# Vaccination Coverage and Physician Distribution in the United States, 1997

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**ABSTRACT.** ***Background.*** **How many physicians are needed in the United States and how they should be allocated geographically and among specialties has been the subject of intense debate, a debate that has often focused more on costs to third-party payers and government than on benefits to health. Child health is a central aspect of public health, and immunization is one of its most cost-effective and easily measured interventions.**

***Objective.*** **To examine the association of immunization rates and delivery characteristics with the distribution of child health physicians in the United States in 1997.**

***Design.*** **Cross-sectional ecological study, using the state as the unit of analysis, immunization rates and delivery characteristics (from the National Immunization Survey) as the main outcome measures, concentration of the principal physician specialties providing routine care to children (pediatric, family, and general physicians from the American Medical Association Masterfile) as the main risk factor, while controlling for demographic and economic factors (from the Bureau of the Census and other sources).**

***Results.*** **Of the 96 689 physicians providing routine care to children, 37% were pediatric, 49% family, and 14% general physicians. Higher rates of vaccination, private sector vaccination, and increased numbers of public and private vaccination sites were all associated with the concentration of pediatricians but not of family or general physicians. The distribution of pediatricians was strongly associated with the distribution of residency positions.**

***Conclusions.*** **Pediatrician distribution is a strong correlate to immunization rates and delivery characteristics. Opportunities to affect pediatrician distribution may exist with allocation of residency positions.** ***Pediatrics*** **2001; 107(3). URL: http://www.pediatrics.org/cgi/content/full/107/3/e31;** ***physician distribution, immunization, workforce.***

ABBREVIATIONS. VFC, Vaccines for Children; NIS, National Immunization Survey; MD, medical doctor.

How many physicians are needed in the United States and how they may best be allocated geographically and among specialties has been the subject of intense debate, particularly in the context of managed care and health care reform.[1–8] This debate has centered on costs rather than on benefits, perhaps because costs are easily calculated and tend to be borne by specific groups (eg, third-party payers and government), whereas the benefits of increased numbers of physicians are less easy to quantify and may be diffused across large populations.

Child health is a central aspect of public health, and vaccination is one of its most cost-effective and easily measured interventions.[9] Halfon, Chang, Wood, Newacheck, Starfield, and others[10–14] have examined physician distribution, access, quality, and utilization of child health care. However, to our knowledge, no previous studies have assessed the association of physician concentration to any child health prevention indicators, such as immunization. In this article, we examine the association of immunization rates and delivery characteristics with the distribution of child health physicians.

## METHODS

### Sources of Data

All data were state-specific for 1997.

#### *Physician Counts*

The methods and data characteristics of the American Medical Association Masterfile have been described in detail.[15] Briefly, the Masterfile is designed to contain data on all physicians in the United States, both members and nonmembers of the association, domestically trained and foreign medical graduates. Updated yearly, the Masterfile uses self-report to classify physicians by specialty, location, type of practice (patient care or nonpatient care), and employment. From the Masterfile, we abstracted counts of pediatric, family, and general physicians who reported that they were primarily engaged in seeing patients. Included were generalists and specialists and federal and nonfederal employees. Excluded were physicians whose primary activity was research, administration, teaching, or were in training. Separately, we abstracted counts of physicians classified as residents, interns, or fellows. The Masterfile does not contain and we did not include in analysis data concerning nonphysicians, such as nurses, nurse practitioners, and physician assistants, although such persons administer a substantial proportion of immunizations.[16]

#### *Birth Cohort*

From the National Center for Vital Statistics Report for 1997,[17] we abstracted counts of live-births, categorized by race and ethnicity. Because immunization occurs during infancy, we did not subtract infant deaths in estimating the cohort subject to immunization activities.

#### *Population and Demographics*

From the US Bureau of the Census, we obtained estimates of the total population residing in each state as of July 1, 1997, the proportion living in metropolitan statistical areas, and median household income.[18]

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*Vaccination Reimbursement Policies*

From a survey of state immunization program managers, we determined the Medicaid fee for administration of 3 vaccinations (any type), and whether a first-dollar vaccination insurance law (where third-party payers are required to reimburse for vaccinations without copayments or deductibles) had been enacted.

*Vaccine Distribution System*

The Vaccines for Children (VFC) program supplies health care providers with federally purchased vaccine for administration to children who are uninsured, Medicaid-eligible, Native American, or Alaska native. Using data from each state's annual VFC report, we categorized states according to their vaccine distribution system: 1) Universal—state distribution of all routine childhood vaccines to all providers, VFC-enrolled or not; 2) VFC private and public—no universal distribution, but VFC program available to all public providers and to all private providers who chose to enroll; or 3) VFC public—VFC program available only to public providers.

*Vaccination Coverage*

The National Immunization Survey (NIS) furnishes annual population-based estimates of provider-verified immunization rates for children 19 to 35 months of age, with methods that have been described in detail.[19] Briefly, telephone interviews based on random-digit dialing are completed for ≥440 children in each state. All the health care providers for each child are contacted to verify immunizations, categorize the type of site in which they practice, and indicate whether their site is VFC-enrolled. From the 1997 survey,[20] we obtained estimates of vaccination coverage by a median age of 27 months, using a 4–3-1–3 series-complete standard: receipt of 4 or more doses of diphtheria-tetanus-pertussis or diphtheria-tetanus vaccine, 3 or more doses of poliovirus vaccine, 1 or more doses of measles-containing vaccine, and 3 or more doses of *Haemophilus influenzae* type b vaccine.

