the health of both normal and diabetic persons. Exercise can ameliorate coronary risk factors, improve sense of well-being and self-esteem, and may contribute to an increased awareness of personal health and safety (*1,3*). Until the relationship between exercise and other preventive health behaviors is better understood, perhaps health promotion programs, which include exercise, should target other known health risks as well.

## References


1. Horton, E. S.: Exercise and diabetes mellitus. Med Clin North Am 72: 1301-1321 (1988).
2. Blair, S. N., Jacobs, D. R., and Powell, K. E.: Relationships between exercise or physical activity and other health behaviors. Public Health Rep 100: 172-180, March-April, 1985.
3. Shephard, R. J.: Exercise and lifestyle change. Br J Sports Med 23: 11-23 (1989).
4. Smith, E. W., McKinlay, S. M., and Thorington, B. D.: The validity of health risk appraisal instruments for assessing coronary heart disease risk. Am J Public Health 77: 419-424 (1987).
5. Caspersen, C. J., Powell, K. E., and Christenson, G. M.: Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100: 126-131, March-April 1985.
6. Folsom, A. R., et al.: Leisure time physical activity and its relationship to coronary risk factors in a population-based sample: the Minnesota Heart Survey. Am J Epidemiol 121: 570-579 (1985).
7. Cooper, K. H., et al.: Physical fitness levels vs selected coronary risk factors. A cross-sectional study. JAMA 236: 166-169, July 12, 1976.
8. Durrant, M. L., Royston, J. P., and Wloch, R. T.: Effect of exercise on energy intake and eating patterns in lean and obese humans. Physiol Behav 29: 449-454 (1982).
9. Blair, S. N., et al.: Comparison of nutrient intake in middle-aged men and women runners and control. Med Sci Sports Exerc 13: 310-315 (1981).
10. Montoye, H. J., Block, W. D., Metzner, H. L., and Keller, J. B.: Habitual physical activity and serum lipids: males, age 16-64 in a total community. J Chronic Dis 29: 697-709 (1976).
11. Marti, B., et al.: Relationship between leisure-time and physical activity and risk factors for coronary heart disease in middle-aged Finnish women. Acta Med Scand 222: 223-230 (1987).
12. The Behavioral Risk Factor Surveys: IV. The descriptive epidemiology of exercise. Am J Prev Med 3: 304-310 (1987).
13. Langlie, J. D.: Interrelationships among preventive health behaviors: a test of competing hypotheses. Public Health Rep 94: 216-225, May-June 1979.
14. Epstein, L., Miller, G. J., Stitt, F. W., and Morris, J. N.: Vigorous exercise in leisure time, coronary risk factors and resting electrocardiograms in middle-aged male civil servants. Br Heart J 38: 403-409 (1976).
15. Williams, A. F., and Wechsler, H.: Interrelationship of preventive actions in health and other areas. Health Serv Rep 87: 969-976, December 1972.
16. Oldridge, N. B.: Compliance in exercise rehabilitation. Phys Sports Med 7: 94-103 (1979).


### Equipment

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# WIC Program Participation— a Marketing Approach


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## Synopsis


*Recent evaluation studies have described the benefits accruing to low-income women and children who participate in the Special Supplemental Food Program for Women, Infants, and Children (WIC). However, participation is not uniform among all groups of eligible persons. This study examines the geographic variation in WIC participation rates of eligible pregnant women in Rhode Island to determine whether the program is effective in reaching the neediest segments of the population.*

*Eight groups of small geographic areas in Rhode Island (census tracts) were formed on the basis of need for maternal and child health services, as determined from a statistical method employing factor and cluster analysis of existing health and* *sociodemographic data. Among these eight groups, participation rates in WIC during 1983–84 ranged from 46 percent to more than 100 percent of estimated eligible pregnant women. The rates were positively correlated with measures of need, strongly (r = 0.92) with an index of maternal risk, and less strongly (r = 0.79) with an index of birth outcomes. The results of this study have enabled the Rhode Island WIC Program to direct its outreach efforts more specifically to geographic areas where the need for the program's assistance is greatest.*

*The procedures described in this report comprise a technique that can be generally applied to measure program effectiveness in marketing and outreach where relevant data are available by small geographic areas. The data requirements are* (a) *population-based estimates of program need and* (b) *program utilization measures. If these data can be aggregated to a common set of small geographic areas, the use of marketing analysis techniques becomes possible, and program benefits in the area of outreach and recruitment can be realized.*

THE SPECIAL SUPPLEMENTAL FOOD PROGRAM for Women, Infants, and Children (WIC) was established in 1972 as a national effort to improve birth outcomes and early childhood development through the provision of nutritional supplements and nutrition education to high-risk groups in conjunction with appropriate health care (*1*). The program is operated at the State level by State health agencies under regulations established by the U.S. Department of Agriculture. The target groups include pregnant, breast feeding, and other post-partum women; infants; and children up to age 5. To be eligible, members of these groups must live in households with incomes below 185 percent of the Federal poverty guidelines and must be at nutritional risk as defined by the program. Those accepted into the program receive free food or food instruments (for example, vouchers, checks, coupons, and so forth) on a monthly basis and are instructed regarding how to meet their own nutritional needs and those of their children.

