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Article

Multilevel analysis of BMI growth trajectories of US school children: Features and risk factors

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ABSTRACT

Childhood obesity continues to be a major focus of public health efforts in the United States, where nearly 17% of children are obese. In this study, we focused on two significant features that characterize U.S. society—school mobility and a single-parent family structure—and how they relate to childhood obesity/overweight. Using a nationally representative sample from the Early Childhood Longitudinal Study—Kindergarten (ECLS-K) class of 1998, we examined the body mass index (BMI) growth trajectories of children to determine how these two key features interacted with demographic characteristics of gender, race/ethnicity, and socio-economic status (SES), which are known to be associated with BMI. We analyzed five waves of data from kindergarten through fifth grade of 9041 students applying a two-level hierarchical linear model (HLM). Results indicated that children who changed schools more than two times from kindergarten to fifth grade had higher BMI growth trajectories compared to children who changed only once or did not change schools. To our knowledge, no prior studies have examined this association. Results also indicated children in single-parent families were more likely to have higher BMI growth trajectories compared to children in two-parent families. Although both school mobility and family structure had an impact on children's BMI, we found that family structure had a larger impact than school mobility. Being in a two-parent family was a protective factor for children; that is, even if children in two-parent families moved schools twice or more, they still maintained a healthy BMI on average. For children in single-parent families, however, moving schools tended to have a greater, negative impact on their BMI statuses.

Introduction

Childhood obesity continues to be a major focus of public health efforts in the United States, where nearly 17% of children are obese (Ogden, Carroll, Kit, & Flegal, 2014). Obesity and being overweight have been shown to have far-reaching negative consequences for children, including effects on their physical and mental health as well as their social and emotional well-being (Sahoo et al., 2015; Stunkard, Faith, & Allison, 2003). Common health-related consequences associated with childhood obesity are cardiovascular disease (Nadeau, Maahs, Daniels & Robert, 2011), asthma (Visness et al., 2010), and type 2 diabetes (Hossain, Kawar, & El Nahas, 2007) among others. Because of the social stigmatization that may occur (Puhl & Heuer, 2009), obese or overweight children are more likely to have low self-esteem and have higher rates of depression and anxiety disorders compared to their normal weight peers (Griffiths, Parsons, & Hill, 2010; Taras & Potts-Datema, 2005). In terms of educational impact, obese and overweight children are more likely to report having problems at school (Schwimmer, Burwinkle, & Varni, 2003), miss school more frequently (Geier et al., 2007), and in some cases may suffer poor academic outcomes (Datar & Sturm, 2006).

It has been well established that childhood obesity has a significant association with certain demographic characteristics of the child, including socioeconomic status (SES), race/ethnicity, and gender (McLaren, 2007; Wang & Lim, 2012). In developed countries, like the U.S., studies suggest that, in general, lower SES groups are at a higher risk for obesity compared to their higher SES counterparts (McLaren, 2007; Monteiro, Moura, Conde, & Popkin, 2004; Wang & Beydoun, 2007; Wang & Lim, 2012; Wang & Zhang, 2006). This relationship between obesity and SES, however, may also depend on additional factors, such as race/ethnicity, gender, and age (Wang & Beydoun, 2007; Wang & Lim, 2012). According to recent data from the National Health and Nutrition Examination Survey (NHANES), the highest prevalence of childhood obesity was among Black and Hispanic children (Ogden, Carroll, Fryar, & Flegal, 2015, pp. 1–8). Several studies suggest, however, that for Black children and adolescents, a higher SES was

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associated with a higher prevalence of obesity, which is counter to the overall trend for U.S. children (Miyazaki & Stack, 2015; Wang, 2011; Wang & Zhang, 2006).

In this study, we wish to explore additional child characteristics, beyond demographics, that may be associated with obesity or being overweight. Specifically, we are interested in how school mobility and family structure, described further in the literature review, influence children's body mass index (BMI), a common measure of obesity/overweight. In the U.S., changing schools and being raised in a single-parent household are more common features of childhood as compared to other developed countries (GAO, 2010; OECD, 2011). Both of these features can have an impact on a child's school success (Rumberger, 2003) and overall health (Chen & Escarce, 2010; Rumberger, 2003). Although some studies have focused on family structure and obesity (Balistreri & Van Hook, 2010; Chen & Escarce, 2010; Gibson et al., 2007), to our knowledge no prior studies have examined the association of school mobility and obesity. In this study, we expand previous literature on family structure and obesity by examining the unique and combined contributions of school mobility and family structure on BMI. By exploring these characteristics together, we are attempting a more holistic approach to studying childhood obesity in that we cover two important aspects of a child's life: family and school. This study was guided by the following research questions:

1) Are there any differences in the BMI growth trajectories between students who change schools from kindergarten to fifth grade and those who do not? That is, is changing schools a risk factor for child obesity/overweight?
2.) What is the association between family structure and BMI? That is, is being in a single-parent family a risk factor for child obesity/overweight? Conversely, is being in a two-parent family a protective factor for child obesity/overweight?
3.) Does the association between school mobility and BMI growth trajectories depend upon family structure?

Literature review

School mobility

Compared to other industrialized countries, the U.S. has one of the highest rates of student mobility (GAO, 2010), defined as making non-promotional school changes. Highly mobile students, or those who change schools more than four times from kindergarten to eighth grade, make up 13% of U.S. school children (GAO, 2010). In some school districts, as many as 75% of children change schools at least once from kindergarten to eighth grade (De La Torre & Gwynne, 2009). Research prior to the 1980s suggested that school moves reflected moving up the SES ladder and focused on benefits of those changes; although this may be true in some cases, research since then has focused on the negative consequences associated with the instability of school moves (Rumberger, 2003). Commonly, school mobility is a result of a residential move related to either the parents' jobs or another financial insecurity (Rumberger, 2003).

School mobility has been linked to lower academic performance (Gruman, Harachi, Abbott, Catalano, & Fleming, 2008) as well as an increased risk of dropping out of school (Gasper, DeLuca, Estacion, & 2012; South, Haynie, & Bose, 2007). In terms of health outcomes, school mobility is associated with an increased risk of behavioral problems (Gruman et al., 2008; Rumberger, 2003) and more symptoms of depression in young adulthood (Herbers, Reynolds, & Chen, 2013). Several studies suggest that, due to the developmental timeframe, school mobility occurring in the elementary grades may have the most negative impact on students (Mehana & Reynolds, 2004; Rumberger, 2003). To our knowledge, no prior research has examined the effect of changing schools during elementary school on child obesity, a focus of the current study.

The association between school mobility and negative educational and health outcomes has several explanations. When a child changes schools, especially during the middle of the school year, they may face a different curriculum and new expectations, posing a challenge to the child (Gruman et al., 2008). They may also find it challenging to form new social relationships with peers and teachers (Rumberger, 2003). Compounding these issues, highly mobile students are more likely to have additional risk factors, such as low socioeconomic status (Burkam, Lee, & Dwyer, 2009), being a racial/ethnic minority (Burkman et al., 2009), and residing in a single-parent home (Rumberger, 2003)—all factors that we consider in the current study.

Family structure

In addition to obesity and school mobility rates, the U.S. also has a relatively high rate of children living in single-parent households, with roughly 26% of children living in this family structure (OECD, 2011). By some estimates, nearly 50% of children in the U.S. will live in a single-parent household sometime before the age of 18 (McLanahan & Percheski, 2008). Family structure is associated with mother's educational level and certain racial/ethnic categories—children with less educated mothers and Black children are more likely to be in single-parent families (McLanahan & Percheski, 2008).

