




The role of income and neighbourhood poverty in the association between the 2009 Special Supplemental Nutrition Program for Women, Infants and Children (WIC) food package change and child obesity among WIC-participating children in Los Angeles County, 2003–2016

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Abstract

Objective: To determine whether a previously reported association between the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) food package change and reduced child obesity risk among WIC-participating children in Los Angeles County holds across levels of family income and neighbourhood poverty.

Design: Analysis of prospectively collected WIC administrative data. The outcome was obesity at age 4 years (BMI-for-age \geq 95th percentile). Poisson regression was applied to a matched sample (n 79 502) to determine if the association between the WIC food package change and child obesity was modified by family income (<50% federal poverty level (FPL), 50–100% FPL, >100% but <185% FPL) and neighbourhood poverty.

Setting: Los Angeles County, California.

Participants: Children who participated in WIC in Los Angeles County between 2003 and 2016; children were grouped as receiving the old WIC food package (2003–2009) or the new WIC food package (2010–2016).

Results: Receiving the new WIC food package (i.e., post-2009) was associated with 7–18% lower obesity risk across all family income categories. Neither family income nor neighbourhood poverty significantly modified the association between the WIC food package and child obesity. However, certain sub-groups seemed to benefit more from the food package change than others. In particular, boys from families with income above poverty but residing in the poorest neighbourhoods experienced the greatest reductions in obesity risk (relative risk = 0.77; 95% CI 0.66, 0.88).

Conclusions: The WIC food package revisions were associated with reduced childhood obesity risk among all WIC-participating families in Los Angeles County, across levels of income eligibility and neighbourhood poverty.

Keywords
Women, Infants and Children
Obesity
Effect modification
Income
Neighbourhood poverty
Los Angeles

The food packages received by beneficiaries of the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) – which includes pregnant and postpartum women, infants and children up to the age of 5 years who live in low-income households – were updated in 2009 to better align them with the Dietary Guidelines for Americans⁽¹⁾. This food package change included the addition of fruits,

vegetables and whole grains; a reduction in the amount of juice and dairy, as well as in the amount of fat allowed in milk; and a reduction in infant formula based on a recalibration of amounts to match infants' age and needs⁽¹⁾. Further, post-2009 mothers of fully breastfed infants do not receive formula and are given the most generous food package in terms of food quantity and variety for 1 year postpartum,

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plus additional complementary foods for their fully breastfed infants from 6 to 12 months, including infant-food fruits, vegetables and meats.⁽¹⁾ Previous research has found the WIC food package change to be associated with healthier growth trajectories⁽²⁾ and lower obesity risk^(2,3) among WIC-participating children. Among children participating in WIC in Los Angeles County between 2003 and 2016, for example, receiving the new food package continuously from 0 to 4 years, compared with the old, was associated with a 10–12% lower obesity risk at age 4 years⁽²⁾. Additional reported benefits related to the food package change include better diet quality for women and children, improved breast-feeding outcomes, and healthier neighbourhood food environments with increased availability of fruits, vegetables and whole grains⁽⁴⁾.

WIC serves only households with family incomes \leq 185% of the federal poverty level (FPL). Although not always discussed, variations in nutritional outcomes across income levels have been observed among WIC families^(5,6). Namely, Nobari *et al.*⁽⁵⁾ found that 2–4-year-old WIC-participating children in Los Angeles County living in the lowest income households ($<$ 50% FPL) had higher obesity prevalence than children living in households with incomes \geq 50% FPL, and this trend was consistent across the years of study (2003–2014). Similar findings were observed for neighbourhood income, with WIC-participating children living in the poorest neighbourhoods having the highest obesity prevalence across time⁽⁵⁾. Freedman *et al.*⁽⁶⁾ found similar trends by family income in weight-for-length among 3–23-month-old WIC-participating children in several US states. Yet, it remains unclear if the 2009 WIC food package differentially impacted children's obesity outcomes, across family income and neighbourhood poverty levels. Identifying if the WIC food package change equitably impacted WIC-participating children is an important policy question, particularly to inform future food package revisions.

