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# Migration-Associated Variation in Gastric Cancer Risk in the United States: Implications for Risk Stratification

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## ABSTRACT

Classic mid-20th-century migrant studies demonstrated that gastric cancer risk declines after migration but does not fully converge to host-country levels, implicating early-life exposures and long disease latency. Whether these migration-associated risk gradients remain detectable in contemporary low-incidence settings has not been systematically evaluated using modern U.S. cancer surveillance data.

We analyzed SEER and state cancer registry data linked to U.S. Census–derived population denominators to estimate crude and age-adjusted gastric cancer incidence from 2010 to 2022 in California and New York. Asian populations were disaggregated into Chinese, Japanese, Korean, and Vietnamese subgroups. Temporal trends were assessed using Joinpoint regression, and U.S. incidence patterns were contextualized against country-of-origin incidence. Scenario-based extrapolations to 2035 were conducted.

Gastric cancer incidence remained consistently higher among Asian populations than among non-Hispanic Whites, with age-adjusted incidence ranging from ~3.6–4.7 per 100,000 in non-Hispanic Whites versus 12–26 per 100,000 in Korean populations. Disaggregated analyses showed persistent differences across subgroups, with Korean populations consistently exhibiting the highest incidence. Incidence declined significantly over time in California (annual percent change ~−1% to −3%) but not in New York. Extrapolations suggest that a clinically meaningful burden will persist among high-risk subgroups through 2035.

These findings demonstrate that migration-associated variation in gastric cancer risk remains detectable and prevention-relevant in contemporary U.S. populations, supporting migration-informed approaches to risk stratification and prevention.

## 1 | Introduction

Gastric cancer has long served as a paradigmatic disease for understanding how migration shapes cancer risk. Classic mid-20th-century migrant studies demonstrated that risk declines following migration but does not converge to host country levels, indicating that migration modifies but does not erase risk trajectories established earlier in life [1].› [2] These findings established a foundational principle: Cancer risk reflects cumulative exposures over time, many of which are acquired before migration.

Whether these migration-structured risk patterns remain observable in contemporary low-incidence settings, and whether they can be meaningfully interpreted using modern cancer surveillance data, remains unclear. This question is increasingly relevant in the United States, where large and heterogeneous populations originating from historically

**Abbreviations:** ACS, American Community Survey; APC, annual percent change; ASIR, age-standardized incidence rate; GBD, Global Burden of Disease; NH API, non-Hispanic Asian or Pacific Islander; PUMS, Public Use Microdata Sample; SEER, Surveillance, Epidemiology, and End Results.

**What's New?**

This study provides contemporary, population-based evidence that migration-associated differences in gastric cancer risk, first described decades ago, remain stable, quantifiable, and prevention-relevant in the United States. By integrating modern cancer registry data with formal trend analysis and conditional extrapolation, the authors show that reliance on historical incidence declines alone may underestimate the future burden among high-risk populations, especially Asian subgroups. The findings highlight a potential misalignment between life-course risk accumulation and age-based prevention frameworks in the United States. The study underscores the importance of migration-informed approaches to gastric cancer prevention in low-incidence settings that incorporate early-life exposure and origin-country risk.

high-incidence regions now reside, and where population-based data offer greater demographic and geographic resolution than in prior eras.

Subsequent U.S.-based registry studies have shown that gastric cancer risk among Asian populations remains patterned by birthplace and early-life context [3–5]. More recently, this body of evidence has been reframed through an immigrant health lens, emphasizing migration as a clinically relevant context for risk interpretation rather than solely an etiologic observation [6]. In this framework, migration serves as a proxy for prior exposure history, including environmental, infectious, and dietary factors that shape long-term cancer risk. However, this conceptual shift has not been accompanied by systematic evaluation using contemporary U.S. population-based data, leaving unresolved how migration history should inform prevention strategies in low-incidence countries [7].› [8].

Although gastric cancer incidence has declined in the United States, the disease remains characterized by late-stage diagnosis, poor survival, and marked racial and geographic disparities [9]. Asian populations, including specific Asian subgroups, continue to experience substantially higher incidence than non-Hispanic Whites, with considerable variation across regions. These disparities suggest that underlying risk is not evenly distributed and may not be fully explained by differences in access to care alone.

At the same time, modern U.S. cancer registries provide substantially greater population granularity than earlier studies but remain limited in their ability to capture the timing and context of prior exposures. As a result, prevention frameworks in low-incidence settings are often organized around age and current residence, implicitly assuming that risk converges with time spent in the host country. This assumption may not hold for diseases such as gastric cancer, where risk may reflect earlier exposures that are not directly measured in contemporary datasets.

In this study, we assess whether contemporary U.S. population-based data continue to reflect migration-structured gastric cancer risk and whether these patterns remain visible and relevant for prevention. Building on prior work calling for migration-informed approaches [6], we apply a migration-informed framework that incorporates country-of-origin risk and prior exposure context to interpret gastric cancer incidence in immigrant populations. We further interpret contemporary population-based registry and census data in the context of established findings from historical migrant studies to describe subgroup-specific risk patterns and consider their implications for risk-stratified prevention.

To address this question, we analyzed SEER and state cancer registry data to characterize gastric cancer incidence across major racial and ethnic groups; disaggregated Asian populations using American Community Survey denominators to estimate subgroup-specific incidence among Chinese, Japanese, Korean, and Vietnamese populations; and contextualized U.S. patterns relative to contemporaneous incidence in countries of origin [10–12]. By examining contemporary population-based data in the context of established migrant epidemiology, this study aims to clarify the prevention relevance of migration-related gastric cancer risk in the contemporary United States.

