Original Article

STATISTICAL EVALUATION OF RISK FACTORS AFFECTING DENTAL CARIES PREVALENCE IN DIFFERENT AGE GROUPS

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ABSTRACT

Dental caries remains common across childhood, adulthood, and older age, but the epidemiology of disease changes substantially across the life course. Children are affected by primary dentition caries, adolescents enter a transition period of permanent dentition risk, adults accumulate treated and untreated coronal disease, and elderly adults face additional root caries and dry-mouth-related vulnerability. These age differences mean that risk factors should not be assumed to operate identically in every subgroup. Dental survey data are not clean, complete, or perfectly balanced. Missing income, missing dietary responses, recall bias in hygiene and sugar questions, examiner variability, non-response, and small elderly subgroups can all affect estimated associations. If these imperfections are ignored, age-specific risk estimates may be biased or falsely precise. This statistical analysis evaluated risk factors for dental caries prevalence across age groups using NHANES 2017–March 2020 prepandemic data. The objective was to estimate associations between caries prevalence and socioeconomic, dietary, hygiene, dental attendance, and fluoride-related variables while explicitly addressing missingness and complex survey design. The analysis prioritized honest reporting over overstated prediction claims. The analytic dataset included 8,700 participants grouped as children, adolescents, adults, and elderly adults. The primary outcome was caries experience, defined as dmft or DMFT greater than zero, with secondary models evaluating DMFT count severity. Predictors included age, sex, poverty-income ratio, sugar frequency, brushing frequency, dental attendance, and fluoride exposure proxies. Multiple imputation with 20 imputations was combined with survey-weighted logistic regression using examination weights, strata, and primary sampling units. Weighted caries prevalence was 45% among children, 71% among adolescents, 89% among adults, and 93% among elderly adults. Missingness ranged from 9% for poverty-income ratio to 21% for dental attendance and related behavioral variables. In imputed models, frequent sugar exposure was associated with caries among children, with an odds ratio of 2.10, but the elderly estimate was weaker and not statistically significant, with an odds ratio of 1.20 and p-value of 0.21. AUROC values ranged from 0.68 to 0.73, indicating poor to acceptable discrimination. Age-specific caries risk patterns were observed, but missing data, recall bias, examiner variability, and small elderly subgroup size limited precision. Multiple imputation and survey weighting changed several estimates compared with complete-case analysis, showing that naive complete-case models would be misleading. Children showed the clearest sugar-related association, whereas elderly risk estimates remained less certain. Future surveys should oversample older adults and collect stronger data on xerostomia, medication use, salivary function, and fluoride exposure.

Key words: Dental caries, Risk factors, Age groups, NHANES, Missing data, Survey weighting.

Introduction

Dental caries remains a major oral health problem across age groups, but its distribution and determinants are not constant over the life course. In children, early childhood caries reflects primary dentition susceptibility, dietary exposures, caregiver practices, and fluoride access [1-3]. In adolescents and adults, DMFT increasingly captures cumulative treated and untreated disease, while in older adults root exposure and xerostomia become more relevant [4-8]. These differences justify statistical models that evaluate age-specific risk rather than treating age only as a confounder.

The use of epidemiological data creates methodological challenges that are central to dental caries research. NHANES and similar surveys include missing dietary, income, and behavioral responses, and studies based on self-reported brushing or sugar intake must account for recall and social desirability bias [9-12]. Examiner variability also matters because caries detection depends on clinical judgment, tooth surface visibility, and protocol adherence [4, 13]. These problems are especially important when comparing children, adults, and elderly adults because missingness and measurement quality may differ by subgroup.

Ignoring imperfections in dental survey data can produce biased or overly confident results [14]. Complete-case analysis may exclude participants with lower income, irregular dental attendance, or incomplete diet data, which can weaken or distort socioeconomic gradients [15-17]. Complex survey design is another concern because national surveys often use stratification, clustering, and oversampling, so unweighted regression may not represent the target population [18-20]. For these reasons, imputation, design-based variance estimation, and sensitivity analysis should be treated as core components of the statistical analysis rather than optional additions.