*Number of Vaccination Sites*

As previously reported, site counts were estimated using state reports and other sources of data.[21,22]

*Proportion of Infants Vaccinated in the Private Sector*

As previously reported, NIS data were examined to estimate the proportion of infants vaccinated entirely in the private sector.[21,22]

### Analytic Approach

We performed a cross-sectional ecological study, using the state as the primary unit of analysis (Washington, DC treated as a state). The principal outcome measures were vaccination delivery characteristics (vaccination sites/1000 infants, proportion of infants vaccinated in the private sector) and vaccination coverage. The principal risk factors examined were the numbers of pediatric, family, and general physicians per 1000 infants in the birth cohort (physician concentration). Potential cofactors included in analysis were the percent of the population living in metropolitan statistical areas (urban percent), the percent of births that were other than white non-Hispanic (minority births), the numbers of physicians-in-training per 1000 persons (resident concentration), and a set of indicators for the probable level of physician reimbursement for vaccination (median household income, Medicaid vaccination fee, presence or absence of a first-dollar insurance law, and vaccine distribution system). The correlation of physician concentration to each of these cofactors was also examined, as was the intercorrelation of the outcome variables. We did not attempt analysis at a more geographically detailed level than the state because our vaccination coverage, delivery system, and reimbursement data were only available on a state basis, and for physician counts doubt has been cast on the accuracy of the American Medical Association Masterfile data below the level of the state.[23]

### Analytic Methods

All analyses were performed in *SAS, Version 6.12* (SAS Institute, Cary, NC). To assess correlation between continuous variables, we used bivariate linear regression and the Spearman test. To examine the extent to which levels of a categorical variable were associated with different distributions of a continuous variable, we used the Wilcoxon rank sum test. If more than one factor was found significant on bivariate analysis, multivariate linear regression was performed. The role of each child physician specialty was tested both by bivariate regression and by forcing into the final model. Statistical significance was assessed at the $P < .05$ level.

## RESULTS

### Distribution of Child Health Physicians (Table 1)

Of the 96 689 office-based physicians in specialties that provide routine care to children, 37% were pediatricians (range among states: 16%–65%), 49% family physicians (23%–72%), and 14% general physicians (7%–22%). An aggregate 24.8 physicians provided care for every thousand infants, with a threefold range among states (15.7–44.4). The sixfold range in pediatrician concentration (3.9–24.9) was considerably higher than the threefold range for family physicians (7.2–25.4) or the fourfold range for general physicians (1.5–6.1).

### Distribution of Other Potential Risk Factors

*Continuous Variables: Median (Range)*

1. Urban percent: 69% (32%–100%)
2. Minority percent: 28% (5%–84%)
3. Household income: $35 312 ($25 505–$50 829)
4. Medicaid fee: $8.00 ($0–$46.14)
5. Residents/1000 persons: .291 (.052–1.512)

*Categorical Variables: Number of States (Percent)*

1. Vaccine distribution system:
   a) Universal: 15 (29%)
   b) VFC public and private: 34 (67%)
   c) VFC public only: 2 (4%).
2. First-dollar insurance law:
   a) Enacted: 19 (37%)
   b) Not enacted: 32 (63%).

### Correlation of Physician Distribution to Other Factors (Table 2)

High pediatrician concentrations were strongly correlated with high resident concentrations and to a lesser extent with high household incomes. High family physician concentrations were associated with high proportions of persons living in rural areas and to a lesser extent with low proportions of minority births. High general physician concentrations were weakly associated with low household incomes and low fees for vaccinations. The distribution of physicians in the 3 specialties were independent, ie, the concentration of each specialty was not significantly associated with the concentration of either of the other 2.

### Risk Factors for Vaccination Site Concentration

The number of vaccination sites/1000 infants ranged from 5.2 to 60.4 (median: 11.7). Increased numbers of sites were present in states with higher concentrations of each of the 3 physician types and in states with Universal vaccine delivery (Table 3). Of the 10 states with the highest concentrations of vac-