## 2 | Methods

### 2.1 | Study Design and Conceptual Framework

We conducted a population-based, descriptive analytic study grounded in a life-course and migration-informed framework. Using contemporary cancer registry and population data, we evaluated whether gastric cancer incidence patterns among Asian subgroups in the United States are consistent with persistent risk linked to early-life geographic exposure and prior health system context. Analyses were not intended to estimate causal effects of migration timing, duration, or generational status.

### 2.2 | Data Sources

Gastric cancer incidence data for California and New York during 2010–2022 were obtained from population-based cancer registries included in the Surveillance, Epidemiology, and End Results (SEER) Program, which provides annual case counts by state, calendar year, age group, and detailed Asian race categories where available [13]. Population denominators and nativity characteristics were derived from the U.S. Census Bureau's 2010–2022 American Community Survey (ACS) 1-year Public Use Microdata Sample (PUMS) data for both states [14].

For Asian subgroups not routinely disaggregated in registry reporting, we applied PUMS person-level weights to estimate annual, age-specific population denominators, enabling estimation of subgroup-specific crude and age-adjusted incidence rates. Nativity-related characteristics (e.g., proportion foreign-born, years residing in the U.S.) were used descriptively to characterize heterogeneity in early-life exposure histories.

SEER case counts and ACS-derived population denominators were not linked at the individual level; rather, incidence rates were calculated by dividing SEER case counts by ACS-derived population estimates within corresponding age–race strata.

## 2.3 | Population Definition and Incidence Estimation

Primary population definitions were based on self-reported detailed race in the ACS PUMS (RAC2P), which assigns individuals to mutually exclusive single-race categories (e.g., Chinese, Japanese, Korean, and Vietnamese) and excludes multiracial responses. This approach aligns with standard cancer surveillance practice and provides stable population denominators for incidence estimation. Due to smaller population sizes and limited case counts in New York, Vietnamese subgroup estimates were restricted to California, where more reliable estimation was possible.

Sensitivity analyses using ancestry-based denominators derived from the first-reported ancestry variable (ANC1P) showed small differences in crude incidence estimates, generally within ~2%–10% across most subgroups, with somewhat larger differences (~8%–18%) observed in smaller populations. These differences had minimal impact on age-adjusted rates and relative incidence patterns.

Crude incidence rates were calculated as annual case counts divided by population denominators and expressed per 100,000 person-years. Age-adjusted incidence rates and corresponding standard errors were calculated by direct standardization to the 2000 U.S. standard population using SAS PROC STDRATE. Age-specific incidence rates were calculated using 5-year age strata (0–84 years), with individuals aged 85 years and older aggregated into a single open-ended group. For presentation and to improve the stability of subgroup-specific estimates, age categories were aggregated into broader groupings in figures and tables.

The aggregated non-Hispanic Asian or Pacific Islander (NH API) category includes additional Asian and Pacific Islander subgroups not analyzed individually, such as Filipino and South Asian populations (e.g., Asian Indian). Chinese, Japanese, Korean, and Vietnamese populations were selected a priori based on their established epidemiologic relevance to gastric cancer, consistently higher incidence compared with other Asian subgroups, and the availability of sufficiently large population denominators to support reliable subgroup-specific estimation. Other subgroups were not examined separately due to smaller population sizes, lower incidence, or both, limiting reliable subgroup-specific estimation.

Analyses of nativity composition and duration of residence were restricted to California, where larger population denominators and case counts allowed more reliable estimation of subgroup-specific distributions. In contrast, smaller population sizes and greater variability in New York limited the precision and interpretability of these estimates when stratified by nativity and duration categories.

## 2.4 | Trend Analysis

Temporal trends in age-adjusted incidence from 2010 to 2022 were evaluated using Joinpoint regression. Confidence intervals were calculated using the Empirical Quantile method, and permutation tests ($n = 5000$) were used to select the final model [15]. Annual age-adjusted incidence rates and their standard errors were modeled on the log scale to estimate annual percent change (APC) and corresponding 95% confidence intervals. Calendar year 2020 was excluded to minimize potential bias related to COVID-19–associated diagnostic disruption.

For all subgroup–state series, zero joinpoints were identified, indicating a single log-linear trend over the study period. Accordingly, the reported APC represents the average annual percent change across the full interval. Statistical significance was assessed using two-sided tests with $p < 0.05$. Given relatively low case counts in some subgroups, no minimum case thresholds were prespecified for joinpoint detection.

## 2.5 | Scenario-Based Extrapolation

To illustrate potential future burden, conditional extrapolations of age-adjusted incidence through 2035 were performed for selected California subgroups. Extrapolations were anchored to the model-fitted age-adjusted incidence rate (ASIR) in 2022 derived from the log-linear Joinpoint model, rather than the raw observed 2022 value, and were limited to a short planning horizon. Projected incidence rates were calculated by applying the observed annual percent change (APC) to the fitted 2022 rate using a log-linear formulation, such that projected rates at year $t$ were estimated as follows: $\text{Rate}_t = \text{Rate}_{2022}(\text{fitted}) \times (1 + \text{APC})^{(t-2022)}$.

Two scenarios were evaluated as follows: (1) Continuation of the full observed APC and (2) partial attenuation, assuming 50% of the observed APC to reflect uncertainty in trend continuation. These scenarios are illustrative and are not intended to represent formal forecasts.

Extrapolation analyses were restricted to selected California subgroups due to larger and more stable subgroup-specific estimates, which reduced year-to-year variability in incidence. In contrast, estimates in New York were more variable due to smaller subgroup sizes and wider confidence intervals, limiting the reliability of extrapolated estimates. Subgroups were selected based on these data characteristics to ensure stable estimation and clear illustration of potential trajectories, rather than based on the direction or magnitude of observed trends.