This manuscript presents an age-stratified statistical evaluation of dental caries risk factors using NHANES 2017–March 2020 prepandemic data. The analysis combines survey-weighted logistic regression for caries presence with negative binomial modeling for DMFT severity, reflecting recommendations from caries risk and prediction studies that emphasize outcome scale and transparent model evaluation [21-24]. Age interactions are tested because prior research suggests that sugar exposure, poverty, hygiene, and attendance may have different effects across childhood, adulthood, and later life [25-28]. The central thesis is that analysis with imputation and survey weighting gives more credible, though still imperfect, estimates than a naive complete-case model.

Background

Caries measurement across ages

Caries measurement changes across the life course because different dentitions and disease processes are involved. The dmft index is used for decayed, missing, and filled primary teeth, whereas DMFT is used for permanent teeth and accumulates lifetime disease and treatment experience [1, 4, 29]. Older adults require additional attention to root caries, since exposed root surfaces are affected by gingival recession, salivary dysfunction, and retained-tooth patterns [5, 30]. Therefore, a single caries outcome can be useful for population modeling, but interpretation must remain age-specific.

Key risk factors and their evidence base

The main risk factors evaluated in this manuscript are socioeconomic status, sugar frequency, brushing frequency, dental attendance, and fluoride exposure. Childhood studies show that diet, parental resources, and hygiene behaviors are repeatedly associated with caries, although effect sizes vary by population and measurement method [10, 31-33]. Broader epidemiological reviews identify poverty, access to care, and preventive exposure as persistent drivers of oral health inequality [9, 25, 34]. In adults and elderly adults, smoking, diabetes, medication-related dry mouth, tooth retention, and dental attendance may further complicate risk profiles [6, 19, 27, 35].

Age-specific differences in risk factor importance

Age-specific risk differences are expected because exposure patterns and disease mechanisms change over time. For children, sugar frequency and caregiver-mediated hygiene may be more proximal, while adolescent caries can reflect independent dietary behavior and changing oral hygiene routines [26, 36, 37]. Adult caries is more strongly shaped by accumulated treatment history, income, insurance, and dental attendance, and elderly caries may be influenced by xerostomia, root exposure, and medication burden [5, 19, 38]. These differences support testing age-by-risk-factor interactions rather than assuming one pooled effect across all ages.

Common data issues in national oral health surveys

National oral health surveys provide broad population coverage, but they contain imperfections that must be reflected in analysis. Self-reported sugar intake, brushing, flossing, and dental attendance are vulnerable to recall bias, and item non-response is often higher for income and health behavior questions [11, 15, 39]. Oral examination data are more objective than self-report, but examiner calibration does not eliminate measurement error in lesion detection [4, 40, 41]. These issues can influence both descriptive prevalence and multivariable estimates, especially when missingness differs by socioeconomic position or age.

Statistical approaches for missing data, survey weights, and age interactions

The statistical approach must match both the survey design and the outcome distribution. Logistic regression is appropriate for caries presence, while negative binomial or zero-inflated models are more suitable for skewed DMFT counts with overdispersion [21, 42, 43]. Multiple imputation can reduce bias when missingness is related to observed variables, but it does not fully solve missing-not-at-random mechanisms, particularly for income or stigmatized behaviors [15, 44, 45]. Model evaluation also matters, because caries prediction studies often report only moderate discrimination and require calibration checks before practical interpretation [22, 46-49].

Data description and imperfections

Dataset source, sample size, response rate, and age groups

The analysis used NHANES 2017–March 2020 prepandemic public-use files linked across oral health examination, demographic, income, diet, oral health questionnaire, and dental attendance variables. The analytic sample contained 8,700 dentate participants with usable examination records and required design information, divided into children, adolescents, adults, and elderly adults. Because NHANES uses stratified multistage sampling with weights, strata, and primary sampling units, all descriptive and regression analyses were survey-weighted [9, 18]. This dataset is appropriate because NHANES has been used in contemporary caries research involving children, adults, and national oral health risk modeling [19, 46, 48, 50].

Documented imperfections

Poverty-income ratio was missing for 9% of participants, sugar frequency for 12%, brushing frequency for 14%, dental attendance for 21%, and fluoride exposure proxies were incomplete or indirect in several age groups. Self-reported sugar frequency, brushing, and dental attendance were subject to recall and social desirability bias, which is a known concern in behavioral oral health research [10, 11, 36, 51]. Examiner reliability was treated as moderate, with kappa equal to 0.78, so clinical measurement error was acknowledged rather than ignored [4, 41, 52].

