A Conceptual Model of Body Mass Index Assimilation

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Abstract

This article proposes a conceptual model of Body Mass Index (BMI) assimilation that links global nutrition patterns to the levels and socioeconomic variations in BMI among newly arrived immigrants and their children, and conceptualizes assimilation as occurring within socioeconomic strata. This approach leads to the expectation that overweight is likely to be positively associated with generation among those from low income countries (as measured by GDP/capita) with low socioeconomic status but negatively associated among those from low income countries with high socioeconomic status. The article next presents as an empirical example an analysis of generational patterns in BMI among children from kindergarten through fifth grade. Using data from the Kindergarten cohort of the Early Childhood Longitudinal Survey (N = 16,664 children), the research estimated growth curve models and tested the significance of interaction terms among parental generational status (i.e., children of immigrants who arrived ages 0-11, children of immigrants who arrived ages 12+, and children of natives), socioeconomic status, and country-of-origin GDP/capita. The results pertaining to changes in BMI, but not baseline BMI (at age 5.5), were consistent with the conceptual model's predictions. Possible explanations for the discrepancy, including factors that may be missing from the conceptual model, are discussed.

A Conceptual Model of Body Mass Index Assimilation

In the United States, overweight appears to increase among immigrants with increasing exposure to U.S. society. For example, overweight and obesity among adults is positively associated with years of U.S. residence (Antecol & Bedard 2006). Among adolescents, the likelihood of being overweight is higher for U.S.-born than foreign-born children (Popkin & Udry, 1998; Gordon-Larsen et al., 2003). Findings such as these tend to be interpreted through the lens of assimilation theory. Assimilation is a social process that results in the decline of ethnic distinctiveness (Alba & Nee, 1997). While classic assimilation theories predict convergence toward the American middle-class for immigrant families (Alba & Nee, 2003), others—such as the segmented assimilation perspective—emphasize variability in the process whereby only some groups experience better outcomes over time (Portes & Zhou, 1993). The literature on immigrant health has drawn upon another application of assimilation theory that emphasizes worsening outcomes for immigrants over time —the negative assimilation model (Hummer et al. 1999; Landale et al., 1999; Rumbaut &Weeks, 1989; Amaro & de la Torre, 2002). The major hypothesis as it relates to overweight and obesity is that exposure to the American environment (e.g. fast food industry and advertising, availability of cheap, pre-packaged food, reliance on cars) leads to the "Americanization" of health behaviors involving diet and exercise and, in turn, overweight and obesity (Blumenthal, 2002; Carter, 2002; Fried & Nestle, 2002).

However, irregularities in research findings cast doubt on the idea that duration in the country or acculturation (i.e., a dimension of assimilation involving the decline of ethnic cultural distinctiveness) increases the likelihood of being overweight. First, Gordon-Larsen et al. (2003) do not find a significant positive relationship between generational status and overweight among Mexican-origin adolescents. If there really is a direct relationship between acculturation and obesity, it is puzzling why it would not be clearly evident among the single largest national origin group. Second, when more direct indicators of acculturation are employed (e.g., an acculturation scale or language usage), the linkage between acculturation and body mass index (BMI) grows murky. For example, Ariza, et al. (2004) found no significant relationship between acculturation and overweight risk factors in Hispanic children ages 5 and 6. Similarly, in some studies of adults, less acculturated persons appear to be more likely to be overweight. Spanish speakers are more likely to be overweight than English speakers among Hispanic women in general (Khan, Sobal & Martorell, 1997), and within the second generation in particular (Sundquist & Winkleby, 2000). Further evidence suggests that among overweight women, less acculturated women are less likely to view their weight as a health problem than more acculturated women (Arcia et al., 2001).

One possible reason for the inconclusive findings is that patterns by duration in the country vary across groups. By lumping together groups that follow different trajectories, researchers may be unable to identify the circumstances in which increased exposure to the U.S. is associated with healthy versus unhealthy outcomes. In addition, as noted by Arcia et al. (2001), "the current understanding that acculturation is a process with substantial variability has not led to an examination of the factors that may explain that variability." Thus, in this paper we introduce a new conceptual model that identifies potential factors affecting the relationship between duration of U.S. residence and body mass index (BMI). Following the exposition of the model, we present an empirical example in which we examine variations in the relationship between duration in the country and BMI among children of U.S. immigrants in middle childhood.

A Model of Body Mass Index Assimilation

The starting point of our argument is that newly-arrived immigrants are likely to carry with them the prevailing lifestyle patterns occurring in the places and social strata from which they originate, and that the "nutrition transition" model provides a framework for predicting what these patterns are likely to be. Described by Popkin and his colleagues (Popkin et al. 1994, 2002; Popkin & Gordon-Larsen, 2004), the nutrition transition is a world-wide historical process occurring over the past two decades involving shifts in food consumption and physical activity patterns. In earlier stages of the transition, diets tend to consist of starchy, low variety, low fat, and high fiber foods, and work tends to be physically intensive.

Obesity is generally rare and positively associated with higher socioeconomic status. But as the production of goods and food becomes more mechanized, lifestyles become more sedentary and the availability and consumption of sugar, fat, and processed foods increases, thus leading to higher prevalence of degenerative disease and disability, including obesity. In the final stage of the transition, behavioral changes in diet and exercise begin to reverse the negative effects of lifestyles associated with modern life. This is more likely to occur for those with higher socioeconomic status who have greater access to preventative health care, high quality foods, and safe places to exercise. Overall, as the nutrition transition proceeds, overweight is expected to increase with economic development and shift from disproportionately affecting the upper/middle class to being a disease of the poor.

The nutrition transition model is supported by research showing a positive relationship between obesity and the level of economic development or urbanization of a country (Popkin & Gordon-Larsen, 2004). Among children, the percentage of children who are overweight has increased in several less developed countries[1], including Brazil (from 4.2 to 14.1% between 1974 and 1997) and China (from 6.4 to 7.7% between 1991 and 1997). Accompanying these changes are changes in diet and activity levels. Consumption of caloric sweeteners (such as sugar and corn syrup) is associated with increases with GNP/capita, urbanization, and tourist-based economic development (Drewnowski & Popkin, 1997; Leatherman & Goodman, 2005), and children's activity levels tend to decline as TV ownership increases and children are less likely to be involved in household work (Popkin & Gordon-Larsen, 2004).

The nutrition transition model is further supported by research showing that the obesity burden shifts toward the poor as economic level of development increases (Monteiro, Moura, Conde, & Popkin, 2004; Monteiro, Conde, Lu, & Popkin, 2004; Sobal & Stunkard, 1989). Among women, the relationship between SES and obesity flips from positive to negative around $2,500 GNP per capita. Less research has been conducted on the nutrition transition among children, but existing evidence is consistent with the results about women. In less developed countries, higher socioeconomic status tends to be associated with higher BMIs (Wang, 2001; Sobal & Stunkard, 1989; Leiberman, 2003; Melgar-Quinonez & Kaiser, 2004). For example, in a study of over 10,000 school-aged Mexican children ages 5-11, Hernandez et al.

