Factors Associated with Five-Year Trends in Childhood Weight Status: Panel Study of Income Dynamics, Child Development Supplement Waves I and II

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I. Introduction

The path to obesity often begins in childhood. Multiple longitudinal studies across several nations have illustrated that individuals who are overweight[1] as children are more likely to be obese[2] as adults.(Garn & LaVelle 1985; Freedman et al 1987; Must et al 1992; Power et al 1997; Whitaker et al 1997; Guo et al 2002; He & Karlberg 2002). Given the substantial comorbidities associated with obesity among adults, including higher rates of diabetes and cardiovascular disease associated with higher rates of mortality (Flegal et al 2005), there is great clinical interest in preventing obesity before it starts in childhood, or at least in addressing children's overweight early in life in an attempt to help individuals reach normal-weight status as they enter adulthood.

Despite the abundance of studies that track the adiposity of children into adulthood, there are remarkably few studies that provide a window on the natural history of transitions in body mass index (BMI) during childhood and adolescence. This deficit in the literature presents a conundrum for clinicians and for public health officials who wish to address the problem of childhood overweight as it presents – ie, in childhood. Are clinicians to throw up their hands once a child has become overweight, knowing that the risks of adult obesity have increased several-fold? How should clinicians counsel children and their parents regarding overweight prevention and treatment at different developmental stages, without information about the likelihood that a child who is overweight at a certain age will stay overweight or become normal weight? At what ages should public health officials target community-based programs,

[1] We will use the following nomenclature to describe body mass index (BMI) categories for children, calculated as kg/m^2: underweight (BMI<5^{th} percentile for age and sex), normal weight (5^{th} to <85^{th} percentile), at risk for overweight (85^{th} to <95^{th} percentile), and overweight (≥95^{th} percentile).
[2] We will use the following nomenclature to describe BMI categories for adults: underweight (<18.5 kg/m^2), normal weight (18.5 to <25 kg/m^2), overweight (25 to <30 kg/m^2), and obese (≥30 kg/m^2).

with an eye toward preventing childhood overweight at developmental stages when such prevention might leave the most lasting effects?

Moreover, the available literature regarding childhood overweight and its downstream consequences in adulthood is largely clinical in its orientation. That is to say, the available variables one can associate with childhood overweight status are largely limited to information that can be found in the clinical record. Thus, clinicians and designers of community interventions are left without many sociodemographic and/or socioeconomic clues about how to target their efforts regarding childhood overweight.

We undertook the present study to address these shortcomings in the literature. Using the Panel Study of Income Dynamics and Waves 1 and 2 of the PSID Child Development Supplement, we wished to characterize near-term (5-year) trends in childhood BMI status in a nationally representative sample, and to examine possible associations with individual and family-level variables that may affect the development of childhood overweight.

II. Methods

Study Sample: The Panel Study of Income Dynamics (PSID) includes a nationally representative sample of nearly 7,000 US families. Data collection began in 1966 and has continued annually. In the PSID the sampling unit is the family, which permits the study of intrafamilial and interfamilial factors and associations over a period of nearly 4 decades. In 1985, and then again in 1999 and 2001, adults in the PSID were asked to self-report their height and weight.

The Child Development Supplement (CDS) of the PSID was first fielded in 1997, to study 3,563 children in PSID families who were aged 1-12 years at the time of the survey. A second wave was completed in 2002, with successful follow-up for 2,907 children (81.6%). The CDS was designed to collect information about characteristics and behaviors of children, including several related to health such as height and weight. Primary caregivers reported children's weight, and a tape measure was used by the survey data collector to assess height.

Categorization by body mass index: Thus, BMI could be calculated for children in the CDS and one or more parents, with the capacity in both generations to evaluate changes over time. BMI for children was calculated at Wave 1 and Wave 2, and BMI for parents was calculated from data they provided in 1985 and 2001. We used accepted definitions of childhood underweight, normal weight, at risk for overweight, and overweight to classify CDS children at Waves 1 and 2, and used accepted definitions of adult underweight, normal weight, overweight, and obesity to classify PSID parents in 1985 and 2001. For children, because of very small numbers and because of our investigative focus on overweight and obesity rather than underweight, we excluded children who were underweight at Wave 1 or Wave 2 from our analysis.

We classified children by their five-year BMI transition groups:

a) from normal weight to same: NW → NW

b) from normal weight to at risk for overweight or overweight: NW → AR/OW

c) from at risk for overweight or overweight to normal weight: AR/OW → NW

d) from at risk for overweight or overweight to same: AR/OW → AR/OW

The sample selection diagram appears below (Figure 1).

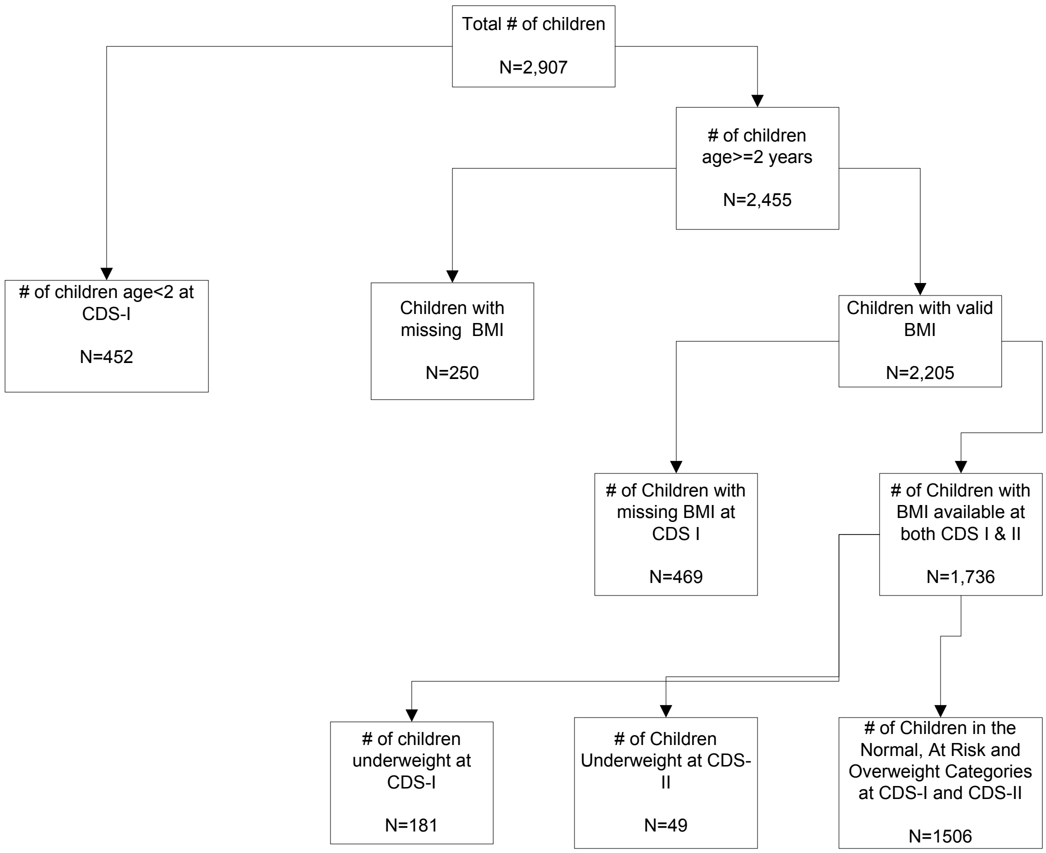

Figure 1. Sample Selection Diagram, PSID-CDS Waves 1 and 2.
In Wave 2 (2,907 children), 2,455 were aged 2-12 years and 2,205 had valid BMI. Of these, 1,736 had BMI data available at Waves 1 and 2, and 1,506 children had non-underweight BMI values at both waves.