The goal of the current study was to investigate if the previously identified association between the new WIC food package and reduced obesity risk among WIC-participating children in Los Angeles County⁽²⁾ was observed among *all* participating households, irrespective of their family income or the poverty level of the neighbourhood in which they live. Since children with the lowest income and living in the highest poverty neighbourhoods had the highest obesity prevalence and, therefore, stood to gain the most from improved diets, we hypothesised that the effect of the WIC food package change on obesity would be stronger among children living in very-low-income households ($<$ 50%FPL), particularly among those living in the poorest neighbourhoods.

Methods

Sample

Administrative data on WIC-participating children in Los Angeles County, California, between 2003 and 2016

from the *Data Mining Project* (<https://apps.phfwic.org/Projects/DataMining.aspx>) were used and analysed in 2019. These data include weight and height (or length) measures taken on the same children during WIC(re) certification visits, as well as socio-demographic information on children and their families. In addition, children's residential addresses were geocoded to 2010-census tract boundaries and linked to data from the American Community Survey to obtain neighbourhood-level variables.

The current study was part of a larger study investigating the impact of the 2009 WIC food package change on children's growth trajectories from 0 to 4 years and obesity at age 4 years⁽²⁾; as such, children's inclusion criteria were to be continuously enrolled in WIC from birth (defined as within 42 d of birth) until age 4 years (inclusive), with at least one weight and height (or length) measurement for each year, either before or after the implementation of the WIC food package change (1 October 2009). Additional inclusion criteria for the current study were for children to live in a census tract with at least five WIC-participating children to protect the identity of WIC participants. Children who met eligibility were grouped based on the dates they participated in WIC: if their enrollment in WIC ended before 1 October 2009, they belonged to the *old food package* group, whereas those whose enrollment began after 1 October 2009 belonged to the *new food package* group. Children whose enrollment in WIC overlapped with the implementation of the food package change were excluded. A total of 155 991 children were eligible for inclusion, with a final analytical sample of 79 502 children attained after sample matching (explained below in the 'Statistical Analysis' section; Fig. 1).

Outcome

Obesity at age 4 years, defined as a BMI-for-age \geq 95th percentile in sex-specific growth curves from the Centers for Disease Control and Prevention (CDC), served as the outcome for Poisson regression analyses. Weight and height (or length) used to estimate obesity at age 4 years, as well as initial weight-for-length z-score used as a covariate in multivariable analyses, were measured by WIC staff during WIC eligibility certification and recertification; measurements by WIC staff in Los Angeles County have been found to have high validity⁽⁷⁾.

Covariates

Available individual-level socio-demographic data included child's age, sex and race/ethnicity as reported by the child's mother (Asian, Black, Hispanic, White and Other); maternal education (less than a high school degree, high school degree or equivalent, and higher than high school) and language preference (English, Spanish and Other); and family size (continuous) and income ($<$ 50, 50–100 and $>$ 100–185% FPL). In addition, census tract-level variables from American Community Survey (2005–2009 for children in the *old food package* group and 2010–2014 for

