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Adolescent individual, school, and neighborhood influences on young adult diabetes risk

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Abstract

Using data from the National Longitudinal Study of Adolescent to Adult Health (Add Health), this study examines the association between adolescent school and neighborhood contexts and the likelihood of diabetes in young adulthood. We apply cross-classified multi-level modeling (CCMM) techniques to examine the simultaneous influence of non-nested school and neighborhood contexts as well as individual, school, and neighborhood-level factors (N = 14,041 participants from 128 schools, 1933 neighborhoods). Our findings suggest that individual-level factors are most associated with young adult diabetes, with small contributions from school and neighborhood factors and a small proportion of the variation explained by school and neighborhood contexts.

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Keywords

Diabetes; Adolescents; Neighborhood; School; Young adulthood

1. Introduction

The incidence of diabetes has markedly risen over recent decades and is expected to further increase moving forward (Hu et al., 2021). Diabetes ranks among the ten leading causes of death globally (Ismail et al., 2021). Based on a recent report by the International Diabetes Federation, over 640 million people worldwide will be living with Type 2 diabetes mellitus by 2040, a roughly 50% increase from 425 million in 2017 (Bellou et al., 2018; Ismail et al., 2021). As type 2 diabetes rates increase worldwide, diabetes has become one of the most common chronic diseases experienced by children (Pansier and Schulz, 2015). Several metabolic, genetic, behavioral, and environmental factors are reported to influence the risk of diabetes such as diet (Ley et al., 2018), physical inactivity (Fletcher et al., 2002), smoking (Bellou et al., 2018), obesity (Wang et al., 2010; Ismail et al., 2021; Walker et al., 2016), and dyslipidemia (Ismail et al., 2021).

Prior research has established that neighborhoods and schools have a critical impact on the development of obesity, diabetes, high cholesterol, hypertension, and other cardiometabolic disease risk factors in children and adolescents (Evans et al., 2016; Richmond et al., 2016; Min et al., 2020; Niu et al., 2019; Abdel Magid et al., 2022). Collectively, neighborhoods and schools – the places where adolescents reside, play, and learn – are where adolescents spend a large majority of their time (Richmond et al., 2016; Niu et al., 2019). Studies have investigated school and neighborhood environments and their relationship to diabetes; however, there has been a paucity of research examining school and neighborhood contexts simultaneously and determining their relative contribution to diabetes risk, particularly longitudinally into adulthood. Focusing on single contexts (e.g., school) fails to account for the fact that individuals belong to multiple environments that each simultaneously influences their health. By ignoring other important contexts, the single-context approach may overestimate the importance of the environment under study (Dunn et al., 2015b).

Our study addresses this gap in the literature within a large, nationally representative cohort of U.S. adolescents ages 11–18 followed into young adulthood. The study features two aims: 1) to examine the extent to which individual-, school-, and neighborhood-level factors are independently associated with the likelihood of developing diabetes by young adulthood (ages 24–32), and 2) to determine the *relative* contribution of schools and neighborhoods on developing diabetes by young adulthood. We use cross-classified multilevel modeling (CCMM) of data from the National Longitudinal Study of Adolescent to Adult Health (Add Health).

2. Methods

2.1. Data collection

This study used data from Add Health, a nationally representative cohort of adolescents in the United States followed from adolescence to adulthood to study social, behavioral, and biological determinants of health (Harris, 2013). The detailed study design and sampling strategy for Add Health has been described in detail elsewhere (Harris and Udry, 2018). Institutional Review Board approval was obtained to conduct secondary analyses of the Add Health data using deidentified data obtained under an Add Health Restricted-Use Data Contract at the University of California, San Francisco.

2.2. Participants

Add Health longitudinally follows a nationally representative sample of adolescents in grades 7 to 12 at baseline (Wave I; interviewed 1994–1995; N = 20,745) into adulthood. A sample of 80 high schools and 52 feeder middle schools from the United States was selected to ensure this sample is representative of U.S. schools with respect to region of country, urbanicity, school size, school type, and ethnicity. The current study uses in-home interview data from adolescence (Wave I) and diabetes in young adulthood (Wave IV; aged 24–32 years; interviewed 2007–2008; N = 15,701). Of respondents who participated in both waves (N = 15,701), we did not impute missing values and excluded those missing diabetes information at Wave IV (n = 127); school contextual data (n = 919); neighborhood contextual data (n = 6); or individual socioeconomic status (SES) measures (n = 555). We also excluded n = 53 participants with pre-existing diabetes in adolescence as reported on the caregiver interview (Wave I). These exclusions resulted in a final analytic sample of 14,041 respondents.