We classified adults by BMI in two ways. First, we categorized them with respect to whether no parents were obese (OB-) vs. one or both parents were obese (OB+) by BMI reported in 2001. Second, we categorized parents regarding their BMI transition groups using data from 1985 and 2001 as reference points, as follows:

a) from not obese to same: OB- → OB-

b) from not obese to obese: OB- → OB+

c) from obese to not obese: OB+ → OB-

d) from obese to obese: OB+ → OB+

For the transition classifications, we chose to use maternal transitions preferentially because of the particularly strong association of child BMI with maternal BMI in the literature (Whitaker et al 1997). In cases where maternal height and weight information were not available, we used paternal information instead.

Predictor variables: Other than parental BMI, candidate factors associated with children's BMI transitions were drawn from the PSID and CDS and included child age at CDS-wave 1 (grouped as preschool [2-5], schoolage [6-9], and peripubescent [10-12]), sex, race/ethnicity (white, black, and other), income (≤200% federal poverty level, >200% federal poverty level), and child birthweight (very low birthweight [≤1500g], low birthweight [1501g-2500g], normal birthweight [2501-4000g], and high birthweight [>4000g]).

Data analyses: Frequencies of child BMI transitions and predictor variables were obtained. To describe child BMI transitions in more detail, age- and sex-specific crude and "moving-averaged" proportions of children in each of the BMI categories were calculated; i.e., for children of a given age and sex who were normal weight at CDS Wave 1, the proportion who were AR/OW at Wave 2 (also called the "transition probability") was calculated. Moving averages were used to bolster the robustness of the transition probabilities given the study sample size, and were based on children grouped by Wave 1 age as follows: 2-3, 2-4, 3-5, 4-6, 5-7, 6-8, 7-9, 8-10, 9-11, 10-12 and 11-12.

Bivariate and multivariate logistic regression models (weighted to be nationally representative) were then fit to the data to investigate the strength of associations of the candidate predictor variables with the child BMI transitions of interest. Transitions were split into two families of models: among children who were NW at Wave 1, comparing those who were AR/OW by Wave 2 to those who remained NW; and among children who were AR/OW at Wave 1, comparing those who were NW by Wave 2 to those who remained AR/OW. In an iterative fashion, models were constructed within each family to examine the incremental effect of adding specific predictor variables, with the exception that parental BMI transitions were substituted for parental BMI rather than being added as a separate variable. Selected interaction terms were tested as well for significance: age*race, sex*race, income*parental obesity, race*parental obesity, age*race*parental obesity, and parental obesity transition*birthweight.

From the combination of variables that appeared most strongly predictive of child BMI transitions across the 2 families of models (age, sex, race, income, age*race, parental obesity*race and age*race*parental obesity), predictive marginal values (adjusted probability of outcome) and standard errors for age*race*parental obesity combinations were obtained. All analyses were performed with SAS-callable SUDAAN v9 (Statistical Analysis System, Cary, NC; Research Triangle Institute, Research Triangle Park, NC) to take the complex sampling design of the survey into account.

III. Results

Characteristics of the Sample

Unweighted and weighted frequencies and weighted proportions for characteristics of the study sample appear in Table 1, below.

Table 1. Characteristics of Study Sample

Demographics		**n**	**Popn. Size**	**%**
Total		***1,506***	***26,439***	***100.0***
Child Age	2-5 yrs	566	9,328	35.3
	6-9 yrs	523	9,802	37.1
	10-12 yrs	417	7,309	27.6
Race/Ethnicity	White	756	17,731	67.1
	Black	595	4,140	15.7
	Other	152	4,547	17.2
Sex	Male	765	13,245	50.1
	Female	741	13,195	49.9
Income	≤200% FPL	556	7,131	31.1
	>200% FPL	842	15,817	68.9
Birthweight	Very low birthweight	22	259	1.0
	Low birthweight	110	1410	5.4
	Normal	1164	20,727	78.8
	High birthweight	195	3,910	14.9
Parental Obesity	OB-	1,018	18,755	70.9
	OB+ (≥1 obese parent)	488	7,685	29.1
Parental BMI Transition	OB- → OB-	725	14,217	76.8
	OB- → OB+	175	2,852	15.4
	OB+ → OB-	45	502	2.7
	OB+ → OB+	70	953	5.1
BMI at CDS Wave 1	Normal	882	16,763	63.4
	At Risk	234	4,085	15.5
	Overweight	390	5,592	21.2
BMI at CDS Wave 2	Normal	916	16,787	63.5
	At Risk	244	4,282	16.2
	Overweight	346	5,371	20.3

As evident in Table 1, the combined Wave 1-Wave 2 CDS sample matches very well to national patterns with respect to age, sex, race/ethnicity, and birthweight, but appears somewhat over-represented in the low-income category. The proportion of households with at least one obese parent (29.1%) also matches well to concurrent NHANES data. The parental BMI transition variable indicates fewer households with an obese parent at the latter time point (20.5%), because maternal BMI was used preferentially to characterize transitions. Nonetheless, there were approximately five times as many households that experienced a parental BMI transition from OB- → OB+ as experienced a parental transition from OB+ → OB- from 1985 to 2001.

Overweight children were disproportionately more likely than normal weight children to be younger, female, non-white, to not have been born at normal weight, and to have ≥1 obese parent or a parent transition OB- → OB+ or remain OB+ (Table 2).

Table 2. Characteristics of Children and Parents, by BMI Category at Wave 2.

	Normal weight	At risk for overweight	Overweight
Age			
2-5 years	61.3%	17.0%	21.7%
6-9 years	59.4%	18.6%	22.0%
10-12 years	71.7%	12.0%	16.3%
Sex			
Female	59.6%	17.0%	23.4%
Male	67.4%	15.4%	17.2%
Race/ethnicity			
White	66.2%	15.1%	18.7%
Black	59.5%	13.9%	26.6%
Other	56.3%	22.6%	21.1%
Birthweight			
Very low birthweight	73.4%	0.0%	26.6%
Low birthweight	58.5%	13.4%	28.1%
Normal birthweight	64.9%	16.8%	18.4%
High birthweight	57.7%	15.2%	27.1%
Household income			
≤200% FPL	63.8%	14.8%	21.4%
>200% FPL	63.8%	16.3%	19.9%
Parent obese			
OB-	71.2%	14.4%	14.4%
OB+	44.5%	20.6%	34.9%
Parental BMI transition			
OB- → OB-	72.1%	13.1%	14.7%
OB- → OB+	46.7%	19.9%	33.4%
OB+ → OB-	49.5%	25.7%	24.8%
OB+ → OB+	32.4%	25.1%	42.5%

Children's BMI Transitions

Aggregate frequencies and proportions of children's BMI transitions from CDS Wave 1 (1997) to CDS Wave 2 (2002) are presented in Table 3.