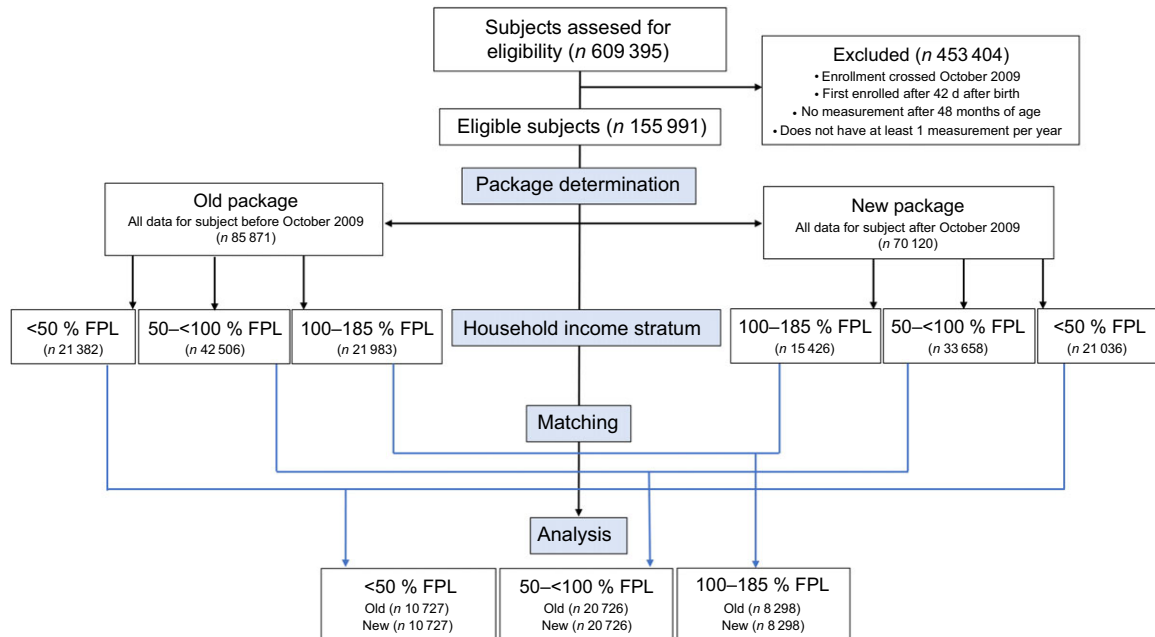


Fig. 1 (colour online) Flow chart of WIC-participating children included in the study

children in the *new food package* group) included percentage of individuals in the census tract of residence (1) with a high school degree or greater, (2) who are non-White and (3) who live below the FPL (i.e., in poverty).

Statistical analysis

To account for changes in the demographic characteristics of WIC participants in Los Angeles over time,⁽²⁾ children receiving the new food package were matched one-to-one to children receiving the old food package. Exact matching was used for child's sex and race/ethnicity; maternal education and language preference; and family income category. Optimal matching was used for age weight-for-length z-score at first measurement^(8,9).

Descriptive statistics were produced to characterise the sample. Further, using this matched sample and accommodating clustering within matched pairs, sex-stratified Poisson regression with robust SE estimation⁽¹⁰⁾ was used to determine whether the association between the WIC food package change and obesity risk at age 4 years varied by family income; this was accomplished by including an interaction term between family income strata and WIC package, adjusting by family size and neighbourhood characteristics. Poisson regression overcomes convergence issues in risk ratio estimation common in binomial regression and has lower sensitivity to model misspecification⁽¹⁰⁻¹²⁾. Moreover, Poisson regression can provide an unbiased estimate of the risk ratio when there is equal follow-up time and the event of interest is not rare⁽¹²⁾, and variance overestimation from applying Poisson regression to binary data can be corrected by using a sandwich estimator for robust error variance estimation⁽¹⁰⁾. Sex stratification of our analysis was deemed necessary since the association between the

WIC food package change and obesity has been found to be different for boys and girls⁽¹³⁾. To assess whether the strength of the association between WIC food package and obesity was further dependent on neighbourhood poverty within each family income category, additional models were run that included interaction terms between percentage neighbourhood poverty (continuous) and (1) WIC food package, (2) family income and (3) the interaction of WIC food package with family income. All analyses were conducted using SAS 9.4 (SAS Institute Inc.). A *P*-value < 0.05 was deemed statistically significant.

Results

Summary characteristics of the sample by child sex, family income and WIC food package type are displayed in Table 1. Overall, children whose family income was above poverty (>100% to <185% FPL) had a lower initial weight-for-length z-score. Regardless of family income, boys and girls receiving the new food package had a lower obesity prevalence at age 4 years than boys and girls receiving the old food package. Even though the sample was predominantly Hispanic overall, Black children were over-represented in the very low-income group (<50% FPL), while Asian children were over-represented in the above poverty group (>100% to <185% FPL). There was minimal variation in average family size (~ four people) across family income groups. As for neighbourhood characteristics, the overwhelming majority of children lived in neighbourhoods where more than 40% of residents had higher than a high school education and were non-White, regardless of family income. As for neighbourhood poverty, boys and



Table 1 Characteristics of the sample of WIC-participating children in Los Angeles County (2003–2016) by family income strata, sex and food package type (old v. new)