Being raised in a single-parent family can have enormous impacts on children who grow up in such an environment (Carlson, 2006; McLanahan & Percheski, 2008). In particular, family structure may contribute to a child's weight status, with children in single-parent families having a higher likelihood of being overweight or obese (Balistreri & Van Hook, 2010; Chen & Escarce, 2010; Gibson et al., 2007). Family structure is likely to affect a child's daily activities, including diet routines, physical activity, or use of family time. Single parents, who balance work, housework, and childcare, might rely on less nutritious, easier meals (Patrick & Nicklas, 2005). In comparison, in two-parent households, parents are able to share the household and childcare responsibilities, leaving more time for nutritious meal preparation and physical activity (Bagley, Salmon, & Crawford, 2006; Rasmussen et al., 2006). Two-parent households may also benefit from a higher household income if both parents work. In this study, we examined whether growing up in a single- or two-parent family environment has an impact on BMI, taking into account other background characteristics as well as school mobility.

Conceptual framework and model

In the present study, our primary independent variables of interest were family structure and school mobility. Because of the well-established association of family SES and childhood obesity and the important role that this factor plays in childhood obesity (McLaren, 2007; Monteiro et al., 2004; Wang & Beydoun, 2007; Wang & Lim, 2012; Wang & Zhang, 2006), we also treated SES as a key independent variable. In our model, SES was considered a risk factor for childhood obesity as most of the literature indicates that the higher the SES, the lower the BMI (McLaren, 2007). Family structure (i.e., single-parent families) was also a risk factor for child obesity/overweight as it is documented in the literature (Chen & Escarce, 2010). School mobility does not appear in the literature as often, but because school moves are associated with other health and behavioral problems (Herbers et al., 2013; Rumberger, 2003), we hypothesized that it may also have an effect on child obesity and considered it as another risk factor. Thus, in our conceptual framework, we considered these three risk factors – family structure, school mobility, and SES – as the main effects on change in BMI. That is, we hypothesized that these factors could have unique partial effects on the increase in BMI even after controlling for the other factors.

In our multilevel growth model for BMI trajectory used in this study, we specify these three factors as exogenous variables (Kline, 2016; Pearl, Glymour, & Jewell, 2016). The reason for this choice was that the major goals of our study were to see whether and how these three

factors might change the shape of the BMI growth trajectory and whether the impact of each factor depends on the level of another factor. It was not our intention to test a more detailed mechanism of how these three factors work together to change the growth trajectory of BMI; given the information available in the dataset, it was not possible to test a more precise model.

Considering the above three variables as risk factors for childhood obesity and specifying them as exogenous variables in our model imply that these factors were hypothesized to have the main effects in our model. We further hypothesized that each pair of risk factors could have interaction effects (i.e., effects modification). For example, the effect of SES on BMI increase may depend on the level of family structure. This could happen if, for example, the negative effect of low SES on BMI increase is larger for a child in a single parent family. Similarly, the negative effect of being in a single parent family could be more pronounced if the child changes school or vice versa, suggesting an interaction effect between family structure and school mobility. These main and interaction effects were examined within the multilevel growth-modeling framework.

Methods

Data source and sample

In this study, we used data from the Early Childhood Longitudinal Study—Kindergarten (ECLS-K) class of 1998 (NCES, 2004). ECLS-K is a nationally representative sample of students who began kindergarten in the 1998–1999 school year and includes information from parents, school administrators, as well as from students. In order to allow for subgroup analysis, some student populations, specifically Asian/Pacific Islanders, were oversampled by ECLS-K, requiring the use of sample weights in this study (Thomas, Heck, & Bauer, 2005).

We used five waves of longitudinal data from ECLS-K, including information from five measurement occasions: Fall Kindergarten and the Spring of Kindergarten, 1st, 3rd, and 5th grades. Although there was information through 8th grade, we did not include this wave because most students change schools from elementary school to middle school during this time, confounding our primary interest of non-promotional school moves. To be included in the study, children had to have a BMI measurement on at least one measurement occasion, not all five—a strength of using multilevel analysis. Students also had to have complete student-level variables for gender, race/ethnicity, SES, and family structure (two parents vs. single parent), as well as non-missing design panel weight information. To adjust for biological differences associated with BMI, two control variables of birth weight and age at the first measurement occasion (i.e. Fall Kindergarten) were also used. This resulted in a sample of 9041 students.

Among the 9041 students in the sample, the composition of gender and race/ethnicity reflected the target population, and SES was approximately reflected in the original quintile percentages, though a slightly lower proportion of the lowest SES quintile was represented. As shown in Table 1, the sample was nearly split between males (50.9%) and females (49.1%). The majority of the students were White (60.5%), followed by Hispanic (17.9%), and Black (14.9%). Over 66% of students changed schools at least once during the study duration of about 5.5 years from Fall Kindergarten to the Spring of 5th grade. About 34% (3046) of the students did not change schools during this time period, compared to 42% (3808) who changed schools one time, and 24% (2187) who changed schools two or more times. Also, 24.1% of the students came from single-parent families. The complete univariate descriptive statistics for all the individual-level demographics are reported in Table 1.

Table 1
Student Level Descriptive Statistics.

	N	%
Gender		
Male	4601	50.9
Female	4440	49.1
Race/Ethnicity		
White	5472	60.5
Black	1344	14.9
Hispanic	1616	17.9
Asian	208	2.3
Others	402	4.4
SES Quintile at Fall Kindergarten		
First Quintile	1640	18.1
Second Quintile	1833	20.3
Third Quintile	1828	20.2
Fourth Quintile	1841	20.4
Fifth Quintile	1899	21.0
School Change		
Did not move schools	3046	33.7
Moved school one time	3808	42.1
Moved school two or more times	2187	24.2
Family Structure		
Two Parents	6863	75.9
Single Parent	2179	24.1
Total	9041	

Note. All results are based on the weighted analysis, weighted by the sample weight.

Analysis

In order to study the BMI growth trajectories and the effects of student and family backgrounds on BMI, a two-level hierarchical linear model (HLM) was used. HLM was one of the most appropriate methods to analyze this data due to the nested data structure of repeated measures (Raudenbush & Bryk, 2002). Level-1 units were the BMI measurement occasions, and level-2 units were the students. Level-2, or student-level, variables included gender, race/ethnicity, SES, the two-way interactions of these variables, as well as two control variables, birth weight and age at Fall Kindergarten. All analyses were conducted using HLM7 software (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011). Throughout the analysis, sample weights provided by ECLS-K were applied in order for inferences to be valid for the target population, i.e. the cohort of U.S. elementary school children who entered kindergarten in the 1998–1999 school year. In order to protect against certain violations of assumptions, such as the homogeneity of variance assumption and the departure from normality, we employed robust standard errors (Raudenbush & Bryk, 2002) instead of the regular standard errors for our inference. In building our final HLM model, we followed a systematic approach to answering our research questions by creating a taxonomy of statistical models (Singer & Willett, 2003) described further in the Results section as the models are built.

Results

Descriptive results

Prior to fitting the HLM models, we first explored the data descriptively. As shown in Table 2, we compared students who changed schools at least once from kindergarten to 5th grade (“movers”) to those who remained in the same school during that time (“non-movers”). First, we see that there are statistically significant differences in race/ethnicity, SES, family structure, and birth weight between the two groups of students in terms of moving status. That is, students in the mover category included more Black students, lower SES students, more single-parent families, and lower birth weight students than those students in the non-mover category. In terms of the dependent variable, BMI, there were marginally statistically significant mean differences between the two groups at Fall Kindergarten ($p = 0.071$) where movers had greater BMIs than non-movers.

Next, in order to explore the effect of family structure on BMI

Table 2
Comparison of Student Level Descriptive Statistics for Non-movers and Movers (weighted).