Recently, the National WIC Evaluation (NWE) addressed the issue of whether WIC participation provides a net improvement in the health status measures that the program was designed to address (*2–5*). For the most part, the NWE and previous studies (*6*) have shown that WIC has been effective in improving birth outcomes and in avoiding nutrition problems among women and children who participate in the program. Generally, the greatest demonstrable improvements have come among those who have participated in the program the longest.

However, not all those who are eligible for WIC participation based on income and nutritional assessment are accepted for participation. To determine which applicants to accept, each applicant is ranked on the basis of the target group she (or he) falls into (pregnant woman, breast feeding woman, infant, and so forth) and her (his) level of nutritional need. (In a few States, income levels below the eligibility cutoff help to determine the rankings.) Applicants are then accepted in order of ranking until all available funds are allocated. Furthermore, WIC Programs in the various States are required to prepare and act upon outreach programs of their own design that are supposed to improve participation among those most in need of their services.

The outreach efforts of individual State programs should be subjected to the same scrutiny as the program's effectiveness in improving participants' health status. Given that WIC is effective in ameliorating poor birth outcomes and developmental deficiencies in childhood, it is clearly important that it reach those most at risk of adverse effects. A major purpose of this study was to examine the performance of Rhode Island's WIC Program in serving persons at highest risk among WIC eligibles.

The analysis we present consisted of two stages:

- Small geographic areas were grouped on the basis of the level of need for maternal and child health services, as determined by a combination of health and demographic measures.
- WIC program penetration was examined for these groups of areas and compared with need levels to determine whether the program was reaching those in greatest need.

## Rhode Island WIC Program

The Rhode Island WIC Program is administered by the Rhode Island Department of Health (*7*). Because there are no city, town, or county health agencies in the State, local operating agencies, consisting of community health centers and hospital outpatient clinics, contract with the department of health to screen and accept applicants, distribute food instruments, and provide nutrition counseling. During the period that the performance of WIC was examined, 1983–84, 15 such agencies together served a typical caseload of 2,700 women (pregnant and post-partum), 3,000 infants, and 8,300 children. The caseload included approximately 47 percent of the income-eligible women, infants, and children in the State.

There are two programmatic ways in which the Rhode Island WIC Program can target those populations that are at high levels of risk for poor birth outcomes and nutritional inadequacies. First, the program's administrators determine the funding allocations among agencies that serve enrollees in different geographic areas. By adjusting these allocations, they can alter the proportions of eligible recipients that are accepted into the program at each site, thereby responding to different levels of need among the areas served. Second, since 1981 the program's outreach efforts have been focused on geographic areas where populations have been characterized as high-need, according to various indicators related to program objectives. For both purposes, the program's administrators desired the ability to identify high-need areas more precisely than was possible with the ad hoc indicators, many of which were based on small numbers of events per area. Ideally, need for the program's services would be determined on the basis of a wide range of risk and outcome measures of maternal and child health. A second purpose of this study, therefore, was to provide the Rhode Island WIC Program with an improved basis for selecting geographic areas in which to concentrate its future outreach efforts so that it can reach the neediest segments of the population it serves and maximize the effectiveness of its limited resources.

## Method

**Creation of census tract groups.** In the first phase of the study, small geographic areas in Rhode Island (census tracts) were grouped according to the level of need for maternal and child health services. The level of need for such services was determined from existing health and demographic data bases; all of these have been designed to provide data aggregated to census tracts. Rhode Island's entire land area is subdivided into census tracts, and as census tracts are established by local committees that aim for homogeneity of demographic, social, and economic characteristics of the populations in each tract, these geographic units are a more useful basis for analytical efforts in public health than units defined for other purposes, such as zip codes, cities, towns, or counties (*8*). There were 213 census tracts in Rhode Island with populations in each averaging close to 4,500 in 1980.