	Very low income (<50% FPL)				Low income (50-100% FPL)				Above poverty (>100% to <185%FPL)															
	Boys		Girls		Boys		Girls		Boys		Girls													
	Old package (n 5433)	New package (n 5433)	Old package (n 5294)	New package (n 5294)	Old package (n 10 520)	New package (n 10 520)	Old package (n 10 206)	New package (n 10 206)	Old package (n 4177)	New package (n 4177)	Old package (n 4121)	New package (n 4121)												
	n	%	n	%	n	%	n	%	n	%	n	%												
Individual and family level characteristics																								
Initial WLZ																								
Mean	0.47	0.47	0.44	0.44	0.46	0.46	0.46	0.45	0.39	0.39	0.36	0.35												
SD	1.16	1.16	1.12	1.11	1.17	1.17	1.12	1.11	1.15	1.15	1.08	1.08												
Obese at last visit*	1410	26.0	1225	22.6	1116	21.1	1025	19.4	2652	25.2	2285	21.7	2148	21.1	2008	19.7	1022	24.5	858	20.5	837	20.3	740	18.0
Race/ethnicity†																								
Asian	63	1.2	63	1.2	78	1.5	78	1.5	243	2.3	243	2.3	229	2.2	229	2.2	189	4.5	189	4.5	180	4.4	180	4.4
Black	478	8.8	478	8.8	467	8.8	467	8.8	272	2.6	272	2.6	269	2.6	269	2.6	94	2.3	94	2.3	98	2.4	98	2.4
Hispanic	4785	88.1	4785	88.1	4663	88.1	4663	88.1	9823	93.4	9823	93.4	9533	93.4	9533	93.4	3783	90.6	3783	90.6	3738	90.7	3738	90.7
White	103	1.9	103	1.9	83	1.6	83	1.6	172	1.6	172	1.6	168	1.7	168	1.7	108	2.6	108	2.6	105	2.6	105	2.6
Other	4	0.1	4	0.1	3	0.1	3	0.1	10	0.1	10	0.1	7	0.1	7	0.1	3	0.1	3	0.1	0	0.0	0	0.0
Maternal language‡																								
English	2722	50.1	2722	50.1	2634	49.8	2634	49.8	3268	31.1	3268	31.1	3219	31.5	3219	31.5	2098	50.2	2098	50.2	1949	47.3	1949	47.3
Spanish	2678	49.3	2678	49.3	2618	49.5	2618	49.5	7103	67.5	7103	67.5	6854	67.2	6854	67.2	1994	47.7	1994	47.7	2099	50.9	2099	50.9
Other	33	0.6	33	0.6	42	0.8	42	0.8	149	1.4	149	1.4	133	1.3	133	1.3	85	2.0	85	2.0	73	1.8	73	1.8
Maternal education‡																								
< High school	3446	63.4	3446	63.4	3411	64.4	3411	64.4	6239	59.3	6239	59.3	6091	59.7	6091	59.7	1785	42.7	1785	42.7	1812	44.0	1812	44.0
High school	1600	29.5	1600	29.5	1533	29.0	1533	29.0	3327	31.6	3327	31.6	3162	31.0	3162	31.0	1674	40.1	1674	40.1	1650	40.0	1650	40.0
> High school	387	7.1	387	7.1	350	6.6	350	6.6	954	9.1	954	9.1	953	9.3	953	9.3	718	17.2	718	17.2	659	16.0	659	16.0
Family size																								
Mean	3.96	4.07	3.98	4.09	4.19	4.20	4.19	4.21	3.92	3.94	3.94	3.95												
SD	1.63	1.60	1.66	1.68	1.24	1.21	1.25	1.22	1.16	1.19	1.18	1.21												
Neighbourhood-level characteristics‡																								
Percentage poverty																								
< 20 %	2156	39.7	1517	27.9	2091	39.5	1431	27.0	4372	41.6	3040	28.9	4370	42.8	2949	28.9	2203	52.7	1651	39.5	2090	50.7	1681	40.8
20–40 %	2766	50.9	3093	56.9	2687	50.8	3005	56.8	5394	51.3	6135	58.3	5079	46.8	5914	58.0	1777	42.5	2209	52.9	1886	45.8	2116	51.4
> 40 %	511	9.4	823	15.2	516	9.8	858	16.2	754	7.2	1345	12.8	757	7.4	1343	13.2	197	4.7	317	7.6	145	3.5	324	7.9
Percentage high school grads																								
< 20 %	9	0.2	2	0.0	8	0.2	1	0.0	20	0.2	0	0.0	23	0.3	2	0.0	9	0.2	1	0.0	7	0.2	0	0.0
20–40 %	732	13.5	496	9.1	788	14.9	495	9.4	1412	13.4	941	8.9	1360	13.3	989	9.7	392	9.4	246	5.9	425	10.3	266	6.5
> 40 %	4692	86.4	4935	90.8	4498	85.0	4798	90.6	9088	86.4	9579	91.1	8820	86.4	9215	90.3	3776	90.4	3930	94.1	3689	89.5	3855	93.4
Percentage non-White																								
< 20 %	7	0.1	3	0.1	4	0.1	4	0.1	22	0.2	2	0.02	15	0.2	6	0.1	18	0.4	6	0.1	8	0.2	6	0.2
20–40 %	53	1.0	47	0.9	44	0.8	31	0.6	135	1.3	139	1.3	123	1.2	129	1.3	70	1.7	69	1.7	61	1.5	83	2.0
> 40 %	5373	98.9	5383	99.1	5246	99.1	5259	99.3	10363	98.5	10379	98.7	10065	98.6	10071	98.7	4089	97.9	4102	98.2	4052	98.3	4032	97.8