Categorical Variables	Non-movers (N = 3,046, 33.7%)				Movers (N = 5,995, 66.3%)				*Comparison*
	N	%			N	%			*p*-value
Gender									.549
Male	1537	50.4			3065	51.1			
Female	1509	49.6			2930	48.9			
Race/Ethnicity***									< .001
White	1949	64.0			3523	58.8			
Black	341	11.2†			1003	16.7††			
Hispanic	535	17.5			1080	18.0			
Asian	67	2.2			141	2.3			
Others	154	5.0			247	4.2			
SES Quintile***									< .001
First Quintile (lowest)	477	15.7†			1163	19.4			
Second Quintile	609	20.0			1224	20.4			
Third Quintile	627	20.6			1201	20.0			
Fourth Quintile	633	20.8			1207	20.1			
Fifth Quintile (highest)	699	22.9††			1200	20.0			
Family Structure***									< .001
Two parents	2421	79.5†			4442	74.1††			
Single parent	625	20.6			1553	25.9			
Continuous Variables	**Mean**	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**	***p*-value**
SES***	0.05	0.77	−4.75	2.75	−0.04	0.81	−4.47	2.67	< .001
Birth Weight (pounds) ¯	7.43	1.31	1.06	13.38	7.35	1.33	1.00	13.13	.086
Age at Fall, K (years)	5.70	0.36	4.50	6.58	5.70	0.36	4.67	6.58	.991
BMI at Fall, K¯	16.28	2.13	9.41	31.94	16.37	2.24	7.91	31.49	.071
BMI at Spring, K	16.40	2.28	4.91	32.52	16.41	2.27	10.27	29.43	.795
BMI at Spring, 1st	16.85	2.78	5.61	38.48	16.87	2.93	9.59	33.53	.711
BMI at Spring, 3rd	18.61	3.80	8.50	40.03	18.55	3.77	9.37	38.66	.482
BMI at Spring, 5th	20.51	4.63	9.83	47.54	20.63	4.69	7.68	45.00	.229

Note. ~$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; †† most contributing cell; † second most contributing cell; all the results are based on the weighted analysis, weighted by the sample weight. For the categorical variables, a chi-square test was conducted; for the continuous variables, a *t*-test was conducted.

Table 3
Correlations among BMI Measured at Each Time Point and Family Structure, SES, and Black Race Indicator.

	Single-Parent Family	SES	Black Race Indicator
BMI at Fall, K	−0.002	−0.072**	−0.003
BMI at Spring, K	0.005	−0.101**	−0.007
BMI at Spring 1st grade	0.040**	−0.124**	0.015
BMI at Spring 3rd grade	0.039**	−0.124**	0.025*
BMI at Spring 5th grade	0.058**	−0.149**	0.050**
SES	−0.290**	–	−0.193***
Black Race Indicator	0.378**	−0.193**	–

Note. ~$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

trajectories descriptively, we examined the correlation coefficients between BMI at each time point, and family structure, SES, and race/ethnicity, respectively. For the exploratory analysis stage, only White and Black students were selected since Black students were a predominantly higher percentage of being in the single-parent family (62.8%) category compared to other race/ethnicity groups (White 15.6%, Hispanic 21.5%, Asian 13.9%, and Others 25.9%); White was chosen as the reference group since it was the majority group (60.5% in Table 1). From Table 3, we can see that being in a single-parent family, being Black, and being in a lower SES family, were associated with increasingly higher BMIs in later years. Furthermore, being in a single-parent family was strongly associated with SES (−0.29, $p < 0.01$) and the Black race indicator variable (0.38, $p < 0.01$).

Multilevel growth model results

In order to develop the final HLM growth model, we started with an unconditional quadratic growth model as a function of time. The unconditional growth model specifies only the level-1 model, which describes the growth trajectory within individuals, and no predictors are included at level 2. At level 1, a quadratic function of time was chosen in order to capture a nonlinear growth pattern, which was clearly indicated by examining the descriptive statistics. The time variable, *YEAR*, was set to zero for Fall Kindergarten. For each subsequent semester, 0.5 (half a year) was added; thus, 0.5 indicated Spring Kindergarten, 1.5 Spring First Grade, 3.5 Spring Third Grade, and 5.5 Spring Fifth Grade in order to reflect the actual duration of time in years. Thus, *YEAR* represents the passage of time in years since the fall of Kindergarten.

Table 4 presents the sequence of models we fitted and their results following a taxonomy of statistical models (Singer & Willett, 2003) in order to answer the research questions posed. First, in Model A, we specified an unconditional quadratic growth model as a function of time as follows:

L-1:

$$BMI_{ti} = \pi_{0i} + \pi_{1i}(YEAR)_{ti} + \pi_{2i}(YEAR^2)_{ti} + \varepsilon_{ti}\ ,\ \ \varepsilon_{ti} \overset{i.\ i.}{\sim} d.\ N(0, \sigma^2)$$

where the subscript *t* represents the *t*th measurement occasion (t = 1, 2, 3, 4, 5) and *i* represents the *i*th child in the sample ($i = 1, 2, \ldots, N$ where $N = 9041$). The *i.i.d.* notation indicates that the level-1 random errors (ε_{ti}) are independent and identically distributed. Because of the coding of the *YEAR* variable, π_{0i} represents the expected initial status of student *i*, that is, their true BMI score at Fall Kindergarten, π_{1i} represents the rate of change of student *i* at Fall Kindergarten, and π_{2i} represents the quadratic rate of change, or the half rate of acceleration, for student *i*. To simplify, we refer to this term, π_{2i}, as the rate of acceleration when there is no possible confusion.

At level 2, the initial status (π_{0i}), the rate of annual change (π_{1i}), and the rate of acceleration (π_{2i}) for student *i* become the outcome variables

Table 4
Results of Fitting a Taxonomy of Multilevel Models for BMI Change to the ECLS-K Data (N = 9041).

			Model A	Model B	Model C
Fixed Effects					
Initial Status at Fall K, π_{0i}		Intercept, β_{00}	16.263***	16.275***	16.355***
	Family Structure	1Parent, β_{01}		−0.003	0.161
	School Moves	1TimeMove, β_{02}		0.019	−0.008
		2TimeMove, β_{03}		0.177	0.188
	Gender	Female, β_{04}		−0.111	−0.108
	Race	Black, β_{05}		0.189	0.382*
		Hispanic, β_{06}		0.588***	0.591***
		Asian, β_{07}		0.080	−0.126
		Other, β_{08}		0.382~	0.409~
	SES	SES, β_{09}		−0.169***	−0.153**
	Gender x Family Structure	Female x 1Parent, β_{010}			−0.023
	Gender x School Moves	Female x 1TimeMove, β_{011}			0.151
		Female x 2TimeMove, β_{012}			−0.599*
	Gender x Race	Female x Black, β_{013}			0.454~
		Female x Hispanic, β_{014}			−0.248
		Female x Asian, β_{015}			−0.050
		Female x Other, β_{016}			−0.022
	Gender x SES	Female x SES, β_{017}			0.004
	Race x Family Structure	Black x 1Parent, β_{018}			−0.622*
		Hispanic x 1Parent, β_{019}			0.004
		Asian x 1Parent, β_{020}			−0.515
		Other x 1Parent, β_{021}			0.004
	Race x School Moves	Black x 1TimeMove, β_{022}			0.205
		Hispanic x 1TimeMove, β_{023}			0.283
		Asian x 1TimeMove, β_{024}			0.379
		Other x 1TimeMove, β_{025}			0.665
		Black x 2TimeMove, β_{026}			−0.949**
		Hispanic x 2TimeMove, β_{027}			0.076
		Asian x 2TimeMove, β_{028}			−1.336**
		Other x 2TimeMove, β_{029}			−0.299
	Race x SES	Black x SES, β_{030}			−0.008
		Hispanic x SES, β_{031}			0.123
		Asian x SES, β_{032}			0.245
		Other x SES, β_{033}			0.149
	SES x Family Structure	SES x 1Parent, β_{034}			0.354**
	SES x School Moves	SES x 1TimeMove, β_{035}			0.093
		SES x 2TimeMove, β_{036}			−0.039
	Family Structure x School Moves	1Parent x 1TimeMove, β_{037}			−0.338~
		1Parent x 2TimeMove, β_{038}			0.199
	Age at Fall K	Age at Fall Kindergarten, β_{039}		0.023*	0.024**
	Birth Weight	Birth Weight, β_{040}		0.021***	0.020***
Linear Rate of Change at Fall K, π_{1i}		Intercept, β_{10}	0.370***	0.370***	0.378***
	Family Structure	1Parent, β_{11}		0.056	0.055
	School Moves	1TimeMove, β_{12}		−0.027	−0.036
		2TimeMove, β_{13}		−0.182*	−0.167*
	Gender	Female, β_{14}		0.058	0.059
	Race	Black, β_{15}		0.092	0.175~
		Hispanic, β_{16}		0.231***	0.199**
		Asian, β_{17}		0.116	0.132~
		Other, β_{18}		0.151	0.165
	SES	SES, β_{19}		−0.070*	−0.068*
	Gender x Family Structure	Female x 1Parent, β_{110}			−0.373*
	Gender x School Moves	Female x 1TimeMove, β_{111}			−0.008
		Female x 2TimeMove, β_{112}			−0.078
	Gender x Race	Female x Black, β_{113}			0.183*
		Female x Hispanic, β_{114}			−0.088
		Female x Asian, β_{115}			−0.366*
		Female x Other, β_{116}			−0.046
	Gender x SES	Female x SES, β_{117}			−0.035
	Race x Family Structure	Black x 1Parent, β_{118}			−0.089
		Hispanic x 1Parent, β_{119}			−0.097
		Asian x 1Parent, β_{120}			0.026
		Other x 1Parent, β_{121}			0.128
	Race x School Moves	Black x 1TimeMove, β_{122}			0.023
		Hispanic x 1TimeMove, β_{123}			0.089
		Asian x 1TimeMove, β_{124}			0.008
		Other x 1TimeMove, β_{125}			0.168
		Black x 2TimeMove, β_{126}			−0.314**
		Hispanic x 2TimeMove, β_{127}			0.019
		Asian x 2TimeMove, β_{128}			−0.177~
		Other x 2TimeMove, β_{129}			−0.165
	Race x SES	Black x SES, β_{130}			0.153~