**TABLE 1.** Distribution of Child Health Physicians, in Descending Order of Total Physicians/1000 Infants

| | State | Birth Cohort* | Physicians Providing Care to Children† | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pediatric | | Family | | General | | Total | |
| | | | # MDs | MDs/1000 Infants | # MDs | MDs/1000 Infants | # MDs | MDs/1000 Infants | # MDs | MDs/1000 Infants |
| 1 | Vermont | 6667 | 102 | 15.3 | 162 | 24.3 | 32 | 4.8 | 296 | 44.4 |
| 2 | Washington, DC | 7905 | 197 | 24.9 | 70 | 8.9 | 34 | 4.3 | 301 | 38.1 |
| 3 | Minnesota | 64 525 | 517 | 8.0 | 1636 | 25.4 | 156 | 2.4 | 2309 | 35.8 |
| 4 | North Dakota | 8356 | 58 | 6.9 | 198 | 23.7 | 41 | 4.9 | 297 | 35.5 |
| 5 | Maine | 13 670 | 132 | 9.7 | 302 | 22.1 | 48 | 3.5 | 482 | 35.3 |
| 6 | Montana | 10 851 | 71 | 6.5 | 241 | 22.2 | 50 | 4.6 | 362 | 33.4 |
| 7 | Washington | 79 024 | 666 | 8.4 | 1613 | 20.4 | 294 | 3.7 | 2573 | 32.6 |
| 8 | Wisconsin | 66 602 | 577 | 8.7 | 1383 | 20.8 | 200 | 3.0 | 2160 | 32.4 |
| 9 | New Hampshire | 14 433 | 166 | 11.5 | 249 | 17.3 | 49 | 3.4 | 464 | 32.1 |
| 10 | Nebraska | 23 327 | 152 | 6.5 | 510 | 21.9 | 81 | 3.5 | 743 | 31.9 |
| 11 | West Virginia | 20 752 | 183 | 8.8 | 343 | 16.5 | 120 | 5.8 | 646 | 31.1 |
| 12 | South Dakota | 10 208 | 50 | 4.9 | 212 | 20.8 | 46 | 4.5 | 308 | 30.2 |
| 13 | Pennsylvania | 144 235 | 1512 | 10.5 | 2239 | 15.5 | 557 | 3.9 | 4308 | 29.9 |
| 14 | Arkansas | 36 720 | 249 | 6.8 | 626 | 17.0 | 200 | 5.4 | 1075 | 29.3 |
| 15 | Wyoming | 6424 | 38 | 5.9 | 112 | 17.4 | 35 | 5.4 | 185 | 28.8 |
| 16 | Maryland | 70 267 | 1103 | 15.7 | 706 | 10.0 | 202 | 2.9 | 2011 | 28.6 |
| 17 | Virginia | 91 990 | 934 | 10.2 | 1390 | 15.1 | 306 | 3.3 | 2630 | 28.6 |
| 18 | Florida | 192 556 | 1972 | 10.2 | 2272 | 11.8 | 1176 | 6.1 | 5420 | 28.1 |
| 19 | Colorado | 56 539 | 469 | 8.3 | 979 | 17.3 | 134 | 2.4 | 1582 | 28.0 |
| 20 | Oregon | 43 895 | 356 | 8.1 | 707 | 16.1 | 155 | 3.5 | 1218 | 27.7 |
| 21 | Kentucky | 53 228 | 437 | 8.2 | 787 | 14.8 | 237 | 4.5 | 1461 | 27.4 |
| 22 | Iowa | 36 933 | 196 | 5.3 | 693 | 18.8 | 117 | 3.2 | 1006 | 27.2 |
| 23 | Tennessee | 74 577 | 709 | 9.5 | 1025 | 13.7 | 270 | 3.6 | 2004 | 26.9 |
| 24 | Connecticut | 42 977 | 651 | 15.1 | 367 | 8.5 | 106 | 2.5 | 1124 | 26.2 |
| 25 | Massachusetts | 82 448 | 1307 | 15.9 | 640 | 7.8 | 213 | 2.6 | 2160 | 26.2 |
| 26 | South Carolina | 51 904 | 370 | 7.1 | 817 | 15.7 | 174 | 3.4 | 1361 | 26.2 |
| 27 | Hawaii | 17 381 | 211 | 12.1 | 148 | 8.5 | 91 | 5.2 | 450 | 25.9 |
| 28 | Indiana | 83 447 | 489 | 5.9 | 1347 | 16.1 | 322 | 3.9 | 2158 | 25.9 |
| 29 | Rhode Island | 12 388 | 177 | 14.3 | 115 | 9.3 | 27 | 2.2 | 319 | 25.8 |
| 30 | Kansas | 37 446 | 230 | 6.1 | 621 | 16.6 | 109 | 2.9 | 960 | 25.6 |
| 31 | Alaska | 9705 | 62 | 6.4 | 142 | 14.6 | 38 | 3.9 | 242 | 24.9 |
| 32 | Ohio | 152 265 | 1419 | 9.3 | 1948 | 12.8 | 418 | 2.7 | 3785 | 24.9 |
| 33 | Idaho | 18 594 | 72 | 3.9 | 332 | 17.9 | 57 | 3.1 | 461 | 24.8 |
| 34 | New York | 263 339 | 3828 | 14.5 | 2042 | 7.8 | 641 | 2.4 | 6511 | 24.7 |
| 35 | Delaware | 10 243 | 105 | 10.3 | 126 | 12.3 | 19 | 1.9 | 250 | 24.4 |
| 36 | North Carolina | 107 013 | 895 | 8.4 | 1474 | 13.8 | 238 | 2.2 | 2607 | 24.4 |
| 37 | New Jersey | 113 141 | 1609 | 14.2 | 812 | 7.2 | 313 | 2.8 | 2734 | 24.2 |
| 38 | New Mexico | 26 874 | 205 | 7.6 | 361 | 13.4 | 83 | 3.1 | 649 | 24.1 |
| 39 | California | 526 033 | 4822 | 9.2 | 5378 | 10.2 | 2409 | 4.6 | 12 609 | 24.0 |
| 40 | Illinois | 180 898 | 1647 | 9.1 | 1957 | 10.8 | 580 | 3.2 | 4184 | 23.1 |
| 41 | Alabama | 61 038 | 457 | 7.5 | 728 | 11.9 | 209 | 3.4 | 1394 | 22.8 |
| 42 | Louisiana | 66 012 | 561 | 8.5 | 598 | 9.1 | 290 | 4.4 | 1449 | 22.0 |
| 43 | Michigan | 133 621 | 1093 | 8.2 | 1380 | 10.3 | 340 | 2.5 | 2813 | 21.1 |
| 44 | Oklahoma | 48 110 | 259 | 5.4 | 575 | 12.0 | 141 | 2.9 | 975 | 20.3 |
| 45 | Georgia | 118 347 | 932 | 7.9 | 1077 | 9.1 | 330 | 2.8 | 2339 | 19.8 |
| 46 | Arizona | 75 753 | 491 | 6.5 | 797 | 10.5 | 199 | 2.6 | 1487 | 19.6 |
| 47 | Mississippi | 42 747 | 244 | 5.7 | 450 | 10.5 | 137 | 3.2 | 831 | 19.4 |
| 48 | Missouri | 74 747 | 600 | 8.0 | 676 | 9.0 | 171 | 2.3 | 1447 | 19.4 |
| 49 | Texas | 333 889 | 2236 | 6.7 | 3277 | 9.8 | 898 | 2.7 | 6411 | 19.2 |
| 50 | Nevada | 27 039 | 134 | 5.0 | 244 | 9.0 | 70 | 2.6 | 448 | 16.6 |
| 51 | Utah | 43 885 | 245 | 5.6 | 378 | 8.6 | 67 | 1.5 | 690 | 15.7 |
| | Total | 3 894 968 | 36 197 | 9.3 | 47 262 | 12.1 | 13 230 | 3.4 | 96 689 | 24.8 |