(2003) found that children of mothers with no schooling were half as likely to be overweight as children of mothers with middle school or high school education. In contrast, socioeconomic status is strongly negatively related to overweight/obesity in the United States and other more developed countries (Sobal & Stunkard, 1989).

We argue that the levels of BMI or overweight among immigrants—especially newly-arrived immigrants—are likely to mirror those within their social strata in their countries of origin. This means that the level of economic development of newly-arrived immigrants' countries of origin is likely to be positively associated with BMI, and negatively associated with the relationship between SES and BMI. "Newly-arrived" could be defined as having moved to the U.S. within the last 5-10 years (as is done in some research on wages). However, because assimilation is theorized to occur in steps across generations as the children and grandchildren of immigrants are socialized in the new country (e.g., Alba & Nee 2003), a more meaningful definition of "newly-arrived" in some applications is having been socialized as a child primarily in the country of origin. Thus immigration scholars commonly make distinctions between the 1.0 generation (foreign born who arrived after some cut-off age such as 6, 12, or 15) and the 1.5 generation (foreign born who arrived at younger ages) (Rumbaut, 1994; Portes & Rumbaut, 1997; Portes & Zhou, 1993). In our empirical example here, we use the latter definition (with the "1.0" generation defined as "newly-arrived"), but we suspect that the model would be supported to some degree no matter what definition were used. We sketch out our expectations for newly-arrived immigrants to the United States in Figure 1a. Among immigrants from more developed countries (i.e., with levels of economic development similar to the U.S.), socioeconomic status is likely to be negatively associated with BMI, as it is for many groups in the U.S. (depicted by the solid line in Figure 1a). However, the pattern is likely to be the reverse among immigrants from less developed countries, among whom socioeconomic status is likely to be positively associated with BMI (depicted by the dotted line in Figure 1a). Although the diagram shows the two lines crossing, we have no theoretical basis for predicting a cross-over. The key point is that the slopes are likely to flip from positive to negative as the level of economic development of the country of origin increases.

We further argue that the association of BMI with duration in the country is likely to depend on immigrants' socioeconomic status. Again, although duration in the country could be measured in years an immigrant has lived in the U.S., assimilation historically has been a slow multi-generational process (Alba & Nee, 2003). Thus an alternative measure is the number of generations a persons' family has lived in the country, e.g. with immigrants making up the first generation (including the "1.0" and "1.5" generations), their children comprising the second, and their grandchildren the third. The idea that generation or duration in the country may be associated with a variety of patterns was emphasized initially by the segmented assimilation framework (Portes & Zhou, 1993), but also has been incorporated into new institutional theories of assimilation (Alba & Nee, 2003). In contrast to the negative assimilation model, these perspectives stress that assimilation processes vary across groups depending on norms in immigrants' countries of origin, the level of resources immigrant groups possess when they arrive in their new country, and the social and economic contexts of reception (Portes and Zhou, 1993; Bean & Stevens, 2003; Portes & Rumbaut, 2001; Alba & Nee, 2003). Different groups may thus assimilate into different social strata, whether it be the relatively healthy lifestyle of the upper-middle class or the relatively inactive lifestyle and high-fat, low nutrition diet that characterizes many of the poor in the United States. This implies that generation or duration in the country is likely associated with convergence in BMI with natives of the same social strata. Because overweight and obesity tend to be concentrated among the poor in the U.S., lower SES groups are expected to assimilate toward higher BMI levels than are higher SES groups.

When combined with the predictions for newly-arrived immigrants, this insight has some interesting implications. Among those from more developed countries, generation might not be strongly associated with BMI because both country of origin and destination are at similar stages of the nutrition transition. In both the country of origin and in the U.S., overweight is likely to be relatively more prevalent and concentrated among the poor. However, among immigrants from less developed countries (that are in earlier stages of the nutrition transition than the U.S.), generation might be associated with a reversal in the relationship between SES and BMI (from positive to negative sloping) as groups assimilate toward lifestyles that are most common within their socioeconomic strata in the United States. Thus as we illustrate in Figure 1b, among those with low socioeconomic status, BMI is likely to be low among new arrivals (Figure 1b, point A), but higher among other immigrants or the second generation (point B) as the group assimilates toward U.S. native lower-class lifestyles (point C). On the other hand, BMI may be negatively associated with generation among higher-SES immigrants from less developed countries; this group is expected to exhibit relatively high BMIs among new arrivals (point D) but lower levels among other immigrants or the second generation (point E), who are likely to be more assimilated toward U.S. native upper-class lifestyles (point F).

An Empirical Example

We next present an empirical example that examines variations in the generational association with BMI from kindergarten through fifth grade. Most large-scale studies on obesity among immigrant children have focused on adolescents (Gordon-Larson et al., 2003; Popkin & Udry, 1998), rather than younger children. One study examined BMI and weight gain among children in Vienna, finding that immigrant children had higher BMIs than their European classmates (Kirchengast et al., 2006). Studies focusing on young children of immigrants in the United States have tended to examine single national origin groups (Suminski et al., 1999; Ariza et al., 2004) and we are not aware of any that have used nationally-representative longitudinal data. It is important to follow young children over time with longitudinal data because the patterns predicted by the conceptual model may not begin to emerge until after children reach older ages (thus the findings concerning baseline BMI may differ from those concerning changes in BMI). Prior research on BMI trajectories among children (Stark et al., 1981; Whitaker et al., 1997; Braddon et al., 1986; Guo et al., 1994) suggest that middle childhood represents one of the critical periods of childhood during which BMI can increase dramatically (referred to as "adiposity rebound").

Data

We analyzed data from the Early Childhood Longitudinal Survey Kindergarten Class of 1998-99 (ECLS-K). The ECLS-K is a longitudinal survey conducted by the National Center for Education Statistics that followed a nationally representative sample of children from kindergarten through fifth grade; data were collected from 1998-99 through 2003-04 school years and released in February 2006. Hispanic, Asian, and Pacific Islander children were oversampled (NCES 2001). Information on the children was collected from parents, teachers, and school administrators covering a wide range of topics ranging from the children's home environment to classroom curriculum during fall and spring of the kindergarten year (wave 1), fall and spring of first grade (wave 2), spring of third grade (wave 3) and spring of fifth grade (wave 4).[2]. Provisions were made to interview non-English-speaking parents in Spanish, Chinese, Lakota or Hmong. We used information from the child (BMI) and parent questionnaires from all four waves.