Table 1. Characteristics of census tract clusters from the eight-cluster solution based on indexes RISK and OUTCOME, Rhode Island

| Cluster | Number of census tracts | 1980 census population | Number of births, 1983–84 | Average index values RISK | Average index values OUTCOME |
|---|---|---|---|---|---|
| A | 79 | 376,115 | 8,820 | −0.56 | −0.57 |
| B | 20 | 87,963 | 1,758 | −0.55 | −1.57 |
| C | 61 | 286,239 | 7,426 | −0.34 | 0.14 |
| D | 9 | 42,495 | 1,399 | 0.91 | 0.04 |
| E | 19 | 70,636 | 2,297 | 0.76 | 1.15 |
| F | 9 | 29,358 | 759 | −0.30 | 1.70 |
| G | 5 | 11,914 | 606 | 3.89 | 1.80 |
| H | 11 | 42,434 | 2,022 | 2.17 | 1.62 |
| State | 213 | 947,154 | 25,087 | 0.00 | 0.00 |

The grouping of census tracts based on level of need for maternal and child health services was accomplished with the use of an analytic method known as "factorial ecology" (*9*). The application of this method to small-area analysis was originally described by Tyron and Bailey (*10*) and has been adapted for use with census tracts in Rhode Island in a previous study (*11*). It consists of three steps: (*a*) selecting a number of measures that are defined on the basis of the geographic areas used and on which the differentiation of areas is to be performed, (*b*) reducing the initial group of measures to a smaller number of composite variables, or indexes, through principal component analysis, and (*c*) grouping the geographic areas on the basis of the values of the indexes through cluster analysis.

The initial variables to be considered were taken from three statewide data bases, the 1980 Census of Population and Housing (*12*), vital statistics birth and death files for the period 1979–83, and hospital discharge data for the period 1979–83. These data bases are the principal sources of demographic, social, economic, and health information relevant to maternal and child health in the State. All are capable of providing summary data at the census tract level. Vital statistics and hospital discharge data were aggregated over a 5-year period to improve the stability of variables based on low numbers of occurrences per census tract.

The determination of which variables to select from these data bases to be included in the analysis

*'. . . cluster F contains census tracts where the population exhibits lower than average levels of risk but experiences a high rate of adverse birth outcomes; conversely, cluster D includes areas where risks are relatively high but the frequency of poor birth outcomes falls at the State average.'*

was made by examination of a variety of sources. Among these were the definition of the priority groups for WIC applicants, previous needs assessments in maternal and child health (*13,14*), and other health-related studies involving geographic differentiation in Rhode Island and elsewhere (*11,15-17*). Included were variables representing a balance among basic societal dimensions relevant to maternal and child health, including demographic characteristics (race, family structure, family size), socioeconomic characteristics (income, poverty status, education, occupation), housing characteristics (value, size, amenities), and health measures (maternal risk, access to care, birth outcomes). The selection process was intended to be inclusive rather than exclusive, because subsequent analytical steps identified redundant and irrelevant variables.

Once variables were selected on the basis of content, measures were defined mathematically to conform to the requirements of principal component analysis. Computed measures were defined as simple ratios, means, or medians for ease in interpreting results. When multiple measures were derived from a single variable in one of the data bases (for example, proportions of the population in various occupational categories), they were defined in such a way as to minimize structural correlation. If measures from different data sources were found to be highly correlated, the redundant items were removed from the input data set. Measures for which there were missing data for one or more census tracts were eliminated, as were measures for which there was insufficient variation among census tracts. After removal of measures that might present computational problems, the process yielded 38 variables for use in the principal component analysis.

Values of the initial 38 variables for each census tract comprised the input to the principal component analysis. The principal components resulting from the analysis were adjusted to meet the requirements for input to the cluster analysis. Input variables to a cluster analysis generally (*a*) should be limited in number, (*b*) should be relatively uncorrelated with each other, and (*c*) should have comparable means and standard deviations.

The first property facilitates the interpretation of the final clusters, and the latter two ensure that the input variables are weighted equally in the process of forming the clusters. The second requirement, for minimum correlation among the input variables, effectively precludes the use of the individual component variables identified in the principal component analysis as input to the cluster analysis. Therefore, the principal components were converted to indexes by computing normalized scale scores for each census tract, based on only those component variables with high factor loadings on their respective principal components and with each retained variable weighted equally. (The alternative of component scores was rejected because component scores are based on all input variables, with weights determined by the factor loadings produced in the principal component analysis, and make interpretation of the final clusters more difficult. In addition, the use of component scores would yield substantially different cluster results only if the principal components were not strongly defined.)

Cluster analysis was then performed on the State's census tracts using a subset of indexes. A heirarchical clustering algorithm, Ward's method (*18*), was employed, and the optimal cluster solution was selected according to the cubic clustering criterion (*19*).

**Estimating WIC enrollment penetration.** The second phase of the study examined the rates of participation of pregnant women in the Rhode Island WIC Program among the census tract clusters. Pregnant women were chosen rather than one or more of the other target groups for these reasons:

1. Pregnant women comprise the highest priority group for WIC outreach efforts. Most WIC-eligible pregnant women fall into the highest ranking category for acceptance into the program. Also, pregnancy is the earliest time when the WIC program can influence a child's nutrition history. Finally, women who enroll in WIC during pregnancy are likely to stay enrolled after giving birth and to enroll their other eligible children.