* 1997 births per National Center for Health Statistics.
† # MDs indicates number of office-based physicians per 1997 American Medical Association Masterfile; MDs/1000 infants, number of office-based physicians divided by birth cohort and multiplied by 1000.

cination sites, 4 were among the 10 states with the highest concentrations of physicians, and 8 had universal distribution compared with 7 of the remaining 41 states (Fig 1). Pediatrician concentration was associated with higher concentration of both public ($P$ = .039) and private sites ($P$ = .005). Family physician concentration was associated with higher concentration of public ($P$ = .009) but not private sites ($P$ = .219). General physician concentration was associated with higher concentration of private ($P$ = .004) but not public sites ($P$ = .422).

### Risk Factors for Private Sector Vaccination

The percentage of children vaccinated entirely in the private sector ranged from 18% to 79% (median: 55%). Higher proportions of private sector vaccination occurred in states with higher pediatrician concentrations and with higher household incomes (Ta-

**TABLE 2.** Factors Correlated With the Distribution of Child Health Physicians

| Factor† | MDs/1000 Infants‡ | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pediatric | | | | | | Family | | | | | | General | | | | | |
| | Bivariate | | | Multivariate | | | Bivariate | | | Multivariate | | | Bivariate | | | Multivariate | | |
| | $R^2$ | β | *P* Value | $R^2$ | β | *P* Value | $R^2$ | β | *P* Value | $R^2$ | β | *P* Value | $R^2$ | β | *P* Value | $R^2$ | β | *P* Value |
| MDs/1000 | | | | | | | | | | | | | | | | | | |
| Pediatric | NA | NA | NA | NA | NA | NA | .107 | −.430 | .018* | | | | .001 | −.001 | .990 | | | |
| Family | .107 | −.250 | .019* | | | | NA | NA | NA | NA | NA | NA | .107 | +.069 | .019* | | | |
| General | .001 | −.006 | .990 | | | | .106 | +1.543 | .019* | | | | NA | NA | NA | NA | NA | NA |
| Resident | .752 | +14.887 | .001* | | +14.537 | .001* | .115 | −7.647 | .015* | | | | .015 | −.583 | .393 | | | |
| Demographic | | | | | | | | | | | | | | | | | | |
| Urban% | .134 | +.091 | .008* | | | | .406 | −.209 | .001* | | −.128 | .006* | .107 | −.023 | .019* | | | |
| Minority% | .129 | +.075 | .010* | | | | .401 | −.174 | .001* | | −.103 | .008* | .002 | −.003 | .756 | | | |
| Economic | | | | | | | | | | | | | | | | | | |
| House income | .079 | +.001 | .045* | | +.001 | .006* | .034 | −.001 | .192 | | | | .153 | −.001 | .005* | | −.001 | .003* |
| Medicaid fee | .021 | −.074 | .306 | | | | .065 | −.169 | .072 | | | | .076 | −.039 | .051 | | −.039 | .033* |
| Vaccine distrib. | .004 | + | .900 | | | | .062 | + | .218 | | | | .001 | + | .979 | | | |
| First $ insure | .078 | + | .048* | | | | .001 | + | .857 | | | | .044 | + | .141 | | | |
| Model | NA | NA | NA | .788 | NA | .001* | NA | NA | NA | .488 | NA | .001* | NA | NA | NA | .230 | NA | .002* |

NA indicates not applicable.
Blank, in multivariate analysis indicates factor not statistically significant at $P < .05$ level.
* Factor statistically significant at $P < .05$ level.
† All factors but Vaccine Distrib. and First $ Insure are continuous variables.
‡ Number of office-based physicians in each specialty (according to American Medical Association Masterfile) divided by birth cohort (according to National Center for Health Statistics) and multiplied by 1000.
Resident = intern and resident physicians; Urban% = proportion of total population living in metropolitan statistical areas; Minority% = proportion of births that are other than non-Hispanic white; House. Income = median household income in dollars; Medicaid Fee = fee in dollars paid by Medicaid for administration of 3 vaccinations; Vaccine Distrib. = vaccine distribution system: (1) Universal; (2) Vaccines for Children (VFC) for public and private providers; or (3) VFC for public providers only. Since it is a categorical variable, β values are not calculated, but a plus sign is indicated in the β column if states with Universal distribution had a higher mean number of MDs/1000 infants than states with other distribution systems; First $ Insure = law requiring that vaccinations be reimbursed by third party payors with no copayment or deductible: Yes or No. Since it is a categorical variable, β values are not calculated, but a plus sign is indicated in the β column if states with such a law had a higher mean number of MDs/1000 infants than states without such a law.

