Association Between WIC Enrollment During Pregnancy and Low Birth Weight Outcomes in Connecticut

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OBJECTIVES: Studies have shown that pregnant women participating in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) give birth to healthier babies. To substantiate this in Connecticut, the association of WIC enrollment at least 12 weeks before delivery with low birth weight (LBW) outcomes was evaluated in Connecticut for calendar year 2000. METHODS: Logistic regression was performed on all singleton birth records in the state with complete information (n=34,551), and corresponding records among women enrolled in the state's HUSKY A public insurance program (n=7,570). The regression model controlled for nine stratified risk factors for LBW: race/ethnicity, maternal age, education level, marital status, parity, previous lost pregnancy, prenatal care initiation, maternal medical risk factors, and tobacco use during pregnancy. RESULTS: The adjusted odds ratio for LBW among all singleton births to women enrolled in WIC at least 12 weeks before delivery was 0.69 (95% CI: 0.60, 0.80). The corresponding odds ratio among HUSKY A enrollees was 0.65 (95% CI: 0.54, 0.77). Separate analysis of birth records containing missing covariate information (n=6,442) was not significantly different from that obtained of records containing complete information. CONCLUSIONS: These data suggest that WIC enrollment in Connecticut at least 12 weeks before delivery was protective against LBW among the entire birth cohort of singleton births, as well as among HUSKY A enrollees.

Introduction

Since implementation of the first statewide Special Supplemental Nutrition Program for Women, Infants and Children (WIC) in Vermont in 1974 (1), disadvantaged pregnant women and young children have been eligible for food supplements and other nutritional services. Nearly 50% of all women in the nation who give birth now receive support from the WIC program. The intention of the federal program is to enhance infant health and development with food supplements to women during pregnancy and to young children after birth. These supplements are provided monthly, historically as coupons, and allow free access to foods such as cereal, milk, eggs, cheese, vitamin C-enriched juices, legumes, carrots and peanut butter. The WIC program also provides nutrition counseling, breastfeeding promotion, and screening for additional social services. The program has been reported to enhance early prenatal care of pregnant women, reduce preterm and low birth weight (LBW) rates, and reduce infant mortality (2).

Women with incomes up to 185% of the federal poverty level are eligible for enrollment in the Connecticut WIC program (3), which is managed by the Connecticut State Department of Public Health (DPH), and which provides WIC services to over 51,000 women and children annually (4). Based on the federal poverty level, residents of Connecticut who are enrolled in the WIC program are also eligible for participation in the state's HUSKY Part A insurance program (5). Implemented in the state in 1997, pregnant women with incomes up to 185% of the poverty level are eligible for enrollment in HUSKY A (6). Evaluation of the state's HUSKY A program in recent years indicates that pregnant women enrolled in the program are at increased risk for LBW, very low birth weight, and preterm births (7).

Studies at the national level have shown that

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participation in WIC is associated with improved birth outcomes (8, 9), and that WIC participation early in pregnancy may be more effective in promoting better infant health (10). Other studies, however, have questioned the effectiveness of the program (11-13). No recent statistical evaluation of Connecticut's WIC program has been documented. This study describes the association of enrollment in the Connecticut WIC program with LBW outcomes among singleton births. This observational study was conducted of all birth records in the state during calendar year 2000 that contained complete information, controlling for multiple maternal risk factors, and comparing results among all singleton births with corresponding births among HUSKY A enrollees. Analysis of records containing missing covariate information was also conducted.

Methods

Variable Construction and Data Use

A three-way linkage of Birth, WIC enrollment, and HUSKY A enrollment data at the record level was performed for the birth cohort of calendar year 2000 within the Connecticut DPH. WIC enrollment records and HUSKY A enrollment records, each previously linked to birth records, were linked by state file number to generate the three-way linked dataset. HUSKY A enrollment data linked to birth records were supplied courtesy of the Connecticut Department of Social Services, and WIC enrollees, linked to corresponding births (n=11,422), were provided courtesy of the Information Technology unit within DPH. The three-way linked dataset of birth records contained all birth records in the state during calendar year 2000, as well as selected WIC and HUSKY A enrollment data. The enhanced dataset contained 12 pairs of duplicate records from the WIC-Birth file (n=24); duplicate records containing the most current entries were retained. An additional 10 pairs (n=20) were incorrectly assigned state file numbers in the WIC-Birth file, and 9 of these 10 pairs were researched and resolved. Information on WIC enrollment for the remaining unresolved pair was removed. One record in the previously linked WIC-Birth dataset did not correspond to any birth record and was deleted. The final three-way linked dataset contained the entire calendar year 2000 birth cohort of 43,075 records.

The date of WIC enrollment before delivery and HUSKY A enrollment status at the time of delivery were obtained from WIC, and HUSKY A enrollment data. All other covariate data fields used in the study were obtained from birth records. The outcome variable, low birth weight (LBW), was also obtained from birth records, and was defined as a birth weight of less than 2,500 grams.

Of the 41,384 singleton births that occurred in Connecticut during calendar year 2000, 34,551 contained complete information in all the data fields needed for the study, and these records were used in the analysis. The remaining 6,833 records contained missing information in one or more of the covariate and/or outcome data fields. Of the records containing missing information, 391 contained missing information about the outcome variable. The remaining 6,442 singleton birth records containing incomplete covariate data were analyzed separately. All analyses were conducted with SAS (Statistical Analysis System, Cary, NC).