2. The link between WIC participation and outcome is best established for pregnant women, as

opposed to post-partum women, infants, and children.

3. Measures of birth outcomes are better defined, more numerous, and more readily accessible than outcome measures for other WIC target groups.

WIC participation rates were estimated for each census tract cluster by dividing the actual number of WIC enrollees by the expected number of WIC eligibles for the period 1983-84. This 2-year period was selected because it was the first period for which WIC enrollment data were completely census-tract coded.

Two years of data were examined to reduce spurious data fluctuations due to small numbers. The number of WIC enrollees was defined as the number of pregnant women enrolled in the program during 1988-34 and was obtained from WIC Program files. For reasons of comparability, enrolled women with dates of expected delivery during this period were counted. No adjustments were made for multiple births or for pregnancies not resulting in live births, as both effects were known to be small compared with variations in WIC enrollment among the clusters.

The expected number of WIC eligibles was obtained by multiplying the total number of births in each census tract during this period, obtained from the vital statistics birth file, by the proportion of mothers in the tract who fell below the WIC income cutoff. This proportion was approximated as the percentage of children less than 5 years old in each census tract living in households with incomes below 185 percent of the poverty level in 1979, as measured by the 1980 census.

Enrollment figures for pregnant women were then summed over census tracts in each cluster and divided by the estimates of WIC-eligible pregnant women for the same period to produce estimates of the Rhode Island WIC Program's penetration by cluster. These penetration estimates could then be analyzed and interpreted in relation to various descriptive measures for the clusters.

## Results

**Census tract clusters.** The factor analysis of the 38 input variables produced four strongly defined principal components. The first component exhibited high levels of correlation with a group of 14 measures representing several societal and health dimensions, such as proportions of minority populations, of persons in poverty, of families headed by females, of persons receiving public assistance, of unmarried mothers, of teenage mothers, and of mothers with inadequate prenatal care. Many of these are thought to be associated with the risk of poor birth outcomes.

Normalized scale scores incorporating these 14 variables were computed for each census tract to create an index labeled "RISK." The second component was defined around eight variables, primarily taken from the census, that measured educational level, occupation, housing costs, and language spoken at home, and it was interpreted as describing the variation in socioeconomic status (SES) above the poverty level. The corresponding index was computed in the same way as the index RISK and was named "HIGH SES." The third principal component was strongly associated with three variables that measured household or family size and accordingly was converted into an index called FAMILY SIZE. The fourth component exhibited high positive loadings on four measures of birth outcomes taken from the vital statistics. This component produced an index labeled "OUTCOME." Nine of the input variables were not strongly correlated with any one of the principal components and were not included in any of the indexes.

The first and fourth indexes were selected for use in the process of differentiating geographic areas by level of need. They comprised 18 measures, from an initial set of 38 variables, with generally clear and direct relevance to WIC Program objectives, as well as to overall maternal and child

Table 2. Selected measures of risk, by census tract cluster, Rhode Island

| Cluster | Persons in poverty[1] | Births to nonwhite mothers[2] | Births to unmarried mothers[3] | Births with low care[4] |
|---|---|---|---|---|
| State | 9.9 | 8.8 | 16.0 | 12.2 |
| A | 6.4 | 1.7 | 8.3 | 7.6 |
| B | 7.0 | 3.3 | 6.7 | 6.5 |
| C | 8.0 | 2.9 | 12.5 | 9.6 |
| D | 19.7 | 15.9 | 27.3 | 18.7 |
| E | 19.2 | 9.8 | 27.7 | 17.2 |
| F | 9.8 | 2.8 | 11.3 | 12.6 |
| G | 39.4 | 68.1 | 54.7 | 34.5 |
| H | 27.1 | 44.9 | 38.1 | 29.6 |

[1] Percentage of persons living in households with incomes below poverty level in 1979 (reference *12*).

[2] Percentage of births occurring to nonwhite mothers.

[3] Percentage of births to mothers who were married at neither the time of conception nor the time of birth.

[4] Percentage of births to mothers with less than adequate prenatal care—defined as less than 5 visits for gestation of 37 weeks or less; less than 7 visits for gestation of more than 37 weeks; first visit later than the fourth month of pregnancy; or unknown prenatal care.

SOURCE: Unpublished data from the Rhode Island vital statistics for 1979-83, Office of Vital Records, Rhode Island Department of Health, for columns 2, 3, and 4.