2.3. Measures

Diabetes in young adulthood (Wave IV) was collected from the Wave IV in-home interview using a composite measure provided by Add Health which included any of the following: self-reported history of diabetes except during pregnancy, measured glucose (fasting glucose ≥126 mg/dl or non-fasting glucose ≥200 mg/dl), or anti-diabetic medication in the past four weeks (Whitsel et al., 2012).

Data from the adolescent (Wave I) in-home interview was used for individual-, school-, and neighborhood-level covariates including biological sex, race/ethnicity, and measures of SES during adolescence. At the individual level, SES was determined based on parental education and receipt of public assistance and highest level of parental education (defined as the maximum level of education by the resident mother, resident father, or resident stepfather/partner) using data from either the caregiver interview if available (87%) and youth interview if there was no caregiver respondent (13%). School-level data on racial composition or SES was not directly available and we therefore aggregated data from the individual-level to calculate school-level proportion White non-Hispanic race, parental receipt of public assistance, and parent with a college degree. At the neighborhood level, we used data from the 1990 Census to create a neighborhood-level SES measure indicating the proportion of residents within each neighborhood who had received public assistance or had a college degree and racial composition based on the proportion of residents who were non-Hispanic White race. Current age in young adulthood at Wave IV (in years) was calculated from the date of Wave IV in-home interview and participant's date of birth.

2.4. Statistical analysis

We examined individual-, school-, and neighborhood-level sociodemographic characteristics stratified by diabetes status in young adulthood (Wave IV) and reported mean (standard deviation; SD) for continuous variables, frequency (percent) for categorical variables at the individual-level and mean (SD) for school- and neighborhood-level aggregated variables. All tests were performed at an alpha-level of 0.05.

We fit a series of cross-classified multilevel (CCMM) logistic regression models to estimate the associations between diabetes in young adulthood with individual-level, school-level, and neighborhood-level factors to examine our first aim (i.e., fixed effects) and calculated the proportion of variance in the likelihood of diabetes attributable to the neighborhood and school levels (i.e., random effects variance parameters) from the same models to examine our second aim. Models were fit using MLwiN (version 3.05; Birmingham, UK) which employs a Bayesian estimation procedure using Markov Chain Monte Carlo (MCMC) methods with non-informative priors and a Metropolis-Hastings sampling algorithm for non-hierarchically nested contexts (Rabash and Browne, 2001; Rasbash et al., 2020; Rodríguez and Goldman, 1995; Browne, 2022). Starting values or priors for the Bayesian estimation procedure are based on estimates from a naïve model assuming hierarchical nesting between levels which is fit using iterative generalized least squares (Rasbash et al., 2020; Rabash and Browne, 2001; Browne, 2022; Dunn et al., 2015b). However, these are considered non-informative priors as the true data structure is ignored and assumed to be hierarchical (Rasbash et al., 2020; Rabash and Browne, 2001; Browne, 2022; Dunn et al., 2015b). The detailed steps and procedures for fitting CCMM and other models in MLwiN are described in detail in the software manuals and elsewhere (Browne, 2022; Dunn et al., 2015b; Rabash and Browne, 2001; Rasbash et al., 2020).

To examine the individual-level, school-level, and neighborhood-level factors and relative contextual contributions, we fit the following series of CCMMs. Model 0 was an initial unadjusted null model (no predictors) to examine the relative contribution of both schools and neighborhoods simultaneously. Model 1 adjusted for individual-level predictors including age, sex, race and ethnicity, parental education, and parental receipt of public assistance. Model 2 included individual-level predictors as well as school-level percentage of students of White non-Hispanic race, percentage of students whose parents receive public assistance, and percentage of students whose parents have a college degree. Model 3 included individual predictors plus neighborhood-level predictors from the Census: percentage of residents' White race, percentage of residents receiving public assistance and percentage of residents with a college degree. Model 4 was fully adjusted and included all individual-, school-, and neighborhood-level predictors. Model 5 included all individual-, school-, and neighborhood-level predictors in addition to adolescent (Wave I) body mass index and tobacco smoking as potential factors associated with diabetes.

