The Association between Household Food Insecurity and Body Mass Index: A Prospective Growth-Curve Analysis

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Short Title: Household Food Insecurity and Body Mass Index

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Abstract

Objective: To examine the co-occurring association between FI and body mass index (BMI) from early adolescence to adulthood, growth curve analyses were used. Gender differences were examined by conducting the analysis separately by gender.

Study Design: Ten data points over a 16-year period were examined from age 15 to 31 years. Data came from the Family Transitions Project, a longitudinal study of 559 adolescents and their families that began in 1989 in the Midwest. Primarily rural, non-Hispanic whites were selected based on the economic farm crisis. We examined participants from adolescence to adulthood from 1991 through 2007. Measures included a two-item FI construct and BMI as indicated by self-reported height and weight from adolescence through middle adulthood. These associations were analyzed using prospective growth curve modeling.

Results: Analyses indicated a general increase in BMI with age, whereas FI declined over time. Higher levels of FI when youth were 15 years led to a faster increase in BMI. Finally, a positive relation was found between the change in FI and BMI over time. These associations held only for females.

Conclusion: Results argue for increasing access to food during key developmental periods such as early adolescence, which could help reduce the long-term implications for health, particularly BMI in girls.

Obesity is a major public health concern in the U.S. with approximately 1-in-3 youth overweight or obese, and significantly heavier than previous generations [1]. Being overweight or obese during the adolescent years increases the risk of adulthood diseases, including cardiovascular and heart disease, diabetes, stroke, cancer, and osteoarthritis [2]. Consequences of obesity for immediate [3,4,5,6] and long-term [6,7] negative biopsychosocial health outcomes have been well-documented. While genetic and biological factors have consistently been shown to be central to whether someone is obese [8,9,10], environmental factors such as the built environment [11,12,13], low levels of physical activity and the family environments matter as well [14,15,16,17]. Understanding the pathways to obesity is critical for implementation of successful prevention and intervention programs.

Food Insecurity

One pathway leading to obesity within the family is the ability to provide food. Due to the influence of economic factors on nutritional practices food insecurity (FI) defines living in a household that does not have the financial means to access enough food to sustain active, healthy living for all members [18]. Sixteen percent of adolescents live in a FI household in the U.S., with twice as many youth whose families live with incomes below 185 percent of the poverty threshold suffering from FI (32%) than those above the poverty threshold [19]. Inadequate amounts of food have multiple implications for children and adult's biopsychosocial functioning [20,21,22,23,24].

FI and Obesity

Growing up in an FI household has been linked to obesity or a higher BMI but not consistently. Within this often inconsistent literature some studies have found a positive association between FI and overweight or obesity [25,26]. Interestingly, studies have shown food

insecure women had a higher BMI than food secure women, but not in men [27,28]. Others have found positive [29], inverse [30], and no relationship [31, 32]. Studies finding no relation are consistent with a broader literature showing no association between FI and nutritional outcomes [33]. Much of this work was cross-sectional and studies have yet to explore whether FI during adolescence leads to obesity or increases in BMI into adulthood [34,35].

The Present Investigation

The current study examines the co-occurring association between FI and BMI from early adolescence to adulthood. Additionally, we extend previous literature with the current cohort and FI by providing a more sophisticated analysis of the relationships between food insecurity and BMI from adolescence into adulthood. Ten data points over a 16-year period were examined from age 15 to 31 years. This study is the first to examine these associations using a prospective growth-curve analysis. Differences in these associations by gender were examined, with an expectation that FI may have a greater impact on females' BMI than it does for males' [36,37,38,39]. In short, **three research questions** were addressed: (1) Is there a longitudinal association between FI & BMI?; (2) What is the direction of this longitudinal association?; and (3) Are there gender differences in this association?

Methods

Sample

Data were drawn from the Family Transitions Project (FTP), a longitudinal study of 559 youth and their families. The FTP represents an extension of two earlier studies: The Iowa Youth and Families Project (IYFP) and the Iowa Single Parent Project (ISPP). In the IYFP, data from the family of origin (N=451) were collected annually from 1989 through 1992. Participants included the adolescent, their parents, and a sibling within 4 years of age of the adolescent.

