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Original Research

Trends in cigarette smoking and the risk of incident cardiovascular disease among Asian American, Pacific Islander, and multiracial populations

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ABSTRACT

Background: Cardiovascular disease (CVD) is the leading cause of death in the United States, and rates of CVD incidence vary widely by race and ethnicity. Cigarette smoking is associated with increased risk of CVD. The purpose of the study was: 1) to examine smoking prevalence over time across Asian and Pacific Islander (API) and multi-race API subgroups; 2) to determine whether the CVD risk associated with smoking differed among these subgroups.

Methods: We identified patients belonging to 7 single race/ethnicity groups, 4 multi-race/ethnicity groups, and a non-Hispanic White (NHW) comparison group at two large health systems in Hawaii and California. We estimated annual smoking prevalence from 2011 through 2018 by group and gender. We examined incidence of CVD events by smoking status and race/ethnicity, and computed hazard ratios for CVD events by age, gender, race/ethnicity, census block median household income, census block college degree, and study site using Cox regression.

Results: Of the 12 groups studied, the Asian Indian and Chinese American groups had the lowest smoking prevalence, and the Asian + Pacific Islander multiracial group had the highest smoking prevalence. The prevalence of smoking decreased from 2011 to 2018 for all groups. Multi-race/ethnicity groups had higher risk of CVD than the NHW group. There was no significant interaction between race/ethnicity and smoking in models predicting CVD, but the association between race/ethnicity and CVD incidence was attenuated after adjusting for smoking status.

Conclusions: There is considerable heterogeneity in smoking prevalence and the risk of CVD among API subgroups.

1. Introduction

Cardiovascular disease (CVD), which includes coronary heart disease (CHD), peripheral vascular disease (PVD), and stroke, is the leading cause of death in the United States (U.S.) [1], but the rates vary widely by race and ethnic group. Recent reports note that CVD mortality is significantly lower among Asian people compared to Non-Hispanic White people [2,3]. However, there is considerable heterogeneity among Asian population subgroups [2,4]; for example Asian Indian and Filipino populations have higher proportional mortality from ischemic heart disease and stroke than Non-Hispanic White populations [5]. Additionally, the prevalence of obesity, diabetes, and hypertension, all contributing conditions to CVD, are higher among Pacific Islanders than among other Asian American groups [6,7].

Cardiovascular health among Asian and Pacific Islander (API) individuals is important, as they represent the fastest growing racial/ethnic group in the U.S. Individuals identifying as a single API group currently comprise 5.9 % of the population (19.3 million); including

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individuals identifying as multiracial (API as well as another racial/ethnic group), that percentage increases to 7.2 %. (23.8 million) [8]. Although API individuals represent over forty diverse cultures, most research studies aggregate them into one category due to limited sample sizes of many Asian subgroups, including Korean, Vietnamese, and Native Hawaiian and other Pacific Islander (NHPI) subgroups [9–12]. Available literature indicates higher levels of CVD risk factors among NHPI individuals compared to the general US population including low levels of physical activity, dietary risk factors, high tobacco use, and high rates of overweight and obesity—as well as consistently high incidence of diabetes and heart disease, and subsequently shorter life expectancy [13]. Although Asian Americans as an aggregated group (not including NHPI individuals) have lower risk for CVD than White populations, some Asian subgroups, such as South Asian populations, are at heightened risk for CVD, facing premature and more severe coronary artery disease, and decreased insulin sensitivity compared to White individuals [14,15]. Moreover, very little is known about CVD in the multi-racial API population. Of the 24 million people who identified as Asian in the 2020 U.S. census, 4.1 million people (17 %), identified as multi-racial [16]. The proportion of multiracial people is even larger among Pacific Islanders. Of the 1.59 million people who identified as Pacific Islander in the 2020 census, 900,000 (57 %) identified as multi-racial. However, very few studies clearly define the multiple racial/ethnic admixtures of individuals included in study populations beyond classifying them as “mixed” or “other.”[17]

Current smoking is associated with increased risk of CVD and is a cause in approximately one of every four deaths from CVD [18]. Since smoking is a modifiable cardiovascular risk factor, disparities in cardiovascular outcomes could be affected by changes in smoking rates. However, available smoking prevalence in API populations is data out-of-date [19–21], and trends over time are rarely reported.

In addition to a paucity of studies reporting results among disaggregated Asian subpopulations, there have been few studies that have examined the impact of smoking on CVD among multi-racial API individuals. [22,23] Only a handful of previous studies have examined the contribution of smoking to ethnic differences in the CVD risks, and these studies yielded inconsistent findings [22,23].

To fill these fundamental gaps in our knowledge of CVD risks among API subpopulations, the purpose of the study was to (1) examine trends in smoking prevalence over time across eleven single- and multi-racial API subgroups, as well as a White, non-Hispanic control group; and (2) determine whether the CVD risk associated with smoking was similar among API and multiracial API subgroups and the non-Hispanic white population. Understanding the impacts of smoking as a CVD risk factor on fast-growing API populations is critical for eliminating racial and ethnic disparities in health and improving population-level cardiovascular care. For researchers and clinicians undertaking such improvements in care, this study may help to focus efforts on high-risk groups in which disparities in smoking prevalence and smoking-related CVD risk are greatest or most urgent.

2. Methods

2.1. Study population

California and Hawaii have the largest API populations in the US [24]. This study included the API and NHW populations served by two large healthcare systems in Hawaii and northern California. Our study population included adults ages 18 years and older with one or more primary care visits at internal medicine, family medicine, or gynecology/obstetrics over any 2-year period between 2011 and 2018. The completeness, sensitivity, and positive predictive values of smoking history documentation in the Epic® electronic health record (EHR) have increased considerably in recent years, indicating that EHRs are now a valid source for identifying persons with a history of smoking for research and clinical purposes [25]. Moreover, evidence shows that smoking prevalence derived from the primary care EHR is aligned with data from the General Household Survey (GHS), a nationally representative survey, suggesting that the EHR is an alternative way of monitoring smoking prevalence in the population [26]. Finally, studies on disaggregated API groups as well as multi-racial groups are often limited by small sample sizes. Utilizing EHR data allows us to examine smaller populations within the larger API category to provide more stable estimates that are difficult to obtain with general survey data [27,28].