## 2.6 | Statistical Software

Spearman correlation between age-adjusted incidence rate and nativity related characteristics for each racial group was calculated. All analyses were conducted using SEER*Stat (version 8.4.5), SAS (version 9.4), and the Joinpoint Regression Program (version 6.0.1) [16]. Key analytical procedures included Joinpoint regression with Empirical Quantile–based confidence intervals and permutation testing ($n = 5000$) for model selection, ACS PUMS weighting using person-level weights (PWGTP), and direct age standardization to the 2000 U.S. standard population using SAS PROC STDRATE.

**TABLE 1** | SEER gastric cancer incidence in California and New York, 2010–2022 (Rates per 100,000 persons).

| | | Non-Hispanic White | | | Non-Hispanic Asian or Pacific islander | | |
|---|---|---|---|---|---|---|---|
| State | Year | Crude rate | Age-adjusted rate (95% CI) | Rate ratio (95% CI) | Crude rate | Age-adjusted rate (95% CI) | Rate ratio (95% CI) |
| CA | 2010 | 6.12 | 4.40 (4.12–4.70) | Reference | 9.37 | 9.86 (8.99–10.79) | Reference |
| CA | 2011 | 6.16 | 4.41 (4.12–4.71) | 1.00 (0.91–1.10) | 8.84 | 8.92 (8.12–9.77) | 0.90 (0.79–1.03) |
| CA | 2012 | 6.61 | 4.66 (4.38–4.97) | 1.06 (0.97–1.16) | 10.29 | 10.16 (9.32–11.05) | 1.03 (0.91–1.17) |
| CA | 2013 | 6.07 | 4.22 (3.95–4.51) | 0.96 (0.87–1.05) | 9.19 | 9.09 (8.31–9.92) | 0.92 (0.81–1.05) |
| CA | 2014 | 6.14 | 4.17 (3.91–4.46) | 0.95 (0.86–1.04) | 9.08 | 8.79 (8.05–9.60) | 0.89 (0.79–1.01) |
| CA | 2015 | 5.99 | 4.05 (3.78–4.33) | 0.92 (0.84–1.01) | 8.68 | 8.25 (7.54–9.01) | 0.84 (0.74–0.95) |
| CA | 2016 | 5.96 | 3.92 (3.67–4.20) | 0.89 (0.81–0.98) | 8.72 | 8.02 (7.34–8.75) | 0.81 (0.72–0.92) |
| CA | 2017 | 5.84 | 3.90 (3.64–4.18) | 0.89 (0.81–0.98) | 8.69 | 7.89 (7.23–8.60) | 0.80 (0.71–0.91) |
| CA | 2018 | 5.99 | 3.95 (3.69–4.23) | 0.90 (0.82–0.99) | 7.95 | 7.09 (6.47–7.75) | 0.72 (0.63–0.82) |
| CA | 2019 | 5.77 | 3.72 (3.47–3.99) | 0.85 (0.77–0.93) | 8.85 | 7.60 (6.98–8.27) | 0.77 (0.68–0.87) |
| CA | 2020 | 5.63 | 3.62 (3.37–3.89) | 0.82 (0.75–0.91) | 7.23 | 6.09 (5.54–6.68) | 0.62 (0.54–0.70) |
| CA | 2021 | 6.09 | 3.86 (3.60–4.14) | 0.88 (0.80–0.97) | 8.27 | 6.85 (6.28–7.47) | 0.70 (0.61–0.79) |
| CA | 2022 | 5.94 | 3.62 (3.37–3.89) | 0.82 (0.75–0.91) | 7.54 | 6.02 (5.49–6.59) | 0.61 (0.54–0.70) |
| NY | 2010 | 7.33 | 5.47 (5.10–5.86) | Ref | 11.70 | 13.33 (11.36–15.55) | Ref |
| NY | 2011 | 7.47 | 5.49 (5.12–5.88) | 1.00 (0.91–1.11) | 11.77 | 13.01 (11.12–15.12) | 0.98 (0.78–1.22) |
| NY | 2012 | 7.36 | 5.32 (4.96–5.70) | 0.97 (0.88–1.07) | 11.29 | 12.85 (10.97–14.95) | 0.96 (0.77–1.20) |
| NY | 2013 | 7.55 | 5.50 (5.13–5.89) | 1.01 (0.91–1.11) | 13.93 | 15.87 (13.82–18.13) | 1.19 (0.97–1.47) |
| NY | 2014 | 6.89 | 4.96 (4.61–5.34) | 0.91 (0.82–1.00) | 12.94 | 13.77 (11.95–15.77) | 1.03 (0.84–1.28) |
| NY | 2015 | 6.85 | 4.84 (4.50–5.20) | 0.89 (0.80–0.98) | 12.74 | 12.86 (11.18–14.73) | 0.96 (0.78–1.19) |
| NY | 2016 | 7.23 | 5.14 (4.79–5.52) | 0.94 (0.85–1.04) | 12.80 | 12.97 (11.30–14.83) | 0.97 (0.79–1.20) |
| NY | 2017 | 7.14 | 4.99 (4.64–5.36) | 0.91 (0.82–1.01) | 11.95 | 12.08 (10.49–13.84) | 0.91 (0.73–1.12) |
| NY | 2018 | 6.74 | 4.74 (4.39–5.11) | 0.87 (0.78–0.96) | 11.77 | 11.13 (9.67–12.76) | 0.84 (0.68–1.03) |
| NY | 2019 | 6.75 | 4.62 (4.29–4.98) | 0.85 (0.76–0.94) | 12.66 | 12.29 (10.75–14.00) | 0.92 (0.75–1.14) |
| NY | 2020 | 6.33 | 4.33 (4.00–4.68) | 0.79 (0.71–0.88) | 9.77 | 8.92 (7.66–10.35) | 0.67 (0.54–0.83) |
| NY | 2021 | 7.40 | 4.77 (4.44–5.13) | 0.87 (0.79–0.97) | 13.15 | 11.63 (10.19–13.21) | 0.87 (0.71–1.07) |
| NY | 2022 | 6.54 | 4.21 (3.89–4.55) | 0.77 (0.69–0.86) | 12.94 | 11.17 (9.79–12.69) | 0.84 (0.68–1.03) |