## Definitions of Variables Used in Computation of Indexes

| Variable definition [1] | Source of data |
|---|---|
| *Index RISK* | |
| N:Black population<br>D:Total population | Census |
| N:Nonwhite, nonblack population<br>D:Total population | Census |
| N:Births to nonwhite mothers<br>D:Births to mothers with known race | Birth certificates |
| N:Births to unmarried mothers<br>D:Births to mothers with known marital status | Birth certificates |
| N:Female-headed families with children<br>D:Total households | Census |
| N:Black female-headed families with children<br>D:Female-headed families with children | Census |
| N:Female-headed families in poverty status<br>D:Female-headed families | Census |
| N:Families in poverty status with 1 or more children<br>D:Families with 1 or more children | Census |
| N:Persons below 75 percent of poverty level<br>D:Persons for whom poverty status is determined | Census |
| N:Deliveries paid by Medicaid<br>D:All deliveries | Hospital discharges |
| N:Households with income from public assistance<br>D:Total households | Census |
| N:Births to mothers age 17 years or less<br>D:Births to mothers with known age | Birth certificates |
| N:Newborns of parity 5 or more<br>D:Newborns of known parity | Birth certificates |
| N:Births to mothers with inadequate prenatal care [2]<br>D:All births | Birth certificates |
| *Index OUTCOME* | |
| N:Deaths before age 1 year | Death certificates |
| D:Live births | Birth certificates |
| N:Newborns weighing 2,500 grams or less<br>D:Newborns with known birth weight | Birth certificates |
| N:Newborns weighing 1,500 grams or less<br>D:Newborns with known birth weight | Birth certificates |
| N:Newborns of 37 weeks gestation or less<br>D:Newborns with known gestation | Birth certificates |

[1] N = numerator, D = denominator.
[2] Defined as less than 5 visits for gestation of 37 weeks or less; less than 7 visits for gestation of more than 37 weeks; first visit later than the fourth month of pregnancy; or unknown prenatal care.

health. The variables from which each of these two indexes were computed are listed in the box, page 552.

For the most part, the measures comprising the index RISK were based on substantial numbers of occurrences per census tract and could be expected to be stable with regard to random variations. Conversely, each of the measures comprising OUTCOME was based on small numbers of occurrences, and random variation was a potential concern. The fact that the principal component analysis grouped these four measures as a single underlying construct is evidence that random variations did not overwhelm the descriptive power of these measures. Moreover, the combination of the four variables into a single index would tend to ameliorate the effects of random variation in the individual variables. The two eliminated indexes, HIGH SES and FAMILY SIZE, showed little overlap with the key variables of RISK and OUTCOME and were primarily composed of the measures of least relevance to maternal and child health concerns. Therefore, the values of the indexes RISK and OUTCOME for each census tract were the input measures for the subsequent cluster analysis.

The cluster analysis performed on the basis of the indexes RISK and OUTCOME produced an optimal solution consisting of eight clusters. As presented in table 1, the clusters ranged in size from 5 to 79 census tracts, with accordingly wide variation in population and number of live births. In most clusters, the census tracts were geographically distributed around the State and generally were not contiguous. Clusters A, B, and C consisted primarily of the State's suburban and rural census tracts. Cluster D included many established urban residential neighborhoods. Clusters E and F were composed mostly of densely populated tracts in cities other than the State's largest, Providence. Clusters G and H lay almost entirely within Providence, with Cluster G composed of five contiguous census tracts at the center of the State's principal urban poverty area.

The eight clusters of census tracts form three distinct groups on the basis of their average scores for the index labeled OUTCOME (table 1). Clusters A and B exhibit lower than average rates of adverse birth outcomes; clusters C and D are near the State average; and clusters, E, F, G, and H have relatively high rates of adverse outcomes. Clusters A and B have similar levels of risk as measured by the average scores for the index RISK and are differentiated because of the particularly low incidence of adverse birth outcomes in the census tracts in cluster B. Differentiation of the individual clusters in the two other groups is due to the variation in level of risk. Of particular interest are clusters where the average scores for the two indexes differ substantially. For example, cluster F contains census tracts where the population exhibits lower than average levels of risk but experiences a high rate of adverse birth outcomes; conversely, cluster D includes areas where risks are relatively high but the frequency of poor birth outcomes falls at the State average. Thus, the cluster analysis has identified specifically those geographic areas where the measures of outcome do not follow the measures of risk.

Table 3. Selected measures of birth outcome, by census tract cluster, Rhode Island

| *Cluster* | *Low birth weight births*[1] | *Premature birth*[2] | *Infant death rate*[3] | *Births with congenital defects*[4] |
|---|---|---|---|---|
| State | 6.3 | 8.9 | 11.6 | 4.6 |
| A | 4.9 | 7.2 | 8.5 | 4.4 |
| B | 3.1 | 4.4 | 4.3 | 4.5 |
| C | 6.4 | 9.2 | 12.8 | 4.7 |
| D | 6.9 | 8.6 | 13.1 | 4.7 |
| E | 8.2 | 12.4 | 15.1 | 4.8 |
| F | 8.9 | 13.8 | 16.3 | 4.8 |
| G | 11.2 | 14.0 | 23.6 | 5.0 |
| H | 9.7 | 14.4 | 16.6 | 4.9 |

[1] Percentage of births with birth weight of 2,500 grams (5 lb., 8 oz.) or less.
[2] Percentage of births of 37 weeks gestation or less.
[3] Deaths before age 1 year per 1,000 live births.
[4] Percentage of hospital newborns with any congenital defect reported on the medical record.