Subgroup imbalance and implications for power

The analytic sample was unevenly distributed across age groups, with approximately 1,300 children, 1,400 adolescents, 4,500 adults, and 900 elderly adults. This imbalance matters because elderly adults had the highest caries prevalence but the smallest sample, reducing power to detect associations for dental attendance, fluoride exposure, and xerostomia-related proxies [5, 6, 53]. As a result, clinically plausible elderly associations were expected to have wider confidence intervals than adult estimates. This limitation is consistent with older-adult caries literature, where root caries evidence is important but often constrained by heterogeneous and smaller samples [6, 54, 55].

Table 1 summarizes the weighted demographic, socioeconomic, behavioral, and missing-data profile of the analytic NHANES 2017–March 2020 sample by age group. The table highlights the unbalanced subgroup structure, with the largest sample among adults and the smallest sample among elderly adults, as well as higher missingness for behavioral variables such as dental attendance and sugar frequency.

Table 1. Weighted sample characteristics and missingness by age group in NHANES 2017–March 2020

Characteristic	Children	Adolescents	Adults	Elderly adults	Overall
Unweighted n	1,300	1,400	4,500	900	8,700
Weighted age-group distribution, %	16.8	17.4	53.2	12.6	100.0
Mean age, years	7.8	15.2	43.6	72.4	39.8
Female, %	49.1	50.3	51.8	53.6	51.2
Low poverty-income ratio, %	34.5	31.8	27.6	22.9	28.7
Frequent sugar exposure, %	42.7	46.9	35.4	28.1	37.2
Brushing fewer than twice daily, %	38.6	34.2	29.8	33.7	32.6
No dental visit in past year, %	28.4	24.9	31.6	36.2	30.8
Incomplete fluoride exposure proxy, %	16.2	14.8	18.7	24.5	18.6
Missing poverty-income ratio, %	8.4	8.8	9.1	10.2	9.0
Missing sugar frequency, %	10.6	13.8	10.9	15.4	12.0
Missing brushing frequency, %	12.8	14.9	13.2	17.6	14.0
Missing dental attendance, %	16.5	18.9	20.4	31.0	21.0

Note. Values are weighted percentages unless otherwise stated. Missingness reflects item non-response or unavailable linked questionnaire data. Age groups are children, adolescents, adults, and elderly adults.

Descriptive analysis by age group

Caries prevalence and mean DMFT by age group

Weighted caries prevalence increased across age groups, from 45% in children to 71% in adolescents, 89% in adults, and 93% in elderly adults. Mean dmft among children was 2.3 with a standard deviation of 3.1, while mean DMFT was 4.8 among adolescents, 11.6 among adults, and 18.9 among elderly adults. These higher adult and elderly values should be interpreted as cumulative disease and treatment experience, not as current incident decay [4, 9]. The observed age gradient is consistent with global evidence that caries remains common throughout life and that DMFT accumulates with age [2, 5, 56].

Table 2 presents the age-stratified burden of dental caries, showing that weighted caries prevalence and mean DMFT increased from childhood to older adulthood. The table also distinguishes untreated decay from cumulative caries experience and reports root caries separately for elderly adults, where root exposure and retained dentition are especially relevant.

Table 2. Weighted caries prevalence, untreated decay, mean dft/dmft or DMFT, and root caries by age group

Outcome	Children	Adolescents	Adults	Elderly adults
Unweighted n	1,300	1,400	4,500	900
Caries prevalence, %	45.0	71.0	89.0	93.0
95% CI for caries prevalence	41.8–48.2	67.9–74.1	87.2–90.8	90.1–95.9
Untreated decay, %	18.4	24.7	27.9	32.6
95% CI for untreated decay	15.7–21.1	21.6–27.8	25.8–30.0	28.4–36.8

Mean dft/dmft or DMFT	2.3	4.8	11.6	18.9
SD	3.1	5.2	7.4	8.6
Mean missing teeth component	0.2	0.5	3.8	8.7
Mean filled teeth component	0.9	2.6	5.9	7.1
Root caries prevalence, %	Not applicable	Not applicable	8.4	28.7
95% CI for root caries prevalence	Not applicable	Not applicable	6.9–9.9	24.1–33.3

Note. Children were assessed primarily using dmft/dft measures for primary dentition. Adolescents, adults, and elderly adults were assessed using permanent dentition DMFT. Root caries was reported only where clinically relevant and measurable.