*Note:* Annual crude and age-adjusted gastric cancer incidence rates (per 100,000 persons) are shown for non-Hispanic White and aggregated non-Hispanic Asian or Pacific Islander populations in California and New York from 2010 through 2022. Incidence counts and population denominators were obtained from SEER population files derived from U.S. Census decennial counts and intercensal/postcensal estimates. Age-adjusted rates were standardized to the 2000 U.S. standard population using SEER methods.

## 3 | Results

### 3.1 | Contemporary Gastric Cancer Incidence Across Migrant-Linked Populations

Using population-based cancer registry data and U.S. Census–derived population denominators, we estimated crude and age-adjusted gastric cancer incidence from 2010 through 2022 in California and New York. These states were selected for primary analysis because they contain the largest Asian populations in the United States and provide incidence estimates with reduced year-to-year variability due to larger population denominators and higher annual case counts.

Across both states and all study years, age-adjusted gastric cancer incidence remained consistently higher among aggregated non-Hispanic Asian or Pacific Islander populations than among non-Hispanic Whites, with no evidence of convergence over time (Table 1). Although absolute incidence declined modestly in both groups, the difference between aggregated Asian and non-Hispanic White populations persisted across calendar years.

The aggregated NH API category includes additional Asian and Pacific Islander subgroups, such as Filipino and South Asian populations (e.g., Asian Indian), which generally have lower incidence or smaller population sizes and were not examined separately.

Across all study years, crude incidence among aggregated non-Hispanic Asian or Pacific Islander populations exceeded corresponding age-adjusted rates, whereas crude and age-adjusted estimates among non-Hispanic Whites were more closely aligned (Table 1). Reporting both crude and age-adjusted incidence allows assessment of overall population burden using crude rates, while age-adjusted rates enable comparisons across populations by accounting for differences in age distribution and age-specific incidence patterns. The close alignment between crude and age-adjusted estimates among non-Hispanic Whites likely reflects similarities between the age distribution of this population and the 2000 U.S. standard population, rather than representing an independent substantive finding.

### 3.2 | Disaggregation Reveals Consistent Differences Across Asian Subgroups

Disaggregating the aggregated Asian category revealed pronounced and persistent heterogeneity in gastric cancer incidence across Asian subgroups. Across the 2010–2022 study period in California, age-adjusted incidence was consistently highest among Korean populations, followed by Japanese populations, with intermediate rates among Chinese populations and lower—but persistently elevated—rates among Vietnamese populations relative to non-Hispanic Whites (Table 2). In absolute terms, these subgroup-specific estimates were based on substantial annual case counts in California, with ~150–190 cases per year among Chinese populations, 90–130 among Korean populations, 50–80 among Vietnamese populations, and 40–70 among Japanese populations across the study period.

For all Asian subgroups, crude incidence exceeded age-adjusted incidence, with the largest absolute differences observed among Korean and Japanese populations. Although incidence declined over time in each subgroup, similar differences across subgroups were observed throughout the study period, with no clear evidence of convergence toward the non-Hispanic White baseline.

Comparable subgroup patterns were observed in New York, with higher incidence among Korean and Japanese populations and intermediate rates among Chinese populations (Table 3). The consistency of these differences across states supports the stability and reproducibility of disaggregated incidence patterns across geographic settings, even as absolute rates varied by state and subgroup.

### 3.3 | Formal Trend Analysis Confirms Declining Incidence in California but Not in New York

Joinpoint regression analysis of age-adjusted incidence rates identified statistically significant declining trends for all four Asian subgroups in California between 2010 and 2022 (Figure 1). Annual percent change (APC) estimates indicated consistent log-linear declines, with APCs of −2.7% for Chinese ($p < 0.001$), −5.8% for Japanese ($p < 0.001$), −3.9% for Korean ($p = 0.0004$), and −3.4% for Vietnamese populations ($p = 0.006$). All Joinpoint models selected zero joinpoints, indicating a single log-linear trend over the study period.

In contrast, no statistically significant trends were detected among Asian subgroups in New York, where APC estimates were not significantly different from zero for any subgroup (Figure S1). These findings indicate that, while declining incidence is evident in California, temporal trends are less clearly defined in New York within the limits of available data and statistical precision.

### 3.4 | Nativity Composition as Context for Persistent Incidence Patterns

Nativity composition varied substantially across Asian subgroups and provides population-level context for observed incidence patterns. Averaged across 2010–2022, Korean and Vietnamese populations had the highest proportions of foreign-born individuals, whereas Japanese populations included a larger U.S.-born and long-term resident component; Chinese populations exhibited intermediate nativity and duration-of-residence distributions relative to other Asian subgroups (Table 4). Although nativity measures were not linked to individual cancer outcomes, these distributions illustrate heterogeneity in early-life exposure histories across populations that persist within U.S. settings.