Table 3. Unweighted Frequencies and Weighted Proportions of Child Transitions in BMI Status, CDS Wave 1 to Wave 2.

	BMI Status at CDS Wave 2		
BMI Status at CDS Wave 1	**Normal weight**	**At risk for overweight**	**Overweight**
Normal weight	648 (75.3%)	126 (13.6%)	108 (11.1%)
At risk for overweight	122 (55.3%)	50 (21.6%)	62 (23.1%)
Overweight	146 (34.0%)	68 (20.0%)	176 (46.0%)

The predominant pattern of BMI status over time in Table 3 is that children who were normal weight at Wave 1 were most likely to be normal weight at Wave 2, whereas children who were overweight at Wave 1 were most likely to be overweight at Wave 2. However, there is evidence of transitions in BMI status as well, particularly for children who were overweight at Wave 1 to be normal weight at Wave 2 (about 1 of every 3), and to a lesser degree for children who were normal weight at Wave 1 to be overweight at Wave 2 (about 1 in 10). Moreover, for children who were at risk for overweight at Wave 1, over half were normal weight at Wave 2 whereas nearly one-quarter shift to overweight.

Given the knowledge that BMI status at Wave 2 differed somewhat by age (Table 2), we disaggregated the transition data for children at different ages and generated transition probabilities of shifts from NW → AR/OW and vice-versa (Figure 2).

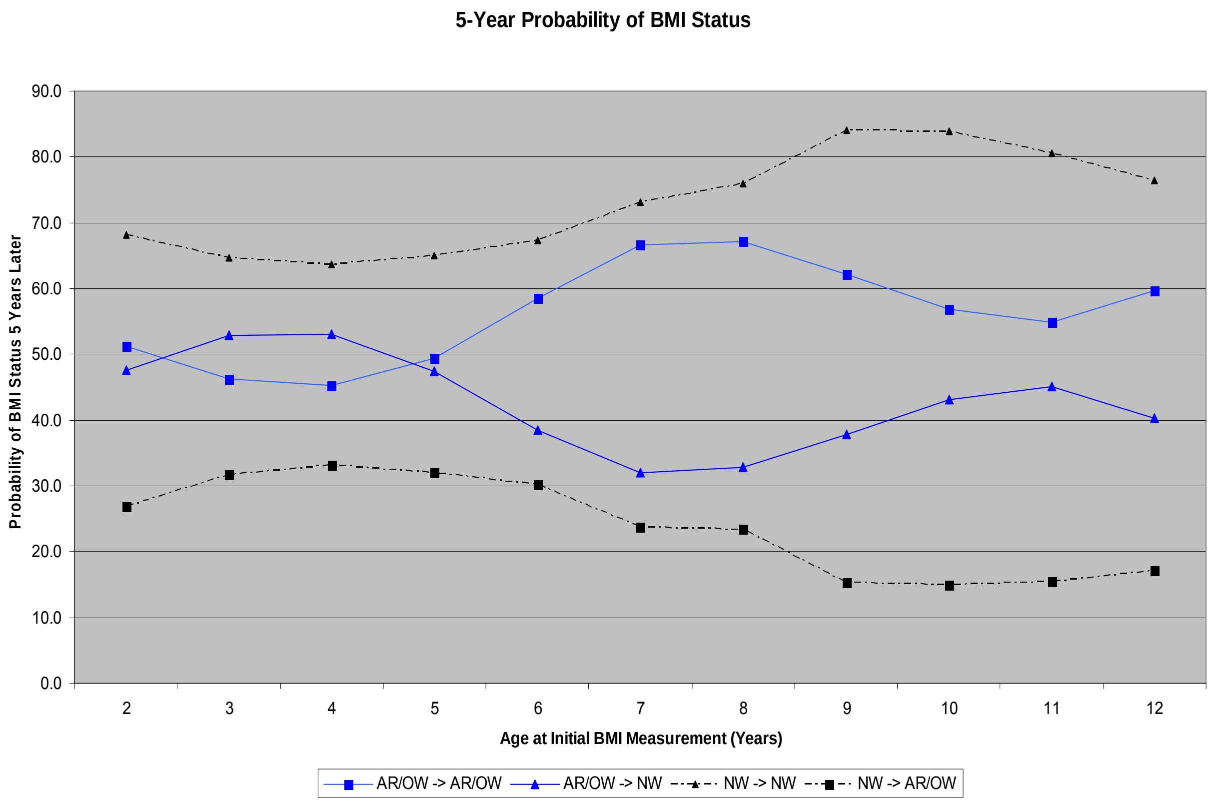

Figure 2. BMI Transition Probabilities for Children, CDS Wave 1 to Wave 2. Probabilities were calculated as moving averages across years, as described in Methods. Solid lines reflect outcomes for children who were AR/OW at Wave 1 and dashed lines for children who were NW at Wave 1. Lines with squares indicate children who were AR/OW at Wave 2, and lines with triangles indicate children NW at Wave 2. Underweight children not shown.

Key patterns of children's short-term BMI transitions are apparent in Figure 2: (a) Among children AR/OW at Wave 1 (solid lines), the probability of transitioning to NW (triangles) versus remaining AR/OW (squares) was equivalent to a coin flip for children aged 2-5 years at Wave 1. However, the probability of transitioning to NW versus remaining AR/OW differed substantially at older ages, particularly for 6- to 9-year-olds. This pattern echoes the importance of the period of adiposity rebound for determining later BMI status. The remaining question is, What factors help determine whether children AR/OW at different ages at Wave 1 will remain AR/OW or improve their BMI to NW 5 years later?

(b) Among children who were NW at Wave 1 (dashed lines), 2/3 or more at every age remained NW at Wave 2 (triangles), and the probability of remaining NW particularly increased after age 6. This pattern also echoes the importance of adiposity rebound. The question remains, What factors help determine whether children NW at different ages at Wave 1 will remain NW or experience a worse BMI in the AR or OW categories by Wave 2?

(c) At all ages, the probability that children who were NW at Wave 1 *remaining* NW exceeds the probability that children who were AR/OW will *transition* to NW. Similarly, the probability that children who were AR/OW at Wave 1 *remaining* AR/OW exceeds the probability that children who were NW will *transition* to AR/OW. In essence, these patterns reflect the predominant inertia of one's BMI. What factors contribute to such inertia?

(d) However, data in Figure 2 also suggest that, at all ages, it is more likely that children will transition from AR/OW → NW (solid line, triangles) than from NW → AR/OW (dashed line, squares). The ages for which these transition probabilities are most similar – ie, ages at which the transition of NW → AR/OW is most similar to that of AR/OW → NW – are ages 6-9 years, again emphasizing the period of adiposity rebound. What factors contribute to the greater 5-year likelihood that an overweight child will normalize BMI than that a normal weight child will increase BMI to the AR/OW level?