**TABLE 3.** Risk Factors for Increased Numbers of Vaccination Sites, Increased Private Sector Vaccination, and Increased Vaccination Coverage

| Factor† | Vaccination Delivery Characteristics‡ | | | | | | | | | | | | Vaccination Coverage§ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vaccination Sites/1000 Infants | | | | | | Proportion of Infants Vaccinated in Private Sector | | | | | | | | | | | |
| | Bivariate | | | Multivariate | | | Bivariate | | | Multivariate | | | Bivariate | | | Multivariate | | |
| | $R^2$ | $\beta$ | *P* Value | $R^2$ | $\beta$ | *P* Value | $R^2$ | $\beta$ | *P* Value | $R^2$ | $\beta$ | *P* Value | $R^2$ | $\beta$ | *P* Value | $R^2$ | $\beta$ | *P* Value |
| MDs/1000 | | | | | | | | | | | | | | | | | | |
| Pediatric | .114 | +.853 | .015* | | [+1.194] | .001* | .417 | +.024 | .001* | | +.037 | .001* | .123 | +.004 | .012* | | +.006 | .001* |
| Family | .119 | +.666 | .013* | | [+.790] | .001* | .004 | −.002 | .658 | | | | .015 | +.001 | .395 | | | |
| General | .168 | +3.726 | .003* | | [+2.515] | .011* | .025 | −.023 | .229 | | | | .005 | +.003 | .620 | | | |
| Resident | .013 | +4.872 | .433 | | | | .149 | +.244 | .006* | | −.330 | .008* | .027 | +.032 | .247 | | | |
| Demographic | | | | | | | | | | | | | | | | | | |
| Urban% | .101 | −.200 | .023* | | | | .089 | +.003 | .034* | | | | .126 | −.001 | .011* | | −.002 | .001* |
| Minority% | .046 | −.113 | .131 | | | | .001 | +.001 | .967 | | | | .034 | −.001 | .198 | | | |
| Economic | | | | | | | | | | | | | | | | | | |
| House Income | .003 | +.001 | .686 | | | | .304 | +.001 | .001* | | +.001 | .002* | .001 | +.001 | .919 | | | |
| Medicaid Fee | .032 | −.229 | .211 | | | | .029 | −.003 | .235 | | | | .002 | −.001 | .738 | | | |
| Vac. Distrib. | .247 | + | .001* | | + | .001* | .066 | + | .195 | | | | .097 | + | .087 | | | |
| First $ Insure | .026 | + | .254 | | | | .006 | + | .581 | | | | .012 | + | .436 | | | |
| Vac. character. | | | | | | | | | | | | | | | | | | |
| Sites/1000 Inf. | NA | NA | NA | NA | NA | NA | .132 | +.005 | .009* | | | | .117 | +.002 | .014* | | | |
| Private Sector% | .132 | +2.489 | .009* | | | | NA | NA | NA | NA | NA | NA | .102 | +.098 | .022* | | | |
| Model | NA | NA | NA | .568 | NA | .001* | NA | NA | NA | .627 | NA | .001* | NA | NA | NA | .394 | NA | .001* |

NA indicates not applicable; blank, in multivariate analysis, factor not statistically significant at $P < .05$ level; [ ], $\beta$ values calculated for physician concentrations in absence of inclusion of Vaccine Distribution System in model.

* Factor statistically significant at $P < .05$ level.

† All factors but Vaccine Distrib. and First $ Insure are continuous variables.

‡ Vaccination sites/1000 infants indicates ratio of total sites (public and private) providing routine childhood vaccinations divided by birth cohort and multiplied by 1000; private sector proportion, proportion of infants vaccinated entirely in the private sector, according to the 1997 National Immunization Survey.

§ Vaccination coverage indicates 4-3-3-1 series completion at a median age of 27 months, according to 1997 National Immunization Survey.

Resident = intern and resident physicians; Urban% = proportion of total population living in metropolitan statistical areas; Minority% = proportion of births that are other than non-Hispanic white; House. Income = median household income in dollars; Medicaid Fee = fee in dollars paid by Medicaid for administration of 3 vaccinations; Vaccine Distrib. = vaccine distribution system: (1) Universal; (2) Vaccines for Children (VFC) for public and private providers; or (3) VFC for public providers only. Since it is a categorical variable, $\beta$ values are not calculated, but a plus sign is indicated in the $\beta$ column if states with a Universal system had a higher mean value of the vaccination delivery characteristic or coverage than states with other distribution systems; First $ Insure = law requiring that vaccinations be reimbursed by third-party payers with no copayment or deductible: Yes or No. Since it is a categorical variable, $\beta$ values are not calculated, but a plus sign is indicated in the $\beta$ column if states with such a law had a higher mean value of the vaccination infrastructure characteristic or vaccination coverage than states without such a law.

