WIC Food Package Changes: Trends in Childhood Obesity Prevalence

Madeleine I.G. Daepp, MSc,[a] Steven L. Gortmaker, PhD,[b] Y. Claire Wang, MD, ScD,[c,d] Michael W. Long, ScD, MPH,[e] Erica L. Kenney, ScD, MPH[b,f]

abstract

OBJECTIVES: To evaluate the association of the 2009 changes to the US Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) food package and childhood obesity trends. We hypothesized that the food package change reduced obesity among children participating in WIC, a population that has been especially vulnerable to the childhood obesity epidemic.

METHODS: We used an interrupted time-series design with repeated cross-sectional measurements of state-specific obesity prevalence among WIC-participating 2- to 4-year-old children from 2000 to 2014. We used multilevel linear regression models to estimate the trend in obesity prevalence for states before the WIC package revision and to test whether the trend in obesity prevalence changed after the 2009 WIC package revision, adjusting for changes in demographics. In a secondary analysis, we adjusted for changes in macrosomia and high prepregnancy BMI.

RESULTS: Before the 2009 WIC food package change, the prevalence of obesity across states among 2- to 4-year-old WIC participants was increasing by 0.23 percentage points annually (95% confidence interval: 0.17 to 0.29; $P < .001$). After 2009, the trend was reversed (−0.34 percentage points per year; 95% confidence interval: −0.42 to −0.25; $P < .001$). Changes in sociodemographic and other obesity risk factors did not account for this change in the trend in obesity prevalence.

CONCLUSIONS: The 2009 WIC food package change may have helped to reverse the rapid increase in obesity prevalence among WIC participants observed before the food package change.

[a]Department of Urban Studies and Planning, Massachusetts Institute of Technology, Cambridge, Massachusetts; Departments of [b]Social and Behavioral Sciences and [f]Nutrition, Harvard T.H. Chan School of Public Health, Harvard University, Boston, Massachusetts; [c]Department of Health Policy and Management, Mailman School of Public Health, Columbia University, New York, New York; [e]Department of Prevention and Community Health, Milken Institute School of Public Health, George Washington University, Washington, District of Columbia; and [d]New York Academy of Medicine, New York, New York

Ms Daepp compiled the data, conducted the analyses, drafted components of the manuscript, and contributed to the conceptualization of the analytic approach; Dr Gortmaker conceptualized the study and contributed to the writing of the manuscript; Drs Long and Wang contributed to the conceptualization of the study and the writing and editing of the manuscript; Dr Kenney oversaw the analysis, contributed to the conceptualization of the analytic approach, and drafted components of the manuscript; and all authors approved the final manuscript as submitted.

DOI: https://doi.org/10.1542/peds.2018-2841

Accepted for publication Jan 29, 2019

Address correspondence to Erica L. Kenney, ScD, MPH, Department of Nutrition, Harvard T.H. Chan School of Public Health, 665 Huntington Ave, Boston, MA 02115. E-mail: elk782@mail.harvard.edu

WHAT'S KNOWN ON THIS SUBJECT: Changes to the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) in 2009 decreased intake of foods and beverages associated with excess weight gain. Surveillance data suggest obesity prevalence among WIC-participating children declined from 2010 to 2014.

WHAT THIS STUDY ADDS: We quantify the association of the WIC package change and childhood obesity using a quasi-experimental study design and accounting for state-level differences, race and/or ethnicity, poverty trends, and trends in macrosomia and high prepregnancy BMI among WIC participants.

To cite: Daepp MIG, Gortmaker SL, Wang YC, et al. WIC Food Package Changes: Trends in Childhood Obesity Prevalence. *Pediatrics.* 2019;143(5):e20182841

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) provides vouchers for nutrient-dense foods and beverages to more than half of all US infants and one-quarter of low-income pregnant and postpartum women and children <5 years of age.[1,2] To be eligible, households must have an income ≤185% of the federal poverty level or participate in several other federal aid programs and be at nutritional or medical risk.[3] In addition to being at risk for poor nutritional status, WIC-eligible children have also been particularly vulnerable to the childhood obesity epidemic.[4]

In 2009, the lists of foods that could be purchased with WIC vouchers (known as the WIC food packages), which includes basic food categories, including milk, cheese, beans, peanut butter, eggs, juice, cereal, and grains, were updated to better align with dietary guidelines. The new package provides extra cash allowances for fruits and vegetables, cuts the previous juice allowance in half, requires low-fat or skim milk for 2- to 4-year-olds, reduces cheese, and requires whole-grain instead of refined-grain products (among other changes).[2] Evidence suggests the revised WIC package has beneficially impacted household diets, including an increase in Healthy Eating Index scores,[5] reductions in juice purchases, and increases in the intake of fruit and whole grains.[6] A recent analysis of Nielsen Homescan Consumer Panel data found that WIC households' purchases of total calories declined by 11% after the package change, whereas purchases of fruits and vegetables increased.[7]