These families were originally recruited for a study of family economic stress in the rural Midwest. When interviewed in 1989, the adolescent was in seventh grade (*M* age = 12.7 years). Families were recruited from schools in eight rural counties. Due to the rural nature of the sample there were few minority families (approximately 1%); therefore, all participants were Caucasian. Seventy-eight percent of eligible families agreed to participate in the study. Families were primarily lower middle- or middle-class with thirty-four percent residing on farms, 12% living in nonfarm rural areas, and 54% living in towns with fewer than 6,500 residents. In 1989, parents averaged 13 years of schooling and had a median family income of $33,700. Fathers' average age was 40 years, while mothers' average age was 38 years.

The ISPP began in 1991 when the adolescent was in 9th grade (*M* age = 14.8 years), the same year of school as the IYFP youth. Participants included the adolescents, their single-parent mothers, and a sibling (N=108). Families were headed by a mother who had experienced divorce within two years prior to the start of the study. Participants were Caucasian, primarily lower middle- or middle-class, one-parent families that lived in the same general geographic area as the IYFP families. In 1994, families from the ISPP were combined with families from the IYFP to create the Family Transitions Project. Measures and procedures for the IYFP and ISPP studies were identical. At that time adolescents from both studies were in 12th grade. In 1994, youth participated in the study with their parents as they had during their earlier years of adolescence. Beginning in 1995, the adolescent (1 year after completion of high school) participated in the study with a romantic partner. In 1997, the study was expanded to include the first-born child of the adolescent, now a young adult.

The present study includes all youth (N=559) who participated from middle adolescence through middle adulthood. Out of the 559 adolescents, 451 came from two-parent households.

The data were collected at ten developmental time points. The time points included when the adolescent was 15 years old (1991), 16 years old (1992), and 18 years old (1994). In adulthood, the time points were when he/she was 19 years old (1995), 21 years old (1997), 23 years old (1999), 25 years old (2001), 27 years old (2003), 29 years old (2005), and 31 years old (2007).

Procedure

Family members participated in annual interviews that included a range of measures, including self-reports of individual behaviors and family functioning. Parents reported on their household FI until the adolescent was 18 years of age; adolescents then reported on their own household FI through adulthood. Adolescents reported on their height and weight which were converted into BMI. Maternal and paternal BMI, education level, as well as family income, and nutritional practices assessed when the adolescent was 15 years of age were used as controls.

Throughout the youth's adolescence (1991-1994), all families of origin were visited in their homes each year by a trained interviewer. Visits lasted approximately two hours and financial incentives were provided for participation. From 1995 through 2007, each young adult, their romantic partner, and their first-born child were visited in their home each year by a trained interviewer. During the visit, the adult and his/her romantic partner completed a number of questionnaires, some of which included measures of health and individual characteristics.

Measures

Body Mass Index (BMI) was assessed through self-reported height and weight from adolescence through middle adulthood (1991-2007). Body mass index (BMI) was calculated using the standard CDC formula [40].

Household Food Insecurity. FI was assessed through mother and father reports when the adolescent was 15 to 18 years old (1991-1994). From ages 19-31 years (1995-2007), FI was

assessed through the young adult's self-report. This measure consisted of two items [36] which align with the 18-item Core Food Security Module (CFSM) used by the USDA in the calculation of official FI rates in the United States [41]. These items have similar response patterns in multiple data sets including the 2004 Current Population Survey [32]. The first question asked if each respondent had enough money to afford the food he/she should have (1=strongly agree to 5=strongly disagree). This item was recoded to (1) yes, more food insecure (answered 4 or 5) and (0) no, less food insecure (answered 1, 2, or 3). The second item asked if the respondent had changed food shopping or eating habits to save money; (1) yes or (0) no. Responses to the items were averaged together to create a total FI score that ranged from (0) no FI to (2) high FI. During adolescence both mother and father responses to the above two items were averaged to create a family FI score that ranged from (0) no FI to (2) FI. Young adults self-report of the two items were used from age 19 to 31 years.

Covariates

Gender. Adolescent gender was coded as (0) female and (1) male.

Adolescent Nutrition Practices. Adolescents reported how often they ate three balanced meals per day when they were 16 years old (1992). Responses ranged from 1 = always to 5 = never. Responses were coded in order to reflect a high level of nutrition.