### 3.5 | Origin-Country Incidence Anchors Contemporary Migration Gradients

To contextualize U.S. incidence patterns, age-adjusted gastric cancer incidence in countries of origin—Japan, Korea, China, and Vietnam—was examined alongside corresponding incidence among U.S. populations in California and New York. Across all Asian subgroups, incidence in the United States was lower than in countries of origin and higher than that observed among U.S. non-Hispanic Whites (Figure 2).

Across subgroups, U.S. incidence broadly reflected differences observed in origin-country incidence, although patterns were not strictly aligned across all subgroups. Incidence was highest among Korean populations, while rates among Japanese, Chinese, and Vietnamese populations were more similar and varied by subgroup and setting. Within the United States, incidence varied by state for several subgroups, most notably among Chinese populations, for whom incidence was higher in New York than in California. Age-adjusted gastric cancer incidence among U.S. non-Hispanic Whites closely approximated overall U.S. incidence estimates reported by GLOBOCAN.

### 3.6 | Scenario-Based Extrapolation to 2035 Illustrates Sensitivity of Future Burden to Trend Assumptions

To illustrate how interpretation of future gastric cancer burden depends on assumptions about trend persistence—rather than to

**TABLE 2** | Annual gastric cancer incidence by race/ethnicity in California, 2010–2022 (Rates per 100,000 persons).

| | Non-Hispanic White | | Chinese | | Japanese | | Korean | | Vietnamese | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Crude rate | Age-adjusted rate | Crude rate | Age-adjusted rate (95% CI) | Crude rate | Age-adjusted rate (95% CI) | Crude rate | Age-adjusted rate (95% CI) | Crude rate | Age-adjusted rate (95% CI) |
| 2010 | 6.12 | 4.40 (4.12–4.70) | 12.27 | 10.52 (8.86–12.17) | 22.21 | 12.01 (8.89–15.13) | 22.83 | 23.16 (18.63–27.68) | 8.73 | 10.59 (7.65–13.53) |
| 2011 | 6.16 | 4.41 (4.12–4.71) | 11.49 | 9.36 (7.84–10.89) | 21.15 | 10.63 (7.76–13.50) | 21.69 | 21.68 (17.17–26.18) | 8.82 | 11.27 (8.07–14.47) |
| 2012 | 6.61 | 4.66 (4.38–4.97) | 11.65 | 9.60 (8.08–11.11) | 25.75 | 13.32 (9.96–16.69) | 27.67 | 25.83 (21.32–30.34) | 11.27 | 11.64 (8.80–14.49) |
| 2013 | 6.07 | 4.22 (3.95–4.51) | 11.83 | 9.71 (8.18–11.23) | 26.14 | 12.29 (9.31–15.26) | 21.55 | 19.67 (15.73–23.62) | 9.42 | 10.50 (7.77–13.22) |
| 2014 | 6.14 | 4.17 (3.91–4.46) | 11.83 | 9.42 (7.96–10.88) | 22.31 | 9.77 (7.22–12.33) | 21.87 | 18.78 (15.14–22.41) | 8.33 | 8.25 (5.97–10.53) |
| 2015 | 5.99 | 4.05 (3.78–4.33) | 10.10 | 7.75 (6.49–9.02) | 18.51 | 8.59 (6.11–11.07) | 22.26 | 18.43 (14.87–21.98) | 10.57 | 10.08 (7.53–12.62) |
| 2016 | 5.96 | 3.92 (3.67–4.20) | 10.68 | 8.45 (7.14–9.76) | 18.17 | 8.42 (5.78–11.05) | 22.64 | 19.32 (15.64–23.01) | 8.63 | 7.58 (5.57–9.60) |
| 2017 | 5.84 | 3.90 (3.64–4.18) | 9.83 | 7.42 (6.23–8.61) | 19.25 | 9.38 (6.55–12.22) | 25.54 | 20.16 (16.50–23.82) | 10.77 | 9.10 (6.96–11.24) |
| 2018 | 5.99 | 3.95 (3.69–4.23) | 9.70 | 7.56 (6.34–8.78) | 15.60 | 6.73 (4.62–8.83) | 21.55 | 16.30 (13.12–19.48) | 9.14 | 7.57 (5.63–9.51) |
| 2019 | 5.77 | 3.72 (3.47–3.99) | 11.73 | 8.70 (7.44–9.96) | 17.74 | 7.43 (4.78–10.07) | 26.30 | 19.14 (15.73–22.56) | 10.72 | 8.44 (6.47–10.42) |
| 2020 | 5.63 | 3.62 (3.37–3.89) | 10.16 | 7.64 (6.45–8.83) | 17.59 | 5.86 (4.03–7.70) | 16.80 | 12.62 (9.80–15.45) | 8.92 | 7.19 (5.39–8.99) |
| 2021 | 6.09 | 3.86 (3.60–4.14) | 10.02 | 7.32 (6.16–8.49) | 15.68 | 7.26 (4.81–9.70) | 23.64 | 16.59 (13.48–19.71) | 11.73 | 9.08 (7.02–11.14) |
| 2022 | 5.94 | 3.62 (3.37–3.89) | 10.61 | 7.39 (6.26–8.52) | 16.68 | 6.14 (4.12–8.16) | 19.07 | 12.28 (9.69–14.88) | 8.59 | 6.48 (4.78–8.18) |

*Note:* Annual crude and age-adjusted gastric cancer incidence rates (per 100,000 persons) are shown for non-Hispanic White, Chinese, Japanese, Korean, and Vietnamese populations in California from 2010 through 2022. Case counts were obtained from the California SEER cancer registry. Population denominators for Asian subgroups were derived from the American Community Survey using the recoded detailed race variable (RAC2P; race reported as "alone"), consistent with SEER race/ethnicity definitions. Age-adjusted rates were standardized to the 2000 U.S. standard population using SEER methods.