To answer these questions prompted by the transition probability findings, we examined iterative multiple regression models as described in Methods. In Tables 4A, 4B, and 4C (beginning on next page), we present findings from models of children who were NW at Wave 1, investigating the outcome that they would transition to AR/OW versus remain NW.

Factors associated with NW children transitioning to AR/OW included:

(a) *age* – Across all models, younger children were more likely than older children to have transitioned to AR/OW by Wave 2, given that they were all NW at Wave 1.

(b) *race/ethnicity* – Although the initial main effects of race/ethnicity were not statistically significant, race/ethnicity was significantly associated with BMI transitions when interaction terms were considered, in that children from the “other” race/ethnicity group were more likely than white children to transition NW → AR/OW when interacted with child age and with parental obesity status.

(c) *parental obesity status* – Presence of at least one obese parent in the household in 2001 strongly predisposed to the NW → AR/OW transition.

(d) *parental obesity transition* – Similarly, children whose parents had obesity at any time (1985 or 2001) were more likely than children whose parents were not obese at either time point to transition NW → AR/OW. Children of parents were obese at both time points were at highest risk.

(e) *birthweight* – Children with high birthweight were more likely to transition, whereas children with very low birthweight were very unlikely to transition.

Factors *not* associated with NW → AR/OW transitions included sex and household income.

Table 4A. Multiple Logistic Regression of At Risk/Overweight Outcome at Wave 2 for Children who were Normal Weight at Wave 1.

Predictors	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value
Intercept	-1.62	0.11		-1.64	0.11		-1.84	0.16		-1.76	0.09	
Age3cat												
2-5yrs	0.99	0.08		0.99	0.08		1.25	0.17		1.04	0.09	
6-9yrs	0.41	0.16		0.42	0.15		0.61	0.2		0.5	0.14	
10-12yrs	Ref.	Ref.	**<0.0001**	Ref.	Ref.	**<0.0001**	Ref.	Ref.		Ref.	Ref.	**<0.0001**
Sex												
Male	Ref.	Ref.		Ref.	Ref.		Ref.	Ref.		Ref.	Ref.	
Female	-0.07	0.14	**0.648**	-0.08	0.15	**0.61**	-0.05	0.15	**0.756**	0.07	0.15	**0.661**
Race/Ethnicity												
White				Ref.	Ref.		Ref.	Ref.		Ref.	Ref.	
Black				0.03	0.2		0.27	0.45		0.09	0.26	
Other				0.16	0.13	**0.372**	0.82	0.27		0.3	0.25	**0.317**
Age*Race Interaction												
2-5yrs * White							0	0				
2-5yrs * Black							-0.52	0.26				
2-5yrs * Other							-0.91	0.33				
6-9yrs * White							0	0				
6-9yrs * Black							-0.06	0.61				
6-9yrs * Other							-0.88	0.33				
10-12yrs * White							0	0				
10-12yrs * Black							0	0				
10-12yrs * Other							0	0	**0.048**			
Income												
<=200 FPL										0.03	0.1	
>200 FPL										Ref.	Ref.	**0.737**

Table 4B. Multiple Logistic Regression of At Risk/Overweight Outcome at Wave 2 for Children who were Normal Weight at Wave 1.

Predictors	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value
Intercept	-1.92	0.18		-2.22	0.16		-2.19	0.18		-2.27	0.16	
Age3cat												
2-5yrs	1.26	0.17		1.28	0.17		1.27	0.18		1.28	0.18	
6-9yrs	0.63	0.21		0.63	0.21		0.62	0.21		0.64	0.21	
10-12yrs	Ref.	Ref.		0	0		Ref.	Ref.		Ref.	Ref.	
Sex												
Male	Ref.	Ref.		0	0		Ref.	Ref.		Ref.	Ref.	
Female	0.08	0.15	**0.5868**	-0.04	0.16	**0.8088**	-0.05	0.15	**0.7317**	-0.05	0.17	0.746
Race/Ethnicity												
White	Ref.	Ref.		0	0		Ref.	Ref.		Ref.	Ref.	
Black	0.37	0.48		0.08	0.6		0.15	0.81		0.14	0.58	
Other	1.38	0.51		0.85	0.61		-0.43	1.22		0.83	0.64	
Income												
<=200 FPL	0.04	0.11		0.05	0.08		0.06	0.08		0.22	0.12	
>200 FPL	0	0	**0.6799**	0	0	**0.5166**	Ref.	Ref.	**0.4492**	Ref.	Ref.	
Age*Race Interaction												
2-5yrs * White	0	0		0	0		0	0		0	0	
2-5yrs * Black	-0.6	0.24		-0.35	0.34		-0.39	0.4		-0.41	0.32	
2-5yrs * Other	-1.55	0.52		-1.12	0.58		-0.5	0.97		-1.1	0.6	
6-9yrs * White	0	0		0	0		0	0		0	0	
6-9yrs * Black	-0.14	0.61		0.06	0.69		0.04	0.73		-0.06	0.65	
6-9yrs * Other	-1.22	0.83		-0.55	0.77		0.37	0.96		-0.59	0.78	
10-12yrs * White	0	0		0	0		0	0		0	0	
10-12yrs * Black	0	0		0	0		0	0		0	0	
10-12yrs * Other	0	0	**0.0148**	0	0	**0.0669**	0	0	**0.0209**	0	0	**0.0731**
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Any Parent Obese												
OB-				0	0		Ref.	Ref.		Ref.	Ref.	
OB+				1.29	0.16	**<0.0001**	1.22	0.1		1.44	0.18	
Race*Obese Parent Interaction												
OB- * White							0	0				
OB- * Black							0	0				
OB- * Other							0	0				
OB+ * White							0	0				
OB+ * Black							-0.12	0.52				
OB+ * Other							1.61	0.44	**0.0004**			
Income*Obese Parent Interaction												
OB- * <=200 FPL										0	0	
OB- * >200 FPL										0	0	
OB+ * <=200 FPL										-0.49	0.2	
OB+ * <=200 FPL										0	0	**0.0231**

Table 4C. Multiple Logistic Regression of At Risk/Overweight Outcome at Wave 2 for Children who were Normal Weight at Wave 1.