Data Analysis

Frequency distributions were evaluated for the entire cohort of singleton births containing complete information, as well as for corresponding birth records of HUSKY A enrollees. For both groups, frequency distributions for either those enrolled in WIC at least 12 weeks before delivery, or for those enrolled in WIC within 12 weeks before delivery or not enrolled, were produced. Overall variation in the distribution of maternal risk factors between those enrolled or not enrolled in WIC were evaluated by the Chi-Square test.

Univariate logistic regression analysis was performed on records in the three-way linked file containing complete information to evaluate the unadjusted statistical association between selected maternal risk factors and LBW. Tests were conducted of singleton births among the entire cohort and corresponding births among HUSKY A enrollees. The following stratified covariates, which have been shown to be significant predictors of LBW (14), were each evaluated: 1) race and ethnicity, four categories; 2) maternal age, four categories; 3) maternal education level, three levels; 4) marital status, two categories; 5) parity, two levels; 6) previous lost pregnancies, two categories; 7) prenatal care initiation, two categories; 8) presence of chronic or pregnancy-related hypertension or other medical risk factors, three categories; and 9) use of tobacco during pregnancy, two categories. Other medical risk factors included anemia, cardiac disease, lung disease, diabetes, genital herpes, hydramnios/

oligohydramnios, hemoglobinopathy, eclampsia, incompetent cervix, previous infant of 4000+ grams, previous preterm or small for gestational age infant, renal disease, Rh sensitization, or uterine bleeding. The frequencies of these other medical risk factors individually in the study population were not sufficient to be considered separately (data not shown).

WIC enrollment was stratified into two categories: enrollment at least 12 weeks before delivery, and enrollment either less than 12 weeks before delivery or not enrolled. The latter category combined women who were ineligible for WIC enrollment, and those who were eligible for WIC but who chose not to enroll in WIC. It also included women who enrolled in WIC late in their pregnancy, as well as those who enrolled in WIC during the third trimester for their unborn child.

A set of three multiple logistic regression analyses was performed on records containing complete information, similar to that described by Strobino and coworkers (15). First, the unadjusted association between WIC enrollment and LBW was evaluated (Model 1). Second, the association of LBW for the multiple stratified covariates was evaluated, in the absence of the WIC variable (Model 2). Third, the association of LBW was evaluated for WIC enrollment, controlling for the multiple covariates used in Model 2 (Model 3). Analyses were performed among all singleton births in the state, and corresponding births among HUSKY A enrollees.

Records with missing covariate information were analyzed separately. For this dataset of at least one missing data field in each record, logistic regression was performed using missing data as an additional stratum, and each record was weighted in direct proportion to its degree of completeness across the ten covariates. Weight for each records was assigned as follows: weight = (9-m)/9, where m=number of missing data fields.

This public health research activity was approved by a review board within the Connecticut State Department of Public Health (protocol #449).

Results

Frequency Distribution of Maternal Risk Factors and Low Birth Weight

Of the 34,551 records used in the study, 5,926 (17.2%) were for women enrolled in WIC at least 12 weeks before delivery (**Table 1**), and a total of 7,570 (21.9%) were for women enrolled in the state's HUSKY A program. Of all records for women enrolled in HUSKY A, 4,017 (53.1%) were co-enrolled in WIC at least 12 weeks before delivery. Among the nine selected maternal risk factors that may contribute to LBW outcomes, six differed in distribution between those enrolled *versus* those not enrolled in WIC at least 12 weeks before delivery ($p < 0.001$). Those maternal characteristics that did not differ were parity, previous lost pregnancies, and prenatal care initiation. Whereas 77.5% of Non-Hispanic Caucasian women with a singleton birth were not enrolled in WIC, only 32.1% of women in this race category were enrolled in WIC. Compared to women not enrolled in WIC, a significantly greater proportion of records among WIC enrollees were of minority race and ethnicity ($p < 0.001$). Similarly, among women less than 18 years old, only 1.5% of the records were for women not enrolled in WIC, while 7.1% were for women enrolled in WIC. A significantly greater proportion of women enrolled in WIC also had a lower level of educational attainment, were unmarried, smoked during pregnancy, and exhibited maternal medical risk factors ($p < 0.001$).

Among births in the state that occurred to HUSKY A enrollees, a similar difference in the distribution of maternal demographic characteristics and risk factors occurred between women enrolled only in HUSKY A *versus* those co-enrolled in both programs (**Table 1**). The magnitude of distribution differences were attenuated, but remained significant for all risk factors except previous lost pregnancies and smoking during pregnancy ($p < 0.001$). Compared to HUSKY A enrollees who were not enrolled in WIC at least 12 weeks before delivery, a significantly greater proportion of women enrolled in WIC were of minority race and ethnicity, were less than 18 years old, had less than 12 years of education, were unmarried, had no prior history of pregnancy, initiated prenatal care before the third trimester, and had chronic or pregnancy-related hypertension ($p < 0.001$).