Adolescent Exercise Practices. Adolescents reported how often they got physical exercise at school, on the job, or in a recreational activity when they were 16 years old (1992). Responses ranged from 1 = regularly to 4 = never. Responses were coded in order to reflect a high level of physical exercise.

Family of Origin per Capita Income. Total annual household income in the past 12 months (1991 dollars) was divided by the number of people in the household, representing the amount of financial resources available for each member of the family.

Parental Education Level. Mothers and fathers reported their highest level of education completed in 1991, which ranged from 9th grade to a master's degree and above.

Parental BMI. Mothers and fathers' BMI was assessed through self-report in 1991 when the adolescent was 15 years old. Body mass index (BMI) was calculated using the standard CDC formula [40].

Analytic Plan

Data were analyzed using M*plus* version 7 with Full Information Maximum Likelihood (FIML) estimation to handle missing data. It should be noted that these models treated time of assessment as a random variable, as reflected by the actual date of the interview; the date of the interview of the adolescent at age 15 was set at zero and the time of the other assessments reflected the difference in years from the age 15 interview. Because M*plus* does not provide standardized results for growth curve models, the values were calculated by hand. A significance value of 0.05 was used in the analysis of study results. All covariates were included in the models and a brief summary is presented below. To ensure results were not affected by different scoring of BMI, sensitivity analyses were conducted for BMI for those under 18 years of age and over 18 years of age; results were similar across the two analyses.

Results

Descriptive statistics for all study constructs are provided in Table 1. General trend analyses for the sample as a whole indicated an increase in BMI with age, whereas FI declined over

time. Results from the 16-year prospective growth-curve analyses are presented by each research question below.

Research Question 1: **Is there a longitudinal association between FI & BMI?**

As shown in **Figure 1,** we hypothesized that FI would predict changes in BMI over time and the random time structural equation model showed the model fit the data well (BIC =43396.45; N=559). We calculated the correlations and covariance among initial level of BMI and FI scores (intercept) and changes in BMI and FI over time (slope). The initial level of FI positively predicted change in BMI across waves (β=.21, $p < .05$), indicating that adolescents with higher FI at age 15 had faster increases in BMI over time. The initial level of BMI failed to predict changes in BMI (β=-.11, $p > .05$), indicating that adolescents' initial BMI is an independent entity in relation with their rate of change in BMI scores across times. Changes in FI over time strongly predicted changes in BMI over time (β=.29, $p < .05$), indicating that if individuals showed a faster increase in FI over time, they also showed a faster increase in BMI across waves. In addition, the initial level of FI was related to changes in FI scores across waves (β=-.63, $p < .001$), meaning that if individuals had higher rates of FI at age 15 they showed a slower increase in FI across waves. There was not a significant relationship between the initial levels of FI and BMI (β=.00, $p > .1$).

Research Question 2: **What is the nature or direction of the longitudinal relationship between FI & BMI?**

Even though we hypothesized that FI would predict changes in BMI over time, we were interested in the direction of the relationship, including reciprocity, between FI and BMI. Assessing the direction of relationship was critical for us in understanding whether FI predicted BMI or BMI predicted FI. Two models were tested to address this research question. Both were

time lagged models with the first using FI to predict subsequent BMI whereas the second model used BMI to predict subsequent FI.

FI Predicting BMI. Our original hypothesis was that FI would predict the subsequent level of BMI at the next wave of assessment. For this lagged analysis FI was from age 15 to 29 whereas BMI was from age 16 to 31. The FI lagged prediction model showed a reasonable fit to the data (BIC=40775.88; N=559) The initial level of FI at age 15 predicted change in BMI across waves (β=.25, $p < .01$), indicating that adolescents from families with higher FI at age 15 had faster increases in BMI from age 16 to 31. Change in FI across waves also significantly predicted changes in BMI across waves (β=.23, $p < .05$), indicating that if adolescents showed a faster increase of FI from age 15 to 29 they were more likely to show a faster increase of BMI from age 16 to 31.