Predictors	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value
Intercept	-2.03	0.13		-2.16	0.16		-2.17	0.16	
Age3cat									
2-5yrs	0.99	0.12		1.04	0.10		1.08	0.11	
6-9yrs	0.34	0.20		0.38	0.19		0.43	0.17	
10-12yrs	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**
Sex									
Male	0.00	0.00		0.00	0.00		0.00	0.00	
Female	-0.10	0.10	**0.32**	-0.08	0.10	**0.40**	-0.08	0.08	**0.32**
Race/Ethnicity									
White	0.00	0.00		0.00	0.00		0.00	0.00	
Black	-0.07	0.22		-0.03	0.24		0.03	0.16	
Other	-0.05	0.33	**0.95**	0.00	0.32	**0.99**	0.02	0.32	**0.97**
Income									
<=200 FPL	-0.03	0.09		0.02	0.09		0.02	0.12	
>200 FPL	0.00	0.00	**0.76**	0.00	0.00	**0.81**	0.00	0.00	**0.86**
Parental Obesity Transition									
OB- → OB-	0.00	0.00		0.00	0.00		0.00	0.00	
OB- → OB+	1.41	0.20		1.33	0.19		1.15	0.32	
OB+ → OB-	0.73	0.11		0.61	0.11		0.55	0.10	
OB+ → OB+	2.40	0.47	**<0.0001**	2.46	0.48	**<0.0001**	2.39	0.37	
Birthweight									
Very low birthweight (<=1500g)				-1.08	0.47		-1.14	0.39	
Low birthweight (1501-2500g)				0.43	0.73		0.37	0.45	
Normal (2501-4000g)				0.00	0.00		0.00	0.00	
High birthweight (>4000g)				0.41	0.11	**<0.0001**	0.19	0.26	
Continued on next page									

Parental Obesity Transition*Birthweight									
OB- → OB- * Very low birthweight							0.00	0.00	
OB- → OB- * Low birthweight							0.00	0.00	
OB- → OB- * Normal							0.00	0.00	
OB- → OB- * High birthweight							0.00	0.00	
OB- → OB+ * Very low birthweight							0.00	0.00	
OB- → OB+ * Low birthweight							0.75	2.62	
OB- → OB+ * Normal							0.00	0.00	
OB- → OB+ * High birthweight							0.57	0.94	
OB+ → OB- * Very low birthweight							0.00	0.00	
OB+ → OB- * Low birthweight							-0.30	0.89	
OB+ → OB- * Normal							0.00	0.00	
OB+ → OB- * High birthweight							0.37	0.32	
OB+ → OB+ * Very low birthweight							0.00	0.00	
OB+ → OB+ * Low birthweight							infinity		
OB+ → OB+ * Normal							0.00	0.00	
OB+ → OB+ * High birthweight							1.98	2.03	**0.0001**

Please note: Tables 4A-4C were edited for space, so that model iterations that did not significantly alter the overall fit are not shown.

Multiple logistic regression models for children who were AR/OW at Wave 1, comparing transition to NW versus remaining AR/OW, are presented in Tables 5A, 5B, and 5C (beginning on next page). Factors associated with AR/OW children transitioning to NW included:

(a) *age* – Across all models, children aged 6-9 years were *less* likely to transition AR/OW → NW than children aged 10-12 years.

(b) *race/ethnicity* – Consistently the main effects for race/ethnicity indicated *less* likelihood of the AR/OW → NW transition for children of “other” backgrounds compared to whites. In interactions with sex and age the sign for this group changed to indicated greater likelihood, while in interactions with parental obesity status the sign remained negative.

(c) *income* – As opposed to the NW → AR/OW transition, for the AR/OW → NW transition income was a predictive factor, indicating that children in low-income households were more likely to transition to NW than children in higher-income households.

(d) *parental obesity status* – Children with at least one obese parent were less likely to transition AR/OW → NW.

(e) *parental obesity transition* – Of interest, children in households with parents who had transitioned OB+ → OB- were *less* likely to make the similar AR/OW → NW transition themselves than were children living in households with OB- → OB- parents.

Factors not associated with the AR/OW → NW transition included sex (although in interaction with race/ethnicity it was associated) and birthweight.

Table 5A. Multiple Logistic Regression of Normal Weight Outcome at Wave 2 for Children who were At Risk/Overweight at Wave 1.

Predictors	Paramet. Estimate (β)	Standard Errors	Overall P-value	Paramet. Estimate (β)	Standard Errors	Overall P-value	Paramet. Estimate (β)	Standard Errors	Overall P-value	Paramet. Estimate (β)	Standard Errors	Overall P-value	Paramet. Estimate (β)	Standard Errors	Overall P-value
Intercept	-0.36	0.29		-0.16	0.22		-0.11	0.16		0.15	0.13		-0.11	0.14	
Age3cat															
2-5yrs	0.29	0.17		0.29	0.17		0.28	0.17		-0.08	0.15		0.06	0.16	
6-9yrs	-0.50	0.23		-0.52	0.23		-0.50	0.22		-1.04	0.15		-0.81	0.07	
10-12yrs	Ref.	Ref.	**0.002**	Ref.	Ref.	**0.0003**	Ref.	Ref.	**9E-04**	Ref.	Ref.		Ref.	Ref.	**<0.0001**
Sex															
Male	Ref.	Ref.		Ref.	Ref.		Ref.	Ref.		Ref.	Ref.		Ref.	Ref.	
Female	0.41	0.26	**0.126**	0.39	0.25	**0.1191**	0.28	0.15		0.46	0.25	**0.075**	0.23	0.12	**0.058**
Race/Ethnicity															
White				Ref.	Ref.		0.00	0.00		Ref.	Ref.		Ref.	Ref.	
Black				-0.41	0.18		-0.22	0.26		-0.96	0.39		-0.70	0.20	
Other				-0.59	0.08	**<0.0001**	-1.04	0.20		-1.95	0.57		-0.91	0.23	**<0.0001**
Race*Sex Interaction															
Male * White							0.00	0.00							
Male * Black							0.00	0.00							
Male * Other							0.00	0.00							
Female * White							0.00	0.00							
Female * Black							-0.43	0.44							
Female * Other							1.01	0.31	**0.006**						

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Age*Race Interaction															
2-5yrs * White										0.00	0.00				
2-5yrs * Black										0.61	0.53				
2-5yrs * Other										1.44	0.41				
6-9yrs * White										0.00	0.00				
6-9yrs * Black										0.83	0.37				
6-9yrs * Other										2.12	0.94				
10-12yrs * White										0.00	0.00				
10-12yrs * Black										0.00	0.00				
10-12yrs * Other										0.00	0.00	**<0.0001**			
Income															
<=200 FPL													0.78	0.17	
>200 FPL													Ref.	Ref.	**0.0001**

Table 5B. Multiple Logistic Regression of Normal Weight Outcome at Wave 2 for Children who were At Risk/Overweight at Wave 1.