For each model, we report odds ratios (OR) and 95% credible intervals (CI) for fixed effects, variance parameter estimates and intra-class correlation (ICC) for random effects allowing for a comparison of variance attributable to each context as a proportion of the total variance (Goldstein et al., 2002; Rasbash et al., 2020). ICCs for each context were calculated by taking the ratio of the variance explained by a given context and dividing by the total variation in the outcome which was estimated using the method described in detail in Goldstein et al. (2002). Unlike multilevel linear regression, the individual-level or residual variance is not directly estimated in a multilevel logistic model as it is a function of the prevalence of the outcome, therefore an approximation of the individual-level variance was estimated using the constant $\frac{\pi^2}{3} = 3.29$ to calculate total variance and ICCs (Goldstein et al., 2002).

All univariate and bivariate analyses were performed in STATA (version 16.0; College Station, TX) and regression models were fit in MLwiN (version 3.05; Birmingham, UK) and implemented using the runmlwin command in STATA.

3. Results

The final sample included N = 14,041 participants from 128 schools and 1933 neighborhoods, of which 874 neighborhoods (45.2%) had a single respondent. Table 1 presents individual-, school-, and neighborhood-level sociodemographic characteristics overall and by diabetes in young adulthood. Overall, mean age in young adulthood at the Wave IV survey was 29.0 years (SD = 1.7), 53.0% of participants were female, 52.8% non-Hispanic White race, 20.5% non-Hispanic Black, and 15.7% Hispanic. In young adulthood at Wave IV, 6.6% had diabetes.

Table 2 presents the fixed effects odds ratio estimates from series of adjusted cross-classified multilevel logistic regression models predicting diabetes in young adulthood. Odds ratios for the individual-, school- and neighborhood-level predictors were similar across models. Model 4 which included predictors at all 3 levels indicated that individual-level factors older age, Black, Hispanic, Asian, multiracial, or another race or ethnicity, and parental receipt of public assistance were associated with an increased odds of developing diabetes by young adulthood. In addition, at the school-level, a higher percentage of students with a parent receiving public assistance was associated with a higher odds of diabetes and at the neighborhood-level, a higher percentage of residents receiving public assistance and higher percent of residents with a college degree were associated with a lower odds of diabetes. In the final model (Model 5) which also included adolescent BMI and tobacco smoking, higher adolescent BMI was also associated with increased odds of diabetes while adolescent tobacco smoking was associated with a lower odds of diabetes.

The intra-class correlations (ICC) from the null cross-classified multilevel logistic regression model indicated that 6.7% of the variation in the likelihood of diabetes in young adulthood was accounted for by school while 2.6% was accounted for by neighborhood, and the remaining 90.7% due to individual variation and unaccounted for by the contextual levels. Random effects variance parameters and ICC values for the series of adjusted models can also be found in Table 2. In Model 1 adjusting only for individual-level covariates, the amount of variation in the likelihood of developing diabetes by young adulthood accounted for by school was attenuated to 1.1% while the percent accounted for by the neighborhood increased to 2.1%, and the remaining 96.8% was unaccounted for by context. Including school-level predictors (Model 2), the school-level variance was similar at 0.6% while the neighborhood-level was attenuated (0.5%), and 98.9% was unaccounted for by context. Including neighborhood-level predictors (Model 3), the school-level variance was 1.2% while neighborhood-level was attenuated to 0.2%, and 98.6% was unaccounted for by context. In the fully adjusted model (Model 4) including predictors at the individual-, school-, and neighborhood-level, the variability accounted for by the contextual levels was 0.6% at the school-level and 0.7% at the neighborhood-level, leaving 98.7% unaccounted for by context. The final model which also included adolescent BMI and tobacco smoking resulted in school- and neighborhood-level variance parameters that were nearly completely attenuated (0.5% and <0.1%, respectively) with the remaining 99.4% unaccounted for by the contextual levels and attributable to individual variation.

4. Discussion

In this multilevel cohort study, we found that individual-level factors had the largest independent associations with the likelihood of diabetes in young adulthood, with smaller contributions from neighborhood- and school-level socioeconomic factors. We found differences in the likelihood of diabetes by individual characteristics including age, race and ethnicity, and SES including receipt of public assistance and parental education. Our results examining the relative contribution of school and neighborhood contexts indicated that the between-level variation in the likelihood of diabetes was largely due to the observed individual characteristics across schools and neighborhoods, and that more of the variability in diabetes was attributable to neighborhood-level rather than school-level with ICC values of 2.1% and 1.1%, respectively, after adjusting for individual-level sociodemographic factors.