The analytic sample was restricted to respondents who had at least one valid measure of BMI[3], and valid measures of parental nativity status, family socioeconomic status and the control variables. Of 21,409 respondents, 4,745 cases were omitted because they did not meet these criteria. The number of children of immigrants among the omitted cases is unknown since most did not have valid parental nativity data. Because we estimate growth curve models, the analytic data file included a separate case for each valid BMI assessment totaling 74,541 observations.

Measures

Generational Status. Children with at least one foreign born parent were defined as children of immigrants. For those with two foreign-born parents, we used mother's duration and country of origin. Children born in Puerto Rico or children of Puerto Rican-born parents were treated as children of immigrants because as migrants they may undergo the same kind of cultural change as immigrants. We distinguished among children of 1.5 generation parents (arrived in the U.S. ages 0-11), children of 1.0 generation parents (arrived in the U.S. age 12 and older), and children of U.S.-born native parents (thus generation is coded as two dummy variables with children of natives as the reference category). We did not distinguish between foreign-born and U.S. born children because so few (271) were born abroad. Of all observations, 78.4% (58,337) were contributed by children of natives, 17.2% (12,900) by children of the 1.0 generation and the remaining 4.4% (3,304) by children of the 1.5 generation (see Appendix Table 1).

BMI. Prior research on child obesity has established body mass index (weight/height^2) as a suitable adiposity index for children (Poskitt 2000). BMI is also a preferred measure because height and weight are easy to obtain with a reasonable degree of accuracy across different settings. In the ECLS-K, children's height and weight were assessed by ECLS-K staff at each wave of data collection and recorded using a Shorr Board and a digital scale. We used raw BMI as the dependent variable rather than BMI z-score or percentile ranking because raw BMI score has been found to be optimal for measuring adiposity change (because the baseline measure is less correlated with change over time in the case of the raw BMI score than is the case for the other measures of adiposity) (Cole, Faith, Pietrobelli, & Heo, 2005). The unweighted average BMI across all observations in the analytic sample was 17.5 (17.8, 17.6, and 17.4 for children of the 1.0, children of the 1.5 generation, and children of natives, respectively) with a standard deviation of 3.5 (Appendix Table 1).

Economic Development of Countries of Origin. We used logged real Gross Domestic Product (GDP) per capita converted to 2000 constant prices (Heston, Summers & Aten, 2006) as an indicator of economic development of immigrants' countries of origin. The GDP/capita is a principle measure of economies used by the World Bank (World Bank 2006). We assigned children the GDP/capita value from the country of birth of the foreign born parent and year in which the foreign born parent was age 12. A drawback of the ECLS-K data (and most other survey data) is that it is impossible to identify the national origin for children of natives (only race/ethnicity is available for pan-ethnic categories). This means that it was not possible to assign children of natives a GDP/capita value for their national origins. GDP/capita ranged from $347 to $73,105; the average was $6,494 for children of the 1.0 generation and $10,643 for children of the 1.5 generation; the standard deviations were $5,826 and $7,395, respectively (Appendix Table 1).

Socioeconomic Status (SES). We used a standard SES scale included in the ECLS-K data (created by NCES) that is based on up to five measures (each parents education and occupational prestige score, along with household income), each of which was standardized to have a mean of zero and a standard deviation of one. Thus the measure indicates socioeconomic status relative to other U.S.-resident parents of young children. NCES uses various imputation methods to account for any missing data (see NCES Base Year User Guide). We used the SES measure from the baseline year of the survey. The SES composite measure ranged from –4.75 to 2.75 with a standard deviation of one. The mean SES was -.21 for children of the 1.0 generation, .07 for children of the 1.5 generation, and .09 among children of natives (Appendix Table 1).

Control variables. A number of socioeconomic and health characteristics that may be associated with children's BMI were used as control variables in the growth curve models. These included gender (male=1, female=0); race/ethnicity (a series of dummy variables comparing non-Hispanic white children with non-Hispanic Black, non-Hispanic Asian, Native Hawaiian or Pacific Islander, non-Hispanic children of mixed race, and Hispanic children of any race); the number of children in the household, and prematurity status (i.e., whether the child was born before 38 weeks of gestation). We also controlled for family structure because single parent families have been found to favor pre-manufactured food and fast food consumption (Crockett & Sims, 1995), and whether the child had two immigrant parents.

Analysis

We estimated growth curve models of children's BMI (Raudenbush & Bryk, 2002; Heo et al., 2003). All models were estimated using STATA Version 9.0 software. The models estimate effects for Level-1 units (the multiple observations for each child across age) and Level-2 units (the children). The Level-1 model fits BMI as a function of age across the time observations for each child: $y_{ja} = \beta_0 + \beta_{1j}a_{ja} + \varepsilon_j$, where y_{ja} is the BMI of child j at age a (measured in months). The Level-2 model fits the Level-1 intercepts and coefficients across all individuals as a function of children's fixed characteristics:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}G1.0_j + \gamma_{02}G1.5_j + \gamma_{03}S_j + \gamma_{04}S^2_j + \gamma_{05}G1.0_jI_j + \gamma_{06}G1.5_jI_j + \mathbf{Z_j}\boldsymbol{\delta_{0j}} + \mu_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}G1.0_j + \gamma_{12}G1.5_j + \gamma_{13}S_j + \gamma_{14}S^2_j + \gamma_{15}G1.0_jI_j + \gamma_{16}G1.5_jI_j + \mu_{1j} \qquad \textit{(Model 1)}$$

where *G1.0* and *G1.5* are dummy variables indicating children of 1.0 and 1.5 generation parents, respectively; S_j is the child's socioeconomic status at baseline; I_j is the natural log of GDP/capita of immigrant children's country of origin; and $\mathbf{Z_j}$ is a vector of control variables. GDP/capita is specified as a spline function with one term for children of 1.0 generation and another for children of 1.5 generation parents. The first equation (β_{0j}) estimates the associations of the child-level factors with the children's initial BMI level in kindergarten (the "intercept" model), while the second equation (β_{1j}) estimates their associations with change in BMI (the "slope" model).

We developed and tested three hypotheses for the children of immigrants based on our conceptual model. Our first was that the GDP/capita of immigrants' country of origin would be positively associated with their children's initial level and subsequent change in BMI, particularly among recently-arrived immigrants (i.e., the "1.0" generation). In Model 1, γ_{05} and γ_{15} estimate the association of GDP/capita with BMI level and change, respectively, among children of the 1.0 generation; γ_{06} and γ_{16} are the corresponding estimates for children of the 1.5 generation. We expected these parameter estimates (particularly γ_{05} and γ_{15}) to be significant and positive.