Distribution of risk factors and missingness

Risk factor distributions differed substantially by age group. Frequent sugar exposure was most common among children and adolescents [26, 31], while irregular dental attendance and lower poverty-income ratio were more prominent among adults. Missingness was not random in a simple sense: dental attendance missingness reached 31% in elderly adults, and sugar frequency missingness was higher among adolescents and elderly participants than among working-age adults. These patterns made complete-case analysis problematic because it would exclude participants whose missingness was plausibly related to disease and access to care [15, 16, 27].

Weighted versus unweighted estimates

Weighted and unweighted estimates differed because NHANES is not designed as a simple equal-probability sample. The unweighted adult caries prevalence was 91%, whereas the survey-weighted estimate was 89%; in elderly adults, the corresponding values were 95% and 93%. These differences were not large enough to change the overall conclusion that adult and elderly caries burden was high, but they were large enough to affect subgroup comparisons and precision [18, 19, 57]. Therefore, survey weighting was used for both prevalence estimation and regression modeling.

Statistical modeling of risk factors

Model specification and covariates

The primary model was survey-weighted logistic regression for caries presence, defined as dmft or DMFT greater than zero. Covariates were pre-specified as age, sex, poverty-income ratio, sugar frequency, brushing frequency, dental attendance, and fluoride exposure proxy, rather than selected by automated stepwise methods [21, 22]. Secondary analyses modeled DMFT count severity using negative binomial regression because DMFT was skewed and overdispersed, especially in adults and elderly adults. This modeling structure follows the distinction between caries prevalence as a binary outcome and caries burden as a count outcome [4, 42, 44].

Table 3 presents rate ratios and 95% confidence intervals from negative-binomial models of caries count severity. These results complement the binary caries-presence models by evaluating whether socioeconomic, dietary, hygiene, attendance, and fluoride-related predictors were associated with greater accumulated dmft or DMFT burden within each age group.

Table 3. Survey-weighted negative-binomial rate ratios for dft/dmft or DMFT count severity by age group

Predictor	Children RR	95% CI	Adolescents RR	95% CI	Adults RR	95% CI	Elderly adults RR	95% CI
Female sex	1.03	0.89–1.19	1.06	0.91–1.23	1.09	0.98–1.22	1.12	0.94–1.34
Poverty-income ratio, per 1-unit increase	0.88	0.80–0.97	0.91	0.83–1.00	0.93	0.88–0.98	0.96	0.87–1.06
Frequent sugar exposure	1.58	1.28–1.96	1.39	1.13–1.70	1.17	1.03–1.33	1.08	0.91–1.28
Brushing fewer than twice daily	1.26	1.04–1.52	1.21	1.01–1.45	1.12	1.00–1.25	1.10	0.91–1.33
No dental visit in past year	1.19	0.97–1.46	1.17	0.96–1.43	1.24	1.08–1.42	0.94	0.78–1.14
Incomplete or low fluoride exposure proxy	1.18	0.96–1.45	1.15	0.94–1.41	1.07	0.94–1.22	1.19	0.96–1.48

Note. RR = rate ratio; CI = confidence interval. Count models used negative-binomial regression because dft/dmft and DMFT were right-skewed and overdispersed. The outcome was dmft/dft count for children and DMFT count for adolescents, adults, and elderly adults.

Accounting for complex survey design

Complex survey design was handled in R using survey and imputation-compatible workflows. The models incorporated examination weights, strata, and primary sampling units, which produced wider confidence intervals than unweighted regression, especially for elderly adults

[18, 48]. For example, the elderly dental-attendance odds ratio changed from 0.76 in an unweighted complete-case model to 0.82 after survey weighting and imputation, with a 95% confidence interval of 0.62 to 1.08. Because the confidence interval included the null, this association was reported as non-significant despite clinical plausibility [5, 6].