(*continued on next page*)

Table 4 (*continued*)

			Model A	Model B	Model C
		Hispanic x SES, β_{131}			−0.049
		Asian x SES, β_{132}			0.040
		Other x SES, β_{133}			0.060
	SES x Family Structure	SES x 1Parent, β_{134}			−0.035
	SES x School Moves	SES x 1TimeMove, β_{135}			−0.010
		SES x 2TimeMove, β_{136}			−0.048
	Family Structure x School Moves	1Parent x 1TimeMove, β_{137}			0.019
		1Parent x 2TimeMove, β_{138}			0.051
	Age at Fall K	Age at Fall Kindergarten, β_{139}		0.024**	0.025***
	Birth Weight	Birth Weight, β_{140}		0.003*	0.002*
Quadratic Rate of Change, π_{2i}		Intercept, β_{20}	0.076***	0.077***	0.079***
	Family Structure	1Parent, β_{21}		−0.004	−0.001
	School Moves	1TimeMove, β_{22}		0.003	0.004
		2TimeMove, β_{23}		0.032*	0.030*
	Gender	Female, β_{24}		−0.005	−0.005
	Race	Black, β_{25}		0.007	−0.001
		Hispanic, β_{26}		−0.019	−0.010
		Asian, β_{27}		−0.030*	−0.032**
		Other, β_{28}		−0.002	−0.005
	SES	SES, β_{29}		−0.003	−0.003
	Gender x Race	Female x Black, β_{210}			0.005
		Female x Hispanic, β_{211}			0.008
		Female x Asian, β_{212}			0.034
		Female x Other, β_{213}			0.008
	Gender x Family Structure	Female x 1Parent, β_{214}			0.066*
	Race x SES	Black x SES, β_{215}			−0.015
		Hispanic x SES, β_{216}			0.024∼
		Asian x SES, β_{217}			−0.002
		Other x SES, β_{218}			−0.011
	SES x Family Structure	SES x 1Parent, β_{219}			0.015
	SES x School Moves	SES x 1TimeMove, β_{220}			0.012
		SES x 2TimeMove, β_{221}			0.007
	Age at Fall K	Age at Fall Kindergarten, β_{222}		−0.003**	−0.003**
	Birth Weight	Birth Weight, β_{223}		-7.9×10^{-5}	-3.8×10^{-5}
Random Effects					
Level 1		Temporal variation, e_{ti}	0.920	0.920	0.919
Level 2		Initial Status at Fall K, r_{0i}	3.801***	3.523***	3.437***
		Linear Rate of Change, r_{1i}	0.654***	0.622***	0.609***
		Quadratic Rate of Change, r_{2i}	0.0142***	0.0138***	0.0135***

Note. $\sim p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

and each outcome of the level 2 model is formulated as the overall mean and the deviation from the overall mean, which represents the random unique effects of student *i*. That is.

$$\begin{aligned}\pi_{0i} &= \beta_{00} + r_{0i} \\ \pi_{1i} &= \beta_{00} + r_{1i}, \begin{pmatrix} r_{0i} \\ r_{1i} \\ r_{2i} \end{pmatrix} i.\ i.\sim d.\ N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, T = \begin{pmatrix} \tau_{00} & \tau_{01} & \tau_{02} \\ \tau_{10} & \tau_{11} & \tau_{12} \\ \tau_{20} & \tau_{21} & \tau_{22} \end{pmatrix}\right] \\ \pi_{2i} &= \beta_{00} + r_{2i}\end{aligned}$$

where β_{00} is the overall mean BMI status at Fall Kindergarten, β_{10} is the overall mean rate of change at Fall Kindergarten, and β_{20} is the overall mean rate of acceleration across students. The r_{0i}, r_{1i}, and r_{2i} are the level-2 random errors associated with each individual growth parameter (π_{0i}, π_{1i}, and π_{2i}) and are considered individual unique effects; they are assumed to be independent, and identically distributed (*i.i.d.*) as normal with mean of 0 vector and a 3 by 3 symmetric covariance matrix of *T*.

The results of the unconditional quadratic growth model (Model A) are presented in Table 4. As shown, results indicated that the overall mean BMI at the initial measurement occasion, Fall Kindergarten, was 16.26. Additionally, the average per semester growth at Fall Kindergarten (i.e. initial annual rate of change, or slope) was 0.37 and the average quadratic rate of change, which was half the rate of acceleration, was 0.08. This implies that the overall average BMI trajectory was a convex quadratic function of *YEAR* and it increased with positive acceleration during the elementary school years. All of the growth parameters (π_{0i}, π_{1i}, and π_{2i}) varied significantly among elementary school aged children, and all of the estimated variances ($\hat{Var}(r_{0i}) = 3.801$, $\hat{Var}(r_{1i}) = 0.654$, and $\hat{Var}(r_{2i}) = 0.014$), were highly statistically significant at the 0.001 level. In particular, the variances of the slope and the rate of acceleration were of substantive significance since their 95% plausible ranges computed by $\hat{\gamma} \pm 1.96\sqrt{Variance}$ were (−1.216, 1.956) and (−0.155, 0.307) respectively. This means that some of the student's initial slope and acceleration can be negative.

In Model B, two key independent variables for our study—family structure and mover status—were entered as predictors at level 2 for the intercept (π_{0i}), the slope (π_{1i}), and the rate of acceleration (π_{2i}) since each of them exhibited statistically and substantively significant variation among students in Model A. In addition, the demographic background variables of gender, race/ethnicity, and SES along with two control covariates of Age at Fall Kindergarten and Birth Weight were entered into the level-2 model. Results from Model B showed that, moving two or more times was a significant predictor for the linear and quadratic rates of change ($\hat{\beta}_{13} = -0.182$, $p < 0.05$; $\hat{\beta}_{23}$=0.032, $p < 0.05$, respectively), controlling for all of the demographic variables and the two control variables regarding biological factors. These values indicated that children who moved at least twice started at the same level as other children, but their BMI increase had a faster speed compared to non-movers or children who only moved once. The single-parent family indicator variable did not show a statistically significant effect on any of the growth parameters. In addition, a lower SES was associated with higher BMIs at Fall Kindergarten ($\hat{\beta}_{09} = -0.169$, $p < 0.001$) and for the linear rate of change ($\hat{\beta}_{19} = -0.070$, $p < 0.05$). In terms of race, Hispanic students had statistically significantly higher