These data collectively indicate that the distribution of demographic characteristics and risk factors known to be associated with adverse birth outcomes in birth records among WIC enrollees were different than those among women not enrolled in WIC. Analysis conducted of WIC enrollment among all births in the state, therefore, requires con-

Table 1
Frequencies of Risk Factors and Low Birth Weight Outcomes
Singleton Births, Connecticut, 2000 (n=34,551)

	Birth Cohort				HUSKY A Enrollees			
	- WIC		+ WIC		- WIC		+ WIC	
Maternal Risk Factor	**Freq**	**Percent**	**Freq**	**Percent**	**Freq**	**Percent**	**Freq**	**Percent**
Race/Ethnicity [1,2]								
Non-Hispanic Caucasian	22,196	77.54	1,901	32.08	1,765	49.68	1,341	33.38
Non-Hispanic African American	2,323	8.12	1,476	24.91	815	22.94	1,000	24.89
Non-Hispanic Other Race	1,423	4.97	131	2.21	132	3.72	79	1.97
Hispanic	2,683	9.37	2,418	40.80	841	23.67	1,597	39.76
WIC Enrollment								
3rd trimester or none	28,625	100.00	na	na	3,553	100.00	na	na
before 3rd trimester	na	na	5,926	100.00	na	na	4,017	100.00
Maternal Age [1,2,3]								
less than 18 years old	438	1.53	421	7.10	226	6.36	319	7.94
18-24 years old	4,390	15.34	2,856	48.19	1,845	51.93	2,155	53.65
25-34 years old	6,726	59.64	2,194	37.02	1,240	34.90	1,318	32.81
at least 35 years old	17,071	23.50	455	7.68	242	6.81	225	5.60
Education [1,2,3]								
less than 12 years	1,877	6.56	1,767	29.82	958	26.96	1,346	33.51
12 years	7,230	25.26	2,857	48.21	1,708	48.07	1,935	48.17
more than 12 years	19,518	67.19	1,302	21.97	887	24.96	736	18.32
Marital Status [1,2,3]								
married	23,029	80.45	1,643	27.73	959	26.99	780	19.42
not married	5,596	19.55	4,283	72.27	2,594	73.01	3,237	80.58
Parity [2]								
none	12,158	42.47	2,545	42.95	1,392	39.18	1,757	43.74
at least one	16,467	57.53	3,381	57.05	2,161	60.82	2,260	56.26
Previous lost pregnancies								
none	21,681	75.74	4,474	75.50	2,583	72.70	2,980	74.18
at least one	6,944	24.26	1,452	24.50	970	27.30	1,037	25.82
Prenatal Care Intitiation [2]								
1st or 2nd trimester	28,111	98.20	5,828	98.35	3,403	95.78	3,942	98.13
3rd trimester or none	514	1.80	98	1.65	150	4.22	75	1.87
Medical Risk Factors [1,2,3]								
none	21,553	75.29	4,239	71.53	2,570	72.33	2,852	71.00
chron or pregn-rel hypertension	817	2.85	206	3.48	110	3.10	133	3.31
other medical risk factor	6,255	21.85	1,481	24.99	873	24.57	1,032	25.69
Tobacco Use During Pregnancy [1,3]								
no	26,793	93.60	4,983	84.09	2,850	80.21	3,251	80.93
yes	1,832	6.40	943	15.91	703	19.79	766	19.07
Low Birth Weight Outcome	1,420	4.96	365	6.16	310	8.73	269	6.70
TOTAL	**28,625**		**5,926**		**3,553**		**4,017**	

[1] - significant difference in the distribution of WIC enrollees (+WIC) and those not enrolled in WIC (-WIC) among the birth cohort ($p < 0.001$).

[2] - significant difference in the distribution of WIC enrollees (+WIC) and those not enrolled in WIC (-WIC) among Medicaid enrollees ($p < 0.001$)

[3] - significant difference in the distribution between WIC enrollees among the birth cohort and WIC enrollees among Medicaid enrollees ($p < 0.001$).

HUSKY A is the state's public insurance program, and includes pregnant women with a Federal Poverty Level up to 185%.

WIC enrollment was categorized as that which occurred at least 12 weeks before delivery (+WIC), or either earlier than 12 weeks before delivery or not at all (-WIC).
na - not applicable

trolling for these covariates. Also, the data suggest that when testing for an association between WIC enrollment and LBW outcomes, the large percentage of HUSKY A enrollment among WIC enrollees may be a significant confounder in the analysis. Although generativity bias is also a consideration when evaluating WIC enrollment among the HUSKY A population, the distribution of risk factors among WIC enrollees in this subgroup better reflects that of records for the entire HUSKY A population.

Univariate Analysis of Maternal Risk Factors and Low Birth Weight

Among all complete birth records, unadjusted logistic regression revealed odds ratios that were significantly associated with increased risk of LBW outcomes for all the maternal risk factors studied except previous lost pregnancies (**Table 2**). Relative to non-Hispanic Caucasian mothers, non-Hispanic African American mothers, and Hispanic mothers exhibited odds ratios of 2.57 (95% CI: 2.27, 2.91) and 1.64 (95% CI: 1.44, 1.86), respectively. Relative to women of ages 25-34 years, increased risk of LBW was observed among younger ($p < 0.01$) or older ($p < 0.05$) women. Also, women who initiated prenatal care beyond the second trimester of pregnancy exhibited an odds ratio of 2.11 (95% CI: 1.61, 2.75), relative to women who initiated care at earlier times during pregnancy. Women with chronic or pregnancy-related hypertension were also at increased risk of LBW outcomes (OR=5.28; 95% CI: 4.43, 6.30).