On the basis of these well-documented improvements in nutrition after the WIC package change, the risk of childhood obesity among WIC-participating children may also have declined. The Centers for Disease Control and Prevention (CDC) reported a decline in the prevalence of obesity and severe obesity among WIC-participating children from 2010 to 2014 but did not directly test whether the WIC package change was associated with a change in childhood obesity trends.[8] Given the variation in childhood obesity rates by state,[9] evaluating longer-term trends in obesity prevalence and the potential differential impact of the WIC package change by state is critical. A focus on state-level trends is particularly important given the level of control that state WIC agencies have over program administration[1]; states had discretion for implementing certain aspects of the revised food packages and may have differed in the extent to which healthier foods were made available.[10] In this article, we evaluate whether national and state-level trends in obesity prevalence among WIC-participating 2- to 4-year-old children changed after the 2009 WIC package revision, adjusting for sociodemographic composition and other risk factors for childhood obesity.

METHODS

Study Design

This quasi-experimental study employed interrupted time-series analysis[11] by using repeated cross-sectional measurements of obesity prevalence among WIC-participating children at the state level to test the potential impact of the 2009 WIC package change on childhood obesity trends. In interrupted time-series analysis, regression models estimate trends in population measures of an outcome before a prespecified time when a policy change (or other intervention) occurs and then test whether the trend changes afterward.[11] In this study, we compared population trends in obesity prevalence among WIC-participating 2- to 4-year-olds before and after 2009 to estimate whether there were changes in obesity prevalence or changes in the trend in obesity prevalence that may be attributable to the package change.[12] To reduce confounding from other concurrent trends, such as the Great Recession of 2007 to 2009, which occurred during a similar time period as the package change and which resulted in an increase in the use of federal food assistance and new populations using such assistance, we controlled for changes in racial-ethnic composition and child poverty at the state level. In an exploratory analysis including a subsample of states with complete data, we also examined whether changes in WIC-participating children's birth weight and maternal BMI were confounders.

Measures and Data Sources

Our primary outcome is obesity prevalence, calculated as the percentage of 2- to 4-year-old children enrolled in the WIC in a given state or territory with sex-specific BMI for age ≥95th percentile on the 2000 CDC growth charts.[13] We obtained the state-level prevalence of obesity among WIC-participating 2- to 4-year-olds in 2008, 2010, 2012, and 2014 from data.gov files[14] derived from the WIC Participant and Program Characteristics (WIC-PC), a national census of participants in the WIC administered every 2 years by the US Department of Agriculture's Food and Nutrition Service.[15] In addition, we used prevalence estimates from Pan et al[13] for 2000, 2004, 2010, and 2014. In a comparison of data for the 2 years of overlap (2010 and 2014), we find negligible differences between the data sets (Supplemental Information). We excluded Hawaii from our main analyses given concerns about data quality.[8] Our data set includes data from 49 states in 6 years, or 294 observations; these data were collected from all 2- to 4-year-olds for whom obesity prevalence was determined, a group that ranged in number from 2 253 471 children in

2000 to 3 152 137 children in 2012 in total across all 49 geographies.

To account for changes in the racial-ethnic composition of the WIC population, we calculated the percentage of 2- to 4-year-old WIC participants classified as white, African American, Asian American and/or Pacific Islander, American Indian, or Hispanic for each state and year. The WIC-PC reports for 2008, 2010, 2012, and 2014 included state-level race-ethnic breakdowns for children between the ages of 2 and 4 years but not for 2000 and 2004. We obtained data on race and ethnicity for 2000 and 2004 from the WIC data[16,17]; when comparing these with the WIC-PC report data[14] for the 3 years of overlap (2008, 2010, and 2012), we found high correlations between measures of racial and ethnic makeup (Supplemental Information).

To account for possible shifts in child poverty, we assessed state-level child poverty rates with the Supplemental Poverty Measure (SPM) for children ages 0 to 17 years,[18] calculated by the Center on Poverty and Social Policy at Columbia University.[18] The SPM is a posttax measure of poverty used by the Census Bureau and the Bureau of Labor Statistics that accounts for in-kind transfers and other benefits as well as nondiscretionary expenses, such as medical or child care costs.[19] The SPM is considered an improvement over the official poverty measure in its use of a poverty threshold updated for contemporary expenditure patterns[20]; we use a measure anchored to nondiscretionary spending (for food, clothing, shelter, and utilities) from 2008 to 2012[20] and adjusted for geographic differences in costs of living.[18]

For the exploratory analysis of whether changes in the 2- to 4-year-olds' history of macrosomia or maternal prepregnancy weight status could have played a role in changes in childhood obesity prevalence among WIC-participating children, we extracted the proportions of WIC participants with a birth weight >4000 g and of WIC-participating mothers with a prepregnancy BMI classified as obese (>29.1, the cutoff used by WIC agencies before Revision 10 of the Nutrition Risk Criteria)[21] from the WIC-PC reports.[14,16,17,22–28] To address the lag between the measurement of maternal prepregnancy BMI and obesity in our population of 2- to 4-year-old children, we include prepregnancy BMI with a 4-year lag. We note that only 41 states reported data on birth weight and prepregnancy BMI in at least 2 time points, and 45.1% of state-year observations are missing data for at least 1 of the 2 variables. We assessed the robustness of our results to the use of state-level birth weight data from the CDC Wonder Database natality public-use data,[29] but these data cover all children in the United States (rather than just the WIC population), and we were unable to identify a comparable data source for prepregnancy BMI. Because of the high incidence of missing data, we consider these analyses secondary and exploratory.