To the best of our knowledge, this is the first study to compare the simultaneous contributions of individual, school, and neighborhood factors, and to examine the characteristics of the contexts themselves, on the likelihood of diabetes in young adulthood. This study adds to previous literature about contextual contribution on adolescent and young adult development by exploring the relative contributions of both school-level and neighborhood-level socioeconomic characteristics to young adult diabetes using a large sample of US adolescents followed into young adulthood. While school and neighborhood contexts accounted for only a small proportion of the variation in the likelihood of young adult diabetes, these findings indicate a small but persistent contextual association despite exposure to those contexts being over a decade prior to the measurement period for the outcome. Future studies are needed to examine whether these contextual associations persist into later adulthood and beyond.

We identified several individual-level factors associated with diabetes that add to the literature by accounting for school- and neighborhood-level factors from adolescence. We observed that Black, Hispanic, Asian, multiracial, and adolescents of another race experienced a higher odds of diabetes in adulthood compared to White adolescents, consistent with prior literature examining racial/ethnic differences in diabetes (Ismail et al., 2021). These findings may be explained in part by family history and genetics, but also by the environmental influences of poor diet and exercise habits that may accumulate from adolescence into adulthood (Fletcher et al., 2002). Additionally, we found that individual-level receipt of public assistance and lower parent education were associated with higher odds of diabetes. These results are in line with prior findings examining diabetes risk among adolescents from low-education households (Bellou et al., 2018). However, none of these prior studies simultaneously accounted for school- and neighborhood-level factors, representing a novel contribution of the current study in that our results are robust to the contextual effects contributing to the likelihood of diabetes.

Our study found that neighborhoods explained more of the variation than schools on developing diabetes by young adulthood. Our results may be explained in part by factors related to the physical neighborhood such as built environment, safety, and access to fresh food and grocery stores that could impact levels of physical activity and nutrition; however, data on these factors was not available. Although the exact mechanism for this finding is unclear, our results add to prior literature showing that neighborhood environment factors such as air pollution and urbanization are associated with greater diabetes risk (Bellou et al., 2018; Ley et al., 2018). Our study builds upon these findings by showing that socio-demographic neighborhood-level factors such as public assistance and parent education are associated with lower odds of diabetes in young adulthood, while simultaneously accounting for other school or individual factors. Prior neighborhood-level studies did not account for school-level factors.

Additionally, with regard to school-level factors, a higher percentage of students with receipt of public assistance was associated with a greater likelihood of developing diabetes in young adulthood. Prior studies have shown that school-level factors such as physical inactivity and meals containing processed meats and sugar-sweetened beverages were associated with higher adolescent diabetes risk (Ley et al., 2018; Ismail et al., 2021; Wang et al., 2010). However, these studies did not account for neighborhood- and individual-level factors or examine diabetes in young adulthood. The socio-demographic breakdown of schools may influence adolescents’ diabetes risk net of their individual factors considering adolescents spend many hours in schools and with their peers.

Interestingly, our findings indicated that the contextual level effects of public assistance were in opposite directions. We found that living in a neighborhood with a higher percentage of residents receiving public assistance was associated with a *lower* odds of diabetes in young adulthood while attending a school with a higher percentage of parents receiving public assistance was associated with a *higher* odds of diabetes. This may be explained by a variety of factors including the potential for lower funding for schools in impoverished areas, school choice facilitating students living in high poverty neighborhoods attending school in higher resource school districts, or neighborhood differences in social capital correlated with measures of SES. However, the exact mechanism underlying these findings is unclear and warrants further study.

This study has a few notable limitations. First, analyses are based on a study that recruited adolescents using school-based sampling, leading to a small sample size per neighborhood. Although 45% of neighborhoods from adolescence (Wave I) had a single respondent, prior research using Add Health has demonstrated no bias in the random effect estimates as a result of small neighborhood sizes (Milliren et al., 2018). Second, limited school and neighborhood-level measures during adolescence were available; therefore, this study may exclude other contextual attributes at the school and neighborhood level that may be associated with young adult diabetes risk such as measures of the built environment and access to green space. Third, as Add Health responses were self-reported, potential errors or inaccuracies in self-reporting may affect our results. In addition, anti-diabetic medication, which was also used to ascertain diabetes status, may be taken for other conditions such as polycystic ovarian syndrome.