The second part of the analysis uses a retrospective (or historical) cohort design. Individuals who otherwise met the criteria above were entered into the cohort if there was no evidence in the EHR of CVD for the previous five years. Thus, all individuals included in the cohort in 2011 had no history of any CVD condition of interest documented in the EHR from at least 2006–2010. Individuals could enter the cohort after 2011 at the time that this criterion was met. Cohort members were followed until 2018 for new CVD events using encounter diagnoses or problem list (whichever occurred first).

Censoring occurred on June 30th of the year when the patient last appears in the EHR. This cohort was divided into three mutually exclusive smoking groups based on the last available instance in the first year of the five-year clearance period using self-reported smoking status in the EHR data: current smoking, former smoking, and never smoking.

2.2. Measurement and study design

Both study sites use instances of the EHR. Both sites maintain research data warehouses that conform with the standards of the Virtual Data Warehouse (VDW) created and maintained by the Health Care Systems Research Network [29]. The VDW is a standardized method for sharing EHR information using standard variables, variable definitions, and formats. The VDW enables rapid and efficient use of EHR data for research purposes across sites while maintaining privacy, and has supported large research networks in the areas of cancer, cardiovascular disease, mental health, and diabetes [30,31].

Participants self-reported race/ethnicity upon joining each health system. For this study, we selected patients who identified as Non-Hispanic White, Asian, Native Hawaiian/Other Pacific Islander, or multiple race categories. This study population was then classified into 8 single race/ethnicity groups (Asian Indian, Japanese, Chinese, Filipino, Korean, Native Hawaiian, Other Pacific Islander, and non-Hispanic White [NHW]) and 4 multi-race groups: Asian + Pacific Islander (*A*+PI), Asian + White (*A*+NHW), Pacific Islander + White (PI+NHW), and Pacific Islander + Asian + White (PI+*A*+NHW). These 12 groups are mutually exclusive.

We identified each person’s self-reported smoking status (current/former/non-smoker) for each year between 2011 and 2018 using the last available status in the calendar year: Annual smoking prevalence was defined as the number of current smokers divided by the total number of eligible patients in that year. Eligible patients were included in the denominator for each year in which they had at least one primary care visit in the previous two years. Approximately 21.8 % of all eligible patients had missing data on smoking status and were excluded from the analysis. To check and understand the missing data, we compared the mean age, gender, race/ethnicity composition, and sites. We found these factors to be quite similar between patients with and without documented smoking status. Although the differences are statistically significant, this reflects the large sample size. Missingness does not seem to threaten the comparisons in our analyses. The average annual percent change was calculated by the difference between smoking prevalence in 2011 and 2018 divided by eight.

CVD conditions included coronary heart disease (CHD), stroke (hemorrhagic and ischemic), and peripheral vascular disease (arterial and venous, PVD); we also included a summary category of any CVD. These conditions were defined by ICD-9 or ICD-10 diagnosis codes associated with an ambulatory (outpatient), inpatient, or emergency department encounters, or present in the problem list.

Table 1
Prevalence of current smoking (unadjusted) among adult patients who used primary care services at two large healthcare systems in northern California and Hawaii, 2011–2018.

