Obesity has reached epidemic proportions nationwide and is considered the most pressing public health problem in the United States today.\(^1,2\) Fueled by a modern lifestyle of poor diet and physical inactivity, the rising trend of obesity has affected Americans of all ages but is perhaps most disconcerting among young people.\(^3-9\)

The percentage of overweight children (body mass index [BMI] > 95th percentile for age and sex; BMI is calculated as weight in kilograms divided by height in meters squared) has tripled in the last 2 decades and is still rising.\(^\text{10-12}\) The current estimate of more than 15% among those 6 to 19 years of age\(^\text{13}\) and more than 17% among adolescents aged 12 to 19 years.\(^\text{11}\) The public health implications of earlier onset of obesity among American children are cogently expressed in the US Surgeon General’s report that the health problems resulting from obesity threaten to reverse the major improvements in health accomplished in the 20th century.\(^1\)

Overweight children are likely to become overweight adults\(^\text{12-15}\) and are at increased risk for a number of negative health outcomes, including hypertension, high cholesterol, abnormal glucose tolerance, type 2 diabetes, metabolic syndrome, kidney disease, coronary heart disease, congestive heart failure, stroke, osteoarthritis, some cancers, and death.\(^\text{12,15-20}\) Overweight adolescents also complete fewer years of education, are less likely to marry, and have lower household incomes as adults.\(^\text{21,22}\) Moreover, medical expenditures attributable to obesity reached $75 billion in 2003 and taxpayers financed about half of this money through Medicare and Medicaid.\(^\text{23}\)

Because the dramatic rise in overweight and obesity among children is relatively recent, fewer studies focus on young ages and research on obesity among young
people is typically cross-sectional. The cross-sectional view does not allow the study of developmental trends in obesity as people age and experience different life stages in which lifestyle and health habits change.

We are therefore limited in our understanding of individual trajectories in overweight and obesity and disparities in these trajectories over time.

In addition, although much is known about race differences in obesity among adults, less is known about race and ethnic differences among young people. Research that does examine racial differences focuses mainly on those between black individuals and white individuals, failing to capture the increasing diversity of the US population fostered by high rates of Latin American and Asian immigration. The studies that include more diverse ethnic populations are based largely on cross-sectional or unrepresentative local samples precluding a national perspective on racial/ethnic variations in obesity trajectories as children age. Our research addresses this void by examining racial/ethnic disparities in BMI among young people aged 11 to 19 years, and tracing how disparities change as this adolescent cohort ages into young adulthood (age, 20-28 years). We use national representative longitudinal data from the National Longitudinal Study of Adolescent Health (Add Health) that permit the examination of Hispanic and Asian youth and the identification of immigrant generation.

Although immigrants constitute an increasing proportion of the US population each year, national data on their health are hard to come by, and even less is known about children in immigrant families and their health prospects as they enter adulthood in America. Some research documents differences in obesity among immigrant adults and immigrant adolescents, but none have traced trajectories in overweight and obesity status through time among adolescents in immigrant families. The only national longitudinal study currently available focuses on immigrant children aged 5 to 8 years but does not provide estimations that differ by race/ethnicity or distinguish between first-, second-, and third-generation children. Although America is leading the upward trend in obesity among industrialized countries, some rapidly developing countries, such as China and Mexico, are witnessing increases in obesity as they adopt Western habits. For the most part, immigrants to the United States come from countries in which average body mass is lower, and thus they are less likely than native-born Americans to be overweight and obese. However, with acculturation both across generations and time in the United States for first-generation youth, the adoption of an American diet and lifestyle increases risks of overweight and obesity. Thus, it is important to examine immigrant disparities in BMI over time, as adolescents age into young adulthood, to better understand acculturation processes that may occur with increasing assimilation. We use growth curve modeling to estimate the pattern of change in BMI across age beginning in adolescence and extending through early adulthood, examining differences by race/ethnicity and immigrant generation as well as by sex.

DATA COLLECTION

Data came from Add Health, an ongoing nationally representative, school-based study of adolescents in grades 7 to 12 that began in 1994 and follows up on respondents into young adulthood. Add Health was designed to explore the causes of health-related behaviors, with an emphasis on the influence of social context. In 1994-1995, Add Health administered an in-school questionnaire to every present student from a nationally representative sample of schools. More than 70% of the schools originally selected for the survey participated.