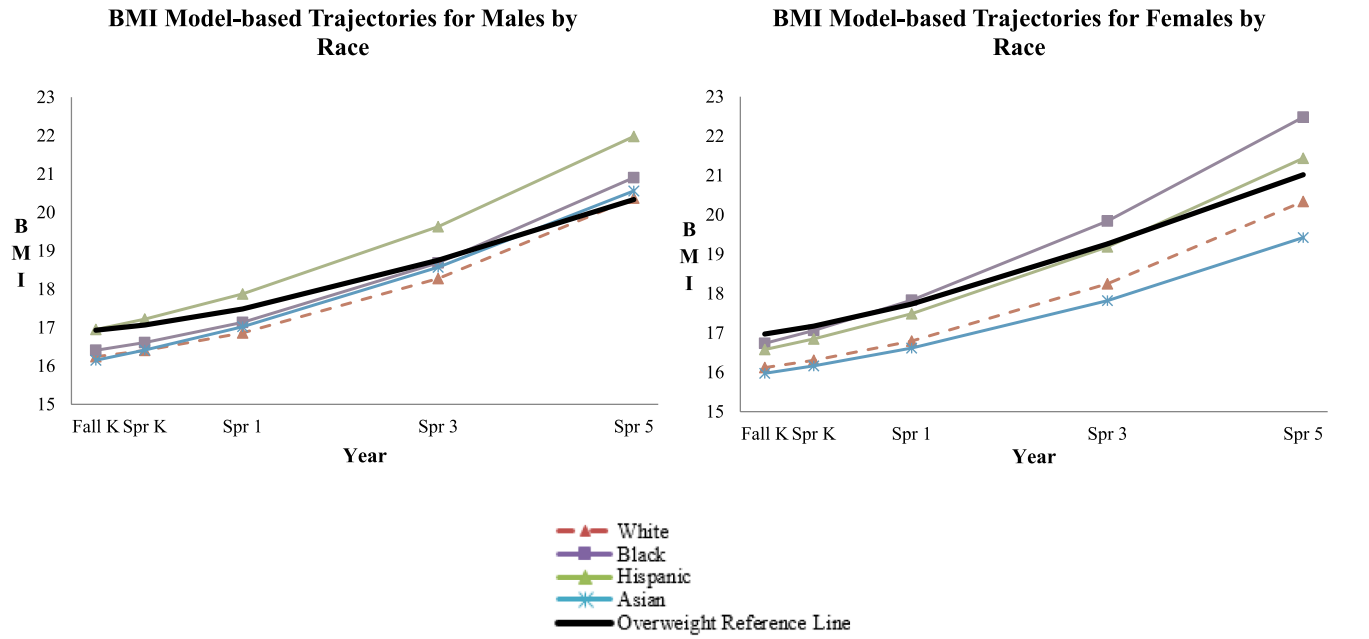

Fig. 1. BMI model-based trajectories by gender and race. *Note*: The "Other" race category was omitted to simplify the graphs. This group's trajectory came between Black and Hispanic's trajectories.

initial statuses and higher initial rates of change as compared to White students ($\hat{\beta}_{06} = 0.588$, $p < 0.001$; $\hat{\beta}_{16} = 0.231$, $p < 0.001$).

Because our descriptive statistics/analyses indicated that single-parent families and frequent moving were concentrated among certain demographic features, such as race/ethnicity and SES, we included interaction terms for our key independent variables of interest and demographic variables in the next model. Interaction effects among demographic variables, were anticipated from the literature (McLaren, 2007; Monteiro et al., 2004; Wang & Beydoun, 2007; Wang & Lim, 2012; Wang & Zhang, 2006). Therefore, in Model C, which was the final model, the demographic variables of SES, gender (*Female*, female dummy variable, male is the reference group), race/ethnicity (*Black*, *Hispanic*, *Asian*, and *Other* are a set of dummy variables; White is the reference group), and a set of all possible two-way interactions among gender, race/ethnicity, SES, mover status, and family structure were included, which resulted in 10 combinations. All interactions were created by multiplying grand mean centered main effects that appeared in Model B. These main effects and two-way interaction terms were included in the level-2 model for each π_{0i}, π_{1i}, and π_{2i}. We tried higher order interactions, such as three- and four-way interactions, but we did not include them in the final model because either they were not statistically significant or the model did not converge, which indicated that the complexity of the model could not have been supported by the current data.

As shown in Table 4, results from Model C indicated the following. As for family structure, the interaction of *Female* by single parent (*1Parent*) was significant for the quadratic rate of acceleration ($\hat{\beta}_{214} = 0.066$, $p < 0.05$) and for the linear rate of change ($\hat{\beta}_{110} = -0.373$, $p < 0.05$). This combination of values implies that for girls raised in a single-parent family, their initial rate of change at Fall Kindergarten was slower, but as they got older, it increased with a higher rate of acceleration compared to girls raised in two-parent families. For the initial status, the interaction of *SES* by *1Parent* was statistically significant ($\hat{\beta}_{034} = 0.354$, $p < 0.01$). In terms of school moves, moving two or more times (*2TimeMove*) was significant for the quadratic rate of change ($\hat{\beta}_{23} = 0.030$, $p < 0.05$), meaning that two-time movers had higher acceleration than one-time movers did. For the initial rate of change, the interaction of *Black* by *2TimeMove* ($\hat{\beta}_{126} = -0.314$, $p < 0.01$) and the main effect of *2TimeMove* ($\hat{\beta}_{13} = -0.167$, $p < 0.05$) were statistically significant. For the initial status, the interaction of *Female* by *2TimeMove* ($\hat{\beta}_{012} = -0.599$, $p < 0.05$), *Black* by *2TimeMove* ($\hat{\beta}_{026} = -0.949$, $p < 0.01$), and *Asian* by *2TimeMove* ($\hat{\beta}_{028} = -1.336$, $p < 0.01$) were statistically significant. Among the background variables, higher SES was associated with lower BMIs at Fall Kindergarten ($\hat{\beta}_{09} = -0.153$, $p < 0.01$). In addition, the main effect of *Black* and *Hispanic* ($\hat{\beta}_{05} = 0.382$, $p < 0.05$, $\hat{\beta}_{06} = 0.591$, $p < 0.001$, respectively) were statistically significant and the interaction effects of *Female* by *Black* ($\hat{\beta}_{013} = 0.454$, $p < 0.10$) and *Female* by *Hispanic* ($\hat{\beta}_{014} = -0.248$, $p < 0.10$) were marginally significant. This indicates that although both Black and Hispanic students had significantly higher BMIs than White students at the initial time point, Hispanic males had higher BMIs than Black males, but Black females had higher BMIs than Hispanic females. For the linear rate of change at fall kindergarten, *Hispanic* ($\hat{\beta}_{16} = 0.199$, $p < 0.01$) and *SES* ($\hat{\beta}_{19} = -0.068$, $p < 0.05$) were statistically significant while *Asian* ($\hat{\beta}_{17} = 0.132$, $p < 0.10$) and *Black* ($\hat{\beta}_{15} = 0.175$, $p < 0.10$) were marginally significant; the interactions of *Female* by *Black* ($\hat{\beta}_{113} = 0.183$, $p < 0.05$), *Female* by *Asian* ($\hat{\beta}_{115} = -0.366$, $p < 0.05$) were also statistically significant and *Black* by *SES* ($\hat{\beta}_{130} = 0.153$, $p < 0.10$) trended towards significance. For the quadratic rate of change, Asian students had significantly lower rates of acceleration than White students ($\hat{\beta}_{27} = -0.032$, $p < 0.01$); in addition, there was a marginally significant *Hispanic* by *SES* interaction ($\hat{\beta}_{216} = 0.024$, $p < 0.10$). It should be noted that there was still a significant amount of variance that remained in each of the growth parameters.