Our second hypothesis was that the relationship between SES and BMI among children of immigrants would depend on country of origin GDP/capita. We expected the relationship to be positive at low GDP/capita levels but increasingly negative at higher levels, particularly among recently-arrived immigrants (as shown in Figure 1a). To evaluate these ideas, we tested interaction terms among generational status, SES and GDP/capita as shown in Model 2 below:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}G1.0_j + \gamma_{02}G1.5_j + \gamma_{03}S_j + \gamma_{04}S^2_j + \gamma_{05}G1.0_jI_j + \gamma_{06}G1.5_jI_j$$
$$\gamma_{07}G1.0_jS_j + \gamma_{08}G1.5_jS_j + \gamma_{09}G1.0_jS_jI_j + \gamma_{0,10}G1.5_jS_jI_j + \mathbf{Z_j}\boldsymbol{\delta_{0j}} + \mu_{0j} \qquad \textit{(Model 2)}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}G1.0_j + \gamma_{12}G1.5_j + \gamma_{13}S_j + \gamma_{14}S^2_j + \gamma_{15}G1.0_jI_j + \gamma_{16}G1.5_jI_j$$
$$\gamma_{17}G1.0_jS_j + \gamma_{18}G1.5_jS_j + \gamma_{19}G1.0_jS_jI_j + \gamma_{1,10}G1.5_jS_jI_j + \mu_{1}.$$

We did not include the squared SES term in the higher order interaction terms because the coefficients for these terms were never significant (thus the model forces the effect of SES-squared to be the same for all groups). In the intercept model, γ_{03} is the estimated SES slope for natives (evaluated at mean SES[4]), ($\gamma_{03} + \gamma_{07}$) is the estimated SES slope for children of 1.0 generation from countries with zero income (lnGDP/capita = 0), and γ_{09} is the estimated increase in the slope associated with a one-unit increase in ln(GDP/capita), or about 170% increase in GDP/capita. In the slope model, the corresponding estimates are γ_{13} , ($\gamma_{13} + \gamma_{17}$), and γ_{19}. For the children of the 1.5 generation, the slope of SES and increase in the slope associated with GDP/capita are ($\gamma_{03} + \gamma_{08}$) and $\gamma_{0,10}$ in the intercept model and ($\gamma_{13} + \gamma_{18}$) and $\gamma_{1,10}$ in the slope model. Our hypothesis predicted that the SES slope for the 1.0 generation would decrease as GDP/capita increased; thus γ_{09} and γ_{19} were expected to be significant and negative. To assess whether the slope was significantly negative or positive among those from high- or low-income countries, we tested the significance of linear combinations of coefficients evaluated at various logged GDP/capita values (using the post-estimation commands in STATA). For example, the SES slope in the intercept model for children of the 1.0 generation from countries with a GDP/capita of $1000 would be ($\gamma_{03} + \gamma_{07}$) + γ_{09}ln(1000).

Our third hypothesis was that among immigrants from lower income countries, generational status would be positively associated with BMI among low-SES children but negatively associated with generation among high SES children (as shown in Figure 1b). A positive relationship of generational status with BMI would mean that "1.0" children would have the lowest BMIs, children of natives the highest and "1.5" children falling in between; a negative relationship would mean the opposite ordering. We further hypothesized that generational differences would diminish as GDP/capita of immigrants' country of origin increased. To assess these ideas, we tested the significance of generational differences evaluated at various levels of SES and GDP/capita. Predicted generational differences were estimated as linear combinations of Model 2 coefficients. We expected that children of the 1.0 generation from countries with relatively low GDP/capita would have a significantly lower predicted BMI than children of natives at low SES levels but higher BMI at higher SES levels. We further expected these differences to be smaller and insignificant among children of immigrants from countries with higher GDP/capita. We expected to find no significant differences (or at least smaller differences than those observed for the 1.0 generation) between children of the 1.5 generation and children of natives.

To help interpret some of the findings, we produced graphs that show predicted values for various groups. Predicted values were generated by plugging into the models various combinations of values for generation, SES (ranging from 2 standard deviations above and below the mean), and ln(GDP/capita) (ranging from 6 to 10) while setting all the other variables to zero (thus the predicted values were for non-Hispanic white girls of married parents with no siblings who were not born prematurely)[5]. To enhance interpretability, we multiplied predicted monthly change in BMI by twelve to obtain predicted annual growth in BMI.

Results

The estimated coefficients for Models 1 and 2 are presented in Table 1. Consistent with prior research, socioeconomic status was negatively associated (and the relationship became increasingly negative at higher SES levels) with both the children's baseline BMI and BMI growth. In addition, boys tended to have higher BMI levels at baseline than girls, and children of single mothers had higher BMIs than children in married couple families. Also, Hispanic, black, and American Indian children had higher BMI levels at baseline than non-Hispanic white children. When we added the interaction terms among generational status, GDP/capita, and SES in Model 2, these effects remained statistically significant, although the race/ethnic differentials were reduced by about one-third for Hispanics and American Indians and by 50% for blacks. Supplementary analyses (not shown) revealed significant race/ethnic differentials only among children of natives. Among children of immigrants, race/ethnic differentials were explained by the interaction of SES and GDP/capita; when we ran the models for children of immigrants alone, race/ethnicity was significant in Model 1 but not Model 2.

[Table 1 here]

Our first hypothesis predicted a positive relationship between BMI and GDP/capita among recently arrived immigrants. Hence we turn to the results concerning generational status and GDP/capita in Model 1. As expected, the slope model shows that among children of the 1.0 generation, BMI increased more among those from higher income countries compared with those from lower income countries. Also, we found no significant relationship of GDP/capita and BMI growth for children of the 1.5 generation, again as expected. The intercept model estimates were less consistent with our first hypothesis. The relationship between GDP/capita and baseline BMI was significantly negative among children of the 1.5 generation when an insignificant relationship was predicted. Also, there was no significant relationship among children of the 1.0 generation even though a positive relationship was predicted. Nevertheless, the slope was significantly more positive for "1.0" children than for "1.5" children. Predicted values for children of immigrants by GDP/capita (not shown) indicate that both BMI levels and growth were greater for the "1.5" children than "1.0" children among those from low income countries. But the reverse was true for children from high income countries. A cross-over occurred around $6,000 GDP/capita in the case of baseline BMI and $7,500 GDP/capita in the case of BMI growth. Thus generational status was associated with higher BMI baseline levels and growth in BMI among immigrants from low income countries, but lower baseline levels and BMI growth among those from high income countries.