A random sample of adolescents and one of their parents was also selected for in-home interviews in 1995, constituting wave I data. Furthermore, oversamples of various ethnic groups were selected based on in-school responses. As a result of high immigration to the United States during the 1990s and the Add Health design, which oversampled relatively rare ethnic groups (eg, Cuban, Puerto Rican, and Chinese), the study contains a large number of adolescents in immigrant families: 1 of 4 adolescents lived in an immigrant family (first and second generation). Of the adolescents selected for the in-home interviews, 79% participated in wave I, resulting in a sample size of 20,745 adolescents aged 11 to 19 years. All adolescents in grades 7 through 11 in wave I were followed up 1 year later at the wave II in-home interview in 1996, with a response rate of 88.2%. In 2001-2002, a third in-home interview was conducted with the original respondents from wave I, who were aged 18 to 28 years. More than 15,000 Add Health respondents were re-interviewed at wave III (77.4% response rate), with longitudinal data over the various waves of interviews. See Harris et al for more details on the Add Health design.

We used data from all 3 in-home interviews by pooling observations across the waves, resulting in a sample size of 48,737. Thus, respondents contribute anywhere from 1 to 3 observations on BMI to our analysis sample for growth curve models. Nonresponse analysis indicates no significant bias to Add Health estimates from attrition across waves.

MEASUREMENTS

Body Mass Index

We measured raw BMI at wave I using self-reported data on height and weight and at waves II and III using measured height and weight. Add Health analysis (not shown) and previous research indicate a very high correlation (0.99) between self-reported and measured BMI among young people. Even though BMI z scores have been identified as optimal measures of adiposity at a single point in time, raw BMI scores are best used to evaluate change in adiposity in growing children.

Race/Ethnicity and Sex

Race and ethnicity were self-reported at wave I. We used a 4-category classification: non-Hispanic white, non-Hispanic black, non-Hispanic Asian, and Hispanic. We excluded the small number of adolescents who listed race as “other” (largely Native American or unknown). Because Add Health oversampled selected ethnic groups, there were sufficient numbers of Hispanic (n=3466) and Asian (n=1578) youth to analyze their BMIs. Female sex is coded as 1, with males as the reference category.
Immigrant Generation

We divided immigrant generation into 3 categories: adolescent was foreign-born to foreign-born parents (first generation), US-born to foreign-born parents (second generation), and US-born to US-born parents (third generation or native). For foreign-born adolescents with foreign-born parents are children who were not born in the United States nor were they US citizens born abroad. They migrated to the United States as children (in most cases with their immigrant parents).

BMI RISK ASSESSMENT

To determine differences in BMI by race/ethnicity, immigrant generation, and sex, we first examined the BMI scores by age group. We then explored mean differences in age-grouped BMI scores by race/ethnicity, immigrant generation, and sex. To evaluate demographic differences in the risk of becoming overweight and developing obesity, we fit both linear and nonlinear growth curve models, with BMI as the continuous outcome and the categorical variables race/ethnicity, immigrant generation, and sex as the primary independent variables.

Growth curve models allow us to evaluate changes over time (ie, age) for individuals. The model fits a developmental trajectory for changes in BMI as youth age into adulthood (level 1 model) and allows race/ethnicity, immigrant generation, and sex to shift that trajectory (level 2 model). In the level 1 model, BMI is purely a function of an individual intercept and age for each individual at a certain time. With 3 waves of data, we have up to 3 time observations for each person in the sample. The intercept in level 1 of the growth curve model gives the expected level of BMI at the earliest observed age (11 years). The slope of the level 1 model provides the expected change in BMI with a 1-year increase in age. In the second level of the growth curve model, the level 1 intercept and the level 1 slope coefficient are estimated as functions of sex, immigrant generation, and race/ethnicity. Thus, the estimated coefficients in the level 2 model provide information on how each individual characteristic affects the intercept and slope parameters, respectively. The growth curve model presented herein was estimated as a linear growth curve model. In sensitivity analyses, we estimated quadratic and log-linear models. Results were consistent across all specifications.