SOURCES: For columns 1, 2, and 3, unpublished data from the 1979–83 Rhode Island vital statistics, Office of Vital Records, Rhode Island Department of Health; for column 4, unpublished data from the Rhode Island Community Hospital Discharge Database for 1979–83, Office of Health Statistics, Rhode Island Department of Health.

Representative measures of maternal and child health risk and outcomes are presented in tables 2 and 3 for the eight clusters. The measures appearing in the tables elucidate the patterns leading to the creation of the principal components. Although the values of these measures in the various clusters parallel closely the values of the scores of the associated indexes, when presented individually they illustrate the magnitude of the variation among clusters of some familiar indicators. The extremely high levels of maternal and child health risk in clusters G and H are apparent in table 2, as the values for those clusters are many times higher than the average rates for the State. The rates of poor birth outcomes in those clusters, on the other hand, show less extreme elevations (table 3).

**WIC enrollment penetration.** Table 4 presents WIC enrollment patterns for the eight clusters defined in

Table 4. WIC program eligibility and enrollment, by census tract cluster, Rhode Island, 1983–84

| Cluster | Number of births | Births to WIC-eligible women (estimated) | | WIC-enrolled pregnant women | |
|---|---|---|---|---|---|
| | | Number | Percent[1] | Number | Percent[2] |
| A .............. | 8,820 | 2,457 | 27.9 | 1,431 | 58.2 |
| B .............. | 1,758 | 456 | 25.9 | 209 | 45.8 |
| C .............. | 7,426 | 2,677 | 36.0 | 1,671 | 62.4 |
| D .............. | 1,399 | 850 | 60.8 | 719 | 84.6 |
| E .............. | 2,297 | 1,428 | 62.2 | 1,100 | 77.0 |
| F .............. | 759 | 291 | 38.3 | 199 | 68.4 |
| G .............. | 606 | 511 | 84.3 | 533 | 104.3 |
| H .............. | 2,022 | 1,417 | 70.1 | 1,426 | 100.6 |
| State..... | 25,087 | 10,087 | 40.2 | 7,288 | 72.3 |

[1] Based on total number of births.
[2] Based on estimated number of births to WIC-eligible women.

this study during the period 1983–84. The items in the table that are of specific interest are (*a*) the estimated percentage of all live births in which the mother was eligible for WIC based on the income criterion, and (*b*) the percentage enrolled in WIC of the estimated number of eligibles. Among all births in the State during this period, an estimated 40.2 percent of mothers were eligible for WIC participation based on income; by cluster, the percentage ranged from 25.9 percent to 84.3 percent. Of the estimated number of WIC-eligible pregnant women statewide, 72.3 percent were enrolled in WIC during their pregnancy; by cluster, the proportion ranged from 45.8 percent to 104.3 percent.

Percentages representing greater than full enrollment based on estimated eligibility may be attributed to several factors.

1. Deteriorating economic conditions locally after 1979, the year for which income data were collected on the census, may have expanded the proportions of births to mothers with incomes below the WIC income limit.

2. Differential trends in birth rates after 1979 may have resulted in a larger proportion of births to mothers with incomes below the WIC income limit.

3. Estimated percentages of eligibles based on census data for annual income may not be exactly comparable with actual determinations of eligibility made by the WIC Program, for several reasons. The WIC Program may use the previous month's income or even current income to determine eligibility and does not routinely disqualify participants for short-term increases in income. There may be nonresponse bias in the income question on the census. There are also small differences in the poverty-income guidelines used with census data and by the WIC Program (*20*).

4. Increased WIC enrollment may result from random fluctuations in the number of births to WIC-eligible women in individual clusters from year to year.

The data in table 4 demonstrate that WIC enrollment rates are generally highest in the four clusters with the highest prevalence of adverse birth outcomes (clusters E, F, G, and H), ranging from more than two-thirds to virtually all eligible pregnant women. Enrollment rates are also higher in the two clusters with average rates of adverse outcomes than in the clusters where outcomes are generally good. Moderate deviations from the overall pattern occur in the figures for clusters D, E, and F. Cluster D, where relatively high levels of risk and average birth outcomes prevail, shows a higher level of WIC participation than those in clusters E and F, where birth outcome levels range from poor to very poor.

