Severe Tooth Loss and Cardiovascular Disease Among Older Adults in Hawai'i: A Cross-Sectional Study of Behavioral Risk Factor Surveillance System Data from 2012 to 2020

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Abstract

Despite mounting evidence of the link between oral health and systemic health, there are limited studies on individual- and community-level race/ethnic and socioeconomic correlates of tooth loss and cardiovascular disease (CVD), particularly with regard to Asian and Indigenous populations. This cross-sectional study examined the association between severe tooth loss and CVD and the individual- and community-level sociodemographic correlates of CVD in Hawai'i, where Native Hawaiian and Asian populations are predominant, utilizing 5 waves of even year data from the Hawai'i Behavioral Risk Factor Surveillance System collected between 2012 and 2020. Weighted Poisson regression was used to estimate the unadjusted and adjusted prevalence of CVD. Independent variables included demographic variables (age, sex, race and ethnicity), socioeconomic status indicators (education, annual household income, health insurance), and health-related variables (BMI, smoking status, diabetes). A significant association was revealed between severe tooth loss and CVD, which persisted (but was attenuated) with adjustment for sociodemographic and health variables. There were also disparities in CVD prevalence by race and ethnicity (Native Hawaiians had a higher prevalence than White respondents, even after adjustment) and community. The tooth loss-CVD linkage, and racial/ethnic disparities in the prevalence of CVD, point to the importance of a holistic, multi-level approach to public health and collaboration between medical and dental health professionals.

Keywords

Tooth loss, cardiovascular disease, older adults, racial/ethnic disparities

Acronyms

BMI = body mass index
BRFSS = Behavioral Risk Factor Surveillance System
CVD = cardiovascular disease
IRB = Institutional Review Board
NH = Native Hawaiian
OPI = Other Pacific Islander
SDoH = social drivers of health
SES = socioeconomic status

Introduction

Cardiovascular disease (CVD) is the leading cause of death in the US[1] and the state of Hawai'i specifically.[2] CVD refers to an array of conditions affecting the heart and blood vessels (such as endocarditis, myocarditis, coronary artery disease, peripheral artery disease, myocardial infarction, and stroke), which dis-proportionately affect older adults (aged 65 years and older).[3] Oral health problems, also common among older adults, are independently associated with CVD and all-cause mortality.[4-6] Meanwhile, socioeconomic and racial/ethnic inequalities render marginalized adults more susceptible to both tooth loss[7-11] and CVD.[12-14] With adults aged 65+ years projected to make up 23% of the US population by 2054 (from 18% today),[15] it is increasingly necessary to address the interrelations of cardiovascular and oral health, and their sociodemographic correlates, among the aging population.

A growing body of literature shows that oral health is related to cardiovascular health. Previous studies have shown that periodontal disease is associated with atherosclerosis,[16] stroke,[17-20] coronary heart disease,[17-21] total CVD,[22] and CVD mortality,[5,19,23] while periodontal treatment has been shown to reduce the markers and risk of CVD.[24-27] Dental caries is also associated with stroke.[28-29] Tooth loss in particular is associated with a wide range of CVD, including coronary heart disease,[30-37] atherosclerosis and atherosclerotic vascular disease,[36,38] cardiac biomarkers,[39] stroke,[6,31] myocardial infarction,[36,40] self-reported CVD,[41] and increased death from CVD.[6,37,42-44] As a result, people with CVD are more likely to present with fewer teeth and poorer oral hygiene.[45]

The association between tooth loss and CVD may be explained by a direct causal mechanism (related to systemic inflammation and/or diet) and an indirect mechanism (related to shared risk factors). Whether the 2 are connected by a causal relationship or by confounding variables remains subject to debate.[46] Tooth loss can be indicative of periodontitis,[38] which may be associated with a systemic inflammatory response and CVD risk in turn.[47,48] Alternatively, tooth loss is associated with difficulty chewing, which has been associated with poorer nutritional status and higher risk for CVD.[49] Additionally, tooth loss and CVD are linked to several common risk factors and behaviors, such as obesity,[50,51] diabetes,[52,53] smoking,[54-56] and poor oral hygiene.[57,58] Importantly, several studies of tooth loss and CVD show that the association is attenuated with adjustment for comorbidities, health risk behaviors (such as smoking), and sociodemographic covariates.[34,40,44]

The risk factors for tooth loss and CVD are distributed unevenly by socioeconomic status (SES)[54,59,60] and race and ethnicity.[61,62] In the state of Hawai'i, inequalities in modifiable risk factors (such as smoking) are more prevalent among Hawai'i's racially/ethnically and socioeconomically marginalized populations,[63] likely contributing to inequalities in CVD and tooth loss: Native Hawaiians (NH), Filipinos, and low-income and low-education groups are more likely to have severe tooth loss,[11,64] while low-income groups, NH, Filipinos, and Pacific Islanders (PI) have elevated risk of CVD and CVD mortality.[62,65] This suggests that an array of socially determined risk factors, including smoking, help account for the tooth loss and CVD association.