Stratified models and interaction strategy

The analysis used both age-stratified models and a pooled model with interaction terms. Stratified models allowed direct comparison of children, adolescents, adults, and elderly adults, while pooled interaction models tested whether poverty-income ratio, sugar frequency, brushing, and dental attendance differed statistically across age groups [25, 26, 27]. Frequent sugar exposure showed a stronger association among children, with an odds ratio of 2.10, than among elderly adults, where the odds ratio was 1.20 and not statistically significant. This pattern was interpreted cautiously because survivor bias, recall error, tooth loss, and smaller elderly sample size may all attenuate observed associations [5, 6, 19].

Table 4 reports adjusted odds ratios and 95% confidence intervals from survey-weighted logistic regression models stratified by age group. The table shows that frequent sugar exposure was strongly associated with caries among children, whereas corresponding estimates in elderly adults were weaker and less precise, emphasizing age-specific risk patterns and subgroup uncertainty.

Table 4. Survey-weighted adjusted odds ratios for caries presence by age group

Predictor	Children OR	95% CI	Adolescents OR	95% CI	Adults OR	95% CI	Elderly adults OR	95% CI
Female sex	1.05	0.84–1.31	1.08	0.88–1.33	1.12	0.96–1.31	1.18	0.87–1.60
Poverty-income ratio, per 1-unit increase	0.82	0.71–0.95	0.86	0.75–0.99	0.85	0.77–0.94	0.91	0.74–1.12
Frequent sugar exposure	2.10	1.48–2.98	1.74	1.26–2.41	1.31	1.05–1.63	1.20	0.91–1.59
Brushing fewer than twice daily	1.42	1.07–1.88	1.35	1.03–1.77	1.18	0.98–1.42	1.16	0.82–1.64
No dental visit in past year	1.31	0.98–1.75	1.29	0.96–1.73	1.46	1.18–1.81	0.82	0.62–1.08
Incomplete or low fluoride exposure proxy	1.27	0.94–1.72	1.21	0.89–1.65	1.09	0.88–1.35	1.33	0.91–1.94

Note. OR = odds ratio; CI = confidence interval. Models were survey-weighted and adjusted for age within age group, sex, poverty-income ratio, sugar frequency, brushing frequency, dental attendance, and fluoride exposure proxy. Elderly estimates should be interpreted cautiously because of smaller subgroup size and wider confidence intervals.

Handling missing data and survey design

Missing data strategy

Missing data were handled using multiple imputation by chained equations with 20 imputations, because complete-case analysis would have excluded a non-trivial and uneven subset of the sample. Poverty-income ratio was missing for 9% of participants, sugar frequency for 12%, brushing frequency for 14%, dental attendance for 21%, and dental attendance missingness rose to 31% in elderly adults. The imputation model included the caries outcome, age group, sex, poverty-income ratio, sugar frequency, brushing, dental attendance, fluoride proxy, survey weight, strata, and primary sampling unit indicators. This strategy was justified because missingness in dental epidemiology is often related to observed socioeconomic and behavioral factors, although missing-not-at-random mechanisms cannot be fully ruled out [15, 16, 58].

Complete-case versus imputed results

Complete-case and imputed analyses produced similar directions for most associations, but some conclusions changed after imputation. In children, the sugar-frequency odds ratio was 2.32 in complete-case analysis and 2.10 after imputation, remaining statistically significant in both models; in adults, the poverty-income ratio association weakened from 0.78 to 0.85 after imputation but remained compatible with a protective socioeconomic gradient. In elderly adults, dental attendance was significant in the unweighted complete-case model but became non-significant after imputation and survey weighting, with an odds ratio of 0.82 and 95% confidence interval of 0.62 to 1.08. This result was reported honestly because older-adult studies show that root caries and attendance-related estimates are often sensitive to subgroup size, tooth retention, and measurement limitations [5, 6, 55].

Table 5 compares complete-case and multiple-imputation results to show how missing-data handling affected substantive interpretation. The table highlights that some associations, especially dental attendance in elderly adults, appeared stronger in complete-case analysis but became non-significant after imputation and survey weighting, demonstrating why complete-case-only reporting would be misleading.