BMI Predicting FI. Next, we examined whether BMI would predict subsequent FI in the next wave of assessment. FI lagged by one wave relative to BMI where FI assessments started from age 16 to 31 whereas BMI assessments were from age 15 to 29. The BMI lagged prediction model showed a reasonable fit to the data (BIC=40668.60: N =559). The initial level of BMI failed to predict change in BMI (β=-.01), meaning that adolescents' initial BMI is not related with their rate of change in BMI scores from age 16 to 31. Change in BMI across also did not significantly predict changes in FI across waves (β=.11), indicating that the rate of increase in BMI from age 15 to 29 was unrelated to the rate of increase in FI from age 16 to 31.

***Research Question 3*: Are there gender differences in the relationship between FI & BMI?**

Since we know that BMI is strongly related to gender [37,38,39,40], we ran models separately for females and males. Coefficients for both models are shown in **Figure 2**.

Females. The model for females (N=293) showed a reasonable fit to the data (BIC=25021.68). Initial level of FI predicted change in BMI across waves in a positive direction (β=.26, $p < .001$), indicating females with higher FI at age 15 had faster increases in BMI. The initial level of BMI, however, failed to predict change in BMI across waves. Changes in FI across waves strongly predicted changes in BMI over time (β=.38, $p < .001$), indicating that if females showed a faster increase in FI across waves they also showed a faster increase in BMI. In addition, the initial level of FI was related to changes in FI scores across waves (β=-.64, $p < .001$), indicating that females came from families where their parents reported a higher FI at age 15 reported a slower increase in FI over time. Finally, there was a non-significant association between the initial levels of FI and BMI.

Males. The structural equation model for males (N=263) showed a reasonable fit to the data (BIC= 19816.48). The initial level of FI did not predict changes in BMI across waves (β= .04, $p > .1$). The initial level of BMI predicted changes in BMI across waves (β = -.24, $p < .001$), indicating that males with higher levels of BMI at age 15 had slower rates of change in BMI across waves. Changes in FI across time failed to predict changes in BMI across waves (β=-.06, $p > .1$). However, the initial level of FI was related to changes in FI across waves (β=-.62, $p < .001$), indicating that if males came from families where the parents reported higher FI at age 15 they reported a slower increase in FI over time. As was true for females there was a non-significant correlation between the initial levels of FI and BMI.

Covariates. In general, across all of the models we found that maternal BMI was positively associated with changes in BMI over time while adolescent nutrition practices, adolescent exercise practices, family of origin per capita income, maternal and paternal education and paternal BMI were not consistently related to changes in BMI over time.

Discussion

The Association between FI, BMI and Gender from Early Adolescence to Adulthood

In this study, we found a general increase in BMI with age, whereas FI declined over time. There was a negative association between initial BMI and the linear change in BMI from age 15 to 31. Similarly, initial FI was negatively related to change in FI over time. As expected higher levels of FI when the youth were 15 led to a faster rate of increase in BMI over the subsequent 16-year period. Finally, a positive relation was found between the change in FI and BMI over time; these associations held for females but not males.

Overall, these findings extend previous research on understanding the associations between FI and BMI over time. We extended previous research by completing a more rigorous test of the association between FI and BMI using prospective data over a 16-year period by measuring FI across 10 data points from early adolescence into adulthood analyzed with a prospective growth curve model. Thus, we were able to not only test the longitudinal relationships between these constructs but also the direction of these relationships. It is important to note why FI may influence BMI trajectories for females but not males. Some have suggested this may be the result of environmental conditions or differential perceptions and behaviors surrounding FI. For example, research has shown that women may be more likely to report FI than men in adulthood and often times, women who are FI are the heads of their household with children [42]. However, in the current study, FI was measured from both mother's and father's report during adolescence and self-report during young adulthood; in addition, it represented FI across 10 different time points over 16 years. This represents a more accurate picture of long-term FI, compared with measuring FI at one point in time. Future research must assess how FI varies over time for individuals and how different patterns of FI (e.g., stable, increasing, decreasing) may

influence BMI trajectories from adolescence (i.e., family of origin household FI) into adulthood (i.e., family of procreation household FI). Research should also explore factors that may influence patterns of FI over time such as moving out of your family of origin household, graduation from high school or college, transitions into full-time employment as a young adult, marriage, or parenthood. Beyond these key environmental or developmental transitions mentioned above, basic biological differences between the sexes may also explain our gendered results. Indeed, Power and Schulkin [43] suggest men and women have different pathways to obesity, likely due to different metabolic functioning. Female brains are more sensitive to levels of leptin, whereas male brains are more sensitive to levels of insulin [43]. In addition, men and women deposit, carry, and use fat differently [43]. The differential patterns of adiposity and metabolic functioning may have evolved in humans because of asymmetrical reproductive demands of males and females [43].