Statistical Analyses

We fitted segmented linear regression models to state-level obesity prevalence data as a function of year (centered at 2009), an indicator for post–WIC-package change (ie, 1 if year >2009 and 0 if otherwise), and an interaction term of the indicator and the number of years since the change. The coefficient for year can be interpreted as the annual percentage-point change in obesity per year on average across states, whereas the coefficient for the indicator of years after 2009 represents the average percentage-point drop in obesity for all years after 2009 (a level change), and the coefficient of the interaction of the indicator and the year represents the average annual percentage-point change for each year after 2009 (a change in slope).[11] All models were fitted with state fixed effects to control for time-invariant differences in obesity prevalence between states as well as with state random effects. Hausman tests[30] fail to reject the null hypothesis of no difference in coefficient estimates from fixed- versus random-effect specifications; thus, we report results from the more efficient random-effect models. The full model specification can be found in the Supplemental Information.

We first fit baseline models including just the year, level, and trend variables as well as the random effects. The level variable was not significant, suggesting there was no immediate drop in obesity prevalence after the year 2009; this variable was thus excluded from the models. We then fit models with controls for child poverty as well as racial-ethnic composition to assess whether changes in the demographics of WIC participants could explain changes in obesity level. Lastly, for our exploratory analysis of the potential impact of changes in trends in macrosomia and prepregnancy BMI on trends in childhood obesity prevalence in this population, we fit a model including the prevalence of macrosomia and high maternal prepregnancy BMI among those states with complete data for these variables. Because complete case analysis may produce biased results when data are not missing completely at random, we further used multiple imputation by chained equations to impute missing data.[31] We imputed 20 data sets in which macrosomia and the percentage of mothers with high prepregnancy BMI were iteratively predicted with regression equations including all covariates used in our main analyses; the resultant model for this exploratory analysis was fit on each data set with results pooled to reflect the uncertainty in the predicted values.[32]

The main analyses were conducted in R 3.4.4. Fixed- and random-effects models were fitted with the plm package.[33] Sensitivity analyses and multiple imputation were conducted by using Stata 14 (Stata Corp, College Station, TX). Two-sided P values $<.05$ were considered statistically significant.

RESULTS

Demographic characteristics of WIC participants from 2000 to 2014 are presented in Table 1. The average obesity prevalence among WIC-participating 2- to 4-year-old children across the states was 12.92% in 2000, rose to an average of 15.13% in 2008, stayed roughly the same in 2010, and then decreased to 14.24% by 2014. Although the sociodemographic composition of the 2- to 4-year-old WIC-participant population changed somewhat over this period, we did not identify statistically significant differences in the state-level mean racial makeup or percentage of children in poverty. The average percentage of 2- to 4-year-old WIC participants born with macrosomia declined from 2000 to 2008 and then leveled off from 2008 to 2014. Meanwhile, the percentage of WIC-participating women who had a prepregnancy BMI >29.1 increased steadily from 2000 to 2014.

Results from the crude interrupted time-series analysis show that before 2009, national obesity prevalence among 2- to 4-year-old WIC participants was increasing 0.26 percentage points annually (95% confidence interval [CI]: 0.22 to 0.31; $P < .001$; Table 2). After 2009, the trend was reduced by 0.55 percentage points (95% CI: −0.66 to −0.43; $P < .001$). Observations are correlated within states, with ~78% of the variance being attributable to variation between states. Predictions for each of the 49 states with complete data are presented in Fig 1.

TABLE 1 State-Level Demographic and Anthropometric Characteristics of Participants in the WIC, 2000–2014