**TABLE 3** | Annual gastric cancer incidence by race/ethnicity in New York, 2010–2022 (Rates per 100,000 persons).

| | Non-Hispanic White | | Chinese | | Japanese | | Korean | |
|---|---|---|---|---|---|---|---|---|
| Year | Crude rate | Age-adjusted rate | Crude rate | Age-adjusted rate (95% CI) | Crude rate | Age-adjusted rate (95% CI) | Crude rate | Age-adjusted rate (95% CI) |
| 2010 | 7.33 | 5.47 (5.10–5.86) | 17.22 | 17.23 (13.82–20.64) | 10.06 | 14.98 (0.00–31.01) | 22.49 | 21.70 (13.98–29.41) |
| 2011 | 7.47 | 5.49 (5.12–5.88) | 16.83 | 15.17 (12.12–18.22) | 15.72 | 16.85 (1.44–32.27) | 26.35 | 36.96 (22.23–51.69) |
| 2012 | 7.36 | 5.32 (4.96–5.70) | 17.49 | 17.13 (13.83–20.42) | 17.83 | 18.54 (4.11–32.98) | 17.94 | 22.25 (12.90–31.60) |
| 2013 | 7.55 | 5.50 (5.13–5.89) | 21.56 | 20.41 (16.96–23.86) | 10.77 | 10.20 (0.00–20.91) | 28.04 | 37.95 (24.91–51.00) |
| 2014 | 6.89 | 4.96 (4.61–5.34) | 20.78 | 19.26 (16.03–22.49) | 18.86 | 18.83 (4.50–33.16) | 22.01 | 23.65 (14.03–33.27) |
| 2015 | 6.85 | 4.84 (4.50–5.20) | 20.48 | 17.67 (14.69–20.65) | 10.64 | 12.13 (0.00–24.61) | 23.95 | 22.24 (14.49–29.98) |
| 2016 | 7.23 | 5.14 (4.79–5.52) | 19.57 | 16.55 (13.73–19.37) | 13.69 | 18.36 (3.02–33.70) | 28.30 | 30.31 (20.41–40.22) |
| 2017 | 7.14 | 4.99 (4.64–5.36) | 18.12 | 15.29 (12.69–17.88) | 15.16 | 13.67 (1.47–25.86) | 23.81 | 23.12 (14.74–31.49) |
| 2018 | 6.74 | 4.74 (4.39–5.11) | 18.63 | 15.09 (12.43–17.76) | 8.33 | 7.54 (0.00–16.47) | 27.45 | 23.19 (15.26–31.11) |
| 2019 | 6.75 | 4.62 (4.29–4.98) | 20.82 | 17.55 (14.65–20.45) | 9.74 | 10.82 (0.00–23.53) | 23.52 | 19.05 (12.04–26.06) |
| 2020 | 6.33 | 4.33 (4.00–4.68) | 14.90 | 11.65 (9.37–13.93) | 2.60 | 1.56 (0.00–4.63) | 24.99 | 21.91 (13.34–30.47) |
| 2021 | 7.40 | 4.77 (4.44–5.13) | 23.01 | 17.35 (14.59–20.11) | 13.71 | 12.75 (1.40–24.09) | 26.18 | 17.74 (11.15–24.33) |
| 2022 | 6.54 | 4.21 (3.89–4.55) | 19.74 | 14.08 (11.75–16.41) | 10.42 | 8.93 (0.05–17.81) | 18.84 | 16.27 (9.51–23.03) |

*Note:* Annual crude and age-adjusted gastric cancer incidence rates (per 100,000 persons) are shown for non-Hispanic White, Chinese, Japanese, and Korean populations in New York from 2010 through 2022. Case counts were obtained from the New York State Cancer Registry and SEER registry tabulations. Population denominators for Asian subgroups were derived from the American Community Survey using the recoded detailed race variable (RAC2P; race reported as "alone"), consistent with registry race/ethnicity definitions. Age-adjusted rates were standardized to the 2000 U.S. standard population using SEER methods.

generate forecasts—we conducted conditional, scenario-based extrapolations of age-adjusted incidence through 2035 for selected California subgroups. Korean and Japanese populations were chosen a priori to represent contrasting but policy-relevant profiles: The highest observed incidence (Korean) and the steepest observed decline (Japanese). Because the observed 2022 incidence for the Korean subgroup fell below the fitted log-linear trend, projections were anchored to the model-fitted 2022 value, resulting in a modest upward adjustment of projected incidence for this group compared with projections based on the raw observed value.

Under a status quo continuation scenario assuming persistence of Joinpoint-estimated annual percent changes, projected age-adjusted incidence declined through 2035 for both subgroups. In contrast, under a plateau scenario assuming partial attenuation of recent declines, projected incidence remained substantially higher—particularly among Korean populations, for whom absolute rates remained elevated despite continued downward trends (Figure 3).

These scenario-based analyses are not forecasts but illustrative stress tests demonstrating that conclusions about future burden are highly sensitive to assumptions about trend continuation. Even in the presence of statistically significant historical declines, plausible attenuation of recent trends yields a sustained, clinically meaningful burden among high-risk populations, underscoring the limitations of relying on historical declines alone for prevention planning.