Ultimately, these results suggest that experiencing FI during early adolescence impacts an adolescents' rate of change in BMI into adulthood, particularly for females. Specifically pertaining to Research Question 2, these results do not support a reciprocal association as our assertion that FI leads to increases in BMI over time was supported. Policy makers, health professionals and researchers must consider the long-term impact that experiencing FI during an important developmental period, early adolescence, can have on weight gain throughout adulthood when creating intervention and prevention programs aimed at reducing U.S. obesity and FI rates.

Limitations. There are limitations to this study that should be addressed. First, BMI was calculated from self-reported height and weight of the adolescent, with different calculations based on age. This should not significantly bias the results, as individuals who are obese tend to

overestimate their height, particularly at older ages, and understate their weight, particularly in young women [44, 45]. In sum, BMI scores that are adjusted for socio-demographic characteristics, tend to narrow, but are nonetheless under-reported [45]. As well, to ensure results were not affected by different scoring of BMI, sensitivity analyses were conducted for BMI under 18 years of age and over 18 years of age; results were similar across the two analyses. Second, we do not have the full set of USDA FI questions to test varying amounts of FI. Yet these two items have been found to have consistent predictive validity [37]. Thirdly, these data could be considered dated, and although FI was not measured by the U.S. Census Bureau until 1995 [46], FI and BMI rates are similar in the US population during the timeline of the current study, as the prevalence of obesity has increased among adult men and women between 1980-2000, whereas between 2005-2014, the prevalence of overall obesity and extreme obesity increased among women but not men [19, 47]. Adolescents aged 12-19 have steadily increased rates of obesity since 1965 [47]. Additionally, in 1990, no states had an obesity prevalence equal to or greater than 15%, but by 2010, thirty-six states had a prevalence equal to or greater than 25%, including Iowa [48]. In 2000, at least 20% of adults in Iowa, and in 2007, between 25 and 29% of Iowans were obese [48]. Finally, the sample was limited in terms of ethnic and racial diversity, as well as geographic location. Future research using more diverse samples is needed. However, models of economic stress with this sample have been extended to other studies using diverse ethnic samples [49].

Conclusion

More broadly, this study contributes to an understanding of the interplay between social and economic circumstances in the family, and the differential developmental pathways leading to increasing BMI trajectories, particularly in females. These results argue for preventive measures

such as increasing access to food during key developmental periods such as early adolescence. Addressing FI during this key developmental period when youth's bodies are rapidly growing and changing during puberty, could help reduce the long-term implications for health, particularly BMI in girls.