	2000	2004	2008	2010	2012	2014	*P*
Prevalence of obesity among 2-to 4-y-old WIC participants, mean (SD)	12.92 (2.40)	14.80 (2.38)	15.13 (2.19)	15.24 (2.24)	14.51 (2.27)	14.24 (2.27)	<.001
Race and/or ethnicity, %,[a] mean (SD)							
American Indian	3.14 (7.58)	3.27 (7.85)	3.62 (8.27)	3.50 (7.93)	3.63 (7.92)	3.56 (7.64)	.999
Asian American or Pacific Islander	2.10 (2.18)	2.25 (2.13)	2.35 (2.15)	2.61 (2.25)	2.94 (2.33)	3.37 (2.52)	.056
African American	21.29 (18.82)	19.82 (7.03)	19.37 (15.42)	19.19 (14.70)	19.95 (4.85)	20.75 (14.97)	.986
Hispanic	20.67 (20.34)	25.22 (21.39)	29.94 (22.15)	30.91 (21.33)	30.79 (20.81)	30.65 (20.37)	.086
White	52.79 (21.98)	49.44 (21.87)	44.72 (20.90)	43.79 (20.21)	42.70 (19.62)	41.67 (19.25)	.059
WIC-participating children with high birth wt, %,[b] mean (SD)	13.22 (2.38)	7.17 (1.78)	6.49 (1.44)	6.62 (1.59)	6.43 (1.76)	6.41 (1.68)	<.001
WIC-participating women with high prepregnancy BMI, %,[c] mean (SD)	21.95 (3.50)	26.22 (2.91)	28.55 (3.33)	29.96 (3.12)	30.66 (4.39)	32.22 (4.31)	<.001
Children in poverty, %,[d] mean (SD)	15.83 (4.36)	14.92 (3.98)	14.14 (3.91)	14.39 (4.01)	14.81 (3.99)	14.97 (4.12)	.412
Total No. 2-to 4-y-old WIC participants	2 253 471	2 550 533	2 790 527	3 206 995	3 152 137	2 915 253	—

Included were 49 states, excluding Hawaii. *P* values are from analysis of variance tests of differences in means. —, not applicable.

[a] Demographic makeup is presented as the number of children with race reported in each category as a percentage of (for 2000 and 2004) all 1- to 4-y-old children enrolled in the WIC or (for 2008–2014) all 2- to 4-y-old WIC participants as a percentage of all children for whom a race in the 5 categories was reported.

[b] The percentage of WIC-participating 1- to 4-y-old children with birth weights between 4001 and 6000 g. This measure is reported by state and local WIC agencies and thus is missing data for some states and territories (eg, $n = 29$ in 2000 and $n = 37$ in 2014).

[c] The percentage of WIC-participating pregnant women with prepregnancy BMI ≥29.1 reported with a 4-y lag. This measure is reported by state and local WIC agencies and thus is missing data for some states (eg, $n = 33$ in 4 years before 2000 and $n = 40$ 4 years before 2014).

[d] Rate for children ages 0 to 17 y calculated with the anchored SPM available from the Center on Poverty and Social Policy at Columbia University for all US states.[19]

TABLE 2 Multivariate Random-Effects Models Predicting the State-Level Obesity Prevalence (Percentage Points) Among 2- to 4-Year-Old WIC Participants, 2000–2014

	Model 1	Model 2
Intercept (95% CI)	15.55*** (14.93 to 16.17)	16.01*** (15.30 to 16.71)
Annual trend[a], yrs (95% CI)	0.26*** (0.22 to 0.31)	0.23*** (0.17 to 0.29)
Change in annual trend after 2009 (95% CI)	−0.55*** (−0.66 to −0.43)	−0.57*** (−0.69 to −0.44)
Race and/or ethnicity, %[b] (95% CI)		
American Indian	—	0.07 (−0.003 to 0.14)
Asian American	—	0.19* (0.01 to 0.37)
African American	—	0.03 (−0.00 to 0.06)
Hispanic	—	0.03 (−0.001 to 0.05)
Children in poverty (standardized)[c], % (95% CI)	—	0.07 (−0.25 to 0.39)
ICC	0.78	0.75
N	294	294
N groups	49	49

Results are reported for models with state random effects; Durbin-Wu-Hausman tests fail to reject the null hypothesis of no significant differences in consistency between models with fixed and random effects. —, not applicable.

a The annual trend is calculated with the year centered in 2009.

b Demographic makeup is presented as the number of children with race reported in each category as a percentage of (for 2000 and 2004) all 1- to 4-y-old children enrolled in the WIC or (for 2008–2014) all 2- to 4-y-old WIC participants as a percentage of all children for whom a race in the 5 categories was reported. We further subtract the population-weighted mean demographic makeup from each of these variables so the intercept in model 2 can be interpreted as the mean overall obesity prevalence in 2009 for a state with a demographic makeup comparable to the demographic makeup of our population across all observations (1.14% American Indian, 3.24% Asian American and/or Pacific Islander, 19.95% African American, 44.16% Hispanic, and 31.5% white) and a child poverty rate equal to the average across state-year observations (14.84).

c Standardized rate for children ages 0 to 17 y calculated with the anchored SPM available from the Center on Poverty and Social Policy at Columbia University for all US states.[19]

* $P < .05$; *** $P < .001$

After adjusting for changes in racial-ethnic composition and child poverty, the results were essentially unchanged. We estimated a pre-2009 annual trend of a 0.23 percentage-point increase in childhood obesity prevalence (95% CI: 0.17 to 0.29; $P < .001$) and a post-2009 change in slope of −0.57 percentage points annually (95% CI: −0.69 to −0.44; $P < .001$). On the basis of these adjusted results, we estimated that after the package revisions in 2009, there was a decline in childhood obesity of 0.34 percentage points per year. The intraclass-correlation coefficient (ICC) was marginally reduced after controlling for sociodemographic variables (0.75), suggesting that between-state differences in sociodemographic makeup explained little of the between-state differences in obesity prevalence.