Understanding of the role oral health plays in the development of CVD among older, marginalized populations in Hawai'i is critical, given that CVD is the leading cause of death in the state and that there are significant differences in overall CVD among Asian subgroups.[62] At-risk subgroups—such as NH, Filipinos, and PI—constitute a large portion of the Hawai'i population and present higher rates of CVD, coronary heart disease, and stroke than the White population.[62] However, few studies have analyzed differences in severe tooth loss and CVD by race and ethnicity, SES, and community, particularly with regard to Asian and Indigenous populations. In 2023, Waitzfelder et al) crucially examined racial/ethnic differentiation of CVD in disaggregated Asian subpopulations and multiracial individuals in California and Hawai'i, including NH and PI; however, the study was limited to people with health insurance (a potential sample bias) and did not include severe tooth loss as a risk factor, individual SES measures, or community-level analysis.[62] Other studies of CVD among NHPI have been limited by relatively small sample sizes and sample biases.[66] Meanwhile, there is a paucity of studies regarding the role of race and ethnicity in the tooth loss/CVD association. Although Wiener and Sambamoorthi adjusted for race and ethnicity in their cross-sectional study of tooth loss and CVD, racial/ethnic groupings were limited to Black, White, and Hispanic.[41] While adjustment for socioeconomic factors is customary,[6,30,34-37,40,42,44] less is known about the experiences of different racial/ethnic groups (independent of socioeconomic strata), especially for Asian and Indigenous populations, that bear upon interrelated oral and cardiovascular health outcomes.

Therefore, the present study aimed to explore the association between severe tooth loss and CVD and the socioeconomic, racial/ethnic, and community-level correlates of CVD in Hawai'i, where NH and Asian populations are predominant. By examining the intersection of severe tooth loss and CVD with key sociodemographic factors at both individual and community levels, the team hopes to contribute to the formulation of inclusive health policies aimed at enhancing cardiovascular, oral, and overall health outcomes for marginalized older adults in Hawai'i.

Methods

Data Source

Five waves of population-representative, cross-sectional data from the Hawai'i Behavioral Risk Factor Surveillance System (BRFSS),[67] collected between 2012 and 2020, were analyzed to examine the prevalence of CVD in association with severe tooth loss, demographics, SES variables, and health-related variables. The BRFSS is a cross-sectional annual telephone survey conducted by the states in partnership with the Centers for Disease Control and Prevention. It collects data from non-institutionalized adults (aged 18 years or older) living in the 50 US states, the District of Columbia, and US territories on health-related risk behaviors, chronic health conditions, and use of preventive services. BRFSS provides valid state estimates, within-state estimates, and comparisons across states. The Hawai'i BRFSS collects detailed racial/ethnic data, including a breakdown of Asian subgroups that were not included in other studies. Hawai'i BRFSS is the most comprehensive data source available on health-related and chronic health conditions in Hawai'i and has been very useful in measuring public health objectives and to identify health equity issues. This data can also provide a means for comparing health issues in Hawaii to states nationally and therefore was chosen to further investigate the important linkage between oral health and racial /ethnic disparities in the prevalence of cardiovascular disease. This study was deemed not-human subjects research by the University of Hawai'i Institutional Review Board (IRB), and therefore not subject to IRB review.

Variables

The dependent variable was CVD, which was measured by asking respondents (yes or no), "Has a doctor, nurse, or other health professional ever told you that you had a heart attack" or "angina/coronary heart disease?" The focal independent variable was severe tooth loss, derived from the question, "Not including teeth lost for injury or orthodontics, how many of your permanent teeth have been removed because of tooth decay or gum disease (1 to 5, 6 or more [but not all], and All)?" Those answering "6 or more (but not all)" or "All" were combined into "severe tooth loss."

