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Parsimonious prediction model for the prevalence of dental visits

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Abstract – Objectives: To analyze the prevalence of dental visits within the last year in the Behavioral Risk Factor Surveillance System or BRFSS (2003) national database by simple sociodemographic factors, and to predict prevalence in States that have not participated in BRFSS 2003. *Methods:* Behavioral Risk Factor Surveillance System is a cross-sectional telephone survey conducted by the state-level authorities in the United States and based on a standardized questionnaire to determine the distribution of risk behaviors and health practices among noninstitutionalized adults. A multivariable logistic regression model considers the complex sample design of the BRFSS was used to predict the prevalence of dental visits based on four nonclinic parsimonious variables. *Results:* White race, high income (≥$35 000), education above high school, and marital status were associated with an annual dental visit with odds ratios of 1.38, 2.09, 1.61, and 1.18, respectively. Utah had the highest percentage (78%) of estimated annual users, while 'Virgin Islands' had the lowest percentage (59%). The model's correct classification rate was 61.5%. *Conclusions:* State and local governments, health promotion organizations, insurance companies, and organizations that administer public health programs (such as Medicare and Medicaid in the U.S.) will benefit by applying this model to the available nonclinical databases, and will be able to improve planning of dental health services and required dental workforce.

Key words: Behavioral Risk Factor Surveillance System; complex samples; dental visit; dentistry; logistic regression; oral health

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Personal health behaviors play a major role in morbidity and mortality. The need to measure health behaviors in the U.S. has led to the development of national surveys such as the Behavioral Risk Factors Surveillance System or BRFSS (1). The BRFSS helps shape public health policy at many levels in local, state, and federal agencies, and ultimately helps America be healthier (1). The BRFSS measures a few indices related to oral health. In the 2003 survey, these indices were: the time since the last dental visit; the time since the last dental cleaning; and the number of permanent teeth lost due to dental caries or gum diseases (1).

We previously analyzed data from the 1998 Community Health Assessment Project (CHAP) in Sedgwick County, Kansas to identify factors that determined whether a person had visited a dentist during the last year (2). The model explained about 70% of the outcome variability and included four variables: race (whites more likely to visit the dentist), annual household income (persons with incomes ≥$30 000 more likely to visit the dentist), attained education (persons with more than a high school education more likely to visit the dentist), and marital status (married persons more likely to visit the dentist). The study in Kansas explored all available variables in the CHAP dataset, and developed the best set of binary variables to produce the best model. These variables (and their categorizations) were selected based on statistical evidence in thorough exploratory analysis. Since the variables serve as well the goal of pragmatism needed in public health projects, we advocate their use. In this present paper, we aimed at analyzing the prevalence of dental visits within the last year in the BRFSS 2003 national database by those same four variables and to predict prevalence in States that have not participated in BRFSS 2003.

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The proposed model will allow public and private healthcare agencies and dental insurance programs to predict the number and percentages of people, in a specific and simply identified sociodemographic stratum, who will use their programs in a specific year at least once and to plan for future dental workforce needs accordingly. Additionally, the model will help health promoters at the individual or community level to prioritize their target populations according to their risk level of underutilization of dental care services, which ultimately will lead to a better use of resources.

Several factors have been identified that relate to the frequency patterns (regular or recent) of dental visits. The most prominent factors positively associated with regular dental visits are: female gender (3–7), nonminority race/ethnicity (3, 7–9), higher education (4, 7, 10, 11), high household income, low cost burden, or nonpoverty status (3, 7, 9, 10, 12–16), having insurance coverage (3, 7, 11, 13, 17, 18), a positive attitude toward dental health, a positive perception of oral health, or having recent pain (6, 7, 13, 15), state or type of residence (urban versus rural versus remote) (3, 6, 16, 17, 19, 20), longer time lived in the new land after immigration (8, 21), and being dentate, having more teeth, or not being a full-denture wearer (3, 6, 15). The correlation between dental visits and age was established to be positive, but the trend is unclear in older ages (3, 5, 7, 11, 17), which can be attributed to the number of teeth as a confounder (22). Other factors mentioned less frequently in the literature are: providers' availability on weekends and extended hours (13), a physician visit during the last year (15), an increased frequency of church attendance (23), being an office worker (11), and scoring higher on a cognitive test (15).