Our exploratory analysis of the potential influence of changes in macrosomia and high maternal prepregnancy BMI on trends in childhood obesity prevalence suggests that, although controlling for macrosomia and prepregnancy BMI may have slightly attenuated the change in trend, these 2 factors have little contribution to the observed drop in childhood obesity prevalence after 2009 (Supplemental Tables 3 and 4).

DISCUSSION

We found, using an interrupted time-series analysis, that the 2009 WIC package change was associated with a shift in the trend of childhood obesity prevalence among 2- to 4-year-old WIC participants from a 0.23-percentage-point annual increase to a 0.34 percentage-point annual decrease. Changes in the racial-ethnic and income composition of the WIC population did not explain this change in trend, nor did changes in maternal prepregnancy BMI or macrosomia prevalence.

A change in the trend in obesity prevalence related to dietary changes resulting from the 2009 package change is plausible. A substantial body of evidence has shown that the dietary habits of WIC participants improved from before to after the package change. Participating families purchased 11% fewer total calories after the package change compared with before[7] and also improved overall diet quality in ways that may protect against obesity and facilitate healthier growth. Participants purchased and consumed less fruit juice, refined grains, grain-based desserts, and sugar-sweetened beverages while increasing purchases and consumption of fruits, vegetables, and whole grains.[5–7,34] This dietary pattern has been associated with less weight gain in both children and adults.[35,36] Small, beneficial reductions in total energy intake could result in small population-wide reductions in average BMI.[12,37,38]

Although overall our analysis revealed declining obesity prevalence after the package change, our results also suggest variation between states that was not explained by differences in racial-ethnic makeup or child poverty. Although the difference may be due to unmeasured heterogeneity in WIC populations across states, another possibility is that differences exist in how effectively the WIC package changes were implemented in each state. For example, recent research documents disparities across states in minimum stocking requirements for WIC-participating vendors.[10] Future researchers should evaluate whether differences in fidelity to the WIC package changes or other implementation factors may have played a role in potential differences in childhood obesity prevalence trends across the states.