Predictors	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value
Intercept	0.02	0.17		0.26	0.19		0.19	0.20	
Age3cat									
2-5yrs	-0.18	0.15		-0.11	0.09		-0.13	0.09	
6-9yrs	-1.09	0.10		-1.11	0.11		-1.09	0.10	
10-12yrs	0.00	0.00		0.00	0.00		0.00	0.00	
Sex									
Male	0.00	0.00		0.00	0.00		0.00	0.00	
Female	0.37	0.16		0.48	0.19		0.44	0.17	
Race/Ethnicity									
White	0.00	0.00		0.00	0.00		0.00	0.00	
Black	-0.97	0.30		-0.68	0.36		-0.27	0.33	
Other	-2.33	0.36		-2.63	0.36		-3.49	0.75	
Income									
<=200 FPL	0.77	0.18		0.75	0.17		0.74	0.17	
>200 FPL	0.00	0.00	**0.0002**	0.00	0.00	**0.0002**	0.00	0.00	**0.0002**
Age*Race Interaction									
2-5yrs * White	0.00	0.00		0.00	0.00		0.00	0.00	
2-5yrs * Black	0.54	0.47		0.31	0.62		0.23	0.60	
2-5yrs * Other	1.77	0.42		2.04	0.36		3.26	0.77	
6-9yrs * White	0.00	0.00		0.00	0.00		0.00	0.00	
6-9yrs * Black	0.81	0.45		0.93	0.42		0.98	0.46	
6-9yrs * Other	1.40	1.37		1.93	1.27		3.27	1.89	
10-12yrs * White	0.00	0.00		0.00	0.00		0.00	0.00	
10-12yrs * Black	0.00	0.00		0.00	0.00		0.00	0.00	
10-12yrs * Other	0.00	0.00	**0.0001**	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**
Continued on next page									

Sex*Race Interaction									
Male * White	0.00	0.00		0.00	0.00		0.00	0.00	
Male * Black	0.00	0.00		0.00	0.00		0.00	0.00	
Male * Other	0.00	0.00		0.00	0.00		0.00	0.00	
Female * White	0.00	0.00		0.00	0.00		0.00	0.00	
Female * Black	-0.55	0.44		-0.79	0.33		-0.86	0.37	
Female * Other	0.73	0.37	**0.1178**	0.97	0.39	**0.0064**	2.21	0.54	**<0.0001**
Any Parent Obese									
OB-				0.00	0.00		0.00	0.00	
OB+				-0.92	0.23	**0.0005**	-0.64	0.21	
Race*Obese Parent Interaction									
OB- * White							0.00	0.00	
OB- * Black							0.00	0.00	
OB- * Other							0.00	0.00	
OB+ * White							0.00	0.00	
OB+ * Black							-0.90	0.34	
OB+ * Other							-2.01	1.03	**0.0007**

Table 5C. Multiple Logistic Regression of Normal Weight Outcome at Wave 2 for Children who were At Risk/Overweight at Wave 1.

Predictors	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value	Parameter Estimates (β)	Standard Errors	Overall P-value
Intercept	-0.13	0.17		-0.09	0.15		-0.02	0.17	
Age3cat									
2-5yrs	0.22	0.11		0.23	0.13		0.17	0.16	
6-9yrs	-0.73	0.11		-0.73	0.12		-0.69	0.11	
10-12yrs	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**
Sex									
Male	0.00	0.00		0.00	0.00		0.00	0.00	
Female	0.45	0.18	**0.02**	0.43	0.22	**0.06**	0.41	0.22	**0.07**
Race/Ethnicity									
White	0.00	0.00		0.00	0.00		0.00	0.00	
Black	-0.65	0.44		-0.66	0.48		-0.62	0.48	
Other	-1.29	0.22	**<0.0001**	-1.26	0.25	**<0.0001**	-1.26	0.24	**<0.0001**
Income									
<=200 FPL	0.88	0.15		0.89	0.15		0.87	0.15	
>200 FPL	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**	0.00	0.00	**<0.0001**
Parental Obesity Transition									
OB- → OB-	0.00	0.00		0.00	0.00		0.00	0.00	
OB- → OB+	-0.40	0.43		-0.39	0.46		-0.55	0.61	
OB+ → OB-	-1.45	0.14		-1.35	0.11		-2.65	0.52	
OB+ → OB+	-0.64	0.69	**<0.0001**	-0.66	0.69	**<0.0001**	-0.61	0.74	
Birthweight									
Very low birthweight (<=1500g)				-0.48	1.79		-0.54	1.82	
Low birthweight (1501-2500g)				-0.10	0.25		-0.14	0.31	
Normal (2501-4000g)				0.00	0.00		0.00	0.00	
High birthweight (>4000g)				-0.22	0.37	**0.60**	-0.48	0.25	
Continued on next page									

Parental Obesity Transition*Birthweight									
OB- → OB- * Very low birthweight							0.00	0.00	
OB- → OB- * Low birthweight							0.00	0.00	
OB- → OB- * Normal							0.00	0.00	
OB- → OB- * High birthweight							0.00	0.00	
OB- → OB+ * Very low birthweight							0.00	0.00	
OB- → OB+ * Low birthweight							-1.09	1.39	
OB- → OB+ * Normal							0.00	0.00	
OB- → OB+ * High birthweight							0.79	0.86	
OB+ → OB- * Very low birthweight							0.00	0.00	
OB+ → OB- * Low birthweight							infinity		
OB+ → OB- * Normal							0.00	0.00	
OB+ → OB- * High birthweight							infinity		
OB+ → OB+ * Very low birthweight							0.00	0.00	
OB+ → OB+ * Low birthweight							infinity		
OB+ → OB+ * Normal							0.00	0.00	
OB+ → OB+ * High birthweight							-0.46	0.44	**0.06**

Please note: Tables 5A-5C were edited for space, so that model iterations that did not significantly alter the overall fit are not shown.

To clarify the effects of several interaction terms in the two different model families, we selected a combination of variables that appeared to most comprehensively reflect the associations with child BMI transitions in both directions. This combination of variables and interactions was: age, sex, race/ethnicity, household income, age*race/ethnicity, race/ethnicity*parental obesity status, and age*race/ethnicity*parental obesity status. We chose to examine parental obesity status instead of parental obesity transitions because of the overall contrast in the latter variable between OB- → OB- parents and the others, which was equivalent to the OB- versus OB+ dichotomy.

From this model, we calculated the predictive marginal (adjusted) probability of AR/OW at Wave 2 for children who were NW at Wave 1, and of NW at Wave 2 for children who were AR/OW at Wave 1. The findings appear below, in Figures 3 and 4 (next page). In both instances, the influence of parental obesity is apparent. For example, among children NW at Wave 1, whether an obese parent was present was associated with a significantly higher probability of AR/OW at Wave 2 for white children in all 3 age groups, for black children aged 6-9 years old, and for “other” children aged 2-5 years. Among AR/OW children at Wave 1, whether an obese parent was present was associated with a significantly lower probability of NW at Wave 2 for white and black children aged 6-9 years, and a similar though not statistically significant trend was apparent for almost every other age*race/ethnicity subgroup. Taken together, these data illustrate how the effect of parental obesity cuts across ages and race/ethnicity groups to promote AR/OW among previously NW children, and to promote persistent AR/OW among already AR/OW children. In other words, when accounting for children’s age, sex, race/ethnicity, and household income, parental obesity may be the core component of children's BMI "inertia," promoting persistent AR/OW in the minority of children already AR/OW and opposing NW among the majority of children who are NW.