Analysis of complete birth records for singleton births to HUSKY A enrollees demonstrated that the unadjusted odds ratios for LBW outcomes were generally attenuated when compared to all singleton births in the state (**Table 2**). Women 18 to 24 years old and women of non-Hispanic Other races exhibited a risk of LBW that was not statistically significant ($p \geq 0.05$). Significantly greater risk of LBW outcomes persisted, however, for the other risk factors. These data collectively indicate that the risk factors chosen for the study are appropriate as covariates in the multivariate regression, and are necessary to control for differences between women enrolled in WIC *versus* those not enrolled in the program. Also, the significance of these risk factors for LBW is consistent with other studies (14), indicating that the dataset is of sufficient quality to perform the study.

Multivariate Analysis of WIC Enrollment and Low Birth Weight

Logistic regression analysis of WIC enrollment and LBW was performed on complete records, controlling for nine multiple covariates (**Table 3**). The unadjusted regression coefficient for WIC enrollment at least 12 weeks before delivery, relative to enrollment at later times or not enrolled, was 0.229 (SE = 0.060) (Model 1). Its inclusion with other covariates (Model 3) made a significant contribution to the overall fit of the regression model ($\chi^2 = 27.99$; $p< 0.01$), and decreased the coefficient for WIC to –0.367 (SE = 0.070). The other covariates in the regression model did not change significantly in magnitude compared to the absence of the WIC variable (Model 3 *versus* Model 2). Most coefficients for these covariates were significant to the regression model. Non-Hispanic Other races, maternal age less than 25 years, previous pregnancy losses, and prenatal care in the third trimester, were not significant ($p \geq 0.05$). When converted to odds ratios, WIC enrollment at least 12 weeks before delivery was associated with a significantly reduced risk of LBW (OR = 0.69; 95% CI: 0.60, 0.80).

When logistic regression of WIC enrollment on LBW was performed among complete records for HUSKY A enrollees (**Table 4**), the unadjusted regression coefficient for WIC enrollment at least 12 weeks before delivery (Model 1) was –0.287 (SE = 0.087; **Table 3**). Similar to results observed among all births, inclusion of WIC in the regression model made a statistically significant contribution to the regression model ($\chi^2 = 22.84$, $p < 0.01$), and inclusion of covariates decreased the WIC coefficient to –0.434 (SE = 0.091). The difference in the WIC coefficient from Model 1 to Model 3, however, was not statistically different. The covariates used in the regression model did not change significantly with the addition of WIC. Those covariates that were significant included: race and ethnicity, maternal age of at least 35 years, education no more than 12 years, no previous pregnancies, and medical risk factors. Maternal age less than 25 years, marital status, previous lost pregnancies, and prenatal care initiation were not significant contributors to the regression model. When the coefficients in Model 3 were converted to odds ratios, WIC enrollment at least 12 weeks before delivery was significantly protective against LBW (OR=0.65; 95% CI: 0.54, 0.77). Multivariate regression of WIC enrollment and LBW for complete records among either non-Hispanic African American women or Hispanic women did not differ from the results seen among women enrolled in HUSKY A (data not shown).

Table 2
Unadjusted Odds Ratios of Low Birth Weight Outcomes
Selected Maternal Risk Factors
Singleton Births, Connecticut, 2000

	All Births n=34,551	HUSKY A Enrollees n=7,570
Maternal Risk Factor	**OR (95% CI)**	**OR (95% CI)**
Race/Ethnicity (Non-Hispanic Caucasian)		
Non-Hispanic African American	2.57 (2.27, 2.91) ***	1.94 (1.58, 2.40) ***
Non-Hispanic Other Race	1.16 (0.91, 1.48)	0.97 (0.53, 1.77)
Hispanic	1.64 (1.44, 1.86) ***	1.35 (1.09, 1.67) ***
Maternal Age (25-34 years old)		
less than 18 years old	2.38 (1.88, 3.00) ***	1.50 (1.09, 2.08) **
18-24 years old	1.56 (1.39, 1.75) ***	1.13 (0.93, 1.38)
at least 35 years old	1.15 (1.02, 1.31) **	1.86 (1.35, 2.57) ***
Education (more than 12 years)		
12 years	1.65 (1.49, 1.84) ***	1.27 (1.00, 1.62) **
less than 12 years	2.32 (2.03, 2.65) ***	1.57 (1.22, 2.01) ***
Marital Status (married)		
Not Married	1.99 (1.81, 2.20) ***	1.45 (1.16, 1.81) ***
Parity (at least one)		
none	1.65 (1.50, 1.81) ***	1.42 (1.20, 1.68) ***
Previous Lost Pregnancies (none)		
at least one loss	1.11 (1.00, 1.24)	1.05 (0.87, 1.27)
Prenatal Care Intitiation (1st or 2nd trimester)		
3rd trimester or none	2.11 (1.61, 2.75) ***	1.68 (1.11, 2.53) **
Maternal Medical Risk Factor (none)		
chronic or preg-assoc hypertension	5.28 (4.43, 6.30) ***	4.23 (3.02, 5.93) ***
other medical risk factor	2.44 (2.21, 2.71) ***	2.40 (2.00, 2.87) ***
Tobacco Use During Pregnancy (no)		
yes	2.43 (2.13, 2.77) ***	1.58 (1.30, 1.92) ***