Our analysis is subject to a number of limitations. We lack individual-

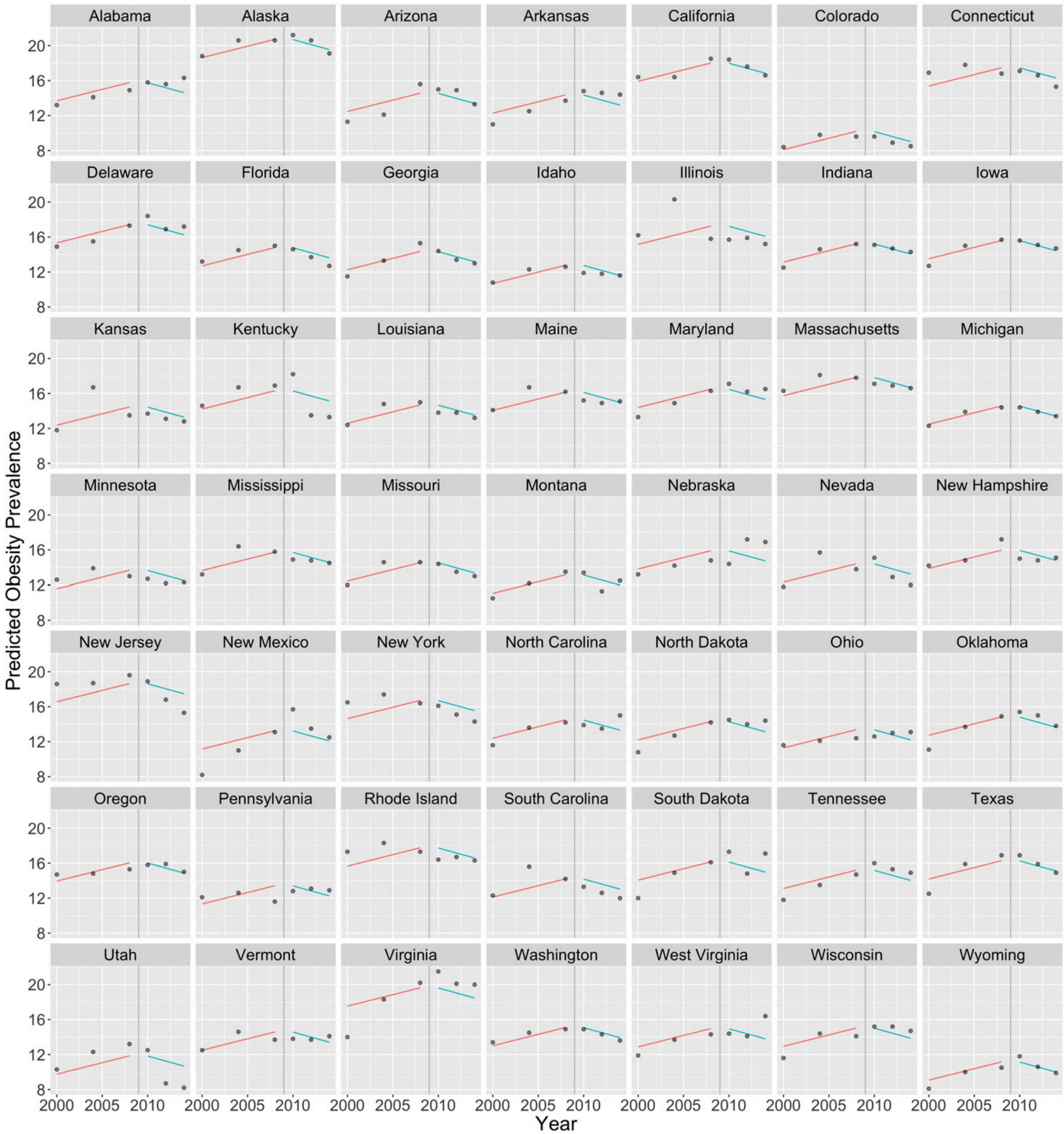

FIGURE 1
Obesity prevalence and prediction by state. Black points indicate the measured obesity prevalence among children ages 2 to 4 years in each year; lines show the fit from model 1 in Table 2, with red indicating the predicted trend before 2009 and blue indicating the trend after 2009.

level BMI data over time as well as data on how energy intake and expenditure may have changed, which would provide a mechanistic explanation of our findings. Perhaps most importantly, we are unable to control for the possibility that some other event between 2008 and 2010 may be driving the results. The Great Recession, for example, may have led to changes in the WIC population such that families who had previously had higher incomes and lower obesity risk were newly enrolling. However, we included controls for socioeconomic and demographic variables to account for these changes. Furthermore, we might expect to see changes driven by the Great Recession manifest most strongly in states that were more strongly affected, but Fig 1 does not reveal evidence of heterogeneity in the change in trend between the most strongly affected states (FL, NV, AZ, and CA) and states considered more “recession proof,” such as North Dakota, South Dakota, Kansas, or Oklahoma.[39] The Patient Protection and Affordable Care Act was another major policy change in 2009, but existing evidence suggests no relationship between increased access to health insurance and obesity risk.[40,41] Although it has been suggested that the decline could be the result of other public health interventions, such as increased breastfeeding promotion in addition to that provided by WIC or obesity-prevention efforts in child care settings,[13] this is unlikely. First, carefully controlled studies suggest no causal link between breastfeeding and childhood obesity.[42–44] Second, although there are promising child care initiatives to prevent obesity,[45] these were not widely disseminated in 2009 and thus could not logically have influenced obesity trends at that point. Similarly, although the Head Start program, which also reaches 2- to 4-year-olds in poverty, has been linked with potential reductions in obesity risk,[46] there was no substantial change in Head Start in 2009 that could explain such changes in obesity trends. The inclusion of a control group of non–WIC participants would improve our ability to control for non–WIC-related policies, societal trends, or interventions that could have been impacting obesity in this population at the same time, but we are unable to identify a control group similar in age and socioeconomic characteristics to our sample because such a high proportion of low-income children participate in the WIC. Although the NHANES can provide estimates for this age group overall, the sample sizes for this age group are small once children participating in the WIC are excluded.[47] Comparing existing NHANES data on trends in childhood obesity prevalence with the WIC trends does not suggest that the overall trends in childhood obesity prevalence exactly mirrored the WIC trends. Although obesity prevalence leveled off between 2011 and 2014 for children ages 6 to 11 years, most of whom would have been too old to be affected by the WIC package change,[48] changes in the prevalence of obesity for 2- to 5-year-olds were found to have declined from 2003 to 2004 and have had no clear trend since. As more years of data as well as data on state-level differences in program implementation become available, further research should continue to evaluate the effect by, for example, examining heterogeneity in the change in trend on the basis of differences in WIC package changes by state.

CONCLUSIONS

This analysis demonstrates that the 2009 WIC package was associated with a reversal of the increasing trend in obesity prevalence among WIC participants observed from 2000 to 2014.

ACKNOWLEDGMENTS

We thank Dr Heidi Blanck of the Obesity Prevention and Control Branch at the CDC for her comments.