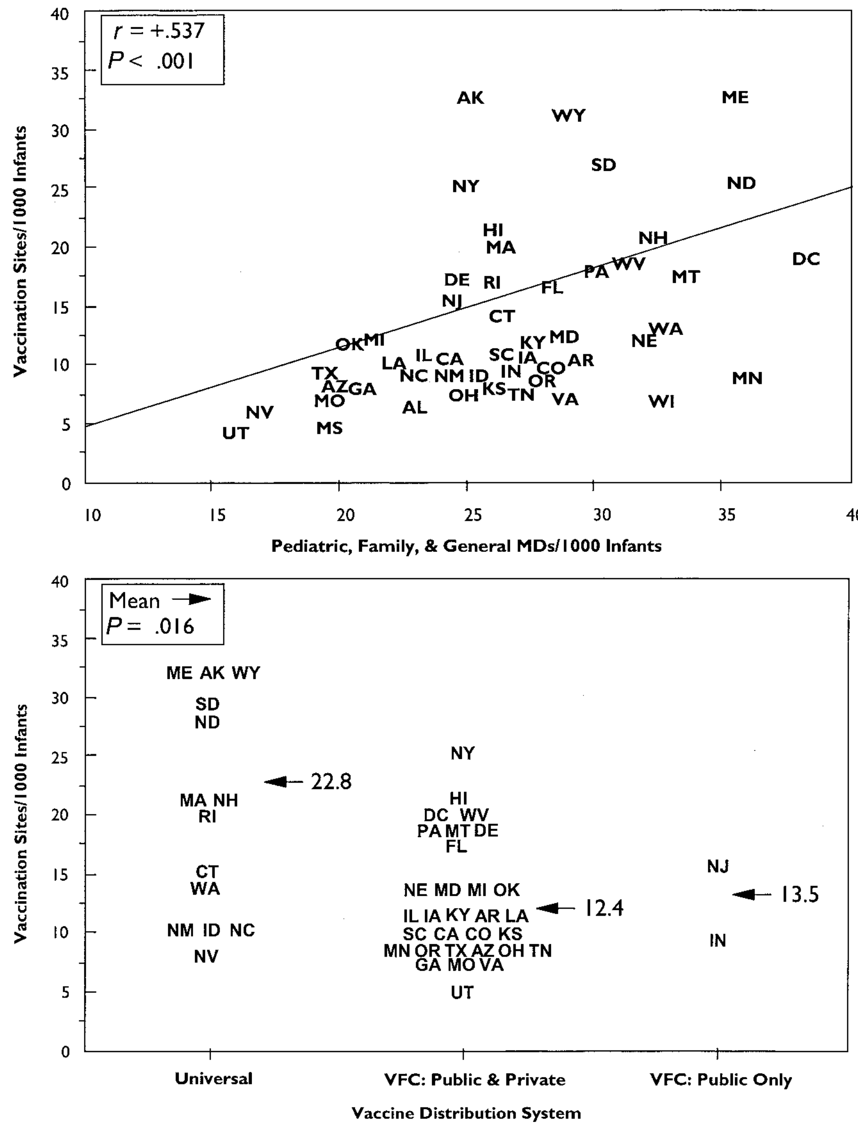


**Fig 1.** Vaccination sites/1000 infants. One outlying value is not shown on each graph: Vermont, 60.4 sites/1000 infants, 44.4 child health medical doctors (MDs)/1000 infants, universal vaccine distribution.

ble 2). Of the 10 states with the highest private sector proportions, 8 were among the 10 states with the highest pediatrician concentrations, and 5 were among the 10 states with the highest incomes (Fig 2).

### Risk Factors for Vaccination Coverage

The percentage of children 29 to 35 months of age who were 4–3-1–3 series-complete ranged from 69% to 86% (median: 77%). High levels of vaccination coverage were present in states with high pediatrician concentrations and low urban proportions (Table 3). These 2 risk factors were positively correlated ($r = +0.322$; $P = .021$), approximately equal in strength, but opposed in effect; thus a model combining them explained more of the variability in coverage than would have been expected from the sum of the factors individually ($R^2 = 0.394 > [0.123 + 0.126] = 0.249$). Of the 10 states with the highest coverage, 5 were among the 10 states with the highest pediatrician concentrations and 4 were among the 10 states with the lowest proportions of persons living in urban areas (Fig 3). Two other factors found significant on bivariate analysis lost significance when paired with pediatrician concentration in a multivariate model: vaccination site concentration (correlation with pediatrician concentration: $r = +0.369$; $P = .008$) and private sector proportion (correlation with pediatrician concentration $r = +0.752$; $P < .001$).

## DISCUSSION

In summary, we found that pediatrician concentration, but not family or general physician concentration, was significantly associated with higher vaccination coverage, higher proportion of children vaccinated in the private sector, and greater numbers of both private and public vaccination sites.