WIC, Special Supplemental Nutrition Program for Women, Infants and Children; FPL, federal poverty level; WLZ, weight-for-length z-score.

*Measured.

†Self-reported.

‡Obtained from the American Community Survey.

Table 2 Risk ratios (RR) for the association between the 2009 WIC food package change and obesity at age 4 years by family income among a matched sample of WIC-participating children in Los Angeles County, 2003–2016 (*n* 79 502)

	Boys			Girls		
	RR	95 % CI	Interaction <i>P</i>	RR	95 % CI	Interaction <i>P</i>
Very low income (< 50 % FPL)						
New food package	0.85	0.79, 0.92	0.71	0.88	0.81, 0.96	0.28
Old food package	1.00			1.00		
Low income (50–100 % FPL)						
New food package	0.87	0.82, 0.91	Ref.	0.93	0.88, 0.99	Ref.
Old food package	1.00			1.00		
Above poverty (> 100 % to < 185 % FPL)						
New food package	0.82	0.76, 0.88	0.16	0.88	0.81, 0.95	0.22
Old food package	1.00			1.00		

WIC, Special Supplemental Nutrition Program for Women, Infants and Children; FPL, federal poverty level.

Table 3 Effect modification of the association between the 2009 WIC package change and obesity at age 4 years by family income and neighbourhood poverty

Household income	Food package	Neighbourhood poverty prevalence 10 %		Neighbourhood poverty prevalence 30 %		Neighbourhood poverty prevalence 50 %		<i>P</i>
		RR	95 % CI	RR	95 % CI	RR	95 % CI	
Boys								
Very low (< 50 % FPL)	New	0.91	0.80, 1.03	0.84	0.78, 0.91	0.78	0.66, 0.92	0.23*
	Old	1		1		1		0.83†
Low (50–100 % FPL)	New	0.91	0.83, 0.99	0.85	0.81, 0.90	0.8	0.71, 0.90	0.17*
	Old	1		1		1		Ref.†
Above poverty (> 100 % to < 185 % FPL)	New	0.84	0.75, 0.94	0.81	0.74, 0.88	0.77	0.64, 0.93	0.51*
	Old	1		1		1		0.81†
Girls								
Very low (< 50 % FPL)	New	0.92	0.80, 1.06	0.88	0.80, 0.96	0.83	0.69, 1.00	0.47*
	Old	1		1		1		0.67†
Low (50–100 % FPL)	New	0.94	0.86, 1.04	0.93	0.87, 0.99	0.92	0.80, 1.05	0.79*
	Old	1		1		1		Ref.†
Above poverty (> 100–< 185 % FPL)	New	0.88	0.78, 0.99	0.88	0.80, 0.97	0.88	0.72, 1.09	0.99*
	Old	1		1		1		0.87†

WIC, Special Supplemental Nutrition Program for Women, Infants and Children; FPL, federal poverty level; RR, relative risk.