Our second hypothesis predicted that the SES slope among children of immigrants (particularly among recently-arrived immigrants) would shift from positive to negative as GDP/capita increased. Hence we focus on the interaction terms among generational status, SES, and GDP/capita in Model 2. None of the terms associated with "1.5" children (neither the main effect nor any of the interaction effects with GDP/capita and SES) were significantly associated with BMI growth, as we expected. Thus the SES slope for this group did not differ from children of natives nor did it depend on GDP/capita. But for "1.0" children from countries with very low GDP/capita, the relationship between SES and growth in BMI was more positive than among natives. This is evident from the significant and positive interaction term between "1.0" children and SES. Furthermore, the three-way interaction term was significant and negative, meaning that the SES slope became significantly more negative as GDP/capita increased. To illuminate the results further, we calculated the predicted SES slopes for children of immigrants across a range of different GDP/capita levels (shown in Appendix Table 2), and graphed predicted values by GDP/capita and SES in Figure 2 (the upper graph shows predicted baseline BMI and the lower graph shows predicted annual change in BMI). At the lowest GDP/capita levels (<=$665 GDP/capita) the SES slope for "1.0" children was not significantly different from zero and significantly more positive than children of natives. But at $1,097 GDP/capita, the SES slope was significant and negative, and at $4,915 GDP/capita was no longer significantly different from children of natives. This is illustrated in the lower graph of Figure 2. We found a similar interaction effect in the intercept model predicting baseline BMI, except that it was unexpectedly significant for "1.5" but not "1.0" children (Figure 2, upper graph). The SES slope for "1.5" children from countries with very low GDP/capita (<=$1,097) was significantly positive and greater than the native slope, but significantly declined at higher GDP/capita levels (and had flipped from positive to negative around $4,915 GDP/capita).

[Figure 2 about here]

Our third hypothesis predicted that among immigrants from low income countries, generational status would be positively associated with BMI among low-SES children but negatively associated among high SES children. We further predicted that generational differences would diminish at higher GDP/capita levels. Both parts of this hypothesis were supported by the results of the BMI growth model. We generated predicted generational differences from children of natives at various SES and GDP/capita levels based on Model 2 coefficients. The results (displayed in Appendix Table 3) showed that the average BMI of children of the 1.0 generation increased less than among children of natives only in the case of those with a combination of low SES (<=0) and low GDP/capita (<=$2,981). But they gained more weight than children of natives in cases where SES was high (>=2) and GDP/capita was low (<=$2,981). We found no significant differences in weight gain between "1.5" children and children of natives. As we show in the lower graph of Figure 3 (which plots the predicted values by SES for children of natives and children of immigrants from very low income countries (where GDP/capita = $403)), among immigrants originating from low-income countries, generation in the U.S. was significantly associated with greater BMI growth among low-SES children and lower BMI growth among high-SES children. But for immigrants from higher-income countries, there was no significant association of generation and BMI growth (graph not shown).

[Figure 3 about here]

The results of the intercept model (predicting baseline BMI) were inconsistent with the expectations of the third hypothesis. Specifically, among high SES (>=0) children of immigrants from lower income countries (<=$2,981 GDP/capita), predicted baseline BMI levels were significantly greater for "1.5" children than children of natives, while baseline levels among "1.0" children were not significantly different from children of natives. Thus for high SES immigrants from low income countries, the generational pattern was curvilinear, with children of immigrants who have lived in the country since childhood appearing to have higher BMI baseline levels than both children of more recently arrived immigrants and children of natives. This is illustrated in upper graph of Figure 3 in the case of those from very low income countries (where GDP/capita = $403).

Summary

All three of the hypotheses generated from our conceptual model of BMI assimilation were supported in the analyses of growth in BMI from kindergarten to fifth grade. First, we found that children of immigrants from higher income countries (measured by GDP/capita) tended to gain more weight (measured by changes in BMI) than children from lower income countries. Moreover, this association appeared only among children of the 1.0 generation. Second, we found that the relationship between family socioeconomic status and weight gain was significantly more positive among children of immigrants from lower-income countries compared to those from higher-income countries. Again, this association appeared only among children of the 1.0 generation. Third, we found that weight gain was positively associated with generation only in the case of lower-SES children from low income countries, and negatively associated with generation in the case of higher-SES children from low income countries.

The three hypotheses received less support in analyses of baseline BMI among kindergarteners. The relationship of SES with baseline BMI was dependent on GDP/capita (appearing as a positive relationship among children from low income countries but becoming more negative as GDP/capita increased) as we expected. However, this pattern appeared for "1.5" children rather than "1.0" children. In addition, among high SES children of immigrants from low income countries, we expected to find the highest BMIs among the "1.0" children and lowest among children of natives, with the "1.5" children falling between the two. Instead, the highest BMIs occurred among children of the 1.5 generation.

Discussion

In this article, we proposed a new conceptual model of BMI assimilation that provides a logical basis for predicting variations in the relationship between generational status and BMI. The model links the level of economic development of countries of origin (and by inference stage in the nutrition transition) with the level and socioeconomic variation in BMI among newly-arrived immigrants, and it conceptualizes assimilation as occurring within socioeconomic strata. This approach leads to the expectation that BMI assimilation is likely to entail a reversal in the relationship between socioeconomic status and BMI from positive to negative sloping. In contrast to the negative assimilation health model, which predicts that generational status would be uniformly associated with worse health outcomes, the implication of the proposed model of BMI assimilation is that the generational patterns are likely to vary in predictable ways. For some groups—those from less developed countries with low socioeconomic status—overweight is likely to be positively associated with generation. But for other groups—those from less developed countries with high socioeconomic status—overweight is likely to decline across generation.

The conceptual model introduced here represents only a first step toward explaining variation in BMI assimilation. First, the model is primarily descriptive in nature. The mechanisms, such as child feeding practices, food insecurity, and children's activity patterns, that may link generational status and children's BMI are not specified. Further development and testing of the conceptual model deserves further study. Also, although our conceptual model makes predictions about the *effects* of generational status on BMI, the data used in our empirical example restrict us to making statements about correlation but not causation. Generational groups may differ due to differences in selection on unmeasured characteristics. For example, immigrants tend not to be selected randomly from sending country populations, and the type of selection may vary over time and across countries. Further research that makes direct comparisons of non-immigrants in sending countries with U.S. immigrants would be helpful for teasing apart selection from direct effects of immigration. Another problem related to the measurement of generational status is that, due to limitations in sample size, we defined children of immigrants as those with at least one immigrant parent. This means that we did not distinguish between those with two versus one immigrant parent or between U.S.-born and foreign-born children.

A second limitation is that the actual immigrant adaptation and assimilation process is likely to be much more complex than what is implied by the proposed conceptual model. All three of the hypotheses derived from the conceptual model were supported in our empirical example, specifically in the case of BMI growth. But the results concerning children's baseline BMI deviated from our predictions; high SES children of the 1.5 generation from low income countries had especially high baseline BMIs even though we expected this result only among the most recently arrived immigrants (i.e., children of the 1.0 generation). One possibility is that we have mis-specified the model. Prior research suggests that percentile BMI is a better measure for cross-sectional comparisons, but the BMI raw score is better for measuring change over time (Cole et al., 2005). However, when we estimated models of only kindergarteners predicting the percentage overweight (defined as having a percentile BMI at or above the 85^{th} percentile for the child's age and sex), we obtained similar results.