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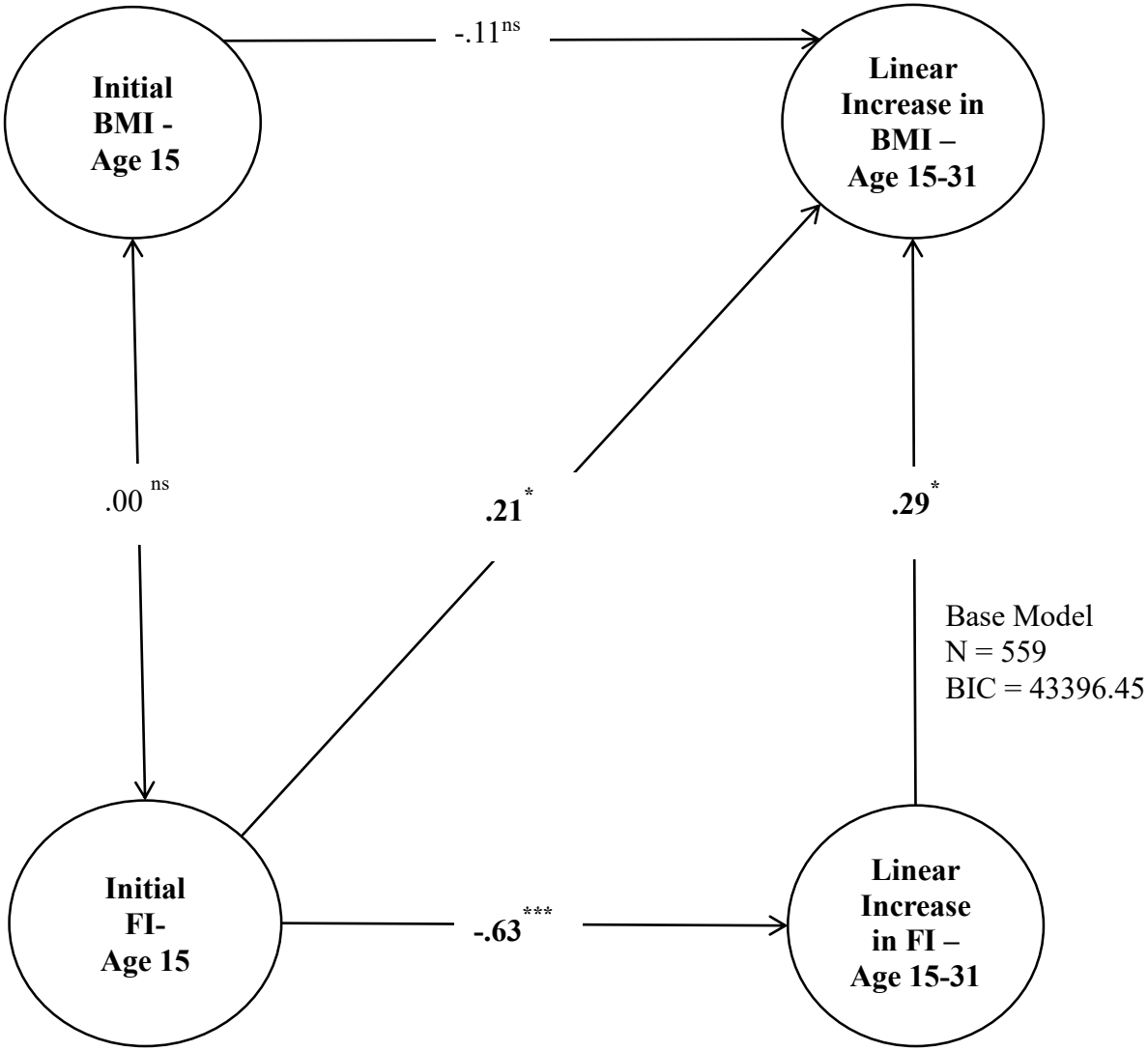
Table 1. Descriptive statistics (*n*=559)