	Year	NHW	Asian Indian	Chinese	Filipino	Japanese	Korean	Native Hawaiian	Other PI	PI+*A*+NHW	*A*+NHW	*A*+PI	PI+NHW
Female	2011	5810 (6.0 %)	88 (0.6 %)	202 (1.2 %)	883 (6.3 %)	673 (6.9 %)	226 (8.5 %)	138 (20.8 %)	209 (14.2 %)	498 (16.8 %)	335 (10.2 %)	585 (16.5 %)	415 (16.9 %)
	2012	5829 (5.6 %)	88 (0.5 %)	196 (1.1 %)	878 (6.0 %)	616 (6.2 %)	205 (7.4 %)	107 (17.0 %)	196 (13.1 %)	460 (15.2 %)	325 (9.7 %)	565 (15.9 %)	402 (16.2 %)
	2013	5802 (5.1 %)	97 (0.5 %)	185 (0.9 %)	842 (5.3 %)	551 (5.5 %)	181 (6.3 %)	97 (15.6 %)	190 (11.9 %)	435 (14.1 %)	307 (8.6 %)	504 (14.0 %)	350 (14.2 %)
	2014	5693 (4.8 %)	106 (0.5 %)	181 (0.9 %)	831 (5.0 %)	550 (5.3 %)	158 (5.1 %)	89 (14.5 %)	176 (10.8 %)	432 (13.7 %)	282 (7.7 %)	519 (14.3 %)	345 (13.6 %)
	2015	5732 (4.6 %)	113 (0.5 %)	180 (0.8 %)	927 (5.0 %)	579 (5.3 %)	201 (6.0 %)	101 (15.3 %)	183 (9.1 %)	472 (13.2 %)	292 (7.3 %)	576 (14.4 %)	381 (13.6 %)
	2016	5317 (4.3 %)	116 (0.5 %)	187 (0.8 %)	829 (4.6 %)	512 (4.8 %)	191 (5.7 %)	80 (13.2 %)	178 (9.2 %)	414 (12.2 %)	265 (6.8 %)	536 (13.8 %)	346 (13.3 %)
	2017	4830 (4.1 %)	107 (0.5 %)	182 (0.8 %)	840 (4.6 %)	491 (4.6 %)	179 (5.3 %)	75 (12.8 %)	176 (9.4 %)	404 (11.7 %)	270 (6.9 %)	537 (13.9 %)	349 (13.3 %)
	2018	4599 (3.9 %)	111 (0.5 %)	166 (0.7 %)	797 (4.3 %)	490 (4.7 %)	174 (5.2 %)	75 (12.9 %)	185 (9.8 %)	387 (11.1 %)	232 (5.8 %)	511 (13.1 %)	337 (13.1 %)
Male	2011	6458 (8.5 %)	843 (5.8 %)	579 (4.8 %)	1500 (16.0 %)	756 (11.6 %)	177 (12.9 %)	115 (18.9 %)	302 (22.6 %)	377 (20.7 %)	357 (15.8 %)	587 (21.0 %)	320 (18.2 %)
	2012	6596 (8.2 %)	905 (5.9 %)	548 (4.5 %)	1514 (15.5 %)	737 (11.2 %)	187 (13.3 %)	112 (17.7 %)	271 (20.7 %)	362 (19.3 %)	349 (15.1 %)	546 (19.4 %)	309 (17.6 %)
	2013	6691 (7.7 %)	922 (5.4 %)	581 (4.3 %)	1471 (14.2 %)	705 (10.4 %)	186 (12.4 %)	113 (18.6 %)	315 (22.5 %)	319 (16.4 %)	325 (13.7 %)	518 (18.1 %)	278 (15.5 %)
	2014	6721 (7.3 %)	1047 (5.5 %)	630 (4.4 %)	1518 (13.9 %)	673 (9.9 %)	184 (11.8 %)	110 (17.3 %)	287 (20.3 %)	343 (16.8 %)	319 (13.4 %)	533 (18.3 %)	289 (16.1 %)
	2015	6960 (7.3 %)	1076 (5.3 %)	609 (4.0 %)	1563 (13.6 %)	676 (9.7 %)	191 (11.4 %)	86 (14.3 %)	312 (20.5 %)	366 (17.1 %)	316 (12.6 %)	545 (18.0 %)	311 (16.5 %)
	2016	6709 (7.0 %)	1002 (5.0 %)	612 (3.9 %)	1648 (13.8 %)	703 (10.0 %)	195 (11.3 %)	84 (14.4 %)	335 (20.8 %)	376 (17.0 %)	344 (13.2 %)	559 (17.9 %)	291 (15.3 %)
	2017	6198 (6.7 %)	940 (4.9 %)	612 (3.9 %)	1548 (13.0 %)	671 (9.6 %)	186 (10.7 %)	71 (12.9 %)	296 (18.9 %)	357 (16.2 %)	315 (12.2 %)	552 (17.8 %)	300 (15.7 %)
	2018	5918 (6.4 %)	958 (4.8 %)	590 (3.7 %)	1488 (12.4 %)	625 (9.2 %)	212 (11.7 %)	69 (13.1 %)	305 (19.2 %)	352 (16.1 %)	327 (12.0 %)	542 (17.5 %)	283 (15.1 %)
All	2011	12,268 (7.1 %)	931 (3.1 %)	781 (2.7 %)	2383 (10.2 %)	1429 (8.8 %)	403 (10.0 %)	253 (19.9 %)	511 (18.2 %)	875 (18.3 %)	692 (12.5 %)	1172 (18.5 %)	735 (17.5 %)
	2012	12,425 (6.8 %)	993 (3.1 %)	744 (2.5 %)	2392 (9.8 %)	1353 (8.2 %)	392 (9.4 %)	219 (17.4 %)	467 (16.6 %)	822 (16.7 %)	674 (11.9 %)	1111 (17.5 %)	711 (16.8 %)
	2013	12,493 (6.2 %)	1019 (2.9 %)	766 (2.3 %)	2313 (8.8 %)	1256 (7.4 %)	367 (8.4 %)	210 (17.1 %)	505 (16.9 %)	754 (15.0 %)	632 (10.6 %)	1022 (15.8 %)	628 (14.7 %)
	2014	12,414 (5.9 %)	1153 (2.9 %)	811 (2.3 %)	2349 (8.6 %)	1223 (7.1 %)	342 (7.4 %)	199 (15.9 %)	463 (15.3 %)	775 (14.9 %)	601 (10.0 %)	1052 (16.1 %)	634 (14.6 %)
	2015	12,692 (5.8 %)	1189 (2.8 %)	789 (2.1 %)	2490 (8.3 %)	1255 (7.0 %)	392 (7.8 %)	187 (14.8 %)	495 (14.1 %)	838 (14.7 %)	608 (9.3 %)	1121 (16.0 %)	692 (14.8 %)
	2016	12,026 (5.5 %)	1118 (2.6 %)	799 (2.1 %)	2477 (8.2 %)	1215 (6.9 %)	386 (7.6 %)	164 (13.8 %)	513 (14.5 %)	790 (14.1 %)	609 (9.3 %)	1095 (15.7 %)	637 (14.1 %)
	2017	11,028 (5.2 %)	1047 (2.6 %)	794 (2.1 %)	2388 (7.9 %)	1162 (6.6 %)	365 (7.1 %)	146 (12.9 %)	472 (13.7 %)	761 (13.5 %)	585 (9.0 %)	1089 (15.6 %)	649 (14.3 %)
	2018	10,517 (5.0 %)	1069 (2.5 %)	756 (1.9 %)	2285 (7.5 %)	1115 (6.4 %)	386 (7.4 %)	144 (13.0 %)	490 (14.1 %)	739 (13.1 %)	559 (8.3 %)	1053 (15.1 %)	620 (14.0 %)