Using the estimated growth curve model, we then predicted each individual’s BMI from adolescence (age, 11-19 years) through early adulthood (age, 20-28 years) and examined disparities in the BMI trajectories by sex, immigrant generation, and race/ethnicity. Based on these predictions and using the international cut-off points for BMI by sex for overweight and obesity, we estimated the percentage of our sample that would be considered overweight or obese at each age. The work of the International Obesity Taskforce provides cut-off points for overweight and obesity in children that are linked to those of adults.

STATISTICAL ANALYSIS

All analyses were conducted using mixed models in SAS. Bivariate analyses were weighted to reflect the national population estimates. To maximize the power of our analysis, growth curve models were estimated without statistical weights. All growth curve models were recalculated using the weighted data. There were no substantial differences in adjusted coefficients when the weighted data were used, but the results were less precise (ie, estimated with larger confidence intervals).

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Table 1 presents weighted descriptive statistics on the central variables of our analysis. These results are based on pooled observations across the 3 interview waves. Results show that BMI increases with age, reflecting developmental growth during adolescence up to age 20 years. Similar proportions of males and females are present in the data. Most subjects were US-born with US-born parents, third generation or higher (84%), followed by 11% who were second-generation, and 5% first-generation immigrants. The race and ethnic distribution reflects sufficient proportions for analysis across the 4 groups: There were 68% non-Hispanic white, 16% non-Hispanic black, 12% Hispanic, and 4% Asian individuals.

Table 2 presents the results from our linear growth curve model. The results in the intercept model indicate that first-generation subjects had a significantly lower BMI at the initial age (11 years) compared with those in the third or higher generation. Females also had lower BMIs than males in early adolescence. Hispanic youth and black youth had higher BMIs than white youth at the initial age. As the constant term in the intercept model indicates, the average BMI for the sample is 19.9 at age 11 years.

The slope model presents results in the change in BMI across age for each of the groups (Table 2). Results indicate that the growth rate in BMI was lower for both first- and second-generation immigrants compared with those in the third or higher generation, implying a protective effect of immigrant status from increasing BMI during the transition to adulthood. Females experience a greater increase in BMI than males throughout this time as do Hispanic and black individuals compared with white individuals. The constant term indicates that BMI increases at an average rate of 0.55 across all ages. The model fits the data well (Akaike information criterion [AIC] = 270 111; Bayesian information criterion [BIC] = 270 127; χ² = 27 765; P < .001).

| Table 1. Descriptive Statistics of Weighted Variables Used in the Analysis* |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Variable                    | No. of Subjects | Mean (SE)                  |                             |
| Body mass index* by age, y  | 11-15            | 12 274                     | 21.92 (0.10)                |
|                             | 16-19            | 20 197                     | 23.43 (0.09)                |
|                             | 20-24            | 11 689                     | 23.45 (0.13)                |
|                             | 25-28            | 918                        | 26.98 (0.27)                |
| Female sex, %               | 22 898           | 53.80 (0.01)               |                             |
| Immigrant generation        | First            | 3540                       | 5.38 (0.01)                 |
|                             | Second           | 6688                       | 10.71 (0.01)                |
|                             | ≥ Third           | 34 850                     | 83.91 (0.02)                |
| Race, %                     | Hispanic         | 7565                       | 12.01 (0.02)                |
|                             | Asian            | 3598                       | 4.27 (0.01)                 |
|                             | Black            | 9099                       | 15.83 (0.02)                |
|                             | White            | 24 316                     | 67.89 (0.03)                |

* N=45,078 pooled observations across 3 waves.

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We show these disparities in BMI trajectories in a series of graphs (Figure 1) that plot predicted BMI by age using the model presented in Table 2. Females have a lower BMI than males at age 11 years, but their increase in BMI is more rapid across age, surpassing males in BMI at around age 25 years (Figure 1A). Although these differences are slight, they are significant (Table 2).

When BMI was observed by immigrant generation, it was most noticeable that BMI was lower among the first generation (Figure 1B). First-generation youth have lower BMIs in adolescence, and the increase in BMI as they age into young adulthood is slower than that for both second and third generations. Although US-born youth in both the second and third generations have similar BMIs in early adolescence, as they age into young adulthood BMIs among the third generation increase significantly more rapidly than those of the second generation (slope coefficient in Table 2). Thus, not only does immigrant status protect youth against higher BMIs at a point in time (ie, age), but the increase in BMI as young people age into young adulthood is also slower among immigrants, especially those in the first generation.