Another possible explanation for the unexpected results is that the model fails to identify at least some major factors affecting generational patterns in children's BMI, particularly factors affecting children during pre-school years. One idea is that immigrant parents from low-income countries who are new to the middle and upper class may overindulge their children because they now can afford what they themselves were denied as children. Such parents may be more likely to view overweight in a positive light given that they (or their parents) likely grew up in countries and points in history at the beginning stages of the nutrition transitions. The data used in our empirical example did not include any measures of parents' beliefs of what a healthy weight would be for their children. Further empirical work focusing on generational variations in beliefs about healthy weight (particularly among higher-SES immigrants from low income countries) could be fruitful. If this idea were supported, it would suggest that while low SES children tend to be the most at risk of overweight, this is not uniformly the case among children of immigrants. Interventions targeting at-risk populations may need to focus on middle- and upper-SES children of immigrants, particularly those originating from lower-income countries.

Another possible reason for the discrepant findings is that neither the conceptual model nor the empirical example accounted for variations in the meaning of socioeconomic status across time and international contexts. The SES measure used in the empirical example was measured in the U.S., standardized relative to a U.S. population, and did not change much over the course of the ECLS-K study (so we were unable to model the effects of changes in SES on BMI). However, socioeconomic status is a multi-faceted concept with dimensions related to absolute status (such as income, skills, and training) as well as relative status compared with others. Comparison groups vary over time and across groups, and for immigrants, comparison groups can vary across international contexts (Feliciano 2005). Further research that explores the effects of SES relative to others in their countries of origin independently of SES relative to Americans could provide additional insight into the relationship between SES and immigrants' health outcomes, including BMI.

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Table 1

Growth Curve Models of Body Mass Index (BMI) from Kindergarten through Fifth Grade

	Model 1		**Model 2**	
	Baseline BMI (β_{0j})	Growth in BMI (β_{1j})	Baseline BMI (β_{0j})	Growth in BMI (β_{1j})
Intercept	16.149 ***	0.064 ***	16.126 ***	0.064 ***
	(0.050)	(0.001)	(0.046)	(0.001)
SES	-0.093 ***	-0.011 ***	-0.117 ***	-0.011 ***
	(0.025)	(0.001)	(0.027)	(0.001)
SES-squared	-0.058 ***	-0.001 ***	-0.057 ***	-0.001 ***
	(0.014)	(0.000)	(0.013)	(0.000)
Children of 1.0 Gen.	-0.221 [a]	-0.021 *	-0.408 [a]	-0.022 *
	(0.524)	(0.010)	(0.497)	(0.010)
x ln(GDP/capita)	0.043 [a]	0.003 *	0.071 [a]	0.003 *
	(0.059)	(0.001)	(0.056)	(0.001)
x SES	---	---	0.546	0.029 **
			(0.420)	(0.011)
x ln(GDP/capita) x SES	---	---	-0.065	-0.003 *
			(0.050)	(0.001)
Children of 1.5 Gen.	1.896 *	-0.011	2.070 *	-0.007
	(0.855)	(0.021)	(0.841)	(0.021)
x ln(GDP/capita)	-0.203 *	0.001	-0.215 *	0.001
	(0.094)	(0.002)	(0.093)	(0.002)
x SES	---	---	1.839 *	0.021
			(0.884)	(0.022)
x ln(GDP/capita) x SES	---	---	-0.207 *	-0.002
			(0.098)	(0.002)
Hispanic	0.364 ***	---	0.244 ***	---
	(0.060)		(0.057)	
Asian	-0.203	---	-0.170	---
	(0.108)		(0.101)	
Black	0.260 ***	---	0.132 *	---
	(0.058)		(0.055)	
American Indian	0.552 ***	---	0.391 **	---
	(0.134)		(0.124)	
Native Hawaiian	-0.067	---	-0.250	---
	(0.174)		(0.158)	
Other Race/ethnicity	-0.020	---	-0.129	---
	(0.111)		(0.103)	
N children in family	-0.106 ***	---	-0.085 ***	---
	(0.015)		(0.014)	
Born Prematurely	-0.248 ***	---	-0.234 ***	---
	(0.050)		(0.046)	
Single Mother	0.113 *	---	0.108 *	---
	(0.050)		(0.046)	
Single Father	-0.100	---	-0.093	---
	(0.145)		(0.134)	
Other Family type	-0.123	---	-0.065	---
	(0.123)		(0.115)	
2 Foreign-born parents	0.164	---	0.116	---
	(0.087)		(0.080)	
Boys	0.116 **	---	0.134 ***	---
	(0.035)		(0.033)	

N = 72,502

* p<.05; ** p<.01; ***p <.001

[a] significantly different from corresponding term for children of the 1.5 generation.