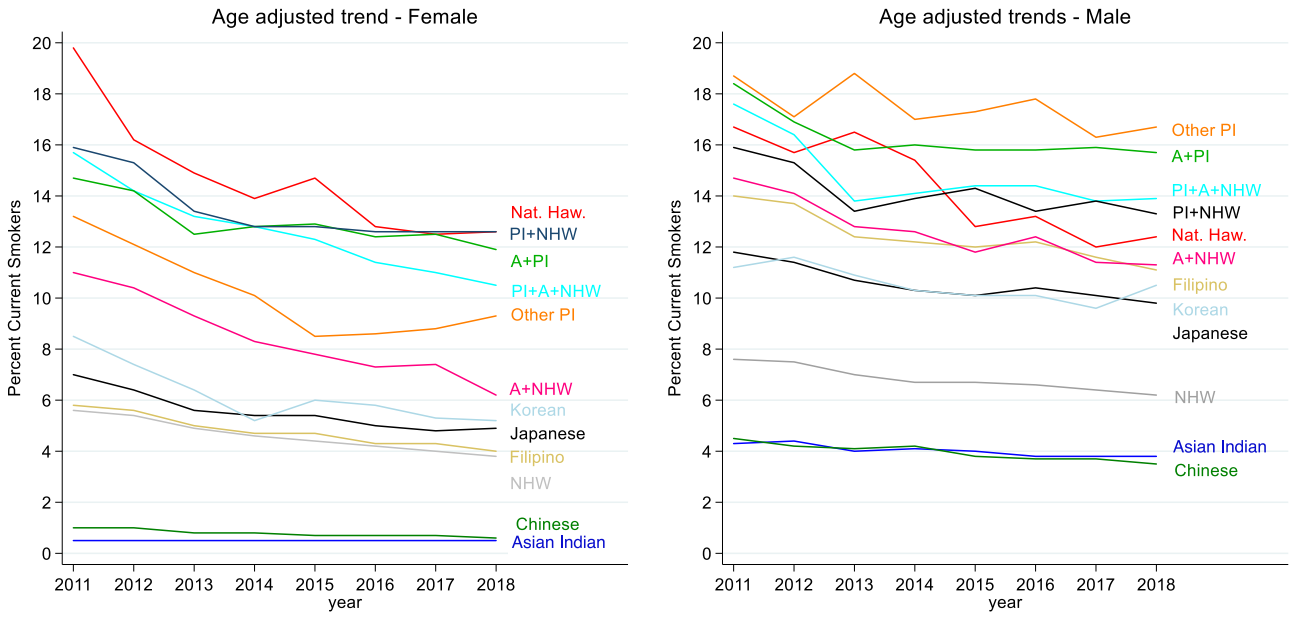


Fig. 1. Age-adjusted smoking prevalence by gender and race/ethnicity at two large healthcare systems in northern California and Hawaii, 2011–2018.

We also extracted baseline demographic information including age, gender and study site, as well as median household income level, and the percentage of population with a college degree in their census ZIP Code Tabulation Areas [32], based on residential address.

2.3. Data analysis

We calculated crude (unadjusted) and age-adjusted annual smoking prevalence estimates for each of the 12 race/ethnicity groups by gender using EHR data. To examine whether smoking increases the risk of CVD and explains observed racial/ethnic disparities in CVD, we examined CVD incidence rates (per 100,000 person-years) for CVD events and the Kaplan-Meier survival curves showing CVD events by smoking status and race/ethnicity from 2011 to 2018. We computed hazard ratios (HR) of CVD events accounting for age, gender, race/ethnicity, census block median household income, proportion of census block with a college degree, and study site using Cox regression (Model 1). Adding smoking status to Model 1, we estimated HRs adjusted for smoking status (Model 2). To examine if there were racial and ethnic differences in the relationship between smoking and incident CVD, multiplicative interaction terms between smoking and race/ethnicity were tested. Statistical significance for all comparisons including interactions was defined as $p < 0.05$. SAS® Version 9.4 (Cary, NC) was used for all analyses. This work was reviewed and approved by the Institutional Review Boards at of all study sites and granted a waiver of Health Insurance Portability and Accountability Act Authorization and a waiver of informed consent as a data-only study.

3. Results

3.1. Trends in smoking prevalence

Overall, the Asian Indian and Chinese American groups had the lowest smoking prevalence and *A*+PI group had the highest of all 12 groups (Table 1). All API and multi-race subgroups except for Asian Indian and Chinese American groups had higher smoking prevalence than NHW regardless of gender. Indeed, in 2018, the highest smoking prevalence (13.1 %), among *A*+PI and PI+NHW women, was 2.35 times higher than among NHW women (3.9 %) and 25.2 times higher than the lowest smoking rate (0.5 %), among Asian Indian American women. Similarly, in 2018, the highest smoking rate (19.2 %), among other Pacific Islander men, was two times higher than for NHW men (6.4 %) and 4.19 times higher than the lowest smoking rate (3.7 %), among Chinese American men. Of the Asian single race groups, Filipino American men had the highest smoking prevalence (12.4 %) followed by Korean (11.7 %) and Japanese American men (9.2 %), while Korean American women had the highest prevalence (5.2 %) followed by Japanese (4.7 %) and Filipino American women (4.3 %). Of the Native Hawaiian/Other Pacific Islander single race groups, Other Pacific Islander men had higher smoking prevalence (19.2 %) than Native Hawaiian men (13.1 %), while Native Hawaiian women had higher smoking prevalence (12.9 %) than Other Pacific Islander women (9.8 %). Of all the multi-race groups, *A*+PI men had the highest smoking prevalence (17.5 %) followed by PI+*A*+NHW (16.1 %), PI+NHW (15.1 %) and *A*+NHW men (12 %), while both *A*+PI and PI+NHW women had the highest smoking prevalence (13.1 %) followed by PI+*A*+NHW women (11.1 %) and *A*+NHW (5.8 %). The Appendix contains information on the baseline characteristics of the overall sample at the first year they entered the cohort.