Figures 1 and 2 shed further light on the patterns of WIC enrollment among the clusters. Figure 1 shows that WIC enrollment penetration, the estimated percentage of eligibles that are actually enrolled, is highly correlated with the average values of the index RISK ($r=0.92$). Figure 2 shows that the correlation of WIC enrollment penetration with the index OUTCOME is weaker ($r=0.79$). Simple linear regression reveals that enrollment penetration increases with increasing values of both indexes, and the regression coefficients for both indexes are found to be significantly different from zero ($P<0.001$ for RISK, $P<0.05$ for OUTCOME).

## Discussion

This effort was designed to provide the Rhode Island WIC Program with a strong statistical basis for examining and improving its performance in identifying and serving the population most at need of its services. In the process of developing indexes of need and grouping small geographic areas on the basis of the level of need in their populations, several results have been produced that are of general utility and interest for maternal and child health programs. They include (*a*) the production of empirical indicators of risk and outcome for maternal and child health, (*b*) the identification of areas where birth outcomes are poor and WIC penetration is low, (*c*) the identification of areas where low risk is associated with poor outcomes and areas where good outcomes prevail despite high risk, and (*d*) the development of improved methods of measuring effectiveness for WIC Program outreach efforts.

The primary conclusion to be drawn from these results is that rates of enrollment in the WIC Program are generally highest in areas of the State where high proportions of the population are at risk for poor birth outcomes and where birth outcomes are actually poor. Enrollment rates appear to be more strongly associated with measures of risk than with measures of outcome, but the relationship between risk and outcome in small geographic areas may have been altered differentially by the effects of the WIC Program, as well as by those of other maternal and child health programs and by differences in access to medical care. Nevertheless, this study's findings have improved the Rhode Island WIC Program's ability to identify geographic areas with poor birth outcomes and unmet need for the program's assistance. Those areas are now being targeted for increased outreach efforts that should improve participation rates in the program and result in improved birth outcomes in these high-need areas.

A second finding of this study is that the geographic patterns of the measures of risk are different from the geographic patterns of the measures of birth outcomes in Rhode Island. There are many census tracts where high levels of risk do not result in poor birth outcomes and low levels of risk do not result in good birth outcomes. There are enough census tracts in Rhode Island where this divergence occurs so that the measures of risk and measures of outcome among the initial 38 variables separate into distinct constructs in the principal component analysis.

The indexes for risk and outcome produced on the basis of the principal component analysis represent a simplified way to quantify these two concepts for geographic areas. The cluster analysis solution goes further in distinguishing risk and outcome; four clusters of census tracts are identified where the prevalence of adverse birth outcomes is not what would be expected based on the levels of risk observed. As mentioned previously, one possible implication of this finding is that in some areas where levels of risk in the population are high, interventions such as the WIC Program and other public health efforts are yielding improved outcomes. Similarly, there may be areas where risk is low but other factors are leading to poor outcomes.

This interpretation leads to the final conclusion

Figure 1. Dependence of WIC enrollment penetration on index RISK

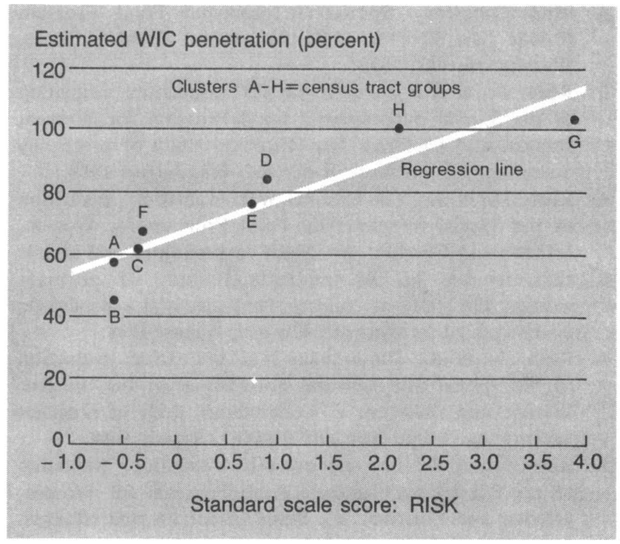
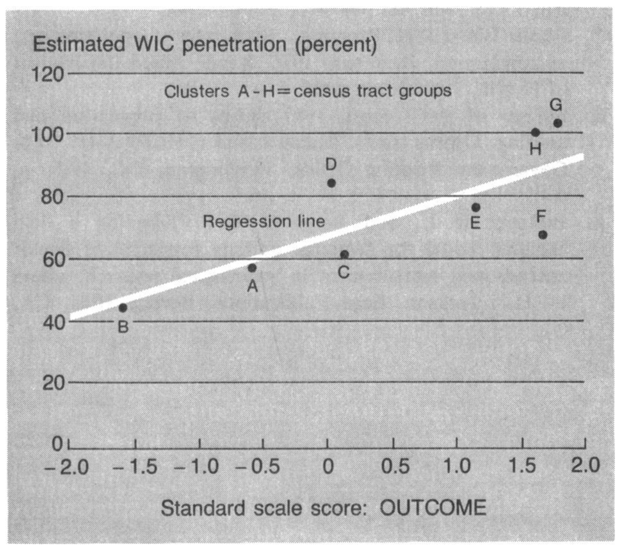