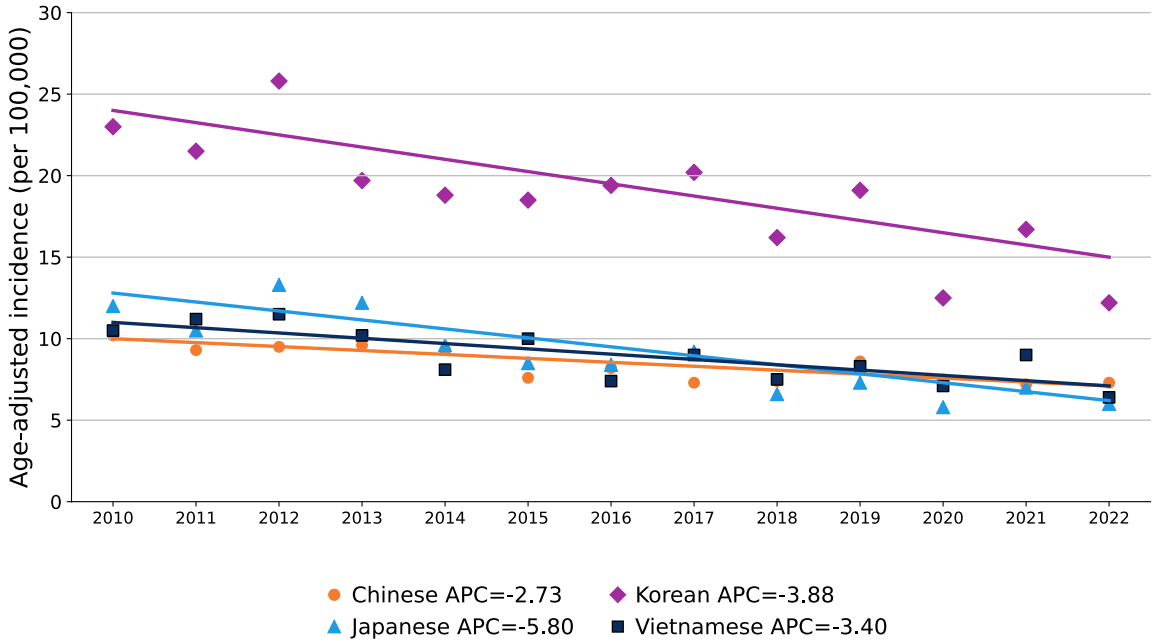


**FIGURE 1** | Age-adjusted gastric cancer incidence trends from 2010 to 2022 among Chinese, Japanese, Korean, and Vietnamese populations in California. Age-adjusted incidence rates (per 100,000 person-years) are shown for each subgroup. Points represent annual estimates, and lines represent fitted trends from Joinpoint regression analysis. Rates were age-standardized to the 2000 U.S. standard population. Annual percent change (APC) and corresponding 95% confidence intervals (CI) are shown.

**TABLE 4** | Nativity composition and duration of U.S. residence among asian subgroups in California, 2010–2022.

| Population | U.S.-born (%) | Foreign-born (%) | Lived in U.S. 0–9 years (%) | Lived in U.S. 10–19 years (%) | Lived in U.S. ≥ 20 years (%) |
|---|---|---|---|---|---|
| Chinese | 31.8 | 68.2 | 17.7 | 14.8 | 67.5 |
| | Rho | 0.34 | −0.24 | 0.87 | −0.80 |
| | P for Rho | 0.26 | 0.42 | < 0.01 | < 0.01 |
| Japanese | 60.2 | 39.8 | 10.3 | 6.8 | 82.9 |
| | Rho | −0.68 | −0.17 | 0.58 | −0.80 |
| | P for Rho | 0.01 | 0.58 | 0.04 | < 0.01 |
| Korean | 28.9 | 71.1 | 14.2 | 15.7 | 70.1 |
| | Rho | 0.77 | 0.81 | 0.49 | −0.71 |
| | P for Rho | 0.00 | 0.00 | 0.09 | 0.01 |
| Vietnamese | 31.5 | 68.5 | 11.8 | 13.1 | 75.1 |
| | Rho | 0.43 | 0.29 | 0.69 | −0.65 |
| | P for Rho | 0.14 | 0.33 | 0.01 | 0.02 |

*Note:* Nativity composition and duration of U.S. residence among Asian subgroups in California, averaged across 2010–2022. Percentages were derived from the American Community Survey using recoded detailed race (RAC2P) definitions. Duration of U.S. residence reflects number of years lived in the United States among foreign-born individuals and is shown to illustrate heterogeneity in early-life exposure and migration timing. U.S.-born percentage was calculated as the complement of foreign-born status. Values represent mean percentages across study years (2010–2022), derived from ACS population denominators using RAC2P-defined populations.

## 4 | Discussion

This study demonstrates that migration-associated patterns in gastric cancer risk, first described in classic mid-20th-century migrant cohorts, remain detectable and prevention-relevant in contemporary U.S. populations. Despite substantial declines in overall gastric cancer incidence and major shifts in immigration patterns, Asian subgroups originating from historically high-incidence regions continue to exhibit consistent differences in risk across states and analytic approaches. The persistence