In order to assist and facilitate the interpretation of the results, we created graphs of our key findings based on the results of Model C. To put these results in context, each graph includes a reference line, adjusted for age and gender, at the 85th percentile for BMI, which is considered overweight for children and at risk of becoming obese (CDC, 2009; CDC, 2018); for figures that do not separate by gender, the average of males and females is used as the reference line. Fig. 1 shows the association of gender and race with BMI trajectories. Comparing left to right, we see that boys' BMIs are higher than girls' BMIs at Fall Kindergarten, but girls' BMIs tend to catch up, with the exception of

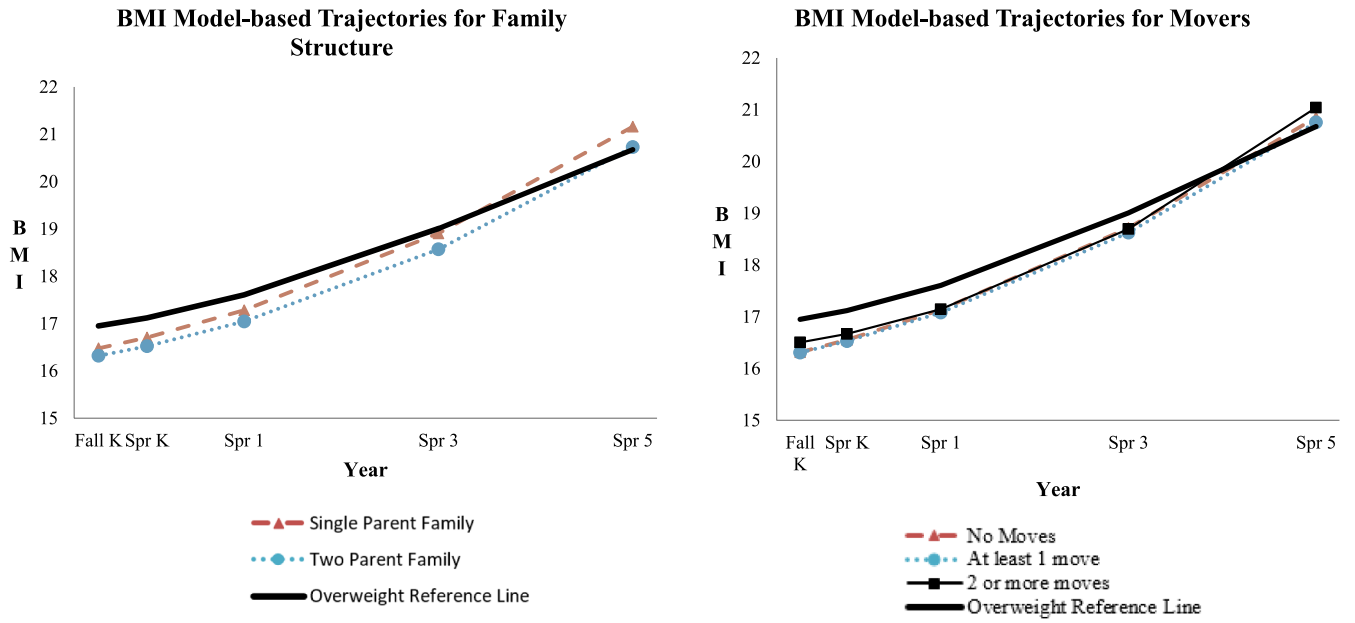

Fig. 2. BMI model-based trajectories for family structure and school moves.

Asian and White girls. Furthermore, Hispanic males have the highest BMI trajectories, while Black girls have the highest BMI trajectories, which is an indication of the interaction between race and gender on BMI trajectories. For boys across all racial/ethnic groups, the average BMI status exceeded the overweight threshold line by Spring of 5th grade, although all of them started below or equal to the threshold line. For girls, all of the subgroup lines began below the threshold line at Fall Kindergarten, but Black and Hispanic students exceeded the threshold line at Spring 5th grade. Fig. 2 shows the association between BMI with the two key independent variables of interest in this study, school moves and family structure. As shown in the graph, at each measurement occasion, children in single-parent families had higher BMIs than those children in two-parent families. Students who moved two or more times had a higher BMI during the Kindergarten year and at Spring of 5th grade; however, there were no distinguishable differences from Spring of 1st grade to the Spring of 3rd grade.

Because there were interactions effects between our key independent variables of interest and SES and gender, we created the graphs shown in Figs. 3–6. In Fig. 3, the interaction of school moves and SES is shown. For all three levels of moving—two or more moves, one move, and no moves—we see that the lower SES students have higher BMIs at each measurement occasion. We also see that, in general, the gaps among their respective BMI trajectories are widening as students get older. In Fig. 4, we show the interaction effect of family structure by gender. We see that for males, being in a single-parent family has a clearer impact on BMI; for females, there is less of a difference between children in single-parent families and two-parent families until Spring 5th grade. However, there is a clear sign of separation of the trajectories starting from Spring 3rd grade, i.e. the single-parent family trajectory increases more quickly than the two-parent family one. This was mainly due to the positive statistically significant interaction between gender and family structure for the quadratic rate of change. Next, in Fig. 5, the interaction effects of family structure by moving status, on BMI trajectories are depicted. For children in single-parent families, changing schools has a clearer impact on BMI, with children moving two or more times having the highest BMIs. For two-parent families, moving does not have an effect. Additionally, for children in single-parent families, all groups exceed the overweight threshold line between the Spring of 3rd grade and the Spring of 5th grade; while for children in two-parent families, children barely exceed the threshold line by the Spring of 5th grade. Lastly, in Fig. 6, we show the interaction effects between family structure and SES on BMI trajectories. For children in two-parent families, the lower the SES, the higher the BMI; for children in single-parent families, however, there is very little difference between SES levels. Additionally, just after the Spring of 3rd grade for single-parent families, on average, all three subgroups exceed the overweight reference line. For two-parent families, in lower SES families, children exceed the reference line at the Spring of 3rd grade; the trajectories of students in medium and high SES families remained at or below the threshold line for the entire time.

Discussion and conclusion

In this study, we focused on two significant features that characterize U.S. society—school mobility and a single-parent family structure—and how they relate to childhood obesity/overweight. Using a nationally representative sample, we examined the BMI growth trajectories of children from kindergarten through fifth grade to determine how these two key features influenced BMI trajectories and whether the influences of these features on the trajectories depend on the demographic characteristics of gender, race/ethnicity, and SES, which are known to be associated with BMI (McLaren, 2007; Wang & Lim, 2012). As shown in nearly all of the figures in the results section, at some point during the elementary school years, the average BMI trajectory of students in the sample crossed over the CDC's reference line, indicating that the students were overweight and at risk of becoming obese. Once again, this highlights the seriousness of the issue and the importance of childhood obesity research in the U.S.

One significant finding of our study was that school mobility in the elementary school years had a significant impact on children's BMI growth trajectories during that time. Results indicated that children who changed schools more than two times from kindergarten to fifth grade had higher BMI trajectories compared to children who changed schools only once or did not change schools. To our knowledge, no prior studies have examined this association. As noted in previous research, school mobility can affect children's educational (e.g. Gruman et al., 2008) and health (e.g. Herbers et al., 2013) outcomes, with elementary school moves having the greatest impact on children (Mehana & Reynolds, 2004; Rumberger, 2003). For these known associations between school mobility and child outcomes, possible explanations may