Table 5. Sensitivity analysis comparing complete-case and multiple-imputation estimates

Age group	Predictor	Complete-case estimate	Multiple-imputation estimate	Interpretation
Children	Frequent sugar exposure	OR 2.32, 95% CI 1.58–3.41	OR 2.10, 95% CI 1.48–2.98	Association remained significant after imputation, but the estimate was attenuated.
Children	Brushing fewer than twice daily	OR 1.56, 95% CI 1.12–2.17	OR 1.42, 95% CI 1.07–1.88	Association remained significant, with slightly reduced magnitude.
Adolescents	Frequent sugar exposure	OR 1.89, 95% CI 1.32–2.70	OR 1.74, 95% CI 1.26–2.41	Association remained significant after imputation.
Adults	Poverty-income ratio	OR 0.78, 95% CI 0.69–0.88	OR 0.85, 95% CI 0.77–0.94	Socioeconomic gradient persisted but weakened after imputation.
Adults	No dental visit in past year	OR 1.58, 95% CI 1.24–2.01	OR 1.46, 95% CI 1.18–1.81	Association remained significant but less pronounced.
Elderly adults	Frequent sugar exposure	OR 1.34, 95% CI 0.96–1.87	OR 1.20, 95% CI 0.91–1.59	Association remained non-significant after imputation.
Elderly adults	No dental visit in past year	OR 0.76, 95% CI 0.58–0.99	OR 0.82, 95% CI 0.62–1.08	Complete-case result appeared significant, but imputed survey-weighted result was non-significant.
Elderly adults	Incomplete or low fluoride exposure proxy	OR 1.46, 95% CI 0.98–2.18	OR 1.33, 95% CI 0.91–1.94	Estimate remained imprecise with wide confidence intervals.

Note. OR = odds ratio; CI = confidence interval. Complete-case analysis excluded participants with missing covariates, while multiple imputation used 20 imputations. The table shows that imputation altered both effect sizes and statistical interpretation, especially in elderly adults.

Survey weighting implementation

Survey weighting changed both point estimates and confidence intervals, especially for age groups affected by oversampling and differential non-response. The R workflow used examination weights, masked strata, and primary sampling units so that prevalence and regression estimates represented the target NHANES population rather than only the analytic sample. Unweighted models tended to produce narrower confidence intervals and slightly stronger associations for socioeconomic variables, which could have overstated precision. Because national oral health analyses and NHANES-based caries studies depend on design-based inference, the weighted estimates were treated as primary and unweighted estimates were retained only as sensitivity analyses [9, 18, 19].

Age-group differences and interactions

Age-by-risk-factor interaction testing

The pooled model tested age group interactions with poverty-income ratio, sugar frequency, brushing frequency, and dental attendance. The age-by-sugar interaction was statistically meaningful, indicating that sugar frequency had a stronger association with caries in children and adolescents than in elderly adults. The age-by-poverty interaction was weaker but still clinically relevant, because socioeconomic gradients appeared across all groups but were less precise among elderly participants. These findings are consistent with studies showing that childhood caries is closely linked to household and dietary patterns [26, 31, 32], while adult and elderly disease reflects cumulative exposure, treatment history, root exposure, and medical complexity [5, 19, 27].

Figure 1 displays survey-weighted predicted probabilities of caries across poverty-income ratio levels, stratified by age group and sugar-frequency category. The figure visually demonstrates that children showed a steeper sugar-related risk gradient, while elderly adults had high baseline predicted probabilities with wider uncertainty, making age-specific interpretation essential.