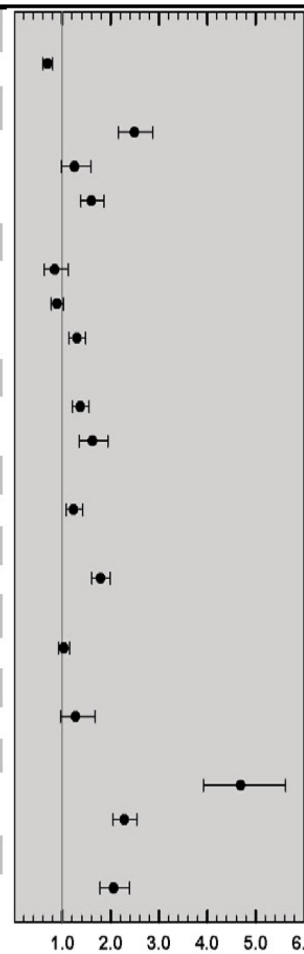
Unadjusted odds ratios for selected predictors of low birth weight outcomes were produced from logistic regression against each stratified predictor alone. The reference category for each risk factor is shown in the shaded area (parentheses). Estimates are shown with 95% confidence intervals in parentheses. The statistical signficance of each odds ratio for increased risk is shown with astericks.

HUSKY A is the state's public insurance program, and includes individuals with a Federal Poverty Level up to 185%.

** < 0.05, *** < 0.01

Table 3
Logistic Regression Among All Singleton Births
Low Birth Weight Outcomes with WIC Enrollment
Connecticut, 2000 (n=34,551)

Covariate	Regression Coefficients: Model 1	Model 2	Model 3
WIC Enrollment (at least 12 weeks before birth)			
more than 12 weeks before birth	0.229 ***		-0.367 ***
Race/Ethnicity (Non-Hispanic Caucasian)			
Non-Hispanic African American		0.854 ***	0.912 ***
Non-Hispanic Other Race		0.216	0.220
Hispanic		0.386 ***	0.345 ***
Maternal Age (25-34 years old)			
Less than 18 years old		-0.188	-0.170
18-24 years old		-0.139 **	-0.118
at least 35 years old		0.272 ***	0.265 ***
Education (more than 12 years)			
12 years		0.286 ***	0.315 ***
less than 12 years		0.431 ***	0.482 ***
Marital Status (married)			
Not Married		0.148 **	0.210 ***
Parity (at least one)			
none		0.593 ***	0.584 ***
Previous Lost Pregnancies (none)			
at least one loss		0.025	0.028
Prenatal Care Intitiation (1st or 2nd trimester)			
3rd trimester or none		0.325 **	0.241
Maternal Medical Risk Factor (none)			
chronic or pregnancy-assoc hypertension		1.536 ***	1.546 ***
other medical risk factor		0.821 ***	0.826 ***
Tobacco Use During Pregnancy (no)			
yes		0.702 ***	0.723 ***
Model Fit (-2 Log L); intercept & covariates	14040.36	13087.12	13059.13
WIC contribution to model (Chi Sq, df=4)			27.990 ***

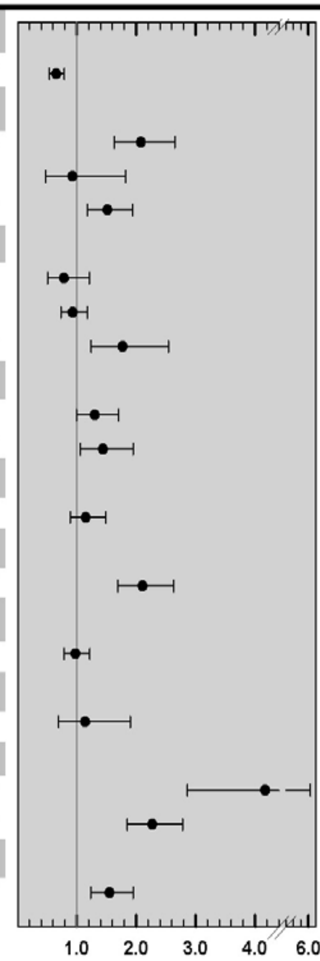


Multivariate logistic regression was performed on all singleton births in the state for low birth weight outcomes. Model 1 was produced by regression of WIC enrollment alone (unadjusted). Model 2 was produced by regression of multiple covariates on low birth weight outcomes, in the absence of WIC enrollment as a covariate (unadjusted for WIC). Model 3 was produced by regression of multiple covariates, in the presence of WIC enrollment (adjusted for WIC). Reference categories for each covariate are identified in shaded areas (parentheses). The coefficients associated with each covariate is shown, and the statistical signficance of each coefficient is shown with asterisks. Calculated odds ratios corresponding to each covariate in Model 3, with associated 95% confidence intervals, are graphed to the right.