**P*-value for the interaction between WIC package and tract percentage poverty in the specified family income stratum.

†*P*-value for the comparison of the interactions between WIC package and neighbourhood poverty between family income levels (reference = low income [50–100% FPL]).

girls with family incomes <50 % FPL were more likely to live in neighbourhoods where more than 40 % of residents lived in poverty. In addition, the proportion of children living in neighbourhoods where more than 40 % of residents lived in poverty was higher for those receiving the new food package, compared with the old, and this was true across all levels of family income.

The new WIC food package was associated with a lower obesity risk at age 4 years for both boys and girls across all family income groups (Table 2). For boys, the new package was associated with reductions in obesity risk ranging from 13 to 18 %; for girls, reductions ranged from 7 to 12 %. The association between the new WIC food package and obesity was not modified by family income (interaction *P*-values > 0.05).

Table 3 displays the results of the Poisson regression models predicting obesity risk by WIC food package, including interactions between family income and neighbourhood poverty. Neighbourhood poverty did not

significantly modify the association between the new WIC food package and obesity across family income groups (all interaction *P*-values > 0.05). However, we observed variations in the strength of the association between the new food package and obesity for some sub-groups. Boys living in census tracts in which half of residents lived in poverty, regardless of family income, experienced the largest obesity risk reduction when receiving the new food package compared with the old (20–23 %). On the other hand, girls living in the same type of neighbourhoods (i.e., with 50 % of residents living in poverty), regardless of family income level, did not experience a significant reduction in obesity risk when receiving the new food package, compared with the old.

Discussion

The goal of the current study was to investigate if a previously identified association between the new WIC food



package and reduced obesity risk among WIC-participating children in Los Angeles County applies to all children regardless of their family income and the poverty level of their neighbourhoods of residence. We hypothesised that children living in the poorest households would benefit the most from the WIC food package change in terms of obesity risk, particularly those living in the poorest neighbourhoods. We only found partial support for this hypothesis. Neither family income nor neighbourhood poverty significantly modified the association between the new WIC food package and obesity risk. However, boys living in the poorest households had a modestly larger obesity risk reduction (18%) compared with boys living in less poor households (13–15%) when they received the new food package *v.* the old. For girls, those living in the poorest households (< 50% FPL) and in households above poverty experienced the same level of obesity risk reduction at 12% if they received the new food package, compared with the old. In other words, both boys and girls whose families had incomes between 50 and 100% FPL experienced the smallest obesity risk reductions associated with the new food package receipt compared with the other sub-groups analysed.

While no previous studies have examined the moderating role of family income in the relationship between the WIC food package and child obesity risk, there is evidence that the effects of childhood obesity interventions may vary by family income⁽¹⁴⁾. The Healthy Living Cambridge Kids intervention, for example, used community- and school-wide approaches to encourage healthy eating and physical activity among kindergarten students in Cambridge, MA⁽¹⁵⁾. After a 3-year intervention – which in schools included the introduction of gardens, cooking classes, nutrition education, improved recipes for school lunches and expanded physical education – BMI *z*-score and obesity prevalence significantly decreased among children in higher income households only⁽¹⁵⁾. On the other hand, an obesity treatment intervention among 2–6-year-olds in ten paediatric clinics in Massachusetts found positive intervention effects (i.e., reduced BMI) only among children living in low-income households⁽¹⁶⁾. In their systematic review of factors that modify (i.e., moderators or effect modifiers) school-based energy-balance interventions, Yildirim *et al.*⁽¹⁷⁾ found that household socio-economic status did not significantly modify the effect of such interventions, though it was not an often-studied moderator. McGill *et al.*⁽¹⁸⁾ conducted a systematic review focused on determining if interventions promoting healthy eating were equally effective across the socio-economic spectrum. They found that ‘price’ interventions (including food taxation, food subsidies or other economic incentives) were more effective at improving healthy eating outcomes among low-income households, whereas ‘person’ interventions (focused primarily on nutrition education) were more beneficial as household income increased⁽¹⁸⁾. These observations are not surprising given that family income has been shown to

play an important role in the causal mechanisms by which social factors influence health⁽¹⁹⁾.