The estimated prevalence of smoking decreased from 2011 to 2018 for both genders in all race/ethnicity groups, based on both unadjusted (Table 1) and age-adjusted prevalence (Fig. 1). The trends were relatively stable, ranging from declines of 0.01 % per year among Asian Indians to 0.34 % per year among Filipinos. The smoking prevalence decrease was especially notable among Native Hawaiian women and men compared to other groups, with annual decreases of 0.99 % and 0.73 %, respectively. However, the unadjusted smoking prevalence among Native Hawaiian women and men were still 2.31 and 1.04 times higher, respectively, than that of NHW in 2018. Among multi-racial groups, the decline in smoking prevalence was largest in the PI+*A*+NHW group, with an annual decrease of 0.65 %, and smallest in the *A*+PI group, with an annual decrease of 0.43 %.

3.2. Survival time to incident CVD and risk factors

At baseline, 313,085 patients were alive and eligible for the survival analysis. Among these patients, 18,282 (5.8 %) were current smokers, 74,096 (23.7 %) were former smokers, and 220,707 (70.5 %) were non-smokers (Table 2). The majority were female (57.3 %). Mean age was 48.4 years (SD=15.7), and the non-Hispanic White group made up 57.7 % of the sample.

Over a median follow-up of 5 years, there were 20,677 incident CVD

Table 2
Population demographics for the analysis of incident cardiovascular disease at two large healthcare systems in northern California and Hawaii, 2011–2018.

		Smoking status		
	All (313,085) Mean (SD)	Current (18,282) Mean (SD)	Former (74,096) Mean (SD)	Never (220,707) Mean (SD)
Age	48.4 (15.7)	44.6 (14.2)	54.0 (15.9)	46.8 (15.3)
Proportion of census block with college degree	0.47 (0.23)	0.36 (0.21)	0.44 (0.23)	0.50 (0.23)
Census block median household income	$97,104.65 ($43,814.71)	$81,106.27 ($35,552.55)	$90,982.36 ($42,152.63)	$10,0475.2 ($44,458.16)
	N (col%)	**N (row%)**	**N (row%)**	**N (row%)**
Female	179,291 (57.3)	8263(4.6)	36,568(20.4)	134,460 (75.0)
Male	133,794 (42.7)	10,019(7.5)	37,528(28.0)	86,247(64.5)
Race/ Ethnicity				
Non-Hispanic White	180,577 (57.7)	9792(5.4)	49,652(27.5)	121,133 (67.1)
Asian Indian	31,830 (10.2)	776(2.4)	2937(9.2)	28,117(88.3)
Chinese	30,315 (9.7)	612(2.0)	2849(9.4)	26,854(88.6)
Filipino	24,438 (7.8)	2013(8.2)	5645(23.1)	16,780(68.7)
Japanese	15,697 (5.0)	1079(6.9)	4453(28.4)	10,165(64.8)
Korean	3998 (1.3)	288(7.2)	895(22.4)	2815(70.4)
Native Hawaiian	1443 (0.5)	258(17.9)	437(30.3)	748(51.8)
Other Pacific Islander	3165 (1.0)	480(15.2)	856(27.0)	1829(57.8)
PI+*A*+NHW	5094 (1.6)	726(14.3)	1571(30.8)	2797(54.9)
A+NHW	5735 (1.8)	569(9.9)	1366(23.8)	3800(66.3)
A+PI	6527 (2.1)	1057(16.2)	2071(31.7)	3399(52.1)
PI+NHW	4266 (1.4)	632(14.8)	1364(32.0)	2270(53.2)
Location				
Hawaii	88,237 (28.2)	9250(10.5)	25,713(29.1)	53,274(60.4)
California	224,848 (71.8)	9032(4.0)	48,383(21.5)	167,433 (74.5)
Incident CVD	20,677 (6.6)	1129 (6.2 %)	8129 (11.0 %)	11,419 (5.2 %)

Age, Proportion census block college degree, and Census block median household income are shown as mean (SD); all other values shown as N (%).
Abbreviations: CVD: cardiovascular disease, NHW: non-Hispanic White, PI+*A*+NHW: Pacific Islander + Asian + White, *A*+NHW: Asian + White, *A*+PI: Asian + Pacific Islander, PI+NHW: Pacific Islander + White.

events (incidence rate, 14.2/1000 person-years). The median survival time free of CVD was associated with both race/ethnicity and smoking status. Specifically, the survival time to incident CVD of API multi-race groups was shorter than that of the NHW group, whose survival time was shorter than that of API single race groups (Fig. 2). The survival time of current smokers was shorter than that of former smokers, which was shorter than that of non-smokers.

The Cox models yield similar results to the Kaplan-Meier curves (Table 3). Asian single race groups had lower incidence of CVD than the NHW group (lowest risk group: Korean, HR=0.59; 95 % CI, 0.49–0.70) while multi-racial groups, except for the *A*+NHW group, had higher incidence of CVD than the NHW group, with the highest risk group being *A*+PI (HR=1.34; 95 % CI, 1.22–1.47). The Native Hawaiian and other Pacific Islander groups were not significantly different from the NHW group (Model 1). After adjustment for smoking status (Model 2), the association between race/ethnicity and CVD was attenuated, but not significantly. Both former and current smokers had a higher incidence of CVD than never smokers after adjustment for age, gender, race/ethnicity, census block group median household income, proportion of census block group with a college degree, and study site (current smokers: HR= 1.64, 95 % CI, 1.55 −1.74; former smokers: HR= 1.23, 95 % CI, 1.19 −1.27) (Model 2). We did not find significant interaction between race/ethnicity and smoking status, so the final COX model only includes main effects of risk factors.