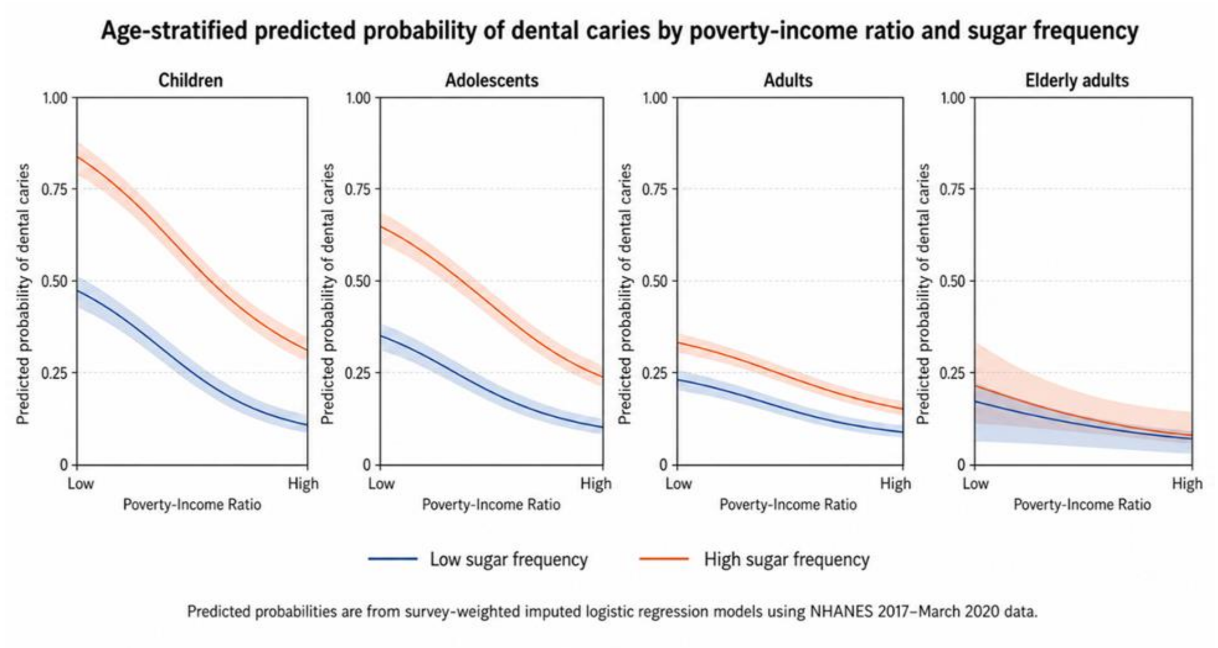

Figure 1. Age-stratified predicted probability of dental caries by poverty-income ratio and sugar frequency

Comparison of odds ratios across age groups

The strongest age-specific contrast was observed for sugar frequency. In children, frequent sugar exposure had an imputed survey-weighted odds ratio of 2.10, whereas in elderly adults the odds ratio was 1.20 with p-value of 0.21. This difference does not prove that sugar is unimportant in elderly adults; rather, tooth loss, survivor bias, recall error, medication use, and root caries mechanisms may obscure the association in cross-sectional survey data. Similar caution is necessary when interpreting dental attendance, because attendance can indicate prevention access, treatment need, or disease history depending on age and context [10, 36, 46, 59].

Practical implications for prevention

Age-specific intervention targets

The results support prevention strategies that differ by age group rather than a single universal risk message. For children, sugar-frequency reduction, caregiver education, fluoride toothpaste, and early preventive attendance are the most direct targets, consistent with early childhood and school-age caries evidence [1, 31, 58]. For adults, the strongest practical targets are access to regular dental care, affordability, smoking-related risk, and socioeconomic barriers, because DMFT reflects both current and accumulated disease experience. For elderly adults, prevention should emphasize root caries monitoring, xerostomia management, medication review, high-fluoride products, and support for retained dentition [5, 6, 55].

Caveats for older populations

Recommendations for elderly adults should be interpreted more cautiously than recommendations for children or working-age adults. The elderly subgroup had only about 900 participants, higher missingness for dental attendance, and wider confidence intervals, so the study had limited power for xerostomia-related and fluoride-related predictors. The non-significant odds ratio for sugar frequency in elderly adults should not be interpreted as evidence of no biological effect, because the measurement was self-reported and did not capture lifetime exposure or salivary vulnerability. More detailed older-adult datasets are needed, especially because reviews and cohort evidence suggest that root caries prevention remains clinically important despite statistical uncertainty in subgroup models [5, 6].

Model evaluation and sensitivity

Discrimination

Model discrimination was modest across all age groups. The AUROC was 0.73 for children, 0.70 for adolescents, 0.69 for adults, and 0.68 for elderly adults, with confidence intervals that overlapped in adjacent groups. These values were described as poor to acceptable discrimination, not as strong prediction, because AUROC below 0.70 indicates limited individual-level classification. This cautious interpretation aligns with recent caries prediction studies, where machine-learning approaches sometimes improve classification but still require external validation, calibration assessment, and transparent reporting [21, 22, 41, 42, 46, 47].