However, the use of many of these explanatory variables to predict the prevalence of dental visits may not be applicable. For example, to collect data on a clinical index or the attitudes toward dental health in a small community with local government would require the same effort of collecting data about the frequencies of dental visits in the community, but a local government knows certain sociodemographic characteristics of its population. Restricting the predicting variables to such known sociodemographic characteristics (e.g. ethnicity, education) as explanatory variables is beneficial; and it is more beneficial in other countries where costly sophisticated surveillance systems (such as BRFSS) that continuously provide estimations of the prevalence of dental visits are not available.

Methods

The BRFSS is a cross-sectional telephone survey conducted by state health departments with technical and methodological assistance provided by the Centers for Disease Control and Prevention (CDC). The survey is conducted in English or Spanish, and it is based on a standardized questionnaire to determine the distribution of risk behaviors and health practices among noninstitutionalized adults. The survey is not designed to evaluate their attitudes or knowledge regarding these behaviors and health practices (1).

The target population is adults 18 years and older with the restriction of interviewing one adult per household. The questions asked during the telephone interview are related to behaviors that are associated with preventable chronic diseases, injuries, and infectious diseases. The home telephone numbers are obtained through random-digit dialing. The data are collected by each state using standard procedures of telephone interviews, and data are then aggregated by the CDC. The data are posted on the BRFSS Web site (http://www.cdc.gov/brfss/technical_infodata/surveydata/2003.htm#data) and are available to the public without prior permission (1). However, the oral health-related questions are among the optional modules of the BRFSS questionnaire (1), so that many States do not ask these questions.

Several factors are used to weight the data for the probability of selecting a telephone number such as the number of adults in a household and the number of telephones in a household. Also a final poststratification adjustment is made for nonresponse and noncoverage of households without telephones. The weights for each relevant factor are multiplied together to get a final weight (1).

The BRFSS 2003 data were downloaded from the BRFSS website. The dependent variable of interest for this analysis was: 'How long has it been since you last visited a dentist or a dental clinic for any reason?'. Possible categorical responses to this question were: within the past year (<12 months ago); within the past 2 years (1 year but <2 years ago); within the past 5 years (2 years but <5 years ago); five or more years ago; do not know/Not sure; never; and refused. The question was recoded into: within the past year (<12 months ago); and >1 year. The independent variables tested for their relationships to the outcome were: (1) 'annual household income', which was categorized as ≥$35 000, versus <$35 000 (The pilot study in

2003 regarding Sedgwick county, KS used a cut-off point of $30 000 which was not available in BRFSS 2003); (2) race, which was categorized as White versus (Black or African American, Asian, Native Hawaiian or other Pacific Islander, American Indian or Alaskan Native); (3) education, categorized as at least some study in college or technical school versus high school graduate or less; (4) marital status, which was categorized as married versus (divorced, widowed, separated, never married, or a member of an unmarried couple). Participants who did not indicate their race, classified themselves as 'other races', refused to answer any question related to this study, or whose answers to any of these questions was 'do not know/not sure' were excluded from the analysis.

STATA version 8.0 (StataCorp LP, College Station, TX, USA) was used to conduct all statistical analyses. The analysis considered the complex design of the BRFSS sample using a Taylor expansion to calculate the standard errors, and assuming the first stage sampling fraction is small (randomly selected geographical regions or districts). Frequency tables for each of the dependent and independent variables in addition were generated. A logistic regression model was calculated and evaluated using the classification table method. Expectations for the number of dental visitors (or the estimated prevalence of dental visits) in all states were calculated based on these estimated probabilities.