** < 0.05, *** < 0.01

Table 4
Logistic Regression Results Among HUSKY A Enrollees
Low Birth Weight Outcomes with WIC Enrollment
Connecticut, 2000 (n=7,570)

Covariate	Model 1	Model 2	Model 3
	Regression Coefficients		
WIC Enrollment (within 12 weeks before birth)			
more than 12 weeks before birth	-0.287 ***		-0.434 ***
Race/Ethnicity (Non-Hispanic Caucasian)			
Non-Hispanic African American		0.686 ***	0.870 ***
Non-Hispanic Other Race		0.130	0.105
Hispanic		0.419 ***	0.516 ***
Maternal Age (25-34 years old)			
Less than 18 years old		-0.246	-0.285
18-24 years old		-0.023	-0.126
at least 35 years old		0.609 ***	0.606 ***
Education (more than 12 years)			
12 years		0.235	0.270 **
less than 12 years		0.381 ***	0.418 ***
Marital Status (married)			
Not Married		0.116	0.144
Parity (at least one)			
none		0.537 ***	0.576 ***
Previous Lost Pregnancies (none)			
at least one loss		-0.036	-0.038
Prenatal Care Intitiation (1st or 2nd trimester)			
3rd trimester or none		0.389	0.285
Maternal Medical Risk Factor (none)			
chronic or pregnancy-assoc hypertension		1.351 ***	1.357 ***
other medical risk factor		0.826 ***	0.834 ***
Tobacco Use During Pregnancy (no)			
yes		0.485 ***	0.495 ***
Model Fit (-2 Log L); intercept & covariates	4078.39	3853.14	3830.30
WIC contribution to model (Chi Sq, df=4)			22.840 ***



Adjusted Odds Ratios, Model 3 (95% CI)

Multivariate logistic regression was performed on singleton births among HUSKY A enrollees for low birth weight outcomes. Model 1 was produced by regression of WIC enrollment alone (unadjusted). Model 2 was produced by regression of multiple covariates on low birth weight outcomes, in the absence of WIC enrollment as a covariate (unadjusted for WIC). Model 3 was produced by regression of multiple covariates, in the presence of WIC enrollment (adjusted for WIC). Reference categories for each covariate are identified in shaded areas (parentheses). The coefficient associated with each covariate is shown, and the statistical signficance of each coefficient is shown with asterisks. Calculated odds ratios corresponding to each covariate in Model 3, with associated 95% confidence intervals are graphed to the right.

** < 0.05, *** < 0.01

Analysis of Incomplete Data

Logistic regression analysis in **Tables 1 - 4** was performed on records containing a complete set of data. The 6,833 records excluded from the analysis contained at least one data field with missing data. Of these records, missing data were found in the field used to measure LBW (n=391 missing fields). In addition, data used to create the covariates were also missing: previous lost pregnancies (n=2,094), tobacco use during pregnancy (n=1,833), race/ethnicity (n=1,453), prenatal care initiation (n=1,306), education level (n=852), and marital status (n=11). Whereas 3,948 records (61%) contained only one missing data field, the remaining records contained 2 missing fields (20%), 3 missing fields (10%), 4 missing fields (8%), or more missing fields (1%). Compared to the frequency distribution of data without missing data fields, this group of records contained at least 50% more births records for Non-Hispanic African American and Hispanic women, births with prenatal care initiation beyond the second trimester, and women with medical risk factors (data not shown). The collection of records containing missing data, therefore, reflected a group of births to women at high risk for LBW. To allow analysis of this group of records with at least one missing data field in each record, logistic regression analysis was performed on this set of birth records, allowing missing data points to be ignored, and weighting each record in proportion to its degree of completeness.

Results of logistic regression on all singleton births during calendar year 2000 with missing data fields are shown in **Table 5**. Enrollment in WIC at least 12 weeks before delivery resulted in an unadjusted regression coefficient of 0.065 (SE=0.123), and an adjusted regression coefficient of –0.434 (SE=0.140). Inclusion of WIC enrollment into the regression model made a significant contribution to the overall fit of the regression model ($\chi^2 = 9.88$; $p < 0.05$). Records with missing data field information for education, prenatal care initiation, and tobacco use during pregnancy were significant to the regression model. Covariates in the regression model did not change significantly in magnitude compared to the absence of the WIC variable (Model 3 *versus* Model 2). The converted odds ratio for WIC enrollment at least 12 weeks before delivery was 0.65 (95% CI: 0.49, 0.85), and was not significantly different from the odds ratio obtained with the analysis of complete data. Permitting equal weight for all records did not change the results significantly, and combining these incomplete records with complete records also did not change the results significantly (data not shown). These results suggest that analysis of the set of records with incomplete data were comparable to that obtained of records with complete data.