One of the covariates was race and ethnicity, including White (the reference group), NH, PI, Filipino, Japanese, Chinese, and Other (races/ethnicities with small sample sizes). In the BRFSS, respondents may choose up to 6 ethnicities, and 1 ethnicity is then created for reporting purposes. The Hawai'i BRFSS race and ethnicity documentation methodology is as follows: If NH was 1 of the multiple ethnicities listed (including part NH), NH is coded; if a non-White ethnicity is listed with a White ethnicity, the non-White ethnicity is coded; if there is more than 1 non-White ethnicity listed, the first 1 is coded; and if there is more than 1 White ethnicity listed, the first 1 is coded.[68]

Other covariates included in the analysis were age (50-59 [the reference group], 60-69, 70-79, and ≥80 years), sex (female [the reference group] and male), education (high school/GED or lower, college 1-3 years, and college 4+ years [the reference group]), annual household income ($0–$24,999, $25,000–$49,999, $50,000–$74,999, ≥$75,000 [the reference group], and unknown), health insurance status (yes or no), body mass index (BMI) (normal weight [the reference group], overweight, obese, underweight, and unknown), smoking status (never [the reference group], former, current, and unknown), and diabetes (yes or no). Since the BRFSS is not designed to generate population estimates at the zip code-level and to protect the privacy of the participants, zip code level data is not be released. Hawai'i Health Data Warehouse aggregated zip codes to 23 communities to show disparities by geographical areas (https://hhdw.org/data-sources/behavioral-risk-factor-surveillance-system/brfss-data-request/).
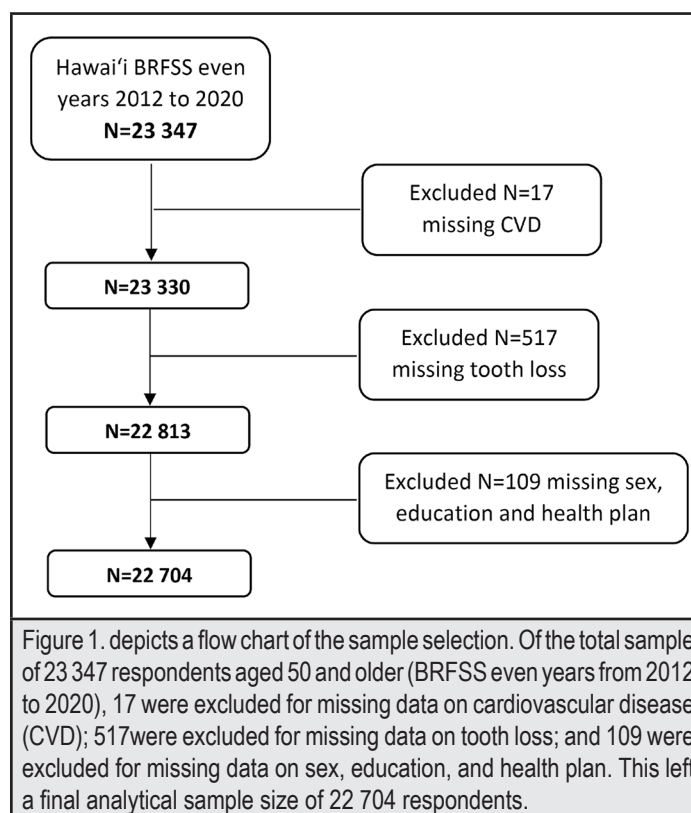
Analytical Sample

The BRFSS oral health questions were asked biannually in even years; therefore, the even year data from 2012 to 2020 were used. The original sample size of participants aged 50 years and older was 23 347, accounting for 60.7% of the total sample of 384 86 aged 18 and older. The final analytical sample size was 22 704 after excluding 2.8% of missing responses, including 17 respondents who did not respond to the CVD question, 517 participants who did not respond to the question on tooth loss, and 109 respondents missing information on sex, education, and health plan (**Figure 1**). Missing responses in income (2462, 10.8%) were coded as "unknown" due to the large proportion of missing.

Statistical Analysis

All analysis was conducted using R version 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria) to account for the complex survey design and followed BRFSS data reporting rules for the analytical sample. Equal survey weights were assigned to each survey year. Descriptive analysis was conducted to summarize the sample characteristics and results were summarized in **Table 1**. For bivariate analyses, the weighted prevalence was calculated of CVD by all the covariates (**Table 2**). **Table 3** summarizes results from the weighted Poisson regression model with quasi-likelihood that was used to estimate the crude prevalence ratios (PR) and adjusted PR controlling for demographic variables (age, sex, race and ethnicity) (Model 1), SES indicators (education, annual household income, and health insurance/health plan) (Model 2), and health-related variables (BMI, smoking status, and diabetes) (Model 3). **Table 4** shows the prevalence of CVD with 95% CI across all communities.