Results

The BRFSS 2003 was a sample of 264 684 households. However, only 10 states (listed in Table 1) participated in the oral module that year; this included 39 300 adults (representing different households) who answered the five questions regarding the time of their last dental visit, race, annual household income, level of education, and marital status in an informative way. The sample had 126 weighted strata and represented 33 643 487 noninstitutionalized adults in the 10 participating states. Only 0.69% did not know or were not sure about their last dental visit and only 0.03% refused to answer this question. The weighted mean age was 45.8 years (95% CI: 45.52–46.09), and 48.6% of the represented population were males. Seventy-two percent of the represented population visited a dental clinic within the last year. The lowest percentage of visitors to a dental clinic within the last year was in Nevada (64%) and the highest was in New Hampshire (76%). The weighted percentages for visiting a dental clinic within the last year as well as each of the four main sociodemographic characteristics analyzed as explanatory variables are detailed in Table 1. Maryland had the lowest percentage of people whose indicated race was white, although this state had the highest percentage of people with high income (≥$35 000). Ohio had the lowest percentage of people whose level of education was above high school, while New York and Nevada had the lowest percentages of married people.

The estimated percentage of the sampled population persons who visited a dental clinic within the last year and who were positive in at least one of the main sociodemographic characteristics ranged from 62% to 85% with the highest percentage among those whose indicated race was white and

Table 1. Percentages of participants visited a dental clinic within last year and their sociodemographic characteristics by state

State	N[a]	% Visited a dental clinic within last year	% White Race	% High annual household income (≥$35 000)	% High education (>high school diploma)	% Marital status
Idaho	810 000	66.45	97.48	53.91	62.74	67.69
Iowa	1 900 000	75.68	97.41	56.68	58.25	63.54
Maryland	3 200 000	74.30	69.61	72.22	68.44	59.48
Nebraska	1 000 000	75.28	95.68	58.59	62.38	67.84
Nevada	1 300 000	63.96	87.38	62.50	60.43	56.22
New Hampshire	800 000	76.37	97.41	69.26	64.69	62.70
New York	11 000 000	72.41	78.75	59.25	61.86	54.21
Ohio	7 000 000	71.26	89.65	57.91	55.15	61.38
South Carolina	2 500 000	66.78	72.60	52.83	56.18	59.35
Virginia	4 500 000	70.41	79.65	66.13	61.97	62.04
Total	34 000 000	71.57	82.59	60.74	60.54	59.18

[a]N estimated from complex survey data.

Table 2. Percentages of participants visited a dental clinic within last year and odds ratios by sociodemographic characteristics[a]

Status	Visited a dental clinic within last year, N[b] (%)	Odds ratio
Race		
White	20 000 000 (85)	1.62*
Nonwhite	3 700 000 (15)	
Income		
High annual household income (≥$35 000)	16 000 000 (67)	2.65*
Lower annual household income (<$35 000)	7 800 000 (33)	
Education		
High education (>high school diploma)	16 000 000 (66)	2.08*
Lower education (≤ high school diploma)	8 300 000 (34)	
Marital status		
Married	15 000 000 (62)	1.60*
Not married	9 000 000 (38)	

[a]Univariate logistic regression.
[b]N estimated from complex survey data.
*P-value < 0.0001.

the lowest percentage among those who were not married (Table 2). Table 2 also details the individual odds ratios for the different sociodemographic characteristics.

All four main sociodemographic characteristics related to dental visits were highly significant (P-value < 0.0001) in a multivariable logistic regression model, also the multivariable Wald test was highly significant (P < 0.0001; Table 3). Race was the least confounded factor by the inclusion of other factors in the model. High income had the highest odds ratio; the odds for people with high annual household income to have visited a dental clinic within the last year were twice as great as the odds for people with lower annual household income. Marital status was associated with the lowest odds ratio; the odds for married people to have visited a dental clinic within the last year were about 1.2 greater than the odds for unmarried people. Estimation of the model fit is not applicable given the current development in mathematical statistics of logistic regression with regard to samples with complex design as is the case in the BRFSS sample (24). However, that being said, one could say with caution, that using unweighted simple regression analysis, the area under the Receiver Operating Characteristic (ROC) curve would be 67.12%.