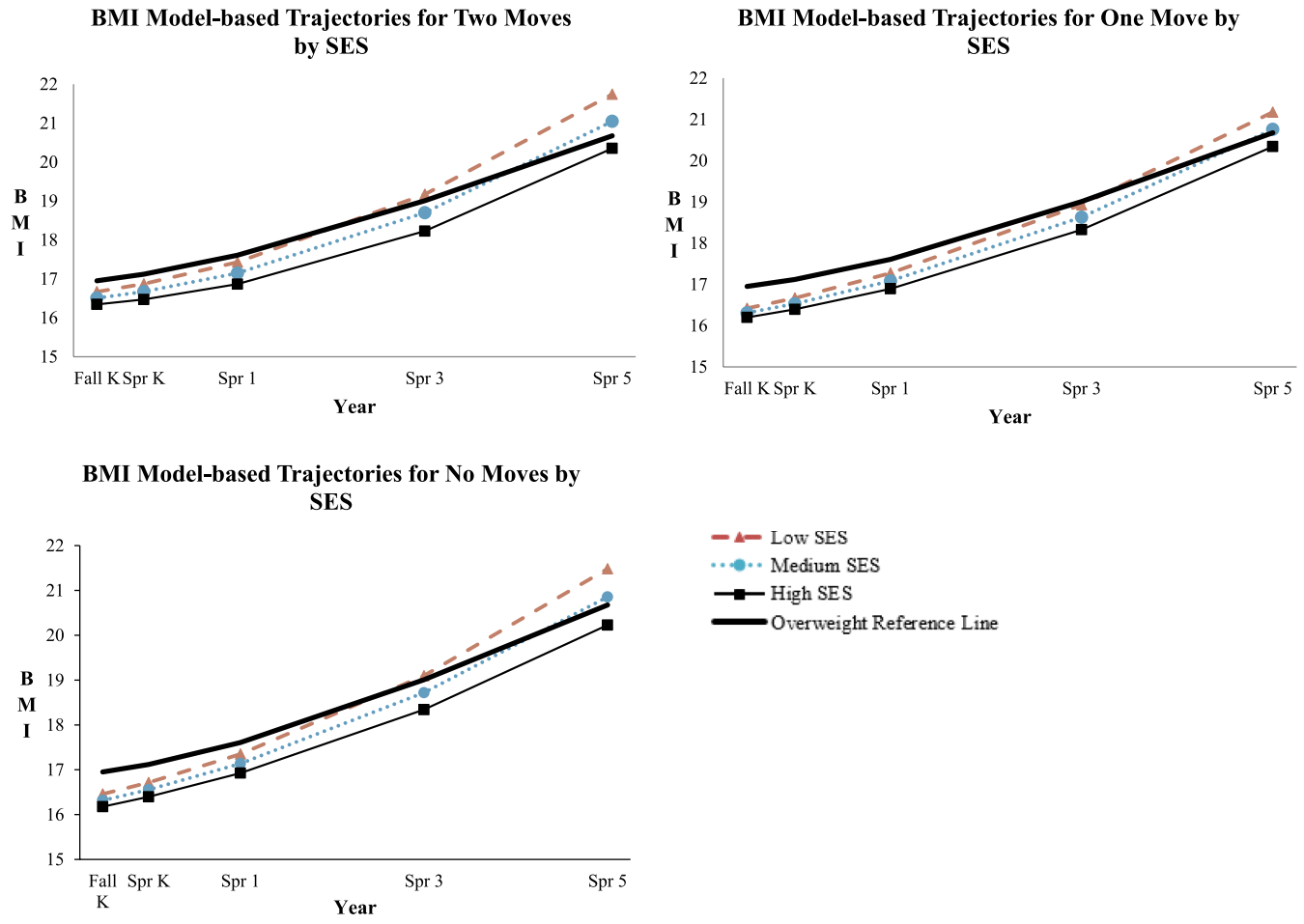

Fig. 3. BMI model-based trajectories for school moves by SES.

be that children face different expectations at a new school or may find it difficult to form peer relationships (Gruman et al., 2008; Rumberger, 2003). Adding to this, children who change schools often may have their eating and exercise habits interrupted more often, which could lead to higher BMIs. In our study, we also found an interaction effect between school moves and family SES, indicating that for lower SES children, school mobility may have a greater impact on BMI. Previous research has also suggested that highly mobile students are more likely

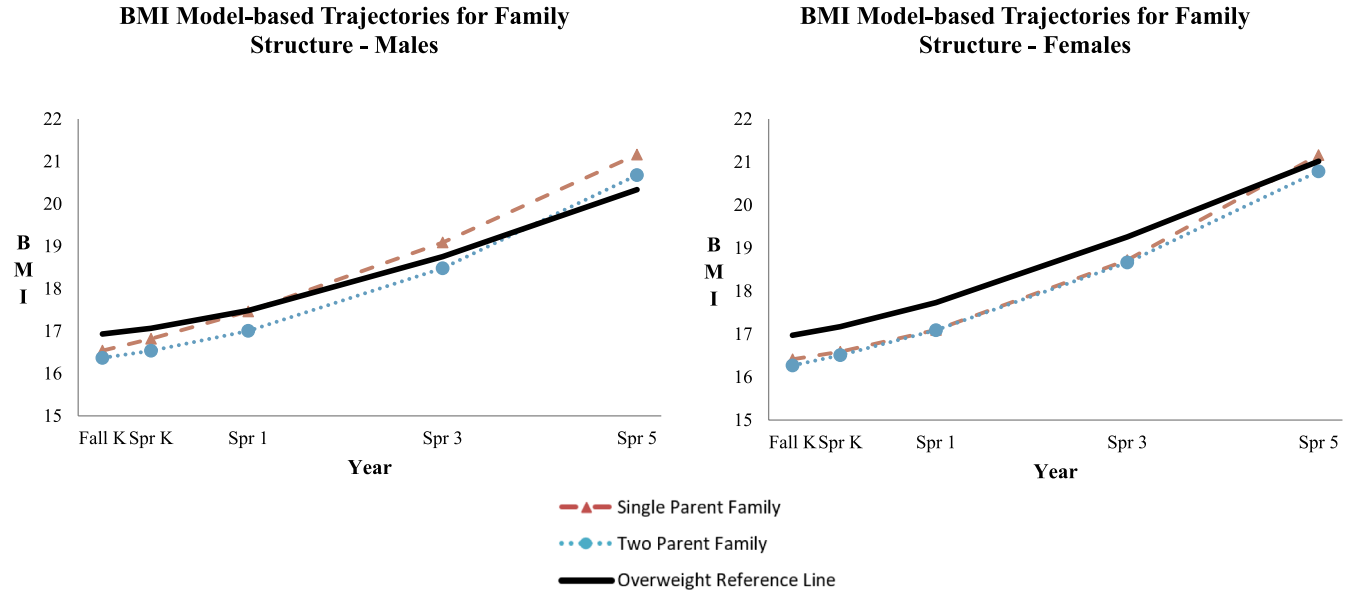

Fig. 4. BMI model-based trajectories for family structure by gender.

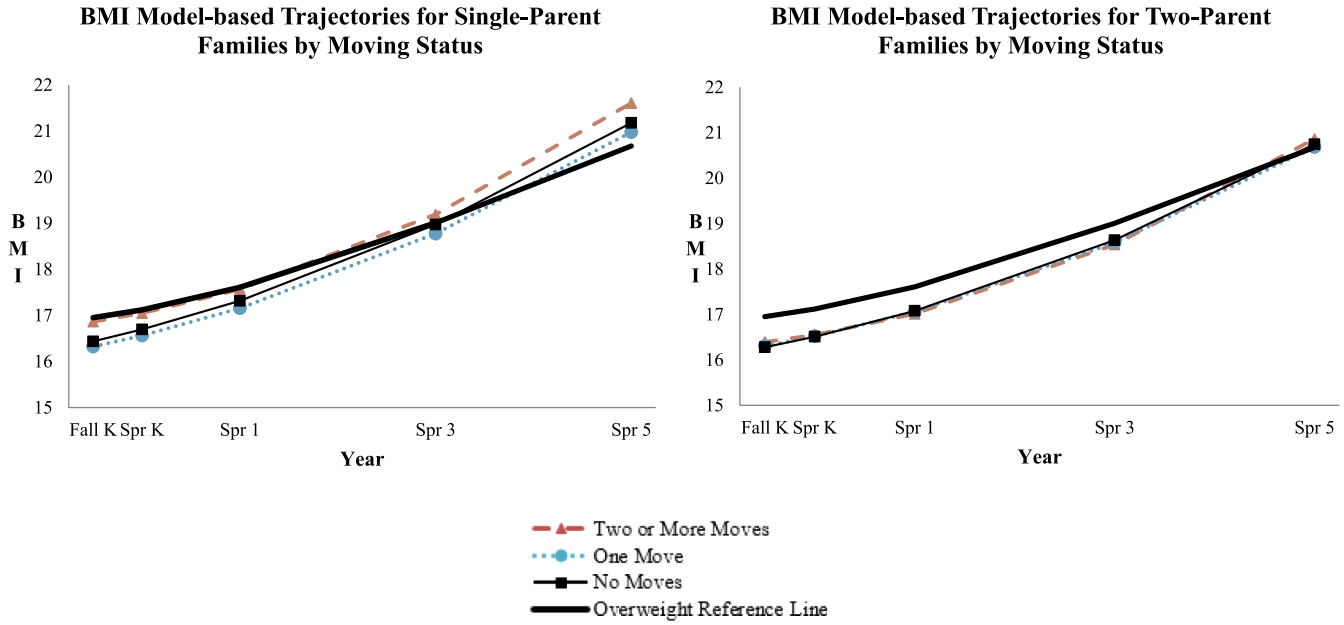

Fig. 5. BMI model-based trajectories for family structure by moving status.