4. Discussion

This paper adds to the growing literature on disaggregated API health outcomes and studies on multiracial Asians and Pacific Islanders by describing smoking prevalence among single-race and multiple-race Asian and Pacific Islanders and examining its association with incident CVD. Compared to other major racial/ethnic groups, API individuals have been understudied in smoking-related health disparities research [20], despite the fact that the U.S. API population is diverse and fast--growing[33] and smoking prevalence in Asian countries is generally much higher than in the U.S [34].. Internationally, smoking prevalence has decreased between 2006 and 2012 among individuals from Japan (27.0 %−23.3 %), India (15.5 %−13.3 %), South Korea (25.6 %−23.9 %), Vietnam (21.4 %−20.6 %), the Philippines (24.3 %−23.7 %), and Samoa (25.1 %−23.6 %), while remaining largely the same in China (23.9 %−24.2 %), North Korea (23.4 %−23.4 %), and Fuji (14.3 %−14.1 %) [35]. In the U.S., smoking rates have declined between 2002 and 2016, with the Asian population generally having lower smoking prevalence (8.0 %), and Pacific Islanders having higher smoking prevalence (18.5 %) than the Non-Hispanic white population (13.3 %) [36, 37]. When disaggregated by Asian ethnic group, Filipino peoples had higher smoking rates (12.4 %) than Asian Indian (5.1 %) and Chinese people (5.9 %), but there remains limited data for other Asian and Pacific Islander groups [38].

Consistent with previous studies [36,38], we found that the smoking prevalence among all 12 race/ethnicity groups studied declined in the past decade for both men and women. Smoking prevalence varied greatly across API subgroups, with multi-race groups such as the *A*+PI group having the highest burden. Previous studies have shown that among U.S. populations, Native Hawaiian and other Pacific Islander populations report the highest smoking prevalence among API subgroups, while Asian Indian, Chinese, and Japanese populations report the lowest, with prevalence among NHW populations at intermediate levels [20,21]. The 2005 California Health Interview Survey data indicated that smoking prevalence was significantly higher among Asian American men than among NHW men, but lower among Asian American women than among NHW women [19]. We also found prominent gender difference in smoking prevalence among API subgroups. Additionally, smoking prevalence was particularly high among some Asian subgroups [39–42]. When comparing our data to California Health Interview Survey estimates from 2017 to 2022 [43], we see similar trends. In the CHIS, Chinese (4.1 %) and Asian Indian (3.2 %) individuals had the lowest prevalence of smoking relative to other Asian groups. In CHIS, smoking prevalence was highest among Korean individuals (9.1 %). Similarly, smoking prevalence was high among Korean individuals in CASPER (7.4 %) and was second to Filipino (7.5 %). However, in all cases, with the exception of Filipino (7.5 % in CASPER, 5.1 % in CHIS) and Japanese (6.4 % in CASPER, 5.6 % in CHIS), the prevalence of smoking was generally lower in CASPER when compared to CHIS.Prior data suggests that nationally, smoking prevalence rates are highest among Filipino men (16.8 %) and women (9.0 %) compared to Asian Indian and Chinese populations [38]. According to the smoking prevalence data from the California Health Interview Survey in 2021, the overall smoking rate is 5.9 % (5.3–6.6 %) in Central and Northern California [44]. In California, the highest smoking prevalence rates have been reported by Vietnamese-, Korean-, and Filipino- American men and Japanese- and Korean- American women, and the lowest rates reported by Chinese- and Japanese-American men and Chinese- and Filipino-American women [19]. These data are consistent with our findings that among Asian subgroups, Korean and Filipino men and Japanese and Korean women had the highest smoking prevalence, while we found that Chinese and Asian Indian men and women had the lowest

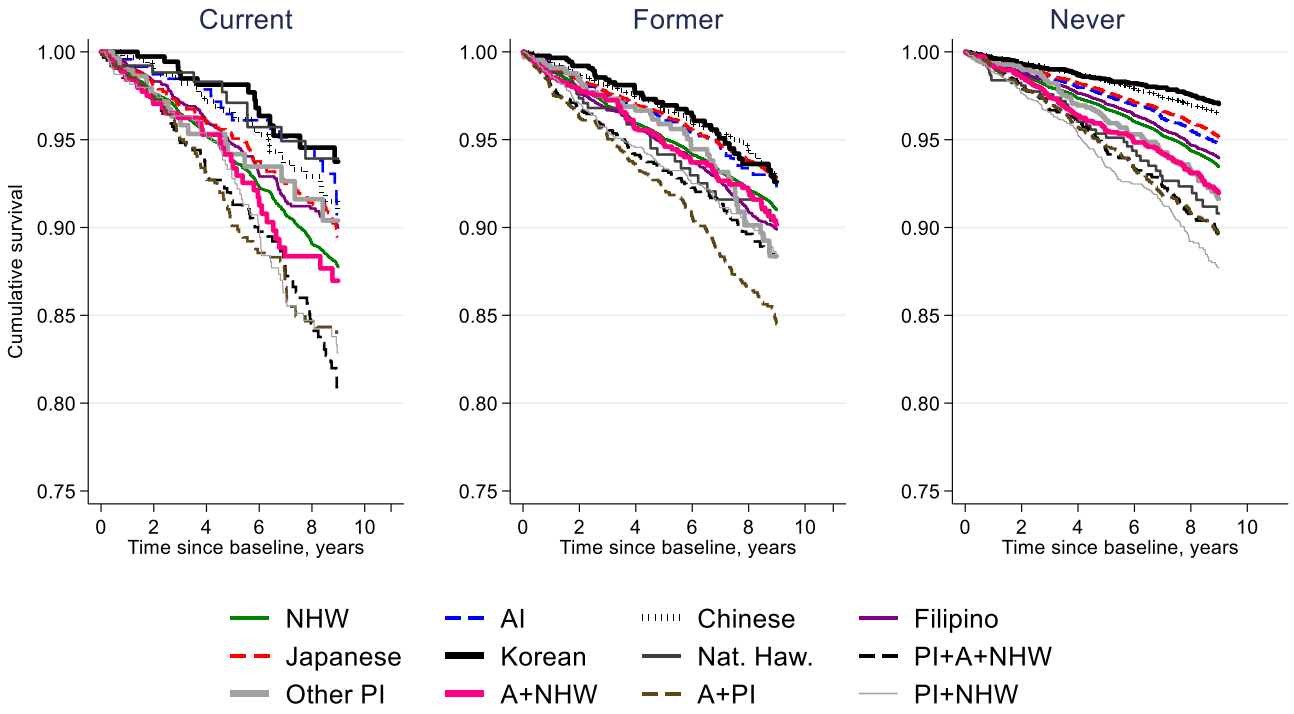


Fig. 2. Kaplan-Meier survival curves by smoking status and race/ethnicity at two large healthcare systems in northern California and Hawaii, 2011–2018.