Data on young adult neighborhood and school contexts after Wave I were not collected and, thus, a longitudinal analysis of school or neighborhood over time could not be conducted. We examined the impact of socioeconomic factors during adolescence which were contemporaneous with our school and neighborhood contextual measures. However, we did not account for changes in SES or other factors between adolescence and young adulthood. Future studies should consider examining the associations between adult measures of SES independently or in addition to parental measures during adolescence. Further, while Add Health employed a complex sampling survey design allowing for national estimates, data were unweighted in these analyses as complex sample weighting techniques for CCMMs are not well-established. Therefore, our findings may not be nationally representative. Additionally, we performed a complete case analysis and excluded respondents with missing data for contextual school or neighborhood information or individual measures of SES rather than other approaches for missing data such as single or multiple imputation. While it is not feasible to impute contextual information, we also did not apply imputation for missing individual-level receipt of public assistance or parental education given the numerous assumptions required and lack of complete data for other measures related to SES (e.g., employment status, income) that could be used for robust imputation. Despite this, we used data from both caregiver (if available) and adolescent respondent interviews for our measures of SES to minimize the amount of missing data and exclusions. Finally, our school-level measures of socioeconomic status were aggregated directly from individual-level data and our measure of public assistance relied on maternal (and not paternal) report of receiving assistance. Despite being a common methodology in multilevel research (Dunn et al., 2014), future studies could use administrative or school-level data if available to preclude any concerns about the indicators accurately reflecting the students in the sample. Nevertheless, Add Health is one of the few large, national samples of adolescents in the U.S. that collected school- and neighborhood-level data, along with follow-up into young adulthood, and was thus appropriate to apply the CCMM framework. Overall, our study's findings among Add-Health participants provide further evidence of a high prevalence of diabetes among U.S. young adults and merit further scrutiny (Nguyen et al., 2011).

This paper demonstrates the value of cross-classified multilevel models (CCMM) in determining the relative importance of multiple contexts simultaneously. Our results underscore the need to extend current analytic approaches from basic multilevel modeling to allow for cross-classification, acknowledging the multiple non-nested contexts individuals simultaneously exist within. Although some studies have used CCMMs to examine health-related outcomes (Huang et al., 2020; Dunn et al., 2015a, 2015b; Richmond et al., 2016; Milliren et al., 2017; Pinchak and Swisher, 2022; Abdel Magid et al., 2022), the CCMM method is not widely utilized, perhaps due to a lack of applied examples (Barker et al., 2020). Expanded work in this area is needed, particularly to help inform the allocation of limited public health resources to the most salient and actionable contextual-level factors. Without clear data showing the relative importance of multiple contexts, the field risks enacting misguided policies and interventions to contexts that may be incapable of having large effects on reducing health risk and promoting health outcomes.

In conclusion, in this study we find that individual-level factors including race and ethnicity and indicators of socioeconomic status were associated with young adult diabetes, with smaller yet significant contributions from neighborhood and school SES. In addition, we found a small proportion of variation in the likelihood of diabetes in young adulthood was explained by the school and neighborhood contexts themselves, with most of the variation due to individual characteristics. The CCMM methodology described in this paper can be extended to several other health outcomes, and at other stages in the life course, to examine the role of social contexts on health and ultimately inform the development of interventions to improve population-level health.

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Data availability

The authors do not have permission to share data.

Abbreviations

CCMM	cross-classified multilevel modeling
Add Health	National Longitudinal Study of Adolescent to Adult Health
SES	socioeconomic status
ICC	intra-class correlation

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Table 1.

Individual-, school-, and neighborhood-level characteristics of participants in adolescence by diabetes in young adulthood of the National Longitudinal Study of Adolescent to Adult Health (N = 14,041).