Figure 1a
Predicted Patterns for Newly-arrived Immigrants

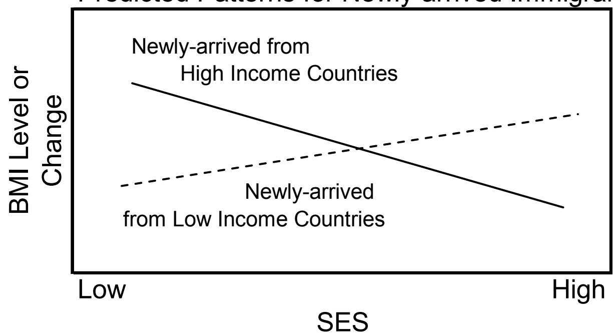


Figure 1b. Predicted Patterns for Immigrants from Low-Income Countries

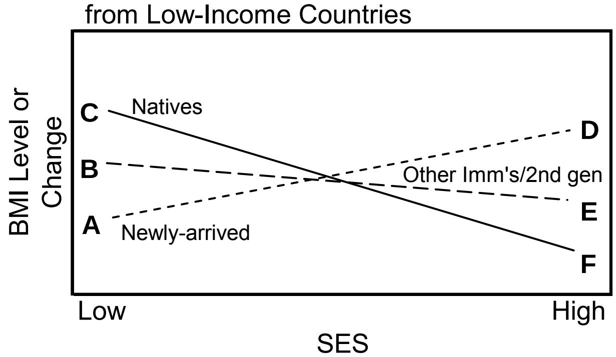
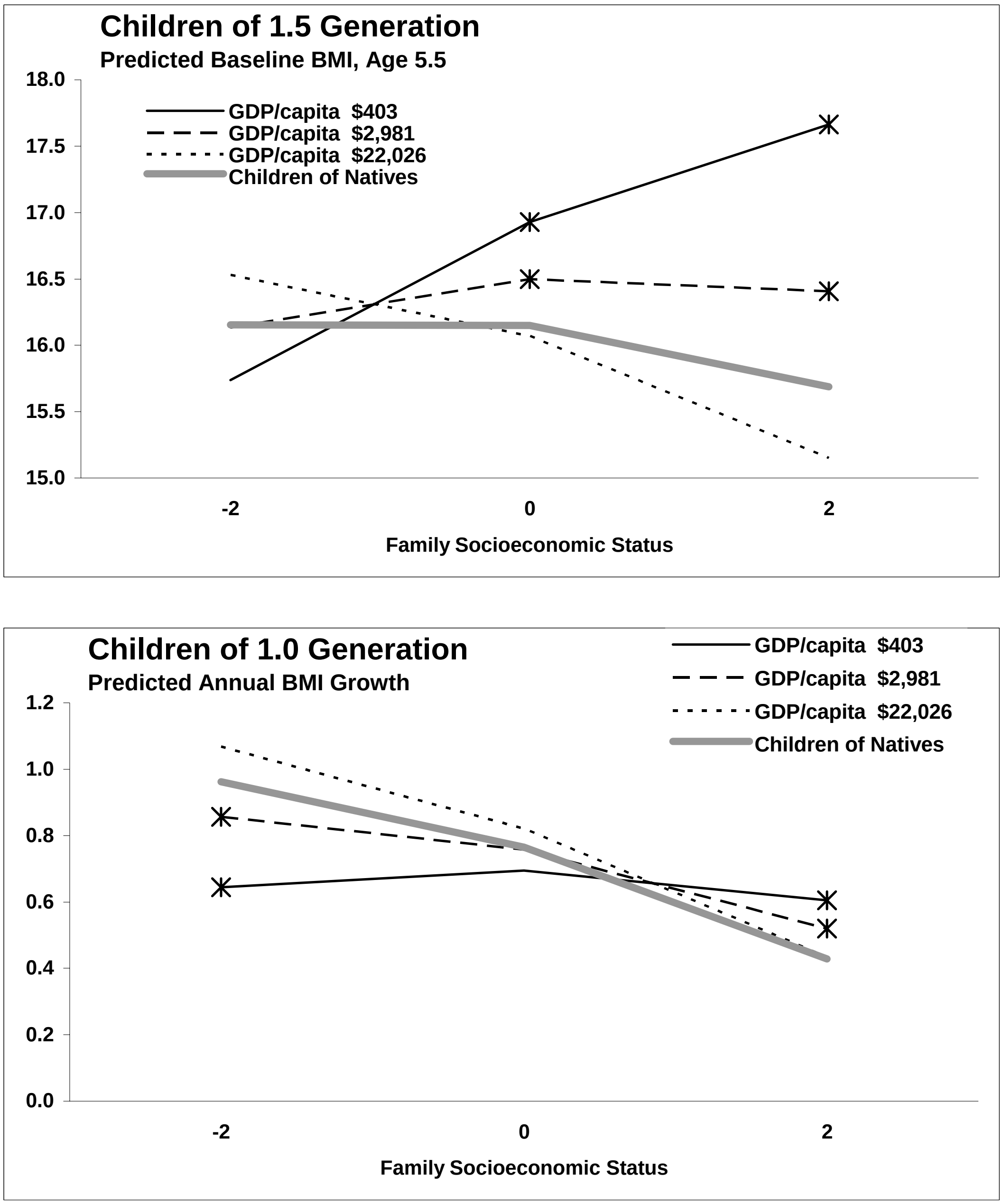


Figure 2

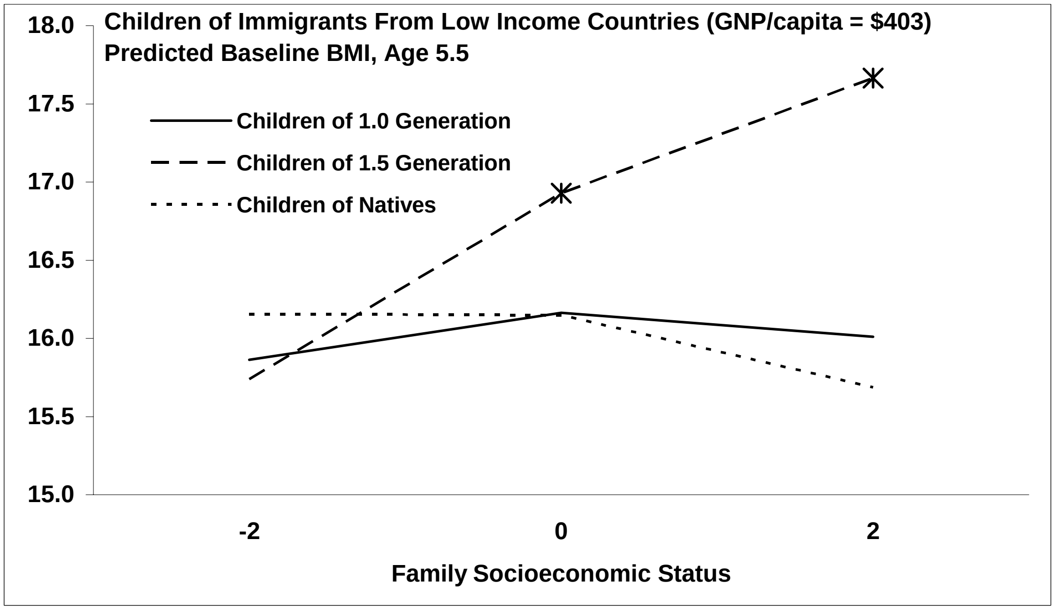
Predicted Baseline BMI and Annual Growth in BMI Among Children of Immigrants by Socioeconomic Status and Country-of-origin GDP/capita