smoking prevalence rates. One of the reasons for the difference is due to different Asian subgroups (i.e., Vietnamese vs. Asian Indian) and geographic areas (i.e., California vs. California and Hawaii combined) being included in the two studies. Following an increase in smoking prevalence among men in most low- and middle-income countries in Asia in the 1980s, the prevalence showed a modest decrease in the mid-1990s in many of these countries [45]. However, smoking prevalence in men did not decrease in several countries in Asia (including Indonesia, which has a male adult daily smoking prevalence of 57.1 %, the highest in the world). Higher-income populations in Asia, including Japan, Hong Kong (China), and Singapore, have had some of the highest decreases in male smoking prevalence in Asia from 1980 to 2012 [46]. For Asian women, the prevalence of smoking remains very low, but smoking behaviors vary by countries and regions [47].

The combination of toxicologic evidence and evidence on cardiovascular effects show that smoking results in inflammatory responses and alterations in lipid composition [48,49], which can lead to many cardiovascular conditions [50,51]. In our sample, both current and former smokers had higher risk of CVD compared to non-smokers, consistent with previous studies examining Asian populations [48, 52–55]. Multi-race groups had higher risk of CVD compared to NHW. There is growing evidence that API individuals may have unique social determinants of health such as acculturation, socioeconomic status, social context, and health literacy that contribute to their risk for CVD [56–58], and these factors may interact with smoking to further increase their risk. In our study, differences in smoking rates seemed to exacerbate racial/ethnic disparities in CVD incidence, as there was some (non-significant) attenuation in the effect of race/ethnicity on CVD incidence after adjusting for smoking status.

Taken together, these findings suggest that promoting education and awareness about the heterogeneity of CVD and smoking prevalence in the API and multi-race groups is important. Discouraging cigarette smoking and better understanding the heterogeneity of CVD and smoking prevalence can promote better cardiovascular health among API and multi-racial groups [59,60]. Cultural diversity exists within the API population, so smoking cessation interventions that are tailored to the specific needs and preferences of API subgroups may be particularly important in reducing their risk for CVD. For example, a media-led campaign among Vietnamese-American men, including but not limited to Vietnamese-language media, health education materials, and activities targeting physicians, youth, and businesses, had a significant effect on decreasing smoking rates and increasing smoking abstinence [61]. Kaholokula et al. also recognized that religion/spirituality is an integral part of Native Hawaiian culture, and found that church-based support of smoking cessation may help Native Hawaiians for whom religion/spirituality is an important source of inspiration and guidance [62]. Such interventions may need to take into account many unique social and cultural factors that contribute to their smoking behaviors. Therefore, a multicomponent strategy may be beneficial for addressing the social, psychological, and cultural factors related to smoking among API and multi-race groups.

We acknowledge several limitations of the current study. The study included patients who were currently receiving care from one of two different health care systems, so the results may not be generalizable to other US API populations or patients not in regular care. Moreover, using data from two large health systems with a generally insured patient population may limit the generalizability of our findings, although a high proportion of the US population is insured, including Medicare and Medicaid coverage (these two groups are included in the KP membership). Also, a recent study found that Kaiser Permanente members were comparable to those living in the communities from which the membership was drawn, and the membership was sufficiently large and diverse to support research activities [63]. Second, the measurement of some smoking behaviors, such as duration of smoking, age at which patient first smoked, type of tobacco smoked, level of smoking, and passive smoking, are limited by the available data and not reported in this study [64,65]. Third, validating smoking status can be challenging in clinical settings and may lead to misclassification of smoking status and information bias. We did check smoking status at all encounters during the year of enrollment. More comprehensive assessments of smoking behaviors, and biological confirmation of smoking, are required to better understand potential biases in self-reported smoking data that could impact results of studies such as this one. Finally, CVD was defined by ICD codes, and the true rates may have been higher; however, there is little reason to think this under-reporting would differ by API subgroup.

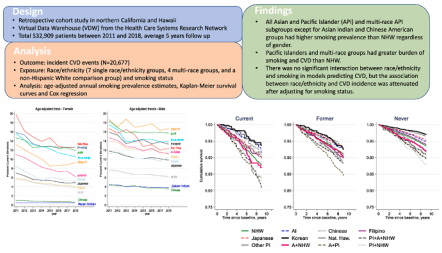
Table 3
Hazard ratios of incident CVD among API and NHW patients at two large healthcare systems in northern California and Hawaii, 2011–2018.