	Overall (N = 14,041)	Diabetes in Young Adulthood	
		Yes (n = 929)	No (n = 13,112)
***Individual-level* N = 14,041**	**N (%)**		
Age in young adulthood (years), *mean (SD)*	29.0 (1.7)	29.2 (1.7)	28.9 (1.7)
Sex			
Female	7440 (53.0%)	511 (55.0%)	6929 (52.8%)
Male	6601 (47.0%)	418 (45.0%)	6183 (47.2%)
Race and ethnicity			
Non-Hispanic White	7418 (52.8%)	291 (31.3%)	7127 (54.4%)
Non-Hispanic Black	2875 (20.5%)	361 (38.9%)	2514 (19.2%)
Hispanic	2208 (15.7%)	160 (17.2%)	2048 (15.6%)
Asian	786 (5.6%)	51 (5.5%)	735 (5.6%)
Another race or ethnicity	179 (1.3%)	18 (1.9%)	161 (1.2%)
Multiracial	575 (4.1%)	48 (5.2%)	527 (4.0%)
Parent Receipt of Public Assistance			
No	12,805 (91.2%)	793 (85.4%)	12,012 (91.6%)
Yes	1236 (8.8%)	136 (14.6%)	1100 (8.4%)
Parental Education			
Less than high school	1672 (11.9%)	161 (17.3%)	1511 (11.5%)
High school graduate/GED	3650 (26.0%)	245 (26.4%)	3405 (26.0%)
Some College	4180 (29.8%)	269 (29.0%)	3911 (29.8%)
College graduate or beyond	4539 (32.3%)	254 (27.3%)	4285 (32.7%)
Adolescent BMI (kg/m^2)			
Underweight (<18.5 or <5th percentile)	466 (3.3%)	10 (1.1%)	456 (3.5%)
Normal/healthy Weight (18.5–24.9 or 5th-84.9th percentile)	9674 (68.9%)	452 (48.7%)	9222 (70.3%)
Overweight (25–29.9; 85th – 94.9th percentile)	2064 (14.7%)	189 (20.3%)	1875 (14.3%)
Obese (≥30 or ≥95th percentile)	1510 (10.8%)	241 (25.9%)	1269 (9.7%)
Unknown	327 (2.3%)	37 (4.0%)	290 (2.2%)
Adolescent Smoking			
No	10,369 (73.8%)	735 (79.1%)	9634 (73.5%)
Yes	3672 (26.2%)	194 (20.9%)	3478 (26.5%)
***School-level* N = 128 schools**	**Mean (SD)**	**Median (IQR)**	**Min – Max**
Percent of students Non-Hispanic White race	47.5 (25.5)	55.0 (42.7)	0–85.9
Percent of parents receiving public assistance	10.4 (9.4)	7.2 (11.6)	0–45.4
Percent of parents with college degree	31.7 (16.9)	28.3 (21.9)	5.5–91.2
***Neighborhood-level* N = 1933 neighborhoods**	**Mean (SD)**	**Median (IQR)**	**Min-Max**
Percent of residents Non-Hispanic White race	66.9 (32.6)	79.6 (48.9)	0–100

	Overall (N = 14,041)	Diabetes in Young Adulthood	
		Yes (n = 929)	No (n = 13,112)
Percent of residents receiving public assistance	10.5 (9.7)	7.2 (10.2)	0–61.8
Percent of residents with college degree	23.7 (14.6)	20.3 (18.9)	1.1–82.5

Abbreviations: SD – standard deviation; IQR – interquartile range; BMI – body mass index.

Table 2.

Logistic cross-classified multilevel models (CCMMs) predicting diabetes in young adulthood from individual-, school- and neighborhood-level factors during adolescence in the National Longitudinal Study of Adolescent to Adult Health (N = 14,041).