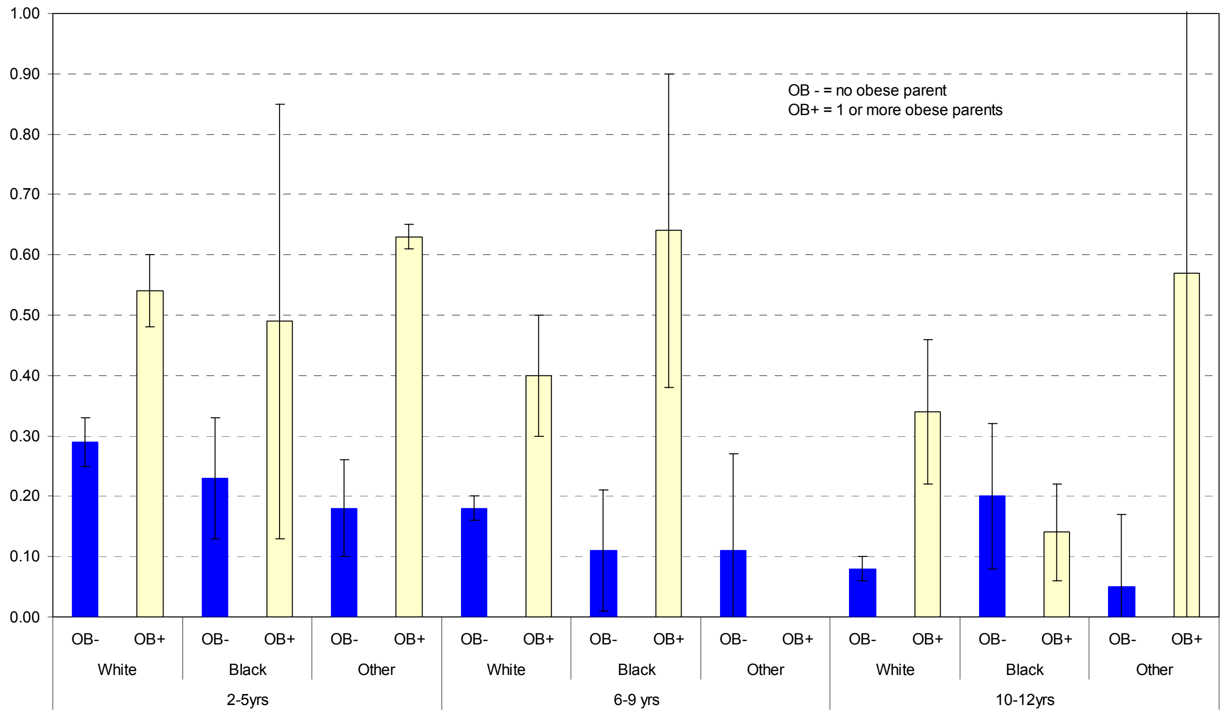

Figure 3. Adjusted Probability of AR/OW at Wave 2 for Children NW at Wave 1.
Point estimates and 95% confidence intervals are shown. Absence of a bar indicates no observations were available for estimation.

(Figure 4 on next page)

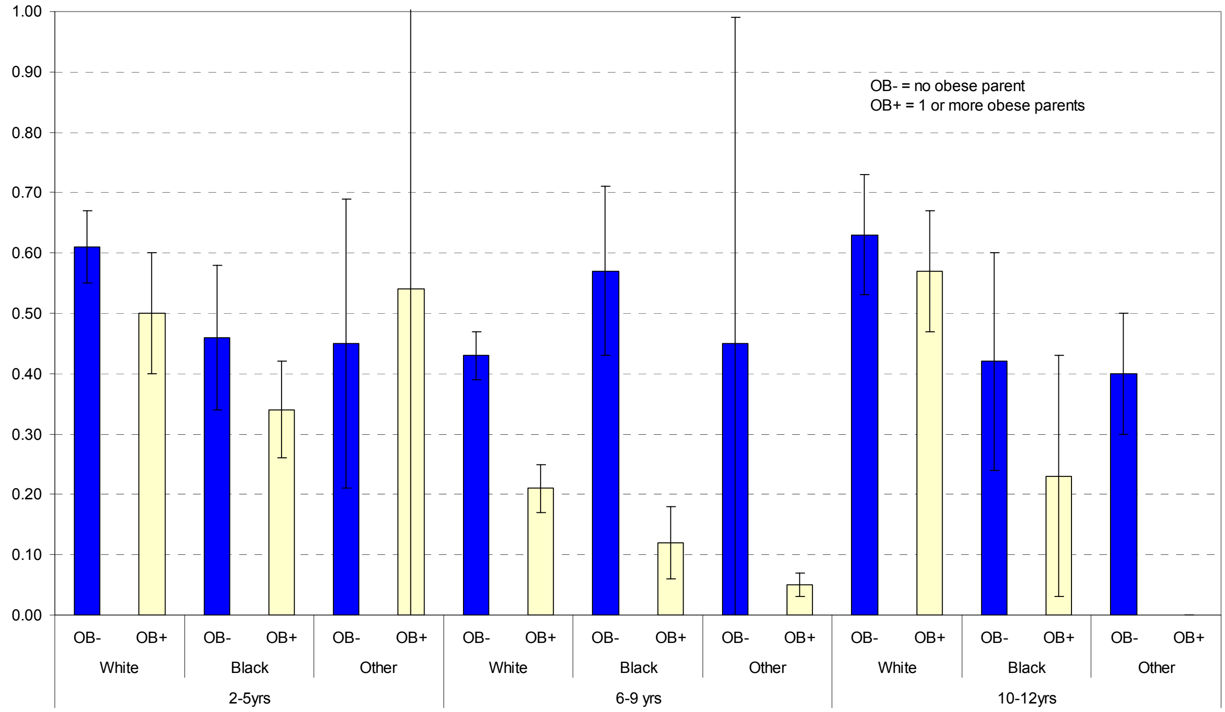

Figure 4. Adjusted Probability of NW at Wave 2 for Children AR/OW at Wave 1.
Point estimates and 95% confidence intervals are shown. Absence of a bar indicates no observations were available for estimation.

IV. Comments and Conclusions

The fateful link between childhood overweight and adult obesity has been established in several longitudinal cohorts. What has not been as clear or as comprehensively studied is the shorter-term trajectory of children's BMI status. Understanding the short-term BMI trajectory for children is essential for targeting opportunities to intervene on the epidemic of childhood and adult obesity.

The PSID-CDS represents perhaps the best opportunity to examine children's BMI trends in the context of familial dynamics, not only of intergenerational BMI but of multiple sociodemographic and behavioral factors measured in the PSID over several waves that may promote overweight among individuals in the first two decades of their lives. The present study offers an early glimpse of the potential for PSID-CDS data to illuminate the developmental pathways of childhood overweight.

Nonetheless, as we consider the insights gained from this analysis, we must be mindful of limitations of these data. Chief among these, which is perhaps most evident in our multiple regression analyses, is the small number of individuals of “other” race/ethnicity background in the sample which prevented us from drawing stronger conclusions about them in models with several interaction terms and in the analyses of adjusted probabilities of BMI transitions. We anticipate that the majority of individuals in the “other” category are of Latino descent. Although many nationally representative datasets have similar sampling challenges beyond groups of white and black study participants, the deficit of Latino participants in the PSID-CDS sample is regrettable for two reasons. First, from NHANES and the National Longitudinal Survey of Youth it is evident that youth of Latino backgrounds are at increased risk for overweight, at rates similar to those their black peers. Second, Latinos now comprise a share of the youth population equivalent to or exceeding that of blacks, and therefore trends among Latino youth are increasingly relevant to overall national trends.