	Model 1 HR (95 % CI)	Model 2 HR (95 % CI)
Race/ethnicity		
Non-Hispanic White	1 (reference)	1 (reference)
Asian Indian	0.76 (0.71,0.83)**	0.80 (0.74,0.87)**
Chinese	0.61 (0.57,0.64)**	0.64 (0.60,0.68)**
Filipino	0.85 (0.80,0.90)**	0.86 (0.81,0.92)**
Japanese	0.65 (0.61,0.69)**	0.66 (0.62,0.71)**
Korean	0.59 (0.49,0.70)**	0.59 (0.49,0.70)**
Native Hawaiian	1.00 (0.80,1.25)	0.96 (0.76,1.20)
Other Pacific Islander	0.97 (0.81,1.16)	0.95 (0.80,1.14)
PI+*A*+NHW	1.40 (1.25,1.56)**	1.36 (1.22,1.51)**
A+NHW	1.12 (0.98,1.28)	1.11 (0.97,1.26)
A+PI	1.34 (1.22,1.47)**	1.32 (1.20,1.45)**
PI+NHW	1.32 (1.19,1.47)**	1.29 (1.17,1.44)**
Female (reference=male)	0.69 (0.67,0.71)**	0.72 (0.70,0.74)**
Age, per year	1.06 (1.06,1.06)**	1.06 (1.06,1.06)**
California (reference=Hawaii	1.04 (1.00,1.08) *	1.06 (1.02,1.10)**
Census block median household income, per 10,000	1.00 (1.00,1.01)	1.00 (1.00,1.01)
Proportion census block college degree, per 10 %	0.96 (0.95,0.97)**	0.96 (0.95,0.97)**
Smoking status		
Current	–	1.64 (1.55,1.74)**
Former	–	1.23 (1.19,1.27)**
Never	–	1 (reference)

* $P < 0.05$.
** $P < 0.01$.

5. Conclusions

Overall, we found considerable heterogeneity in both smoking prevalence and the risk of CVD among disaggregated Asian and Pacific Islander groups in addition to multi-racial API groups. Although some groups, such as those of Chinese ethnicity, had lower smoking prevalence and CVD risk when compared to the NHW population, other groups, including the Native Hawaiian and Pacific Islander groups, had greater burden of smoking and CVD than the NHW group. Rates of smoking and CVD were particularly high for multiracial Asian and Pacific Islander groups, who represent a growing population in the U.S. The disaggregation of data on API individuals and on mixed racial categories is crucial to understanding and addressing racial and ethnic disparities in smoking prevalence and CVD. Our findings may provide policymakers with an entry point for better understanding this heterogeneous group of peoples and developing more relevant and impactful approaches to address population-level disparities in smoking prevalence and CVD.



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Availability of data and materials

The datasets generated and/or analyzed during the current study are not available for replication because they contain patient health information that could compromise the privacy of research participants but are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Jiang Li: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Yihe G. Daida:** Writing – review & editing, Conceptualization. **Adrian Matias Bacong:** Writing – review & editing, Validation. **Ana Gabriela Rosales:** Writing – review & editing, Validation, Methodology, Formal analysis, Data curation. **Timothy B. Frankland:** Writing – review & editing, Validation, Data curation. **Alexandra Varga:** Writing – review & editing, Data curation. **Sukyung Chung:** Writing – review & editing, Validation. **Stephen P. Fortmann:** Writing – review & editing, Funding acquisition, Conceptualization. **Beth Waitzfelder:** Writing – review & editing, Funding acquisition, Conceptualization. **Latha Palaniappan:** Writing – review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Population demographics for the analysis of smoking prevalence at two large healthcare systems in northern California and Hawaii, 2011–2018

Race/Ethnicity	Age in years mean (SD)	Female, N (%)	Income median (25th, 75th)	Education% college median (25th, 75th)	Baseline Smoking Status, N (%)		
					Current	Former	Never
All	45.0 (17.1)	298,367 (56.0)	88,143 (65,625, 115,000)	0.46 (0.29, 0.64)	42,952 (8.1)	106,895 (20.1)	383,062 (71.9)
Non-Hispanic White	50.1 (17.3)	170,761 (55.4)	87,978 (64,764, 117,000)	0.48 (0.32, 0.65)	23,703 (7.7)	74,656 (24.2)	209,611 (68.1)
Asian Indian	38.2 (10.7)	29,419 (52.6)	103,259 (82,580, 127,000)	0.63 (0.48, 0.76)	1974 (3.5)	4195 (7.5)	49,793 (89.0)
Chinese	45.9 (16.0)	29,627 (60.2)	102,118 (76,587, 133,000)	0.58 (0.39, 0.72)	1432 (2.9)	4103 (8.3)	43,663 (88.7)
Filipino	43.9 (16.3)	25,740 (57.7)	78,674 (61,136, 95,053)	0.25 (0.15, 0.38)	5005 (11.2)	7896 (17.7)	31,686 (71.1)
Japanese	53.5 (18.9)	14,209 (58.9)	81,357 (63,000, 102,000)	0.36 (0.25, 0.50)	2292 (9.5)	5459 (22.6)	16,358 (67.9)
Korean	44.0 (14.5)	5001 (65.9)	88,636 (62,000, 117,000)	0.48 (0.31, 0.66)	786 (10.4)	1397 (18.4)	5410 (71.2)
Native Hawaiian	44.9 (17.4)	885 (49.8)	74,219 (56,096, 90,703)	0.24 (0.13, 0.36)	347 (19.5)	416 (23.4)	1015 (57.1)
Other Pacific Islander	40.7 (14.4)	3151 (51.6)	66,595 (47,156, 85,144)	0.23 (0.12, 0.36)	1140 (18.7)	1180 (19.3)	3789 (62.0)
PI+*A*+NHW	38.6 (16.3)	4875 (56.7)	73,958 (57,986, 89,038)	0.25 (0.16, 0.36)	1574 (18.3)	1830 (21.3)	5195 (60.4)
***A*+NHW**	37.2 (14.7)	5636 (57.6)	80,393 (62,000, 101,000)	0.35 (0.23, 0.52)	1274 (13.0)	1768 (18.1)	6737 (68.9)
***A*+PI**	42.2 (17.2)	5370 (51.4)	73,998 (57,250,89,401)	0.24 (0.15, 0.35)	2122 (20.3)	2429 (23.2)	5900 (56.5)
PI+NHW	43.9 (17.8)	3693 (54.5)	73,438 (56,739, 88,143)	0.25 (0.15, 0.36)	1303 (19.2)	1566 (23.1)	3905 (57.6)

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