	Model 1	Model 2	Model 3	Model 4	Model 5
	Individual Cross-Classified	**Individual & School Cross-Classified**	**Individual & Neighborhood Cross-Classified**	**Individual, School, & Neighborhood Cross-Classified**	**Individual, School, & Neighborhood Cross-Classified**
Fixed effect estimates, *Odds Ratios (95% Credible Interval)*					
Individual-level					
Age in young adulthood (years)	**1.08 (1.06, 1.11)**	**1.09 (1.06, 1.12)**	**1.07 (1.04, 1.11)**	**1.09 (1.07, 1.13)**	**1.11 (1.08, 1.14)**
Female	1.06 (0.92, 1.22)	1.06 (0.92, 1.21)	1.06 (0.93, 1.21)	1.07 (0.94, 1.22)	1.11 (0.96, 1.26)
Race and ethnicity					
Non-Hispanic White	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Non-Hispanic Black	**3.18 (2.62, 3.81)**	**2.80 (2.29, 3.42)**	**3.00 (2.44, 3.60)**	**2.86 (2.34, 3.47)**	**2.65 (2.13, 3.26)**
Asian	**1.61 (1.10, 2.23)**	1.46 (0.99, 2.02)	**1.61 (1.10, 2.21)**	**1.49 (1.04, 2.13)**	**1.50 (1.04, 2.04)**
Hispanic	**1.62 (1.29, 2.01)**	**1.41 (1.09, 1.79)**	**1.63 (1.29, 2.02)**	**1.46 (1.14, 1.84)**	**1.31 (1.02, 1.67)**
Another race or ethnicity	**2.46 (1.37, 3.92)**	**2.15 (1.23, 3.41)**	**2.49 (1.42, 3.96)**	**2.16 (1.19, 3.47)**	**1.92 (1.05, 3.05)**
Multiracial	**2.22 (1.58, 2.99)**	**2.08 (1.51, 2.80)**	**2.19 (1.54, 2.96)**	**2.10 (1.48, 2.83)**	**1.97 (1.44, 2.62)**
Parent receipt of public assistance	**1.35 (1.09, 1.65)**	**1.24 (1.00, 1.52)**	**1.34 (1.08, 1.64)**	**1.27 (1.01, 1.56)**	**1.25 (1.01, 1.54)**
Parental Education					
Less than high school	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
High school graduate/GED	**0.79 (0.64, 0.97)**	**0.81 (0.65, 1.00)**	0.82 (0.65, 1.02)	0.86 (0.68, 1.09)	0.83 (0.66, 1.03)
Some college	**0.80 (0.64, 0.98)**	0.84 (0.66, 1.04)	0.86 (0.68, 1.06)	0.90 (0.72, 1.14)	0.88 (0.70, 1.10)
College graduate or beyond	**0.73 (0.58, 0.91)**	**0.79 (0.62, 1.00)**	0.82 (0.63, 1.04)	0.86 (0.68, 1.10)	0.87 (0.68, 1.11)
Adolescent BMI (kg/m^2)					
Underweight or normal/healthy weight	–	–	–	–	1.0 (Reference)
Overweight	–	–	–	–	**1.97 (1.64, 2.35)**
Obese	–	–	–	–	**3.60 (3.01, 4.22)**
Unknown	–	–	–	–	**2.55 (1.73, 3.55)**
Adolescent tobacco smoking		–	–	–	**0.84 (0.70, 1.00)**
School-level, per 10%					

	Model 1	Model 2	Model 3	Model 4	Model 5
	Individual Cross-Classified	**Individual & School Cross-Classified**	**Individual & Neighborhood Cross-Classified**	**Individual, School, & Neighborhood Cross-Classified**	**Individual, School, & Neighborhood Cross-Classified**
Percent of students Non-Hispanic White	–	0.98 (0.94, 1.01)	–	0.98 (0.94, 1.03)	0.97 (0.93, 1.01)
Percent of parents receiving public assistance	–	**1.16 (1.02, 1.31)**	**-**	**1.28 (1.11, 1.46)**	**1.22 (1.09, 1.38)**
Percent of parents with college degree	–	0.98 (0.91, 1.05)	–	1.05 (0.98, 1.12)	1.05 (0.99, 1.12)
Neighborhood-level, per 10%					
Percent of residents Non-Hispanic White	–	–	0.98 (0.95, 1.01)	0.99 (0.96, 1.04)	1.01 (0.97, 1.04)
Percent of residents receiving public assistance	–	–	**0.93 (0.82, 1.05)**	**0.86 (0.75, 0.97)**	**0.87 (0.76, 0.98)**
Percent of residents with college degree	–	–	**0.88 (0.80, 0.94)**	**0.86 (0.80, 0.93)**	**0.88 (0.81, 0.96)**
Random effect variance parameter estimates, ***mean (intra-class correlation; ICC; %)***					
School	0.04 (1.1%)	0.02 (0.6%)	0.04 (1.2%)	0.02 (0.6%)	0.02 (0.5%)
Neighborhood	0.07 (2.1%)	0.02 (0.5%)	0.01 (0.2%)	0.02 (0.7%)	0.001 (0.04%)
Individual (residual), ***ICC***	96.8%	98.9%	98.6%	98.7%	99.4%

Bold text indicates statistically significant estimates.