Figure 1. depicts a flow chart of the sample selection. Of the total sample of 23 347 respondents aged 50 and older (BRFSS even years from 2012 to 2020), 17 were excluded for missing data on cardiovascular disease (CVD); 517 were excluded for missing data on tooth loss; and 109 were excluded for missing data on sex, education, and health plan. This left a final analytical sample size of 22 704 respondents.

Results

Table 1 presents an overview of the sample characteristics including weighted and unweighted statistics from 5 waves of BRFSS data. The numbers reported are weighted statistics. It shows that 16.9% of respondents reported experiencing severe tooth loss. Females constituted the majority of the sample at 52.4%, while males comprised the remaining 47.6%. White respondents represented nearly 28.5% of the sample and NH made up 12.8%. The percentages of Filipino, Japanese and Chinese, respondents were 14.5%, 26.7%, and 6.2%, respectively. Almost all participants (95.6%) had health insurance and the majority (54.0%) identified as never-smokers. Finally, 16.7% of the sample reported having diabetes.

Table 2 illustrates bivariate associations, presenting the weighted prevalence of CVD by all covariates. Across the entire sample, the prevalence of CVD was 9.1%. The prevalence of CVD for those with severe tooth loss was 15.9%, more than 2 times higher than those without severe tooth loss. Moreover, significant disparities in the prevalence of CVD were observed across almost all covariates. Males, for instance, showed a significantly higher prevalence of CVD compared to females. Regarding racial/ethnic differences, NH demonstrated a 50% higher prevalence of CVD compared to Whites.

Model 1 of **Table 3** shows that, when adjusting for all the demographics, the adjusted prevalence ratio (APR) of CVD associated with severe tooth loss was 1.66 (95% CI: 1.45, 1.91, *P*<.001), suggesting a 66% higher prevalence than those without severe tooth loss. Adjusted for education, household income, and health plan in Model 2, the APR of severe tooth loss was reduced to 1.53 (95% CI: 1.33, 1.77, *P*<.001). The APR of severe tooth loss was further reduced to 1.36 (95% CI: 1.18, 1.56, *P*<.001) after BMI, smoking status, and diabetes were incorporated. These findings suggest that SES and health-related factors partially accounted for the association between severe tooth loss and the prevalence of CVD. As for racial/ethnic disparities, compared to Whites, NHs, reported a 54% higher prevalence of CVD (APR=1.54, 95% CI: 1.32, 1.79, *P*<.001) and the APR reduced after SES and health indicators were included in Models 2-3. No other racial/ethnic disparities in CVD were identified. Interestingly, compared to those who have no health plan, those having a health plan exhibited close to 50% higher prevalence of CVD in Model 2 (PR=1.48, 95% CI: 1.04, 2.11, *P*<.031), but this was no longer significant when BMI, smoking status and diabetes were added in Model 3

Table 4 describes the prevalence of CVD by community. It shows that the prevalence of CVD ranged from 6.2% in Salt Lake/Foster Village and North Shore/La'ie to 13.9% (95% CI: 10.3%, 18.5%) in Nanakuli/Waianae. The highest prevalence of CVD was found in Nanakuli/Wai'anae (O'ahu), Hilo (Hawai'i island Lahaina/Wailuku (Maui), and Puna/Kau (Hawai'i island). It was lowest in Salt Lake/Foster Village (O'ahu), North Shore/La'ie (Oahu), Kaimuki/Palolo/Waikiki (O'ahu), and Upcountry/Hana (Maui).