As for neighbourhood poverty, we hypothesised that children living in the poorest neighbourhoods would benefit the most in terms of obesity risk reduction after the WIC food package change. This hypothesis is based on multiple reports that the new WIC food package has improved the neighbourhood food environment, as in response to the WIC food package change, food stores stocked more fresh produce and whole grains⁽⁴⁾. Similarly, there is evidence that stores in the poorest neighbourhoods, which are often convenience stores selling mostly high-fat, high-sugar foods, improved the most to be able to keep their WIC authorisation⁽²⁰⁾. Further, there have been several large initiatives established in Los Angeles County to support changes in the food environment, such as the *Healthy Eating and Active Communities* initiative funded by the California Endowment⁽²¹⁾ and the *Healthy Eating and Active Living* initiative funded by Kaiser Permanente⁽²²⁾. While neighbourhood poverty did not significantly modify the association between the new WIC food package and obesity, we found that boys, but not girls, living in neighbourhoods with 50% poverty experienced the largest obesity risk reductions (20–23%) when receiving the new food package compared with the old. This is not the first time we have reported sex patterning of our results⁽¹³⁾; reasons for this and previously identified sex differences could not be fully explained with the available data and thus warrant further study. Previous studies do support the notion that neighbourhoods may affect boys and girls differently, with the effects varying based on the neighbourhood characteristics and the outcomes under study^(23,24).

The current study has several strengths and limitations. Strengths include the use of a well-characterised sample, including children who participated in WIC between 2003 and 2016. Sample matching was used to minimise the impact of secular trends and confounding, as the characteristics of WIC-participating families have changed over time and other larger changes (e.g., Great Recession) occurred in the studied time frame. The Great Recession may explain why WIC participants were more likely to live in poorer neighbourhoods after the WIC food package change compared with before; however, we are unable to test this hypothesis given our data. Sample matching reduced our sample size and thus our power to detect associations. Our sample was predominantly Hispanic, given that we restricted our sample to children who participated in WIC from birth until their fifth birthday and Hispanic families are more likely to participate in WIC for longer. Thus, our results may not be generalisable to other WIC populations unless they are also largely composed of Hispanics. Moreover, our study did not involve randomisation or a control group of WIC-eligible, non-participating children, so our results cannot be interpreted as causal. It is important to point out, though, that WIC in Los



Angeles County currently reaches over half of all children 1–5 years⁽²⁵⁾, so finding a control group of children who have never been in WIC is extremely difficult.

Conclusions

The new WIC food package was associated with lower child obesity risk across families in all low-income strata. Neither family income nor neighbourhood poverty significantly modified the association between the new WIC food package and obesity risk among WIC-participating children in Los Angeles County. The current study adds to the mounting evidence of the beneficial impacts of the current WIC food package on dietary behaviours and obesity-related outcomes. Implementation of further changes to the WIC food package as recommended by an expert panel in 2017⁽²⁶⁾ – including additional cash value for fruits and vegetables; further reductions of juice, milk and peanut butter; and reduction in amounts of jarred infant food – should be prioritised in order to maximise the health benefits of WIC participation.