Another limitation of this study is the self-reported nature of the parents’ heights and weights and the children’s weights. Self-reported growth parameters have social desirability biases which tend to exaggerate height and minimize weight among adults and adolescents, but exaggerate weight among younger children. Therefore, it is possible that we may have misclassified adults and adolescents in lower BMI categories and younger children in higher BMI categories. However, the proportions of children and adults in the different BMI categories at the most recent time points (2001 for adults, 2002 for children) are quite similar to proportions reported from the concurrent NHANES.

With these limitations in mind, we believe that this analysis provides two central findings regarding near-term trends in childhood BMI status. The first major finding to highlight is the strong influence of parental obesity. Other investigators, most notably Whitaker et al (1997), have illustrated that parental obesity increases the odds of a child developing obesity as a young adult, even among children as young as 1-2 years of age. Yet, that study did not reveal through its methods the timing of overweight onset for children in the cohort, nor whether children moved in and out of "overweight-ness" during childhood. Furthermore, Whitaker and colleagues' study suggested that parental obesity was a stronger influence than a child's own BMI status on future BMI only among children aged 1-2 years. In contrast, our findings suggest that parental BMI has an influence on short-term BMI trajectory for children through the peripubertal period, particularly in promoting the later development of AR/OW status among previously NW children but also perhaps in hindering the shift back to NW status among AR/OW individuals.

This insight about the broad timeframe for parental influence is an important contribution to the literature on obesity, because the seminal work of Whitaker et al indicated that parental obesity was most influential during very early childhood. Their work, though not perhaps actively discouraging investigators to examine the influence of parental obesity at children's later ages, has generally encouraged investigators to look at other explanations for older children's shifts to higher BMIs. Our work would suggest, in contrast, that investigators as well as clinicians should be mindful of the parental obesity influence *throughout* childhood, as we continue to search for effective interventions – especially those targeting family nutrition and activity habits.

The second major finding we wish to emphasize is the importance of timing in children's dynamic shifts in BMI. The period of adiposity rebound has been identified by several investigators as a key determinant of later adult obesity.(Dietz 1994; Guo et al 1994; Guo et al 2002; He & Karlberg 2002) We similarly found that children aged 6-9 years old had much greater differences in probabilities of BMI transitions over just a 5-year period than did children in the pre-rebound ages (2-5 years). For example, we found that children aged 3 years who were NW at Wave 1 had approximately 30% chance of being AR/OW by Wave 2, compared to children of the same age AR/OW at Wave 1 who had about a 45% chance of remaining AR/OW. In contrast, 7-year-olds who were NW at Wave 1 had only about 25% chance of becoming AR/OW by Wave 2, compared to a >65% chance of AR/OW children remaining AR/OW.

The contribution of the present study is that the BMI transition probability "gap" related to adiposity rebound is not only a phenomenon that manifests by young adulthood. Rather, the PSID-CDS data reveal footprints of this gap as early as the schoolage years. This adds further evidence to the literature suggesting that overweight-prevention interventions targeting adolescents come too late for most, and that interventions targeting schoolage children may come too late for many. While our data do indicate that a minority of AR/OW children in the schoolage and peripubertal years will indeed have BMIs in the NW range 5 years later, the overriding message from these data suggests that securing healthy behaviors prior to adiposity rebound (ie, in early childhood) may be a key to successful obesity prevention programs in the future.

Finally, a related finding from this analysis but one that deserves further mention is what we referred to above as the “inertia” of childhood BMI status – akin to Newton’s First Law that bodies at rest tend to stay at rest and bodies in motion tend to stay in motion (with the irony, of course, that physical activity and BMI are inversely related). During the years of adiposity rebound and beyond, there is greater likelihood that children will remain in their current BMI status than that they will transition to the other status, over the next 5 years. This is good news for children whose BMIs put them in the NW range (at least, that they will not develop overweight and obesity until later in life, if at all), and discouraging news for children with BMIs in the AR/OW range. Prior investigators’ work has indicated that the risk of adult obesity was higher for the latter group; the present work indicates that their increase in risk is somewhat more immediate.

The inertia issue is important to furthering our understanding of opportunities for intervention because it underscores the fact that the increased risks of cardiovascular disease, diabetes, orthopedic problems, sleep apnea, and other obesity-related conditions not only have their origins in childhood, but likely start to accumulate in childhood (Freedman et al 1999). Therefore, while it is true that a minority of obese adults were obese children (Freedman et al 2005), their obesity-related comorbidities may develop earlier and therefore have detrimental effects at younger ages.

Conclusions

In summary, the PSID-CDS provides a unique opportunity to examine short-term trends in individual children’s BMI status, controlling for multiple sociodemographic and family variables not available in other datasets. As the sample size permits, we intend to extend our current analysis to include other measures in the CDS that may be related to BMI status, such as children's health conditions, activity levels, and sedentary activities, as well as grandparental BMI status.

Furthermore, the strong parental obesity influence on childhood BMI trends naturally raises the question of the heritable component of obesity, and the mechanisms through which genes putatively related to obesity are making certain children more susceptible to environmental influences such as calorically dense foods and television access. To the extent that findings from studies like the PSID-CDS can be combined with insights from genetics research, today's scarce menu of intervention options can be enriched and offer providers and public health programs more potent opportunities to reverse the obesity epidemic.

REFERENCES

Dietz WH. Critical periods in childhood for the development of obesity. *Am J Clin Nutr.* 1994;59:955-959.

Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA.* 2005;293:1861-1867.

Freedman DS, Dietz WH, Srivivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics.* 1999;103:1175-1182.

Freedman DS, Khan LK, Serdula MK, Dietz WH, Srinivasan SR, Berenson GS. The relation of childhood BMI to adult adiposity. *Pediatrics.* 2005;115:22-27.

Freedman DS, Shear CL, Burke GL, Srinivasan SR, Webber LS, Harsha DW, Berenson GS. Persistence of juvenile-onset obesity over eight years: the Bogalusa Heart Study. *Am J Pub Health.* 1987;77:588-592.

Garn SM, LaVelle M. Two-decade follow-up of fatness in early childhood. *Am J Dis Child.* 1985;139:181-185.

Guo SS, Roche AF, Chumlea WC, Gardner JD, Siervogel RM. The predictive value of childhood body mass index values for overweight at age 35 years. *Am J Clin Nutr.* 1994;59:810-819.

Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr.* 2002;76:653-658.

He Q, Karlberg J. Probability of adult overweight and risk change during the BMI rebound period. *Obesity Research.* 2002;10:135-140.

Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-term morbidity and mortality of overweight adolescents. *N Engl J Med.* 1992;327:1350-1355.

Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British birth cohort. *Am J Clin Nutr.* 1997;66:1094-1101.

Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med.* 1997;337:869-873.