Table 1. Unweighted and Weighted Sample Characteristics, Hawai'i Behavioral Risk Factor Survey Respondents Ages 50+, 2012-2020 Even Years (Continued on next page)		
	Sample Size (%)	**Average Weighted Population (Weighted %)**
Total Sample	N = 22704	N = 510384
Severe tooth loss (6+)		
Yes	3935 (17.3%)	86417 (16.9%)
No	18769 (82.7%)	423967 (83.1%)
Age group		
50-59	6885 (30.3%)	182124 (35.7%)
60-69	8286 (36.5%)	169216 (33.2%)
70-79	5153 (22.7%)	101984 (20.0%)
80+	2380 (10.5%)	57060 (11.2%)
Sex		
Female	12320 (54.3%)	267484 (52.4%)
Male	10384 (45.7%)	242900 (47.6%)
Race and ethnicity		
White	9033 (39.8%)	145374 (28.5%)
Native Hawaiian	3409 (15.0%)	65518 (12.8%)
Other PI	333 (1.5%)	7146 (1.4%)
Filipino	2212 (9.7%)	74037 (14.5%)
Japanese	4525 (19.9%)	136399 (26.7%)
Chinese	1010 (4.4%)	31603 (6.2%)
Other	2182 (9.6%)	50306 (9.9%)

Table 1. Unweighted and Weighted Sample Characteristics, Hawai'i Behavioral Risk Factor Survey Respondents Ages 50+, 2012-2020 Even Years (Continued from previous page)

	Sample Size (%)	Average Weighted Population (Weighted %)
Education		
College 4 or more years	9928 (43.7%)	156270 (30.6%)
College 1-3 years	6573 (29.0%)	175788 (34.4%)
High school or GED	6203 (27.3%)	178325 (34.9%)
Household income		
$75,000 or higher	7035 (31.0%)	168435 (33.0%)
$50,000-$74,999	3440 (15.2%)	77720 (15.2%)
$25,000-$49,000	4996 (22.0%)	109566 (21.5%)
$0-$24,999	4771 (21.0%)	94612 (18.5%)
Unknown/missing	2462 (10.8%)	60050 (11.8%)
Health plan		
No health plan	975 (4.3%)	22436 (4.4%)
Has health plan	21729 (95.7%)	487947 (95.6%)
BMI categories		
Normal weight	8808 (38.8%)	192125 (37.6%)
Overweight	7830 (34.5%)	175890 (34.5%)
Obese	4696 (20.7%)	108974 (21.4%)
Underweight	615 (2.7%)	13601 (2.7%)
Unknown/missing	755 (3.3%)	19794 (3.9%)
Smoking status		
Never smoker	11932 (52.6%)	275381 (54.0%)
Former smoker	7836 (34.5%)	167249 (32.8%)
Current smoker	2295 (10.1%)	50503 (9.9%)
Unknown/missing	641 (2.8%)	17251 (3.4%)
Diabetes		
No diabetes	19305 (85.0%)	424924 (83.3%)
Has diabetes	3399 (15.0%)	85460 (16.7%)

Table 2. Weighted Prevalence of CVD and Unadjusted Prevalence Ratio of CVD Among Adults Ages 50+ Years by All Covariates, Hawai'i Behavioral Risk Factor Survey, 2012-2020, Even Years (Continued on next page)

	Prevalence (95% CI)	Prevalence Ratio (95% CI)	*P*-value
Total Sample	9.1% (8.5,9.6)		
Severe tooth loss (6+)			
No	7.7% (7.1, 8.2)	Ref	
Yes	15.9% (14.3,17.7)	2.08 (1.83, 2.37)	<.001
Age group			
50-59	5.3% (4.6, 6.1)	Ref	
60-69	8.5% (7.7, 9.3)	1.59 (1.34, 1.89)	<.001
70-79	11.8% (10.6,13.2)	2.22 (1.86, 2.65)	<.001
80+	17.8% (15.4,20.4)	3.34 (2.74, 4.07)	<.001
Sex			
Female	6.5% (5.9, 7.3)	Ref	
Male	11.8% (11.0,12.7)	1.81 (1.59, 2.05)	<.001

Table 2. Weighted Prevalence of CVD and Unadjusted Prevalence Ratio of CVD Among Adults Ages 50+ Years by All Covariates, Hawaiʻi Behavioral Risk Factor Survey, 2012-2020, Even Years (Continued from previous page)