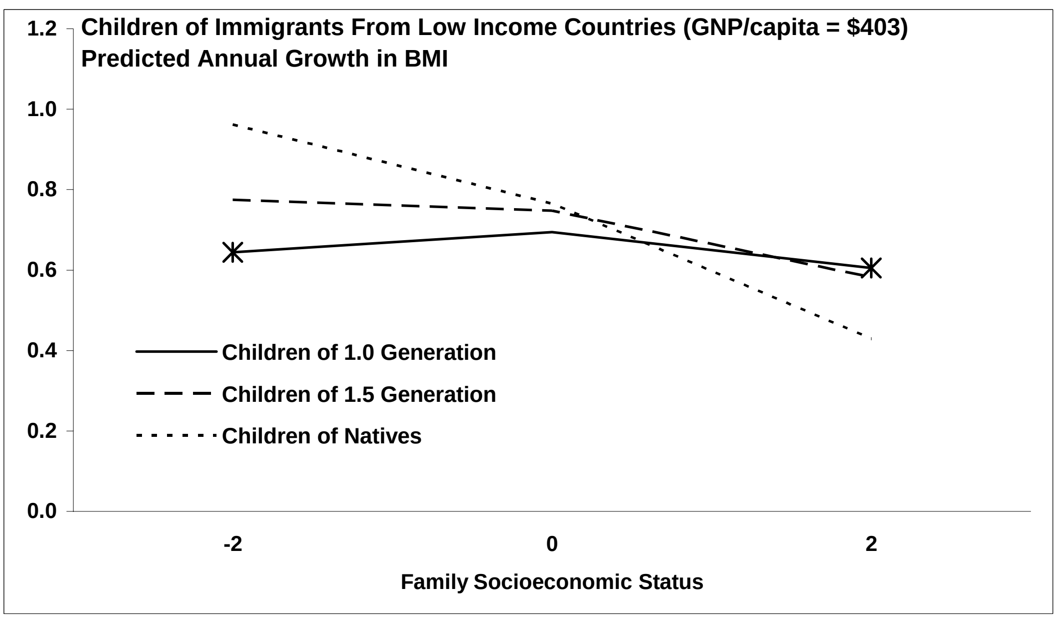


* significantly different from children of natives (p <.05)
Predicted values are based on Model 2 in Table 1.

Figure 3

Predicted Baseline BMI and Annual Growth in BMI Among Immigrants from Low-income Countries by Generational Status and Socioeconomic Status





* significantly different from children of natives (p <.05)
Predicted values are based on Model 2 in Table 1.

Appendix Table 1

Unweighted Characteristics of Analytic Sample

	All (N = 74,541)	Children of 1.0 Gen. (N = 12,900	Children of 1.5 Gen. (N = 3,304)	Children of Natives (N = 58,337)
BMI (Mean)	17.5	17.8	17.6	17.4
(Standard Deviation)	(3.5)	(3.7)	(3.6)	(3.5)
Generation (%)				
Children of 1.0 Generation	17.2	100.0	0.0	0.0
Children of 1.5 Generation	4.4	0.0	100.0	0.0
Children of Natives	78.4	0.0	0.0	100.0
Two foreign born parents (%)	12.2	63.9	27.5	0.0
GDP/capita of country of origin (Mean)		6,493	10,643	-
(Standard Deviation)		(5,826)	(7,395)	-
Socioeconomic Status (Mean)	0.00	-0.21	0.07	0.09
(Standard Deviation)	(1.00)	(0.88)	(0.79)	(0.77)
Gender (%)				
Male	50.8	51.1	50.0	50.7
Female	49.2	48.9	50.0	49.3
Race/Ethnicity (%)				
White	59.0	13.1	37.9	70.1
Black	12.7	4.3	4.1	15.2
Hispanic	16.8	50.2	37.0	8.4
Asian	5.7	26.3	13.0	0.8
Native Hawaiian	1.2	3.3	2.4	0.6
American Indian	1.9	0.2	0.2	2.3
Other Race	2.7	2.6	5.4	2.6
Born less than 38 weeks gestation (%)	14.9	12.4	19.1	15.2
Parental Marital Status (%)				
Two Parents	78.0	85.5	81.0	76.0
Single Mother	18.3	12.7	16.3	19.9
Single Father	1.5	0.8	1.9	1.6
Other family type	2.1	1.0	0.8	2.5
N children in HH (Mean)	2.5	2.7	1.1	2.4
(Standard Deviation)	(1.2)	(1.4)	(1.1)	(1.1)

Appendix Table 2

Predicted Relationship (Slope) of SES with Baseline BMI and Growth in BMI by Generational Status and Country-of-origin GDP/capita

	Baseline BMI		Growth in BMI per month	
Children of Immigrants	1.0 Gen	1.5 Gen	1.0 Gen	1.5 Gen
GDP/capita (2000 real dollars)				
403	0.000	0.561 [a]	-0.002 [a]	-0.002
665	-0.026	0.441 [a]	-0.003 [a]	-0.004
1,097	-0.051	0.321 [a]	-0.004 * [a]	-0.005
1,808	-0.077	0.201	-0.006 * [a]	-0.007
2,981	-0.103	0.081	-0.007 * [a]	-0.008 *
4,915	-0.128 *	-0.039	-0.009 *	-0.010 *
8,103	-0.154 *	-0.159	-0.010 *	-0.011 *
13,360	-0.180 *	-0.279 *	-0.011 *	-0.013 *
22,026	-0.205 *	-0.399 *	-0.013 *	-0.015 *
Children of Natives	-0.117*		-.011*	

Note: Predicted SES slopes based on Model 2, Table 1. Because the SES slope is curvilinear, we evaluate it at SES = 0.

[*] significantly different from zero (p<.05)

[a] significantly different from children of natives (p<.05)

Appendix Table 3

Predicted Baseline BMI and Growth in BMI by Generational Status, Socioeconomic Status, and Country-of-origin GDP/capita

	GDP/Capita				
	$403	$1,097	$2,981	$8,103	$22,026
Predicted Baseline BMI (difference from children of natives)					
Children of 1.5 Generation					
Low SES (-2)	-0.58	-0.31	-0.05	0.22	0.48
(-1)	0.10	0.13	0.15	0.18	0.20
Average SES (0)	0.78 **	0.57 **	0.35 **	0.14	-0.08
(1)	1.46 **	1.01 **	0.55 **	0.10	-0.36 *
High SES (2)	2.14 **	1.45 **	0.75 *	0.06	-0.64 *
Predicted Annual Growth in BMI (difference from children of natives)					
Children of 1.0 Generation					
Low SES (-2)	-0.30 **	-0.20 **	-0.11 **	-0.01	0.09
(-1)	-0.19 **	-0.12 **	-0.06 **	0.01	0.07
Average SES (0)	-0.07 *	-0.04	-0.01	0.02	0.05
(1)	0.04	0.04	0.04	0.04	0.03
High SES (2)	0.15 *	0.12 *	0.08 *	0.05	0.02

* p<.05; ** p<.01; ***p <.001

Note: Predicted values based on Model 2, Table 1.

[1] Following United Nations' definitions, the term "less developed countries" (or regions) refers to countries in Africa, Asia (except Japan), Latin America and the Caribbean, and Oceania (except Australia and New Zealand). A less developed country is a country with a relatively low standard of living, undeveloped industrial base, and moderate to low Human Development Index (HDI).

[2] A thirty percent subsample was selected for the fall first grade interview. Data from this interview were used in the analyses.

[3] Any respondents with BMI scores classified as outliers by the CDC growth charts were omitted from the sample.

[4] Because the effect of SES is specified as a quadratic, the SES slope depends on the value of SES. For example, for children of natives the derivative is: $\gamma_{03} + 2\gamma_{04}S_j$, which reduces to γ_{03} when evaluated at the mean (SES = 0).

[5] The decision to set all control variables to zero was an arbitrary choice. This choice determines the overall level of the predicted values, but has no effect on the predicted differences among groups.