to have additional risk factors, including low SES (Burkman et al., 2009). While some school moves may be inevitable for children due to factors such as their family's economic situation, other factors, such as dissatisfaction with a school, may be prevented through school interventions designed to build trust and social capital in the school community (Fiel, Haskins, & Turley, 2013).

Consistent with the literature (Balistreri & Van Hook, 2010; Chen & Escarce, 2010; Gibson et al., 2007), we found that family structure was significantly associated with children's BMI growth trajectories—that is, children in single-parent families were more likely to have higher BMIs compared to children in two-parent families. As noted earlier, due to time constraints on single parents, these families may rely on less nutritious, easier meals (Patrick & Nicklas, 2005); in two-parent households, in which parents are able to share household responsibilities, there may be more time allotted for healthier meal preparation and physical activity (Bagley et al., 2006; Rasmussen et al., 2006).

Although both school mobility and family structure had an impact on children's BMI, we found that family structure had a larger impact than school mobility. Our results indicated that being in a two-parent family was a protective factor for children; that is, even if children in two-parent families moved schools, they still maintained a healthy BMI on average. For children in single-parent families, however, moving tended to have a greater, negative impact on their BMI statuses. This finding underscores the central role that family structure plays in

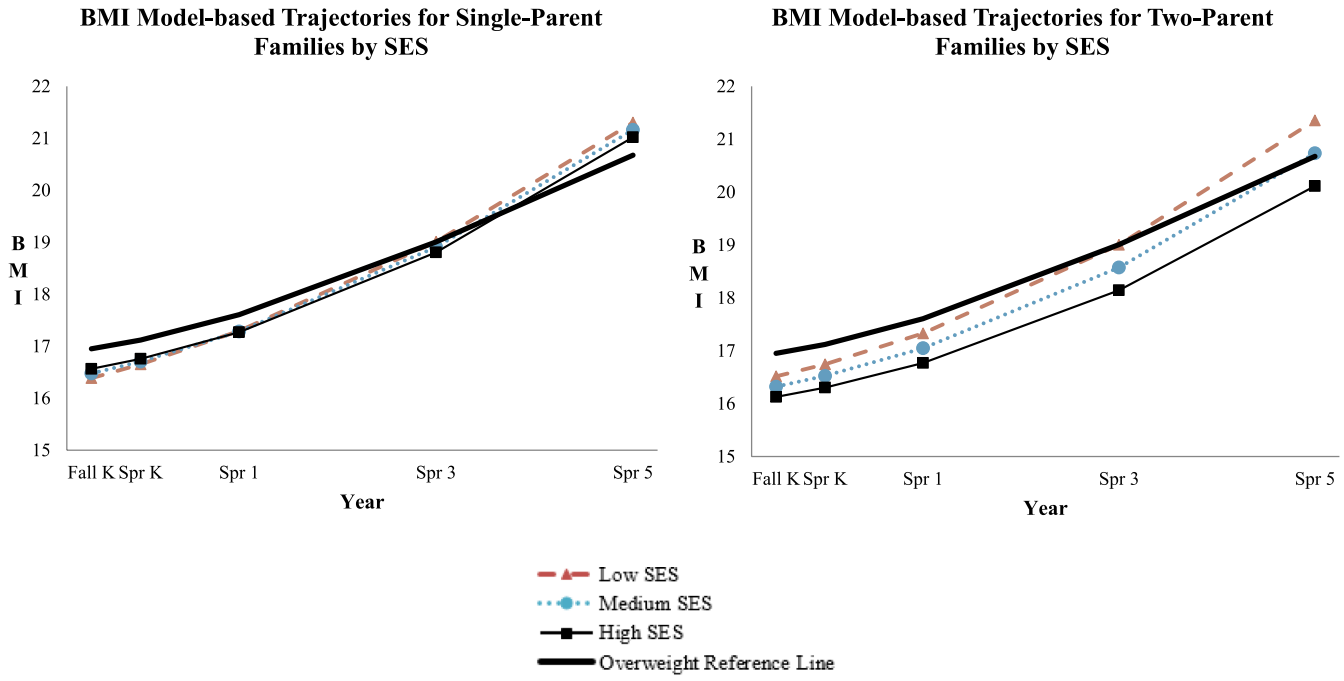

Fig. 6. BMI model-based trajectories for family structure by SES.

children's lives, particularly in terms of health. Early on, children are primarily exposed to their family's health habits and are likely to adopt similar habits of their own (Gruber & Haldeman, 2009). Health care providers who work with children regarding their weight status should keep the context of the child's family structure in mind. Furthermore, policies that could provide additional support for single-parent families, such as more flexible work hours or paid family leave, might also help support the health of the child. Single-parents families may struggle with having the time and resources to provide healthy, nutritious daily meals or exercising with their children. Having policies that allow single-parent families more time with their children might encourage these healthy behaviors.

In line with previous research, we also found that children's BMI trajectories varied by certain demographic features, in particular race/ethnicity (Wang & Beydoun, 2007). Our results indicated that Black girls had the highest BMI trajectories while Hispanic boys had the highest trajectories, a trend that is seen in other studies as well (Ogden et al., 2014; Wang & Beydoun, 2007). Notably, however, in our previous research using the same ECLS-K dataset (citation blinded for review) in which we excluded students who changed schools, we found that Black boys, rather than Hispanic boys, had the highest BMI trajectories. For Hispanic boys, therefore, moving may have a greater impact on their BMI trajectories compared to Black boys. In order to confirm this conjecture, we examined the mean BMI at each measurement occasion separated by the number of school moves. We found that for non-movers, Hispanic and Black boys had similar BMIs at each time point; however, for two-time movers, Hispanic boys had much higher BMIs compared to Black boys (see supplemental materials). As Hispanics continue to be a growing portion of the U.S. population (Passel, Cohn, & Lopez, 2011), it is important to focus obesity prevention strategies tailored to this group.

Limitations and future directions

One limitation of the present study is that the data set did not include information regarding why a child changed schools. That is, we could not separate school moves that occurred along with a family's residential relocation from those that occurred without a residential relocation (as is the case when a school closes, for example). Changing schools without leaving the community could be quite different from the school moves associated with entire family relocation in terms of the psychological impacts that such moves may trigger. Therefore, in order to understand fully the link between school moves and BMI change, it would be useful to have information on the type and the nature of the child's school moves in future studies of this topic.

Though we found that single-parent family structures and school moves are risk factors for child obesity, we have not identified the mechanism of how these two factors lead to child obesity. Both factors are often strongly associated with a family's SES, especially in terms of lack of economic resources (i.e., low income or poverty) and lack of physical resources such as less time for childcare because of parent's work schedule. Future studies could focus on the mechanisms that link family structure, school moves, and childhood obesity.

Ethics approval

In this study, we used publicly available data—Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K)—from the National Center for Education Statistics (https://nces.ed.gov/ecls/kindergarten.asp).

According to Virginia Tech's IRB office, this type of research does not require IRB approval (https://www.irb.vt.edu/documents/Activities%20Requiring%20Approval.pdf).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2019.100455.

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