ABBREVIATIONS

BMI: Body Mass Index
CDC: Centers for Disease Control and Prevention
CI: confidence interval
ICC: intraclass-correlation coefficient
SPM: Supplemental Poverty Measure
WIC: Special Supplemental Program for Women, Infants, and Children
WIC-PC: Special Supplemental Nutrition Program for Women, Infants, and Children Participant and Program Characteristics

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Ms Daepp is supported by the National Science Foundation Graduate Research Fellowship (grant 1122374). Drs Gortmaker, Long, and Kenney were supported by The JPB Foundation. Dr Wang was supported by the National Institutes of Health (grant 1R01CA172814-01A1). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. Oliveira V, Frazao E. *The WIC Program: Background, Trends, and Economic Issues, 2015 Edition*. Washington, DC: United States Department of Agriculture; 2015
2. USDA Food and Nutrition Services. *Special Supplemental Nutrition Program for Women, Infants and Children (WIC): Revisions in the WIC Food Packages*. Alexandria, VA: USDA Food and Nutrition Services; 2009. Available at: https://www.federalregister.gov/documents/2009/12/31/E9-30991/special-supplemental-nutrition-program-for-women-infants-and-children-wic-revisions-in-the-wic-food. Accessed February 15, 2019
3. USDA Food and Nutrition Services. The Special Supplemental Nutrition Program for Women, Infants and Children (WIC program). Available at: https://fns-prod.azureedge.net/sites/default/files/wic/wic-fact-sheet.pdf. Accessed April 15, 2018
4. Rossen LM, Schoendorf KC. Measuring health disparities: trends in racial-ethnic and socioeconomic disparities in obesity among 2- to 18-year old youth in the United States, 2001-2010. *Ann Epidemiol*. 2012;22(10):698–704
5. Tester JM, Leung CW, Crawford PB. Revised WIC food package and children's diet quality. *Pediatrics*. 2016;137(5):e20153557
6. Schultz DJ, Byker Shanks C, Houghtaling B. The impact of the 2009 Special Supplemental Nutrition Program for Women, Infants, and Children food package revisions on participants: a systematic review. *J Acad Nutr Diet*. 2015;115(11):1832–1846
7. Ng SW, Hollingsworth BA, Busey EA, Wandell JL, Miles DR, Poti JM. Federal nutrition program revisions impact low-income households' food purchases. *Am J Prev Med*. 2018;54(3):403–412
8. Pan L, Park S, Slayton R, Goodman AB, Blanck HM. Trends in severe obesity among children aged 2 to 4 years enrolled in special supplemental nutrition program for women, infants, and children from 2000 to 2014. *JAMA Pediatr*. 2018;172(3):232–238
9. Long MW, Ward ZJ, Resch SC, et al. State-level estimates of childhood obesity prevalence in the United States corrected for report bias. *Int J Obes*. 2016;40(10):1523–1528
10. Pelletier JE, Schreiber LRN, Laska MN. Minimum stocking requirements for retailers in the Special Supplemental Nutrition Program for Women, Infants, and Children: disparities across US States. *Am J Public Health*. 2017;107(7):1171–1174
11. Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther*. 2002;27(4):299–309
12. Hall KD, Gortmaker S, Lott M, Yang YC. From calories to weight change in children and adults: the state of the science. Available at: http://healthyeatingresearch.org/research/from-calories-to-weight-change-in-children-and-adults-the-state-of-the-science/. Accessed February 15, 2019
13. Pan L, Freedman DS, Sharma AJ, et al. Trends in obesity among participants aged 2-4 years in the Special Supplemental Nutrition Program for Women, Infants, and Children - United States, 2000-2014. *MMWR Morb Mortal Wkly Rep*. 2016;65(45):1256–1260
14. Centers for Disease Control and Prevention. Nutrition, Physical Activity, and Obesity - Women. Available at: https://catalog.data.gov/dataset/nutrition-physical-activity-and-obesity-women-infant-and-child-dfe5d. Accessed February 13, 2019
15. Connor P, Bartlett S, Mendelson M, Lawrence K, Wen K. WIC participant and program characteristics: 2010 report. 2011. Available at: https://fns-prod.azureedge.net/sites/default/files/WICPC2010.pdf
16. Bartlett S, Olvera R, Gill N, Laramie M. *WIC Participant and Program Characteristics 2000*. Alexandria, VA: USDA Food and Nutrition Service; 2002
17. Bartlett S, Bobronnikov E, Pacheco N. *WIC Participant and Program Characteristics, 2004*. Alexandria, VA: USDA Food and Nutrition Service; 2006
18. Nolan L, Pac J, Wimer C, et al. Poverty in the 50 states: long-term trends and the role of social policies. 2016. Available at: https://www.povertycenter.columbia.edu/recent-publications/2016/9/20/poverty-in-the-50-states-long-term-trends-in-the-and-the-role-of-social-policies. Accessed February 12, 2019
19. Garner TI. Supplemental Poverty Measure thresholds: laying the foundation. In: *Allied Social Science Associations Annual Meetings*; December 29, 2010; Denver, CO
20. Wimer C, Fox L, Garfinkel I, Kaushal N, Waldfogel J. Progress on poverty? New estimates of historical trends using an anchored supplemental poverty measure. *Demography*. 2016;53(4):1207–1218
21. U.S. Department of Health and Human Services, Food and Nutrition Service. WIC policy memorandum 98-9, revision 10: nutrition risk criteria. 2009
22. Johnson B, Thorn B, McGill B, et al. WIC participant and program characteristics 2012 final report. Available at: https://fns-prod.azureedge.net/sites/default/files/WICPC2012.pdf. Accessed February 15, 2019
23. Thorn B, Tadler C, Huret N, et al. *WIC Participant and Program Characteristics 2014*. Alexandria, VA: USDA Food and Nutrition Service; 2015
24. Randall B, Bartlett S, Kennedy S. Study of WIC participant and program characteristics, 1996. Available at: https://fns-prod.azureedge.net/sites/default/files/pc96fr.pdf. Accessed February 15, 2019
25. Bartlett S, Brown-Lyons M, Moore D, Estacion A. *WIC Participant and Program Characteristics 1998*. Alexandria, VA: USDA Food and Nutrition Service; 2000
26. Bartlett S, Olvera R, Bobronnikov E, et al. *WIC Participant and Program Characteristics 2002*. Alexandria, VA: USDA Food and Nutrition Service; 2003
27. Bartlett S, Bobronnikov E, Mendelson M. *WIC Participant and Program Characteristics 2006*. Alexandria, VA: USDA Food and Nutrition Service; 2007
28. Connor P, Bartlett S, Mendelson M, Condon K, Sutcliffe J. *WIC Participant and Program Characteristics 2008*.