There are 16 possible combinations of the main sociodemographic characteristics. The expected probabilities for a participant, falling in a particular sociodemographic category or combination, to have visited a dental clinic within the last year ranged from 47% among those who were negative on the main sociodemographic characteristics to 83% among those who were positive on all of them (Table 4). It is interesting to note that nonmarried people who did not classify themselves as white with low income and high education shared similar probability (58.93%) of visiting a dental clinic within the last year with those who were married, white, with low income and education (59.23%). Also nonmarried people who did not classify themselves as white, with high income and high education shared similar probability of visiting a dental clinic within the last year (74.95%) with those who were married, white, with high income and low education (75.18%).

The logistic model above can be used as a testing tool to estimate the probability of visiting a dental clinic within the last year. The best cut-off point among the expected probabilities which resulted in the highest possible sensitivity and specificity of the test simultaneously was 73%. At this cut-off point, the sensitivity of the test is 63%, the specificity is 61%, the positive predictive value is 79%, and the negative predictive value is 39%.

Table 5 details the expected percentages of annual users of dental services (the prevalence of dental visits) by state. The expectations were based on the expected probabilities of visiting a dental clinic within the last year for each sociodemographic combination in the different states, including those who did not participate in the study. Inferences from these expectations are limited by the model

Table 3. Odds ratios relating sociodemographic characteristics to the likelihood of an annual dental visit[a]

Variable	Parameter coefficients (SE)	Odds ratio	OR (95% CI)	P-value
White race	0.32 (0.06)	1.38	1.24–1.54	<0.0001
High annual household income (≥$35 000)	0.73 (0.05)	2.09	1.91–2.28	<0.0001
High education (>high school diploma)	0.48 (0.04)	1.61	1.48–1.75	<0.0001
Married	0.17 (0.04)	1.18	1.09–1.28	<0.0001

[a]Multivariable logistic regression.

Table 4. Expected probabilities of visiting a dental clinic within last year by the different sociodemographic types

White race	High annual household income (≥$35 000)	High education (>high diploma)	Marital status	Lower bound of the estimated probability (95%)	Estimated probability (%)	Upper bound of the estimated probability (95%)
N	N	N	N	44.30	47.11	49.94
N	N	N	Y	48.14	51.26	54.37
N	N	Y	N	56.04	58.93	61.76
N	N	Y	Y	59.72	62.88	65.94
N	Y	N	N	61.76	65.00	68.12
N	Y	N	Y	65.84	68.68	71.39
N	Y	Y	N	72.50	74.95	77.26
N	Y	Y	Y	75.82	77.94	79.92
Y	N	N	N	53.27	55.16	57.04
Y	N	N	Y	57.18	59.23	61.25
Y	N	Y	N	64.62	66.46	68.26
Y	N	Y	Y	68.03	70.06	72.01
Y	Y	N	N	69.79	71.95	74.02
Y	Y	N	Y	73.64	75.18	76.67
Y	Y	Y	N	79.16	80.52	81.81
Y	Y	Y	Y	82.10	82.99	83.85

Y, positive attribute; N, negative attribute.

power of correct classification. The results showed that 'Virgin Islands' had the lowest percentage (59%) and Utah had the highest percentage (78%) of estimated annual users. California had a percentage of 72.9% with a rank of 43 nationwide.