	Prevalence (95% CI)	Prevalence Ratio (95% CI)	*P*-value
Race and ethnicity			
White	8.7% (8.0, 9.6)	Ref	
Native Hawaiian	12.8% (11.4,14.4)	1.46 (1.26, 1.70)	<.001
Other PI	10.3% (6.9,15.1)	1.18 (0.79, 1.76)	.42
Filipino	7.5% (6.1, 9.3)	0.86 (0.69, 1.08)	.20
Japanese	8.4% (7.4, 9.7)	0.96 (0.82, 1.14)	.66
Chinese	7.9% (6.0,10.4)	0.91 (0.68, 1.22)	.51
Other	9.5% (7.7,11.7)	1.09 (0.87, 1.36)	.47
Education			
College 4 or more years	7.1% (6.4, 7.8)	Ref	
College 1-3 years	9.1% (8.2,10.1)	1.30 (1.12, 1.49)	<.001
High school or GED	10.7% (9.7,11.8)	1.52 (1.32, 1.75)	<.001
Household income			
$75,000 or higher	6.9% (6.1, 7.8)	Ref	
$50,000-$74,999	7.9% (6.7, 9.3)	1.15 (0.93, 1.41)	.192
$25,000-$49,999	9.7% (8.6,10.9)	1.40 (1.18, 1.66)	<.001
$0-$24,999	13.5% (12.1,15.1)	1.96 (1.66, 2.31)	<.001
Unknown/missing	8.4% (6.9,10.3)	1.22 (0.97, 1.54)	.088
Health plan			
No health plan	6.2% (4.3,8.7)	Ref	
Has health plan	9.2% (8.6,9.8)	1.49 (1.05, 2.12)	.027
BMI categories			
Normal weight	7.2% (6.4, 8.0)	Ref	
Overweight	9.3% (8.4,10.2)	1.29 (1.11, 1.50)	<.001
Obese	12.1% (10.8,13.5)	1.68 (1.43, 1.97)	<.001
Underweight	10.2% (6.9,15.0)	1.43 (0.95, 2.15)	.087
Unknown/missing	8.1% (5.7,11.4)	1.13 (0.79, 1.62)	.51
Smoking status			
Never smoker	7.1% (6.4, 7.9)	Ref	
Former smoker	12.4% (11.4,13.5)	1.75 (1.53, 1.99)	<.001
Current smoker	9.7% (8.2,11.5)	1.37 (1.13, 1.66)	.002
Unknown/missing	5.3% (3.4, 8.0)	0.74 (0.48, 1.15)	.181
Diabetes			
No diabetes	7.3% (6.7, 7.8)	Ref	
Has diabetes	18.0% (16.2,20.0)	2.49 (2.19, 2.82)	<.001

	Model 1		Model 2		Model 3	
	PR (95%CI)	*P*-value	PR (95%CI) Ratio and 95% CI	*P*-value	PR (95%CI)	*P*-value
Total Sample						
Severe tooth loss (6+)						
No						
Yes	1.66 (1.45, 1.91)	<.001	1.53 (1.33, 1.77)	<.001	1.36 (1.18, 1.56)	<.001
Age group						
50-59						
60-69	1.59 (1.35, 1.89)	<.001	1.56 (1.32, 1.85)	<.001	1.51 (1.27, 1.79)	<.001
70-79	2.19 (1.83, 2.62)	<.001	2.12 (1.77, 2.54)	<.001	2.02 (1.69, 2.43)	<.001
80+	3.41 (2.77, 4.20)	<.001	3.22 (2.62, 3.96)	<.001	3.43 (2.79, 4.22)	<.001
Sex						
Female						
Male	1.88 (1.66, 2.13)	<.001	1.95 (1.72, 2.21)	<.001	1.78 (1.57, 2.02)	<.001
Race and ethnicity						
White						
Native Hawaiian	1.54 (1.32, 1.79)	<.001	1.45 (1.25, 1.69)	<.001	1.23 (1.05, 1.43)	.008
Other PI	1.36 (0.90, 2.04)	.1426	1.28 (0.85, 1.92)	.22	1.05 (0.71, 1.55)	.80
Filipino	0.92 (0.73, 1.15)	.45	0.85 (0.68, 1.06)	.140	0.81 (0.65, 1.02)	.068
Japanese	0.90 (0.76, 1.05)	.184	0.89 (0.76, 1.05)	.166	0.86 (0.73, 1.01)	.058
Chinese	0.92 (0.69, 1.21)	.54	0.92 (0.69, 1.22)	.55	0.97 (0.73, 1.28)	.81
Other	1.14 (0.91, 1.44)	.24	1.09 (0.87, 1.37)	.44	1.03 (0.82, 1.29)	.79
Education						
College 4 or more years						
College 1-3 years			1.18 (1.02, 1.37)	.031	1.13 (0.98, 1.31)	.099
High school or GED			1.09 (0.93, 1.27)	.31	1.02 (0.88, 1.19)	.78
Household income						
$75,000 or higher						
$50,000-$74,999			1.03 (0.84, 1.26)	.81	1.03 (0.84, 1.26)	.80
$25,000-$49,000			1.17 (0.97, 1.39)	.094	1.15 (0.97, 1.38)	.112
$0-$24,999			1.57 (1.31, 1.87)	<.001	1.58 (1.33, 1.88)	<.001
Unknown/missing			1.06 (0.84, 1.34)	.60	1.08 (0.86, 1.36)	.50
Health plan						
No health plan						
Has health plan			1.48 (1.04, 2.11)	.031	1.37 (0.96, 1.95)	.083
BMI categories						
Normal weight						
Overweight					1.20 (1.04, 1.39)	.014
Obese					1.47 (1.25, 1.73)	<.001
Underweight					1.25 (0.84, 1.84)	.270
Unknown/missing					1.73 (1.18, 2.52)	.005