Discussion

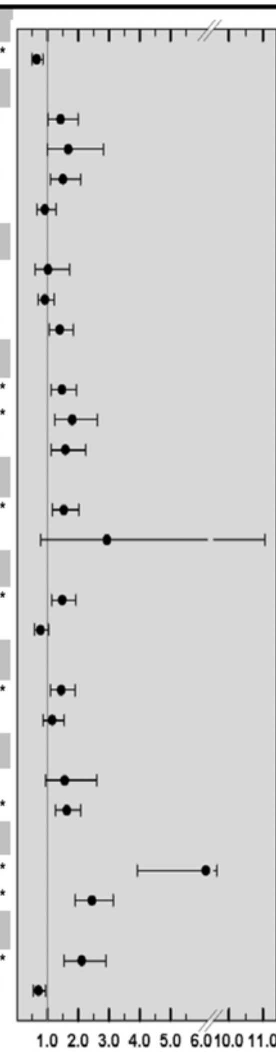
Logistic regression analysis of the Connecticut birth cohort in 2000, controlling for multiple covariates of adverse birth events, revealed a significant protective association between WIC participation before the third trimester of pregnancy and LBW. These results hold when evaluated among all singleton births in the state and among corresponding births to HUSKY A enrollees. The results are also consistent with a separate analysis of records containing missing data in at least one covariate data field.

Recent evidence with observational studies in states across the country have shown a protective association of WIC enrollment against adverse birth outcomes. Gregory and De Jesus (16), for instance, reported that prenatal WIC participation in New Jersey was associated with fewer adverse birth outcomes, and a study in Minnesota noted that the prevalence of cigarette smoking during pregnancy decreased when WIC enrollees learned that they were pregnant (17). Further, Lazariup-Bauer and co-workers reported in New York that WIC enrollment early in pregnancy led to better birth outcomes than enrollment later in pregnancy (18). In Missouri, increased birth weight was positively associated with WIC enrollment and decreased newborn Medicaid costs, and duration of WIC enrollment was positively correlated with increasing birth weight, lower LBW rates, and increased cost savings (19). El-Bastawissi and co-workers in Washington reported a protective association of WIC enrollment against LBW outcomes (20).

Evaluation studies of the WIC program in other states have also shown similar results using more sophisticated study designs. A prospective, randomized-control study in an Oklahoma prenatal clinic evaluation of women in mid-pregnancy found that, after adjusting for gestational age, sex, number of prenatal visits, race, previous LBW events, and

Table 5
Weighted Logistic Regression Among Singleton Births with Missing Data
Low Birth Weight Outcomes with WIC Enrollment
Connecticut, 2000 (n=6,442)

Covariate	Regression Coefficients Model 1	Model 2	Model 3
WIC Enrollment (within 12 weeks before birth)			
more than 12 weeks before birth	0.065		-0.434 ***
Race/Ethnicity (Non-Hispanic Caucasian)			
Non-Hispanic African American		0.279	0.351 **
Non-Hispanic Other Race		0.508	0.510
Hispanic		0.321	0.403 **
missing		-0.117	-0.092
Maternal Age (25-34 years old)			
Less than 18 years old		-0.009	0.006
18-24 years old		-0.110	-0.094
at least 35 years old		0.339 **	0.329 **
Education (more than 12 years)			
12 years		0.349 **	0.386 ***
less than 12 years		0.541 ***	0.597 ***
missing		0.413 **	0.460 **
Marital Status (married)			
Not Married		0.345 **	0.423 ***
Missing		1.004	1.074
Parity (at least one)			
none		0.401 ***	0.391 ***
missing		-0.253	-0.264
Previous Lost Pregnancies (none)			
at least one loss		0.373 ***	0.368 ***
missing		0.134	0.141
Prenatal Care Intitiation (1st or 2nd trimester)			
3rd trimester or none		0.568 **	0.445
missing		0.508 ***	0.490 ***
Maternal Medical Risk Factor (none)			
chronic or pregnancy-assoc hypertension		1.810 ***	1.814 ***
other medical risk factor		0.887 ***	0.892 ***
Tobacco Use During Pregnancy (no)			
yes		0.733 ***	0.745 ***
missing		-0.346 **	-0.351 **
Model Fit (-2 Log L); intercept & covariates	2849.85	2602.45	2592.57
WIC contribution to model (Chi Sq, df=4)			9.880 **



Adjusted Odds Ratio, Model 3 (95% CI)

Multivariate logistic regression was performed on birth records in the state containing missing data, weighting each record in proportion to its degree of completeness. Model 1 was produced by regression of WIC enrollment alone (unadjusted). Model 2 was produced by regression of multiple covariates on low birth weight outcomes, in the absence of WIC enrollment as a covariate (unadjusted for WIC). Model 3 was produced by regression of multiple covariates, in the presence of WIC enrollment (adjusted for WIC). The reference category for each covariate is identified in shaded areas (parentheses). The coefficients associated with each covariate is shown, and the statistical signficance of each coefficient is shown with asterisks. Coefficients for the missing data within each covariate is also shown (missing). Calculated odds ratios corresponding to each covariate in Model 3, with associated 95% confidence intervals are graphed to the right.

** < 0.05, *** < 0.01

smoking during pregnancy, WIC participation was associated with an increased birth weight of, on average, 91 grams (21). In Massachusetts, matched controls from observational data were used to evaluate the association of WIC with LBW (22), showing that WIC enrollment was associated with a reduced risk of LBW, preterm births, and neonatal mortality. A similar approach in Florida showed a modest dose-dependent association of WIC participation with improved LBW outcomes (23).