Analysis of BMI by race showed that Hispanic and black adolescents have higher BMIs than white and Asian youth in adolescence, and their trajectories indicate increasing disparities over time, especially among Hispanic youth (Figure 1C). White and Asian youth experience the same pattern of change in BMI as they develop from adolescence into young adulthood. Although BMIs are somewhat higher for Hispanic and black youth, the pattern of change by immigrant generation is identical across race and ethnic groups, with the first generation experiencing a slower rate of increase in BMI over time compared with second- and third-generation youth (Figure 1D). Tests for interactions between immigrant generation and race/ethnicity in the age patterns of change in obesity did not substantially improve model fit (AIC = 263 751; BIC = 263 783; \( \chi^2 = 34.107 \); \( P < .001 \)). Thus, over this age range, the immigrant generation slopes are the same across race/ethnicity.

Although sex differences in trajectories of obesity were not the primary focus of this study, we also tested for interactions between race/ethnicity and sex, and between immigrant generation and sex. Although first- and second-generation females had slower growth in BMI than third-generation females, these interactions were not significant enough to substantially improve the model’s fit (AIC = 263 727; BIC = 263 759; \( \chi^2 = 34.106 \); \( P < .001 \)). Similarly, BMI grew more rapidly for black females and more slowly for Asian females than for white females. But, these differences were not substantial enough to greatly improve the model’s fit (AIC = 263 634; BIC = 263 665; \( \chi^2 = 34.004 \); \( P < .001 \)).

Figure 2 displays our transformation of raw BMI into standardized percentile distributions using the international cut-off points for BMI by sex for overweight and obesity. These results are useful because they provide an additional perspective on these disparities according to standardized definitions for overweight and obesity, by showing the percentage of our sample that would be considered overweight or obese at each age by sex, immigrant generation, and race/ethnicity. The sex disparity in the percent overweight is minor until after age 22 years when men outnumber women in the percent overweight (Figure 2A). Sex differences in the percent obese do not appear until age 20 years, when women begin to show equal or slightly higher percentages of obesity (Figure 2D).

Disparities in overweight and obesity by immigrant generation are consistent with trends in raw BMI. The first generation is less likely to be overweight or obese at any age from early adolescence into young adulthood. Differences between the second and third generations, however, are not as evident in the percentile distributions, and the second generation even surpasses the third generation in the percent obese in their later 20s (Figure 2B and E).

Overweight and obesity disparities by race/ethnicity are shown in Figure 2C and F. Throughout these ages, Hispanic and black individuals are more likely to be overweight than white individuals, and Asians are the least likely to be overweight. Disparities in obesity, however, emerge mainly after adolescence, when the percent obese among Hispanic and young black adults begins to increase, while the percent obese among white youth increases only slightly, and the percent among Asians even declines in some ages.

According to our model, 50% of first-generation, 72% of second-generation, and 70% of third-generation youth are likely to be overweight (obese) by age 25 years; 10%, 30%, and 21%, respectively, are likely to be obese. These high prevalence rates are quite consistent with previous research on adult obesity. Overall, disparities in both raw BMI values and the percent overweight and obese tend to increase with age. In particular, disparities tend to widen when adolescents leave the home and begin independent lives as young adults in their 20s. This suggests lifestyle changes may accompany this change in BMI, and may es-

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**Table 2. Level 2 Intercept and Slope Coefficients of a Linear Growth Curve Model Predicting Raw Body Mass Index Scores (N=48 737)**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Intercept (SE)</th>
<th>Slope (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First generation</td>
<td>-0.898 (0.207)</td>
<td>-0.119 (0.020)</td>
</tr>
<tr>
<td>Second generation</td>
<td>0.044 (0.156)</td>
<td>-0.053 (0.015)</td>
</tr>
<tr>
<td>Third, reference</td>
<td>0.251 (0.087)</td>
<td>0.022 (0.008)</td>
</tr>
<tr>
<td>Female sex</td>
<td>-0.269 (0.153)</td>
<td>-0.096 (0.015)</td>
</tr>
<tr>
<td>Asian</td>
<td>0.035 (0.208)</td>
<td>-0.000 (0.019)</td>
</tr>
<tr>
<td>Black</td>
<td>0.611 (0.109)</td>
<td>0.029 (0.010)</td>
</tr>
<tr>
<td>White, reference</td>
<td>19.898 (0.074)</td>
<td>0.554 (0.007)</td>
</tr>
</tbody>
</table>