Discussion

The significance of this paper is related to dentistry's challenge to determine the characteristics that are unique to those who visit the dentist regularly. However, it is a bigger challenge to base this determination on nonclinical and sociodemographic information only. The four main binary and parsimonious sociodemographic characteristics suggested in this paper are available in many datasets of the public and private sectors; for example: state and local governments, health promotion organizations, insurance companies, and organizations that administer public health programs (such as Medicare and Medicaid in the U.S.). Applying the proposed model to these populations will help those entities in planning dental health services and required dental workforce. However, such sophisticated planning would require at the same time, predicted or available data about both actual and latent dental demand, accessibility and affordability of dental services, characteristics of the existing workforce and other dental-care system-related factors.

The proposed model – based on the BRFSS survey – provides a limited number of 16 risk categories with the expected probability of not visiting a dental clinic within 1 year ranging from 17% to 53%. It seems appropriate for those who are promoting health at the individual or community level to direct their efforts toward the populations in the highest risk categories, and to prioritize their resources to include populations in the different risk categories appropriately. The model can be used for prediction at the state level, or at the county, city, small community, and specific population level (such as the population of a particular dental insurance plan) wherever the sociodemographic characteristics about the population is already known and there is a need to make such prediction based on a parsimonious model to improve planning. However, the application of the model at the macro level is more appropriate than its application at the micro level. The model may become less robust or beneficial for smaller populations, such as if it would apply to a single practice. Therefore, the model should be applied cautiously until it proves valid for a particular population especially smaller populations whose specific characteristics make them unique.

The target of Healthy People 2010 related to dental visits is that at least 56% of the US population will use the oral health care system each year (25). However, the percentage of people who visit a dentist within a year varies for different populations. For example, this percentage was 87% among the Danes (14); 81% among the Swedish (14); 26% in Nigeria (5); 40% in Turkey (4); 44% among the elderly in Finland (and

Table 5. Expected probabilities of visiting a dental clinic within last year by state

State	Lower bound (95%)	Expected probability	Upper bound (95%)
Alabama	68.17	70.14	72.03
Alaska	72.64	74.44	76.17
Arizona	75.59	77.29	78.91
Arkansas	70.20	72.06	73.85
California	70.05	71.90	73.67
Colorado	74.92	76.57	78.16
Connecticut	74.84	76.44	77.98
Delaware	73.29	75.10	76.85
District of Columbia	62.69	64.81	66.89
Florida	69.20	71.03	72.78
Georgia	69.17	71.14	73.04
Hawaii	64.28	66.40	68.46
Idaho	74.35	76.12	77.80
Illinois	71.31	73.13	74.87
Indiana	73.46	75.29	77.04
Iowa	75.34	77.14	78.86
Kansas	75.95	77.74	79.45
Kentucky	71.87	73.75	75.55
Louisiana	66.03	68.02	69.94
Maine	74.56	76.36	78.08
Maryland	70.78	72.62	74.39
Massachusetts	75.58	77.25	78.85
Michigan	71.88	73.68	75.41
Minnesota	75.26	76.83	78.33
Mississippi	65.57	67.56	69.48
Missouri	71.81	73.68	75.48
Montana	72.77	74.60	76.36
Nebraska	71.97	73.66	75.27
Nevada	72.23	74.01	75.73
New Hampshire	76.29	77.94	79.51
New Jersey	71.45	73.19	74.86
New Mexico	73.22	75.08	76.86
New York	72.33	74.25	76.10
North Carolina	71.46	73.36	75.19
North Dakota	74.19	76.01	77.74
Ohio	72.28	74.11	75.86
Oklahoma	71.89	73.88	75.79
Oregon	74.91	76.72	78.44
Pennsylvania	71.68	73.53	75.29
Rhode Island	75.14	76.88	78.54
South Carolina	67.74	69.67	71.54
South Dakota	73.94	75.79	77.55
Tennessee	71.93	73.85	75.70
Texas	70.80	72.59	74.31
Utah	77.55	79.25	80.87
Vermont	74.42	76.15	77.80
Virginia	71.64	73.46	75.20
Washington	76.21	77.93	79.57
West Virginia	72.01	73.95	75.80
Wisconsin	73.57	75.34	77.03
Wyoming	75.77	77.56	79.26
Guam	57.47	60.00	62.47
Puerto Rico	69.14	71.36	73.50
Virgin Islands	56.47	58.90	61.29