Alexandria, VA: USDA Food and Nutrition Service; 2010

29. Centers for Disease Control and Prevention. Natality public-use data on CDC WONDER online database. Available at: https://wonder.cdc.gov/natality.html. Accessed February 15, 2019

30. Hausman JA. Specification tests in econometrics. *Econometrica*. 1978; 46(6):1251–1271

31. White IR, Royston P, Wood AM. Multiple imputation using chained equations: issues and guidance for practice. *Stat Med*. 2011;30(4):377–399

32. Cummings P. Missing data and multiple imputation. *JAMA Pediatr*. 2013;167(7): 656–661

33. Croissant Y, Millo G. Panel data econometrics in R: the plm package. *J Stat Softw*. 2008;27(2):1–43

34. Andreyeva T, Luedicke J, Tripp AS, Henderson KE. Effects of reduced juice allowances in food packages for the women, infants, and children program. *Pediatrics*. 2013;131(5):919–927

35. Dong D, Bilger M, van Dam RM, Finkelstein EA. Consumption of specific foods and beverages and excess weight gain among children and adolescents. *Health Aff (Millwood)*. 2015;34(11): 1940–1948

36. Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB. Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med*. 2011;364(25): 2392–2404

37. Hall KD, Butte NF, Swinburn BA, Chow CC. Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model. *Lancet Diabetes Endocrinol*. 2013;1(2): 97–105

38. Gortmaker SL, Wang YC, Long MW, et al. Three interventions that reduce childhood obesity are projected to save more than they cost to implement. *Health Aff (Millwood)*. 2015;34(11): 1932–1939

39. Hacker JS, Huber GA, Nichols A, Rehm P, Craig S. Economic insecurity across the American states. Available at: http://economicsecurityindex.org/assets/state_reports/ESI_cross_state.pdf. Accessed February 15, 2019

40. Pernenkil V, Wyatt T, Akinyemiju T. Trends in smoking and obesity among US adults before, during, and after the Great Recession and Affordable Care Act roll-out. *Prev Med*. 2017;102:86–92

41. Baicker K, Taubman SL, Allen HL, et al; Oregon Health Study Group. The Oregon experiment–effects of Medicaid on clinical outcomes. *N Engl J Med*. 2013; 368(18):1713–1722

42. Ip S, Chung M, Raman G, et al. Breastfeeding and maternal and infant health outcomes in developed countries. *Evid Rep Technol Assess (Full Rep)*. 2007;(153):1–186

43. Owen CG, Martin RM, Whincup PH, Davey-Smith G, Gillman MW, Cook DG. The effect of breastfeeding on mean body mass index throughout life: a quantitative review of published and unpublished observational evidence. *Am J Clin Nutr*. 2005;82(6):1298–1307

44. Kramer MS, Matush L, Vanilovich I, et al; PROBIT Study Group. Effects of prolonged and exclusive breastfeeding on child height, weight, adiposity, and blood pressure at age 6.5 y: evidence from a large randomized trial. *Am J Clin Nutr*. 2007;86(6):1717–1721

45. Alkon A, Crowley AA, Neelon SE, et al. Nutrition and physical activity randomized control trial in child care centers improves knowledge, policies, and children's body mass index. *BMC Public Health*. 2014;14:215

46. Lumeng JC, Kaciroti N, Sturza J, et al. Changes in body mass index associated with Head Start participation. *Pediatrics*. 2015;135(2):e449–e456

47. Ogden CL, Carroll MD, Lawman HG, et al. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. *JAMA*. 2016;315(21):2292–2299

48. Ogden CL, Carroll MD. Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960–1962 through 2007–2008. *NCHS Health E-Stat*. 2010;

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Madeleine I.G. Daepp, Steven L. Gortmaker, Y. Claire Wang, Michael W. Long and Erica L. Kenney

Pediatrics 2019;143;
DOI: 10.1542/peds.2018-2841 originally published online April 1, 2019;