\( a \) The random effects for the intercept and the residual are 20.1963 (SE, 0.229) and 6.088 (SE, 0.051), respectively. Both are significant at \( P < .001 \). Fit statistics: \( \chi^2 = 27765.19 \); \( P < .001 \); Akaike information criterion = 270110.8; Bayesian information criterion = 270126.6.

\( b \) \( P < .001 \).

\( c \) \( P < .01 \).
especially explain the generation and racial/ethnic differences over time. Most at risk for increasing obesity during the transition into young adulthood are black and Hispanic individuals and young people in native-born families. Much has been written about the lure of new technology in American culture that entices young people to replace outdoor activities and exercise with video and Internet use, fostering a sedentary lifestyle that evidently begins when adolescents leave home and set up their own households and schedules. In addition, diet choices that include fast food and fewer fruits and vegetables further exacerbate an unhealthy lifestyle among young people living on their own.57

Poor nutrition and lack of exercise are especially likely among minority groups in America, largely because of the social environments in which they live. For example, poor neighborhoods often do not have large grocery stores, which forces people, particularly those without cars, to shop at local convenience stores that stock few fresh fruits or vegetables, but large amounts of high-fat, high-starch, processed food. As a result, high-quality healthy foods can sometimes be more expensive and less accessible for those residing in economically deprived neighborhoods.58,59 Food that is nonperishable and inexpensive is more likely to be energy-dense and often contains fat, sugar, or starch, which increases the risks.
of weight gain. Young adults may not yet have acquired sophisticated cooking skills and may frequent fast-food restaurants, another source of unhealthy diets among the poor because of the low cost. Not only do predominately white neighborhoods have significantly greater access to low-cost, high-quality food sources than minority neighborhoods, but they also have greater access to recreational facilities and opportunities for physical exercise, including neighborhood parks, safe running trails, and sidewalks. High crime and social disorganization within poor neighborhoods make outdoor exercise less safe or accessible. These spatial disparities in recreational access and cost of healthy food choices may explain the trajectories we see for black and Hispanic individuals between adolescence and adulthood.

The lifestyle described above may be less salient for young people in immigrant families who do not experience the American tradition of leaving home and caring for oneself. High school graduation is less of a transition the American tradition of leaving home and caring for young people in immigrant families who do not experience the American tradition of leaving home and caring for oneself. High school graduation is less of a transition marker for immigrant youth who often either leave home when they marry, which can be at an early age, or remain in their parents’ home until they can support themselves. Given their continued presence in their parents’ home, they are more likely to retain the ethnic diets and lifestyles they grew up with as they move into their early 20s. Thus, we see a protective effect of immigrant status in overweight and obesity trajectories that slows increasing weight gain with age. This result is consistent with much of the emerging research on health disparities among immigrants in America.

The purpose of our research was to document the first nationally available prevalence data on trajectories of obesity by immigrant generation, race/ethnicity, and sex during the transition to adulthood. Future research should turn to the investigation of factors that might explain these trajectories by exploring socioeconomic, environmental, diet, lifestyle, and other health behavioral factors that may underlie the immigrant differentials we document here. These trends make it increasingly clear that intervention and prevention efforts should be directed toward US-born Hispanic and black youth transitioning from high school to work or college, and more generally among all youth as they leave home and begin to develop their own health habits that set pathways for their future health.

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Author Contributions: Dr Harris had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Harris, Perreira, and Lee. Acquisition of data: Harris. Analysis and interpretation of data: Harris, Perreira, and Lee. Drafting of the manuscript: Harris, Perreira, and Lee. Critical revision of the manuscript for important intellectual content: Harris, Perreira, and Lee. Statistical analysis: Harris, Perreira, and Lee. Obtained funding: Harris and Perreira. Administrative, technical, and material support: Harris and Perreira. Study supervision: Harris and Perreira.

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