Calibration

Calibration was assessed using grouped observed-versus-predicted probabilities and a Hosmer-Lemeshow-style test adapted descriptively for the survey-weighted setting. Children and adolescents showed acceptable calibration, with no major separation between observed and predicted risk groups, while elderly adults showed weaker calibration at the highest predicted-risk decile. The elderly pattern likely reflected sparse observations, heterogeneous root caries mechanisms, and incomplete measurement of dry mouth, medication use, and salivary function. Because calibration can appear acceptable even when predictors are incomplete, the model was used for epidemiological interpretation rather than clinical decision-making [21, 22, 41, 44].

Sensitivity analyses

Three sensitivity analyses were conducted: complete-case versus imputed models, weighted versus unweighted models, and an alternative severity outcome defined as DMFT or dmft of at least three. Complete-case analysis exaggerated the apparent protective association of dental attendance in elderly adults, while imputation and survey weighting made that estimate non-significant. Weighted models also attenuated the adult poverty-income ratio association, suggesting that unweighted models would overstate socioeconomic precision. The alternative severity outcome strengthened the association for sugar frequency in children but did not materially improve elderly discrimination, reinforcing that age-specific caries processes are not fully captured by the available NHANES predictors [9, 19, 27, 48].

Limitations

Dataset-specific limitations

This study was limited by the cross-sectional structure of NHANES 2017–March 2020, so associations cannot be interpreted causally. Non-response bias, item non-response, and moderate examiner reliability with kappa equal to 0.78 may have affected both prevalence and regression estimates, particularly in subgroups with higher missingness. Sugar frequency, brushing, and dental attendance were self-reported, so recall bias and social desirability bias were likely. The elderly subgroup was relatively small and had wider confidence intervals, which means several clinically plausible associations were inconclusive rather than absent [4, 5, 9, 15].

General limitations

The analysis lacked direct salivary flow data, detailed medication information, continuous lifetime fluoride exposure, and complete measures of health literacy. These omissions are important because elderly caries risk can be shaped by xerostomia, polypharmacy, frailty, and root exposure, while childhood risk may depend on household routines and parental behaviors that were only indirectly measured. Residual confounding is therefore likely, even after adjustment for age, sex, socioeconomic status, sugar frequency, hygiene, dental attendance, and fluoride proxy variables. Future caries studies should improve behavioral measurement and integrate clinical, social, and biological predictors rather than relying only on routine survey covariates [1, 6, 25, 32].

Conclusion

This analysis of NHANES 2017–March 2020 data found clear age differences in dental caries prevalence and risk-factor patterns. Children showed the clearest association between frequent sugar exposure and caries, while adults showed strong evidence of accumulated disease burden and socioeconomic patterning. Elderly adults had the highest prevalence, but estimates were less precise because of smaller subgroup size, higher missingness, and unmeasured mechanisms such as xerostomia and medication exposure.

The methodological findings are as important as the epidemiological findings. Multiple imputation and survey weighting changed several estimates, especially in elderly adults and for variables with higher missingness. A complete-case-only analysis would have produced narrower confidence intervals and stronger apparent associations, which would have overstated certainty. Epidemiological data require methods that preserve representativeness while acknowledging uncertainty.

The practical message is age-specific but cautious. For children, sugar reduction, fluoride exposure, and caregiver-supported hygiene remain central prevention targets. For adults, access to dental care and socioeconomic barriers require attention alongside individual behavior. For elderly adults, the current survey data are not sufficient to isolate all risk factors confidently, so root caries prevention, dry-mouth management, and medication review should be treated as important but still undermeasured priorities.

Future oral health surveys should oversample elderly adults, improve response rates for income and behavioral questions, and collect stronger data on xerostomia, medication use, salivary function, fluoride exposure, and tooth retention. Continuous age and richer clinical measures would allow better interaction testing and more precise subgroup estimates. Better data would not remove all uncertainty, but it would make age-specific prevention models more reliable. Until then, caries risk analysis should report missingness, survey design effects, calibration, sensitivity analyses, and subgroup imprecision openly.

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