65% after excluding edentulous persons) (15); 60% among young adults and 43% among elderly in Lithuania (6); and 31% among young children (3–4 years) in Australia (17). In the USA, this percentage was: 74% among Maryland school children in 2001 (26); 56% among children with private insurance, 28% among children with Medicaid, compared with 19% among children without Medicaid (in 1996) (18); 71% among dentate and 20% among edentulous adults over 55 years old in 1999 (3), and 63% among all adults in the USA in 2001 (7) compared with 43% in 1996 (25). This variation implies the necessity to validate the proposed model in different cultures.

The residuals of the model ranged between −3.23% and 1.68% for eight of the participating states and were 10% for the other two states (Idaho and Nevada). Idaho had the highest percentage of person whose indicated race was white, while Nevada had the second lowest percentage of married people. Additionally, Nevada had the lowest prevalence of dental visits. The USA is relatively heterogeneous and we should expect that modified or other models might be more appropriate for certain States, however, the methodology will still be the same. A careful application of the model should be considered in regions with extreme values in one or more of the sociodemographic characteristics. Another point to be considered in comparing the results of different surveys is the wording of the question. The California Health Interview Survey (CHIS) in 2003 estimated the percentage of persons visiting a dentist within the last year by 67.2% (95% CI: 66–68.4) among adult Californians. This was different from our estimation of about 73%. However, the BRFSS asked about visiting a dental office, while the CHIS system restricted the question and phrased it as the last visit to a dentist, which might explain some of the discrepancy.

When the results were compared with the Centers of Disease Control and Prevention's 2004 estimation of the prevalence of dental visits in all the USA (except Hawaii) and in the District of Colombia, Virgin Islands, and Puerto Rico (1), the differences between our expected probabilities and the CDC estimation had an average of 3.33% and a median of 2.69%. The best estimation was in the state of Virginia with a difference of 0.04% and the worst estimation was in the state of Oklahoma with a difference of 12.6%.

Although the BRFSS survey is useful for planning, initiating, supporting, and evaluating health promotion and disease prevention programs (1), unfortunately, BRFSS oral data has been rarely cited in the literature. Running an Ovid search with

keywords: 'BRFSS' and ('Oral Health' or 'Dentistry') in the Ovid dataset '1966 to July, Week 2, 2006' returned only five publications as of 20 June 2005. However, since the BRFSS data were limited to persons above age 18 years, our model results are not applicable to children. Although there is no evidence to support such a conclusion, one could surmise that children whose parents visit a dental clinic within a year are also more likely to visit a dental clinic within the same year. A study is recommended to address these issues. However, if this assumption holds, this model could be used to provide a lower bound expectation of the number of annual dental visitors among children whose parents fall into a particular risk category. Additionally, as our model was based on self–reported data, it is worth mentioning that the validity of self-reported dental care use is good, between 68% and 81%, and does not differ by key sociodemographic factors (27).

This study is the first to study BRFSS 2003 from an oral health perspective. The study developed a simple model designed for health administrators to estimate the prevalence of dental visit. However, the study is limited because of the dearth of available methods to evaluate the model's fit. Interaction terms were not evaluated but the expected probabilities of visiting a dental clinic within the last year for different combinations of sociodemographic characteristics were provided. The study inherits some of the limitations of the BRFSS sample itself (such as excluding children and institutionalized adults, and the sampling bias associated with telephone surveys) resulting in possible different implications for different communities. Thus further casting doubt on the robustness of microlevel modeling. The model should be cross-validated and externally validated in other public datasets and in different populations. The author is planning to validate the model using other available BRFSS datasets. Future public health surveys should address the use of dental services in more detail by adding questions related to the type of dental visit and the type of dental provider.

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