No relationship could be identified between vaccination reimbursement factors (vaccine distribution system, first-dollar insurance laws, Medicaid vaccination fees) and vaccination coverage or even proportion vaccinated in the private sector. These findings, however, should not be taken as evidence that laws or policies providing fiscal incentives for vaccination are ineffectual in raising coverage or retaining children in the private sector. Our study lacked data on how long the laws and policies had been in effect in each state and did not examine temporal trends

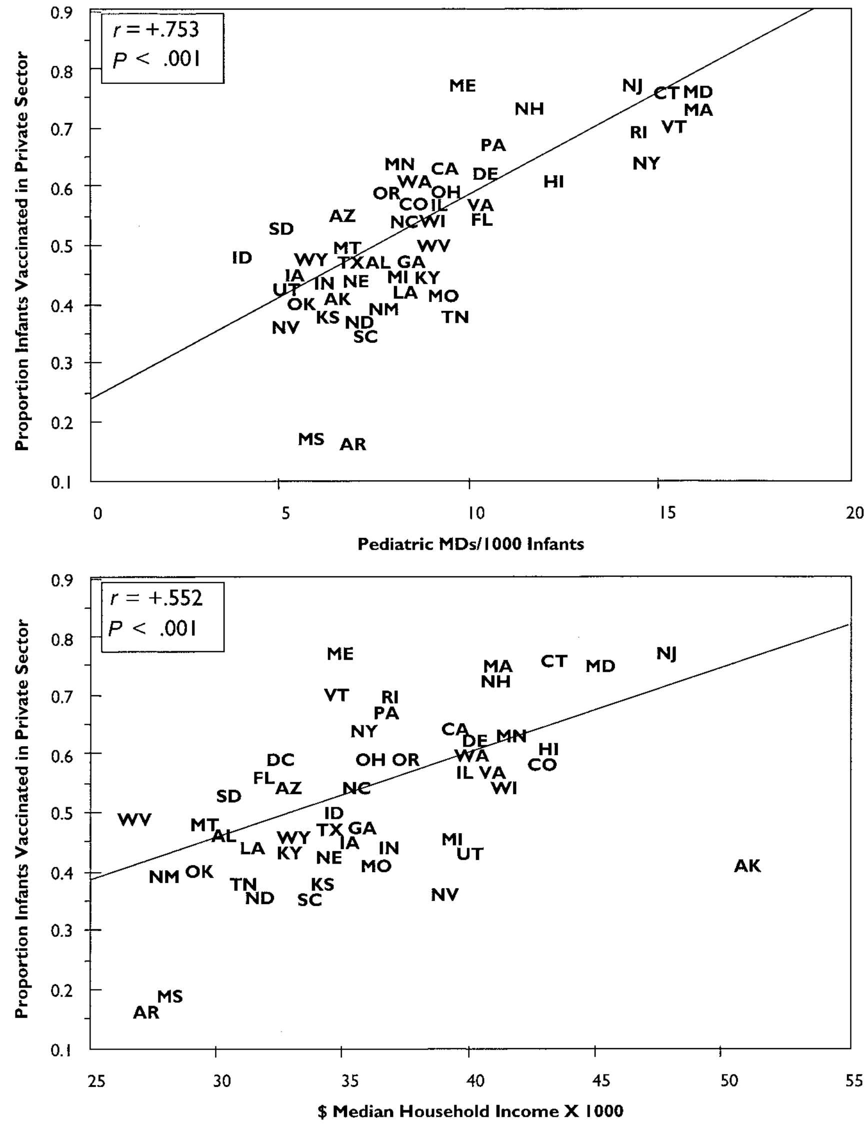


**Fig 2.** Proportion of infants vaccinated in private sector. One outlying value is not shown on the top graph: Washington, DC, 61% of infants vaccinated in private sector, 24.9 pediatric MDs/1000 infants.

within a state after their introduction. The incentive structure which induces physicians to vaccinate is likely to be a set of complex, interacting factors, not all of which are fiscal.

Moreover, economic factors may have powerful but indirect effects, eg, higher household income was associated in our study with higher concentration of pediatricians, which in turn was associated with higher immunization rates. These data suggest that physician concentration may be an important effector arm through which economic factors influence clinically modifiable health outcomes. Increased numbers of physicians may mean that lower income families are provided with greater access to care, and smaller caseloads may mean that physicians have more time for prevention in relation to acute care. It should not be assumed, however, that there is an automatic relationship between increased numbers of physicians and improved preventive care, because in certain reimbursement contexts small caseloads might motivate physicians to emphasize the more lucrative aspects of acute care over prevention.

Because ours is an ecological study examining cross-sectional data for 1 year, the associations we found should be regarded as suggestive rather than causative. Most vaccinations received by the children in our study were administered in the 2 years before the year of analysis, and hence the vaccination patterns of 1997 were more strongly influenced by factors present in previous years than factors present in 1997. Additional studies, preferably longitudinal, are needed to confirm our findings. However, most of the factors we examined, particularly physician concentration, may be difficult, if not impossible, to test in an experimental design, so that ecological studies may be a primary avenue of future investigations. Given the limitations of existing data sources for physician counts, vaccination rates, and other factors, the smallest reliable unit for many analyses may continue to be the state. This is unfortunate, because within large and even small states, very diverse health care environments can coexist (eg, rural southern Illinois vs inner-city Chicago), making interpretation of state-based findings hazardous. In such a situation, associations—even if highly significant—should be viewed very cautiously in light of other studies, particularly those using different methodologies.