Figure 2. Dependence of WIC enrollment penetration on index OUTCOME




of the study. It is possible that the selection of measures from a limited number of existing data files has resulted in the exclusion of some important measures of risk and some key factors in determining birth outcomes. It is also possible that the analysis of data aggregated to small geographic areas is insensitive to some elements of the relationship between risks and outcomes. Thus, the application of small-area marketing techniques has yielded informative findings concerning this relationship, but at the same time it has indicated that further investigations may be needed to answer some of the specific questions posed in the course of this study.

## References


1. 92nd Congress: Special Supplemental Food Program (Public Law 92-433). U.S. Government Printing Office, Washington, DC, 1972.
2. Rush, D., et al.: The national WIC evaluation: evaluation of the Special Supplemental Food Program for Women, Infants, and Children. III. Historical study of pregnancy outcomes. Am J Clin Nutr 48: 412-428, August 1988.
3. Rush, D., et al.: The national WIC evaluation: evaluation of the Special Supplemental Food Program for Women, Infants, and Children. IV. Study methodology and sample characteristics in the longitudinal study of pregnant women, the study of children, and the food expenditures study. Am J Clin Nutr 48: 429-438, August 1988.
4. Rush, D., et al.: The national WIC evaluation: evaluation of the Special Supplemental Food Program for Women, Infants, and Children. V. Longitudinal study of pregnant women. Am J Clin Nutr 48: 439-483, August 1988.
5. Rush, D., et al.: The national WIC evaluation: evaluation of the Special Supplemental Food Program for Women, Infants, and Children. VI. Study of infants and children. Am J Clin Nutr 48: 484-511, August 1988.
6. Rush, D., et al.: The national WIC evaluation: evaluation of the Special Supplemental Food Program for Women, Infants, and Children. II. Review of past studies of WIC. Am J Clin Nutr 48: 394-411, August 1988.
7. Rhode Island WIC Program: State plan of operation and administration, fiscal year 1986. Rhode Island Department of Health, Providence, 1986.
8. Bureau of the Census: 1980 census of population and housing. Census tracts, Rhode Island (PHC80-2-41). U.S. Government Printing Office, Washington, DC, 1983, p. A-1.
9. Jackson, D. J., and Borgatta, E. F.: Selecting a data analysis model for factorial ecology research. *In* Factor analysis and measurement in sociological research, edited by D.J. Jackson. Sage Publications, Beverly Hills, CA, 1981, pp. 51-81.
10. Tyron, R. C., and Bailey, D. E.: Cluster analysis. McGraw-Hill, New York, 1970.
11. Humphrey, A. B., Buechner, J. S., and Velicer, W. F.: Differentiating geographic areas by socioeconomic characteristics. Northeast J Bus Econ 13: 47-64, spring/summer 1987.
12. Bureau of the Census: 1980 census of population and housing. Summary tape files 1A and 3A Rhode Island (machine-readable data file). Washington, DC, 1981.
13. Guyer, B., et al.: Needs assessment under the Maternal and Child Health Services Block Grant: Massachusetts. Am J Public Health 74: 1014-1019, September 1984.
14. Fleming, M.: Creation and implementation of maternal and child health need indices for allocation of block grant funds in Ohio. Proceedings of the Public Health Conference on Records and Statistics 1983. DHHS Publication No. (PHS) 84-1214. U.S. Government Printing Office, Washington, DC, 1983, pp. 359-364.
15. Humphrey, A. B., and Shaw, D. M.: Cluster analysis applications to small area geographic profiling. University of Hawaii School of Public Health, Honolulu, 1977.
16. Sakoda, J. M., and Karon, J. P.: Factor analysis of Rhode Island census tracts, 1970. Rhode Island Health Services Research, Providence, 1974.
17. Humphrey, A. B., Velicer, W. F., and Buechner, J. S.: Factor and cluster analysis of the 1980 Census for Rhode Island. Rhode Island Department of Health, Providence, 1984.
18. Milligan, G. W.: A Monte Carlo study of thirty internal criterion measures for cluster analysis. Psychometrika 46: 187-199, June 1981.
19. Sarle, W. S.: Cubic clustering criterion. SAS technical report A-108. SAS Institute, Cary, NC, 1982.
20. Food and Nutrition Service: Report of the WIC eligibility study. Summary of data, methods, and findings. U.S. Department of Agriculture, Alexandria, VA, July 1987, p. 66 (table 15, Note a).