Table 3. Weighted Prevalence Ratio of CVD Adjusting for Different Sets of Covariates (Continued on next page)

Table 3. Weighted Prevalence Ratio of CVD Adjusting for Different Sets of Covariates (Continued from previous page)						
	Model 1		Model 2		Model 3	
	PR (95%CI)	*P*-value	PR (95%CI) Ratio and 95% CI	*P*-value	PR (95%CI)	*P*-value
Smoking status						
Never smoker						
Former smoker					1.37 (1.20, 1.56)	<.001
Current smoker					1.23 (1.01, 1.50)	.039
Unknown/missing					0.57 (0.35, 0.90)	.017
Diabetes						
No diabetes						
Has diabetes					1.99 (1.74, 2.27)	<.000

Table 4. Prevalence of CVD with 95% CI Across All Communities		
Community	**Sample Size**	**Prevalence of CVD (95% CI)**
Nanakuli/ Waianae - Honolulu	468	13.9% (10.3,18.5)
Hilo – Hawai'i	1191	11.8% (9.5,14.6)
Lahaina/ Wailuku - Maui	1257	11.3% (8.8,14.4)
Puna/ Kau – Hawai'i	1359	11.3% (9.3,13.7)
Kailua/ Waimanalo - Honolulu	824	11.0% (8.2,14.7)
Kona – Hawai'i	1175	10.6% (8.3,13.5)
Mililani/ Wahiawa - Honolulu	804	10.4% (7.9,13.6)
Aiea/ Pearl City - Honolulu	923	9.8% (7.7,12.4)
Hanalei/ Kapaa – Kaua'i	1249	9.4% (7.5,11.7)
Moloka'i - Maui	410	9.3% (5.6,15.1)
N.Hawai'i - Hawaii	969	9.1% (6.9,11.8)
Ka'a'awa/ Kahalu'u/ Kaneohe - Honolulu	833	8.9% (6.6,12.1)
Nu'uanu/ Kalihi/ Moanalua - Honolulu	980	8.4% (6.5,10.9)
Mānoa/ Upper Makiki - Honolulu	931	8.1% (6.2,10.6)
Ala Moana - Honolulu	569	7.8% (5.4,11.0)
Kahului - Maui	1168	7.7% (5.9,10.0)
Wai'alae/ Kahala/ Hawai'i Kai - Honolulu	880	7.7% (5.6,10.4)
Lihue-Waimea – Kaua'i	1625	7.6% (5.9, 9.6)
Lanai - Maui	205	7.5% (3.9,13.9)
Waipahu/ Kapolei/ 'Ewa - Honolulu	1295	7.5% (5.8, 9.8)
Upcountry/ Hana - Maui	1251	7.3% (5.7, 9.4)
Kaimuki/ Palolo/ Waikiki - Honolulu	1124	7.1% (5.3, 9.4)
N.Shore/ Lā'ie - Honolulu	293	6.2% (3.4,11.1)
Salt Lake/ Foster Village - Honolulu	294	6.2% (3.3,11.2)

Discussion

This study examined the association between severe tooth loss and CVD and the individual- and community-level correlates of CVD among older adults in Hawaiʻi. The findings revealed a significant association between severe tooth loss and CVD, a relationship that was partly accounted for by SES and risk factors. After adjusting for covariates (including smoking, BMI, diabetes, income, and education), the association between severe tooth loss and CVD persisted but was attenuated. These findings align with past studies showing a significant association between tooth loss and CVD that is weakened after adjustment for comorbidities, socioeconomic variables, and health risk behaviors.[34,40,44]