These results of WIC evaluation studies at the state level are in agreement with recent assessments of WIC at the national level, which indicate that WIC enrollment was associated with improved birth outcomes (2). Enrollment in WIC nationally was reportedly associated with an increase of 185 grams in birth weight (24). WIC enrollment was also associated with decreased risk of preterm birth (25).

Despite a growing number of studies at the state and national level indicating a protective association of WIC against adverse birth outcomes, and the absence of studies showing negative results, the validity of the results have been questioned. Douglas Besharov and Peter Germanis (13), in a comprehensive evaluation of WIC nationally, cite that several flaws in study design may exaggerate the positive effect of WIC. These sources of bias include: 1) selection bias, 2) simultaneity bias, and 3) lack of generalizability. Selection bias arises when women enrolled in WIC are considered to be more empowered, more motivated, more able and healthier, and with better access to healthcare than women who are not enrolled in WIC. This would bias results toward better birth outcomes. Simultaneity bias refers to the assumption that as the length of time in WIC participation increases, the probability of a healthy birth increases. Lack of generalizability at the national level occurs because each state runs its own WIC program and there may be variations in the way in which WIC is managed. For instance, federal funds for WIC are capped for each state, and, although not currently the situation in Connecticut, some applicants for WIC in other states may be placed on a wait list if all funds are expended.

The first source of bias was addressed in this study by examining not only all births in the state, but also the subgroup of HUSKY A enrollees. There were dramatic and statistically significant differences among all state births between those enrolled in WIC and those not enrolled in WIC (**Table 1**). These differences were less pronounced among HUSKY A enrollees. The data presented here suggest that HUSKY A enrollees who were co-enrolled in WIC may have been among a group widely considered to be the least advantaged of the HUSKY A population (**Table 1**), a finding mirrored by Bitler and Currie (2). The remaining significance in the distribution differences between WIC and non-WIC enrollees among HUSKY A enrollees, however, suggest that selection bias may exist in this study.

The second criticism leveled against studies showing protective results in the association of WIC enrollment with LBW events was addressed in this study by stratifying WIC participation into periods of enrollment. Logistic regression was performed on WIC enrollment categorized into two groups: WIC enrollment at least 12 weeks before delivery, and WIC enrollment either during the third trimester or not enrolled. Protective associations were observed with WIC enrollment at least 12 weeks before delivery.

Other potential sources of error were addressed by controlling for maternal risk factors considered to be predictors of LBW events, including chronic or pregnancy-induced hypertension and tobacco use during pregnancy. The results indicate that the risk factors chosen for the study were appropriate as covariates in the multivariate regression (**Table 2**). Also, the significance of these covariates in the regression model was consistent with other studies (14), indicating that the dataset used in this study was of comparable quality.

This study was conducted only on the WIC program within Connecticut, and it cannot be generalized to the national level. It does, however, contribute to increasing evidence in other states of the protective association of WIC against LBW. The data used for this analysis were from existing birth records, limiting analysis to an observational study. Residual confounding is possible. In addition, recall bias and bias due to self-reporting are possible with these data. Randomized-control study designs are more rigorous in their methodology, and use of these designs would contribute greatly to studies of the effectiveness of the WIC program. Only the Oklahoma study evaluated WIC by a prospective randomized-control study design (21), and a positive association with birth weight was observed, even when initiated at mid-pregnancy.

Another potential source of bias in the data is the large number of records that were excluded from analysis due to missing data. In the analysis among all singleton births, for example, a potential sample size of 41,384 singleton births was reduced to 34,551 when records containing missing data were excluded from the analysis. This represents a decrease of 16%. Separate analysis of this set of incomplete records did not, however, differ from results obtained with complete records (**Table 5** *versus* **Table 3**).

A major component of the WIC program in Connecticut involves food supplementation, but other intervention strategies are also employed. One component of the WIC program is an educational intervention among WIC enrollees to increase awareness of the dangers of smoking during pregnancy. Although the results shown in this study did not show a reduced contribution among WIC enrollees of smoking as a risk factor (**Table 2**), the data contained in birth records do not reflect *changes* in smoking behavior during pregnancy. A strong association between maternal smoking and LBW has been well-documented (26, 27), and although the data shown here also indicate that smoking during pregnancy was a significant risk factor for LBW events, it was not clear if smoking behavior was altered with WIC participation.

Another educational intervention among WIC enrollees is nutritional counseling. Previous evaluations of the WIC program in Maryland have documented improved nutritional care among participants who were involved in nutritional sessions (28), but a similar study in Connecticut has not been performed. Further studies within Connecticut could also evaluate other components of the WIC program, such as alcohol/drug use, or breastfeeding. Also, in a recent study of its WIC program, the Rhode Island Department of Public Health used cluster analysis to evaluate specific focus areas for outreach of WIC services, using census tract information about income level (29). This has not been performed in Connecticut, but could help indicate geographic areas of particular need for WIC enrollment, as well as for referral services for HUSKY A.

In summary, the data evaluated in this study indicated that WIC enrollment in Connecticut during calendar year 2000 was protective against LBW among all singleton births in the state, as well as among HUSKY A enrollees. The protective effects were observed with WIC enrollment at least 12 weeks before delivery.

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