environments (Belachew et al. 2011). Thus, food insecurity was connected to undernutrition rather than to over-nutrition. In Colombia, Jansen and colleagues also found food insecurity and rural living associated with later ages at menarche (Jansen, Herrán, and Villamor 2015). There was not a significant association between age at menarche and low-socioeconomic status, but the researchers did find earlier menarche among the wealthiest groups and children with higher BMI and height (Jansen, Herrán, and Villamor 2015).

The findings from Ethiopia and Colombia are opposite to those from this study. There are various reasons for this including differences in food insecurity experiences between U.S. adolescents and those from developing areas. Undernutrition as a result of food insecurity means there is too little energy to sustain somatic maintenance and growth as well as reproduction. Therefore, menarche is delayed. However, food insecurity in this sample associated with energy-dense food consumption. Although we do not know if food insecurity associated with more calories overall, it is unlikely that the girls were experiencing undernutrition as most of the sample was overweight.

In this sample, menarche was not associated with diet. Again, this could be due to the small sample, or it could be a result of not capturing daily caloric intake. Instead, daily consumption habits and dietary quality were measured, and the variation in diet was minimal for the sample. Since menarche was not associated with diet, and food insecurity did not associate with body size or composition, it may be that the avenue of effect that food insecurity has on the risk of menarche is through psychosocial stress. Studies show that psychosocial stress in childhood, including unpredictability, instability, conflict, and low socioeconomic status, is associated with earlier ages at menarche (Belsky et al. 2007, 2010; Deardorff et al. 2014; Ellis and Garber 2000; Kelly et al. 2017; Richardson, La Guardia, and Klay 2018; Simpson et al. 2012). Food insecurity causes unpredictability, unstable food access, worry, anxiety, shame, and stigma (Connell et al. 2005; Poppendieck 2010). These stressors can signal "risk" of danger, induce energetic tradeoffs, and influence the timing of life history traits such as menarche (Belsky et al. 2007; Chisholm et al. 1993). When experienced before the age of five, psychosocial stress indicates juvenile mortality risk

(Belsky, Schlomer, and Ellis 2012). Once an individual survives the risk, they may experience accelerated maturation in order to reproduce earlier and longer with the goal that some offspring will too survive the early life risk (Belsky, Schlomer, and Ellis 2012; Chisholm et al. 1993; Ellis et al. 2009). Food insecurity may be just one of many psychosocial stressors the girls in our sample face, as most of them are of low economic status, Black or Hispanic, and live in inner-city environments.

Implications

Despite its limitations, this study is the first to anthropologically assess the association between food insecurity and age at menarche in the United States. In addition, it documents food insecurity among adolescents, a group that is largely missing from food insecurity research. Accordingly, this study hopes to begin and add to the conversation of the importance of nutrition during the critical life period of puberty and the effect of food insecurity on the development and experiences of adolescents. Because food insecurity experiences vary based on geographical context, and life history events such as menarche are highly influenced by environment and experiences, comparative analyses are vital to understand the determinants of menarche, the consequences of food insecurity, and ultimately the determinants of health disparities among various populations. Food Insecurity and early menarche are both associated with health consequences, many of which are the same. Food insecurity during childhood can cause obesity, growth stunting, and cognitive delays, and can increase the risk for adult-onset diseases such as type-2 diabetes, hypertension, and cardiovascular disease (Cook and Frank 2008; Hadley and Crooks 2012; Leung et al. 2015). Similarly, early onset of puberty is associated with obesity, growth stunting, adult-onset asthma, cancers, type-2 diabetes, hypertension, cardiovascular disease, depression, and risky behaviors (Allsworth, Weitzen, and Boardman 2005; Benson and Jatoi 2012; Frontini, Srinivasan, and Berenson 2003; Kaltiala-Heino et al. 2003; Remsberg et al. 2005; Vaughan et al. 2015; Villamor and Jansen 2016; Werneck et al. 2018). It is important to understand how food insecurity influences growth and development beyond the first five years of life so that food security initiatives may be successful for preventive health.

There are many limitations to this research. Adolescents are documented as a hard-to-reach population (Mathews et al. 2015; Sterzing, Gartner, and McGeough 2018) and the research topic was sensitive. Thus, the sample size is small for a study on human biology. Although nonparametric measurements were used, the small and nonrandom sample does not allow us to generalize the larger community or population. Future research should build collaborations with local schools or health clinics and utilize national datasets to obtain more reliable results. Convenience sampling was also problematic, in that it heightened the probability of exposure to food insecurity. Furthermore, this study does not account for environmental influences such as endocrine-disrupting chemical exposure or perceived stress, both of which can influence the timing of menarche. Further studies should also obtain caloric intake estimates so that energetics can be better tested. Lastly, there is room for error due to using recalled data for menarche date and diet, particularly if girls reached menarche more than one year prior. A longitudinal approach that captures food insecurity at the time of menarche, and documents the specific date of menarche, would provide more reliable data.

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Author contributions

MB designed the study under the direction and advisement of DH, NRD, and EM. MB implemented the research, data collection, and analyses. EM provided support for statistical analyses. MB drafted the manuscript, and DH, NRD, and EM edited the manuscript and provided critical feedback on the content.

Conflict of interest

The authors declare no conflicts of interest.

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