The study further revealed racial/ethnic differentiation of CVD. Compared to White respondents, NH had a higher prevalence of CVD. Socioeconomic inequalities and uneven distribution of risk factors appear to partly explain the association. NH are overrepresented in lower-income and lower-education groups, and some risk factors (including smoking, obesity, and diabetes) are more prevalent among NH.[63,69-70] However, the higher prevalence of CVD for NH even after adjustment for SES variables, smoking, overweight, and diabetes indicates that the association is partly attributable to variables beyond the scope of the present study. These might include discrimination, cultural values, specific risk behaviors (such as betel nut chewing), and historical traumas.[70-72] For instance, in 2008 Kaholokula et al found specific cultural and material barriers to heart health among NHPI that include "poor knowledge of heart failure, lack of trust in physicians' care, poor physician-patient relations, finances, dietary changes, and competing demands on time".[73] Importantly, in 2023 Waitzfelder et al found a higher prevalence of CVD among multiracial Asian Pacific Islander populations,[62] pointing to the value of racial/ethnic analysis (and well-defined racial/ethnic disaggregation) in the examination of cardiovascular health disparities. Given this evidence of racial/ethnic disparities in cardiovascular health and of the tooth loss/CVD linkage, the specific function of race and ethnicity in the relationship between oral and cardiovascular health warrants further investigation.

The role of racial/ethnic marginalization in this association is particularly important considering the historical good health of NH (documented by Indigenous oral histories and early Western records) prior to colonial contact and subsequent exposure to communicable diseases, violent land dispossession, coerced changes to social structures, and suppression of language and culture.[71,74] The legacies of colonialism and racism continue to subjugate NH, manifest in poorer health outcomes than the general population. In addition to more prevalent CVD, NH have more prevalent severe tooth loss[11] and higher mortality[75] – the *very definition* of racism per Ruth Wilson Gilmore, who describes racism as the production of "group differentiated vulnerability to premature death".[76]

Finally, this study revealed CVD disparities by community in Hawaiʻi, indicating that socioeconomic factors operate on an aggregate level to impact cardiovascular health. The prevalence of CVD was highest in areas with relatively low education and income levels: Nanakuli/Waiʻanae, Hilo, Lahaina/Wailuku, and Puna/Kau. In Makua Valley, Makaha, Waiʻanae Kai, and Nanakuli—the census tracts that make up the general Nanakuli/Waiʻanae area—the median family incomes are $49,226, $44,677, $42,261, and $52,333, respectively.[77] By contrast, the median family incomes of Foster Village and Salt Lake Country Club—comprising the area with the lowest prevalence of CVD, Salt Lake/Foster Village—are $104,625 and $89,728, respectively.[77] These results indicate an association between community-level socioeconomic disparities and cardiovascular disease, supporting previous findings that show inadequate access to care and poorer cardiovascular health outcomes related to rurality.[78]

The Social Drivers of Health (SDoH) framework helps clarify the social systems of power that determine individual and community health outcomes, including the racial/ethnic and community-level disparities in CVD. The SDoH model highlights hierarchical social systems that result in differing social, economic, and environmental conditions, including upstream material and environmental factors (such as housing and air quality) and downstream behavioral factors (such as oral hygiene and smoking). Following this paradigm, policy efforts that aim to improve interrelated oral and cardiovascular health outcomes must account for the structural drivers of risk factors and their unequal distribution among marginalized populations. A holistic, multi-level approach to public health policy is in order: such measures might range from national-level poverty alleviation initiatives to community-level oral hygiene education programs. Interventions on the provider level must prioritize collaboration across medical and dental systems, expanded access to preventive and restorative medical and oral health care, and cultural competence among health professionals.

Strengths/Limitations

This study was subject to several limitations. First, BRFSS data are self-reported and participation is contingent on physical and mental ability to complete the survey. When studying older adults, this limitation can lend to possible over or under-representation of data. Second, a causal relationship cannot be verified with cross-sectional data. Third, individuals were categorized into a single sex and racial/ethnic group, potentially obscuring the specific cardiovascular health outcomes for nonbinary or multiracial/multiethnic individuals. Lastly, there might be the healthy behavior bias as people who take care of their teeth are less likely to have tooth loss and engage in other health promoting behaviors that would also reduce their risk of CVD. Despite these limitations, the study extends important research on the oral health and cardiovascular health linkage by examining the association of tooth loss and CVD and the individual- and community-level sociodemographic correlates of CVD in Hawai'i.

Conflict of Interest

None the authors identify a conflict of interest.

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