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References

1. Taylor J (2006) Updating the WIC Food Packages: It's About Time. National Health Policy Forum, Issue Brief no.819. https://hsrc.himmelfarb.gwu.edu/sphhs_centers_nhpf/177 (accessed February 2006).
2. Chaparro MP, Crespi C, Anderson C *et al.* (2019) The 2009 Special Supplemental Nutrition Program for Women, Infants and Children (WIC) food package change and children's growth trajectories and obesity in Los Angeles County. *Am J Clin Nutr* **109**, 1414–1421.
3. Daepf MIG, Gortmaker SL, Wang YC *et al.* (2019) WIC food package changes: trends in childhood obesity prevalence. *Pediatrics* **143**, e20182841.
4. Schultz DJ, Byker Shanks C & Houghtaling B (2015) 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* **115**, 1832–1846.
5. Nobari TZ, Whaley SE, Prelip ML *et al.* (2018) Trends in socioeconomic disparities in obesity prevalence among low-income children aged 2–4 years in Los Angeles County, 2003–2014. *Child Obes* **14**, 248–258.
6. Freedman DS, Sharma AJ, Hamner HC *et al.* (2017) Trends in weight-for-length among infants in WIC From 2000 to 2014. *Pediatrics* **139**, e20162034.
7. Crespi CM, Alfonso VH, Whaley SE *et al.* (2012) Validity of child anthropometric measurements in the special supplemental nutrition program for women, infants and children. *Pediatr Res* **71**, 286–292.
8. Bergstralh EJ, Kosanke JL & Jacobsen SJ (1996) Software for optimal matching in observational studies. *Epidemiology* **7**, 331–332.
9. Ming K & Rosenbaum PR (2001) A note on optimal matching with variable controls using the assignment algorithm. *J Comput Graph Stat* **10**, 455–463.
10. Zou G (2004) A modified Poisson regression approach to prospective studies with binary data. *Am J Epidemiol* **159**, 702–706.
11. Chen W, Qian L, Shi J *et al.* (2018) Comparing performance between log-binomial and robust Poisson regression models for estimation risk ratios under model misspecification. *BMC Med Res Methodol* **18**, 63.
12. McNutt L, Chuntao W, Xue X *et al.* (2003) Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol* **157**, 940–943.
13. Chaparro MP, Anderson CE, Crespi C *et al.* (2019) The effect of the 2009 WIC food package change on childhood obesity varies by gender and initial weight status in Los Angeles County. *Ped Obes*, e12526.
14. Hillier-Brown FC, Bambra CL, Cairns JM *et al.* (2014) A systematic review of the effectiveness of individual, community and societal level interventions at reducing socioeconomic inequalities in obesity amongst children. *BMC Public Health* **14**, 834.
15. Chomitz VR, McGowan RJ, Wendel JM *et al.* (2010) Healthy Living Cambridge Kids: A community-based participatory effort to promote healthy weight and fitness. *Obesity* **18**, S45–S53.
16. Taveras EM, Gortmaker SL, Hohman KH *et al.* (2011) Randomized controlled trial to improve primary care to prevent and manage childhood obesity: the High Five for Kids study. *Arch Pediatr Adolesc Med* **165**, 714–722.
17. Yildirim M, Van Stralen MM, Chinapaw MJM *et al.* (2011) For whom and under what circumstances do school-based energy balance behavior interventions work? Systematic review on moderators. *Int J Pediatr Obes* **6**, e46–e57.
18. McGill R, Anwar E, Orton L *et al.* (2015) Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health* **15**, 457.
19. Marmot M (2002) The influence of income on health: views of an epidemiologist. *Health Aff* **21**, 31–46.
20. Andreyeva T, Luedicke J, Middleton AE, *et al.* (2011) *Changes in Access to Healthy Foods After Implementation*



- of the WIC Food Package Revisions. Contractor and Coperator Report No. 66.* Hartford, CT: Rudd Center for Food Policy and Obesity Yale University.
21. Samuels SE, Craypo L, Boyle M *et al.* (2010) The California endowment's healthy eating, active communities program: a midpoint review. *Am J Public Health* **100**, 2114–2123.
 22. Kaiser Permanente (2020) HEAL & HEAL Zones. n.d.; <https://community.kp.org/about/program/heal-zones> (accessed February 2020).
 23. Leventhal T & Brooks-Gunn J (2003) Moving to opportunity: an experimental study of neighborhood effects on mental health. *Am J Public Health* **93**, 1576–1582.
 24. Chaparro MP, Bilfield A & Theall KP (2019) Exposure to neighborhood crime is associated with lower levels of physical activity and higher obesity risk among adolescent girls, but not boys. *Child Obes* **15**, 87–92.
 25. Los Angeles County (2020) WIC Data. Demographics. n.d.; <http://lawicdata.org/topics/demographics/> (accessed February 2020).
 26. National Academies of Sciences, Engineering, and Medicine, Health and Medicine Division, Food and Nutrition Board & Committee to Review WIC Food Packages (2017) Review of WIC Food Packages: Improving Balance and Choice: Final Report. Washington (DC): National Academies Press (US).