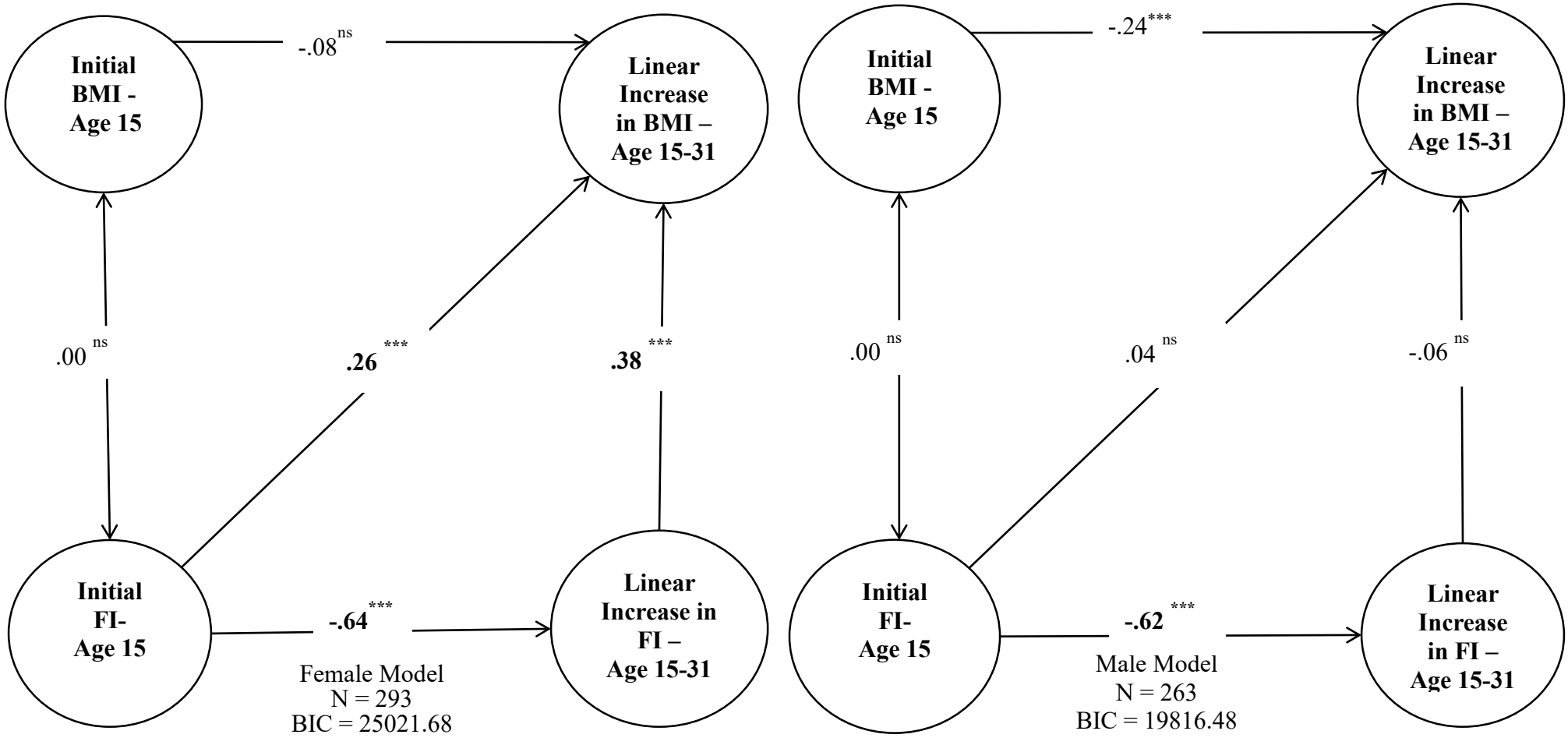
	Body Mass Index		*Food Insecurity*	
	Mean	*SD*	*Mean*	*SD*
15 yrs	21.32	3.52	0.41	0.48
16 yrs	21.93	3.76	0.38	0.48
18 yrs	22.96	4.04	0.29	0.43
19 yrs	23.73	4.30	0.28	0.50
21 yrs	24.45	4.87	0.36	0.56
23 yrs	25.64	5.43	0.29	0.47
25 yrs	26.29	5.87	0.32	0.53
27 yrs	26.75	6.13	0.33	0.54
29 yrs	27.30	6.63	0.34	0.52
31 yrs	27.92	6.79	0.33	0.52
Covariates From Early Adolescence, Age 15 & 16 Years				
	Mean	*SD*	Range	
Family Per Capita Income	8.44	7.28	-39.25 – 60.70	
Gender, Male = 1[1]	0.48	0.50	0 – 1	
Maternal Age[1]	40.11	3.97	31.17 – 55.37	
Maternal BMI[1]	21.48	4.00	13.73 – 42.51	
Paternal BMI[1]	21.06	3.62	12.41 – 38.73	
Maternal Education Level[1]	13.29	1.69	8 – 19	
Paternal Education Level[1]	13.55	2.13	7 – 20	
Adolescent Exercise Practices[2]	1.37	0.62	1 – 4	
Adolescent Nutrition Practices[2]	2.68	1.17	1 – 5	

Figure 1. Statistical parameters pertaining to Research Question 1: Longitudinal associations between BMI and FI



Note. Standardized beta coefficients are reported: $p < .05$*, $p < .001$***.

Figure 2. Statistical parameters pertaining to Research Question 3: Gender differences in the relationship between FI and BMI



Note. Standardized beta coefficients are reported: $p < .05$*, $p < .001$***.