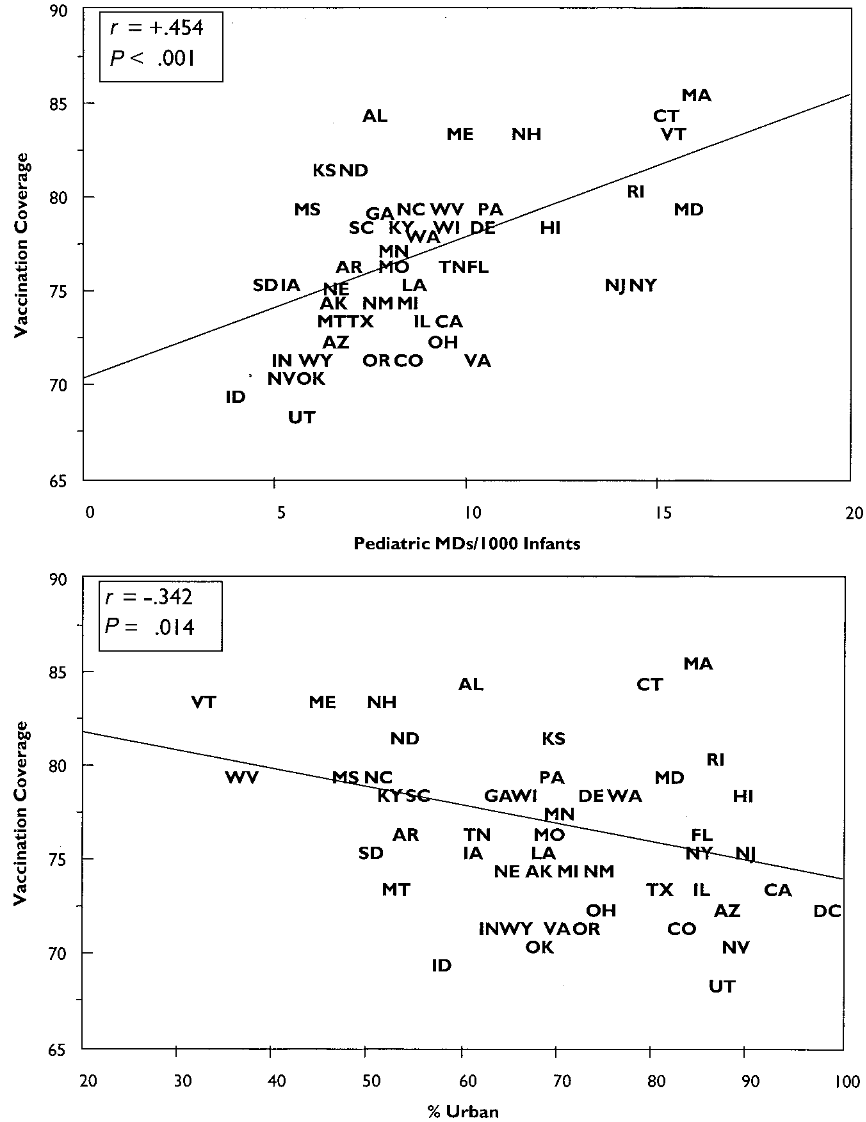


**Fig 3.** Vaccination coverage. One outlying value is not shown on the top graph: Washington, DC, 73% coverage, 24.9 pediatric MDs/1000 infants.

The association of urban residence with low vaccination levels has been found in many other studies.[24–28] The strong correlation we found of pediatrician to residency concentrations was previously found by Chang and Halfon[13] in 1992 data. A number of other studies have also found that residency location is an important factor in determining practice location,[29,30] and a 1997 American Academy of Pediatrics national survey of 500 third-year pediatric residents found that 57% planned to practice in the same state where they were training (R. Pan and W. Cullen, personal communication, 2000). Increasing the number of physicians practicing in rural areas has been an objective of many family physician residency programs,[31–33] and the distribution of family physicians in our study did correlate to the proportion of the population living in rural areas. Because residency positions are often government-funded, these data suggest that allocation of residency positions may represent a modifiable factor to improve health care outcomes for children.

As expected, the greater the number of physicians providing care to children in a state, the greater the number of vaccination sites in our study. While pediatricians were associated with greater numbers of both public and private sites, family physicians were only associated with greater numbers of public sites. Consistent with this, we also found that the proportion of children vaccinated in the private sector was associated only with the concentration of pediatricians. Family physicians have previously been shown to refer children to public clinics for vaccination at higher rates than do pediatricians,[34,35] and this behavior may influence public/private sector proportions.

Pediatrician concentration was correlated in our study with increased immunization rates. However, a high concentration of pediatricians did not invariably produce high vaccination rates, particularly in urban areas (eg, Washington, DC with the highest concentration of pediatricians but a coverage level below the median). We were unable to examine the influence that nonphysician health professionals may have exerted, but the concentrations of family and general physicians were not correlated with immunization coverage. Family and general physicians, despite outnumbering pediatricians almost 2 to 1, may see fewer total infants because of the much larger age range of their patient populations.[36,37] Because infancy is the period during which most immunization takes place, immunization as an outcome indicator may underestimate the contributions of family and general physicians to child and adolescent health.

More generally, the focus of this study on immunization may not adequately represent other aspects of child preventive care or health (eg, mortality and hospitalization rates). Nevertheless, immunization is a key prevention indicator, applies to the nation's entire birth cohort, and has been the subject of a large literature. Despite the ecological nature of this study, the consistency of our findings with that literature is reassuring.

The range of health care outcomes for different groups of children in the United States can be as wide as the range of health care outcomes for children in developing compared with developed nations.[38–40] Physician groups and policymakers are struggling with how to improve child health care outcomes and reduce inequities in access to and quality of care. Our data suggest that pediatrician distribution may be an important correlate to certain child health outcomes and that opportunities may exist to modify pediatrician distribution toward the goal of improving child health.

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**Vaccination Coverage and Physician Distribution in the United States, 1997**

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