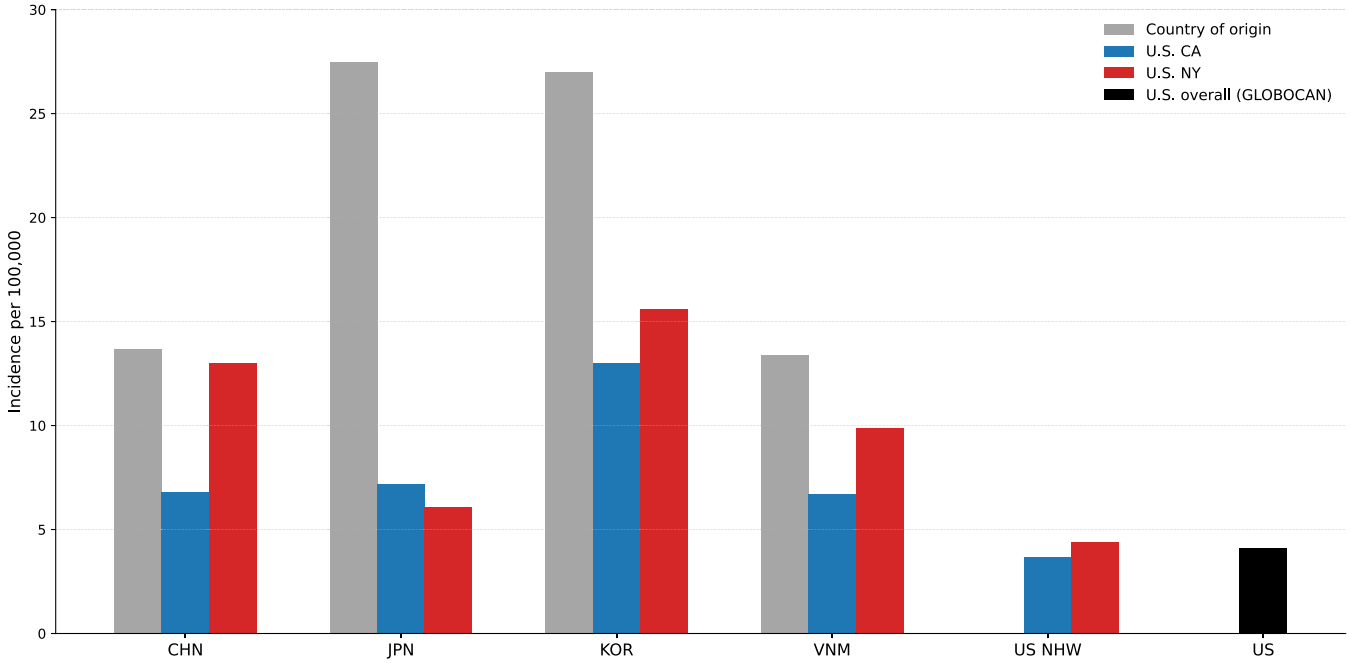


**FIGURE 2** | Gastric cancer incidence in countries of origin compared with Chinese, Japanese, Korean, and Vietnamese populations in California and New York, 2010–2022. Bars represent age-standardized gastric cancer incidence rates (ASIR, per 100,000) for Chinese (CHN), Japanese (JPN), Korean (KOR), and Vietnamese (VNM) populations. Incidence in countries of origin (gray) is compared with incidence among corresponding U.S. populations in California (blue) and New York (red). Age-standardized incidence among U.S. non-Hispanic White (NHW) populations is shown for reference. The black bar represents the overall U.S. gastric cancer incidence estimate from GLOBOCAN. Origin-country estimates are based on GLOBOCAN age-standardized incidence rates for the most recent available year.

of these differences over more than a decade supports a life-course model in which early-life exposure exerts durable influence on gastric cancer risk that is not erased by migration or prolonged residence in a low-incidence setting [17–19].

Importantly, rather than revisiting migrant attenuation as an etiologic observation, this analysis reframes migration as a prevention-relevant life-course exposure that remains detectable within modern cancer surveillance systems. In doing so, it highlights a potential misalignment between the early-life acquisition and long latency of gastric cancer risk and prevention frameworks in low-incidence countries that rely primarily on age and current residence [6, 7].

### 4.1 | Migration Modifies but Does Not Reset Gastric Cancer Risk

Across states, population definitions, and analytic approaches, migration was associated with attenuation of gastric cancer risk but did not eliminate underlying differences in risk. Asian subgroups demonstrated broadly similar patterns in incidence, with persistently higher rates among Korean populations and all subgroups remaining elevated relative to non-Hispanic Whites (Tables 1–3). However, the relative ordering of incidence was not uniform across all subgroups, with Japanese populations exhibiting lower incidence than expected based on origin-country rates. These patterns were reproducible across California and New York and were consistent across alternative population definitions, indicating that the observed differences are unlikely to reflect artifacts of measurement.

Formal trend analysis clarified important geographic differences. In California, age-adjusted incidence declined significantly across all Asian subgroups, with consistent log-linear trends and no detected joinpoints (Figure 1). In contrast, no statistically significant trends were detected in New York, where APC estimates were not distinguishable from zero. Together, these findings indicate that declining incidence is not uniform across settings and that historical momentum observed in some states cannot be assumed elsewhere. The absence of statistically significant trends in New York likely reflects limited statistical precision due to smaller annual subgroup-specific case counts, rather than evidence of stable or increasing risk.

Contemporary data also revealed meaningful heterogeneity within the United States that is not captured by aggregated race categories or national incidence estimates. In particular, gastric cancer incidence among Chinese populations was substantially higher in New York than in California, whereas between-state differences were smaller for Japanese, Korean, and Vietnamese populations (Figure 2). This pattern suggests that migration-linked risk varies across host-country contexts and reflects more than country of origin alone, including heterogeneity in early-life exposure, origin-region risk within countries, and migration cohort characteristics that are not visible in conventional surveillance frameworks [19–21].

National and state-level estimates from the most recent Global Burden of Disease (GBD 2023) [22] study provide important context on overall gastric cancer trends in the United States, including temporal patterns in incidence and mortality. However, the lack of detailed race/ethnicity stratification limits their ability to

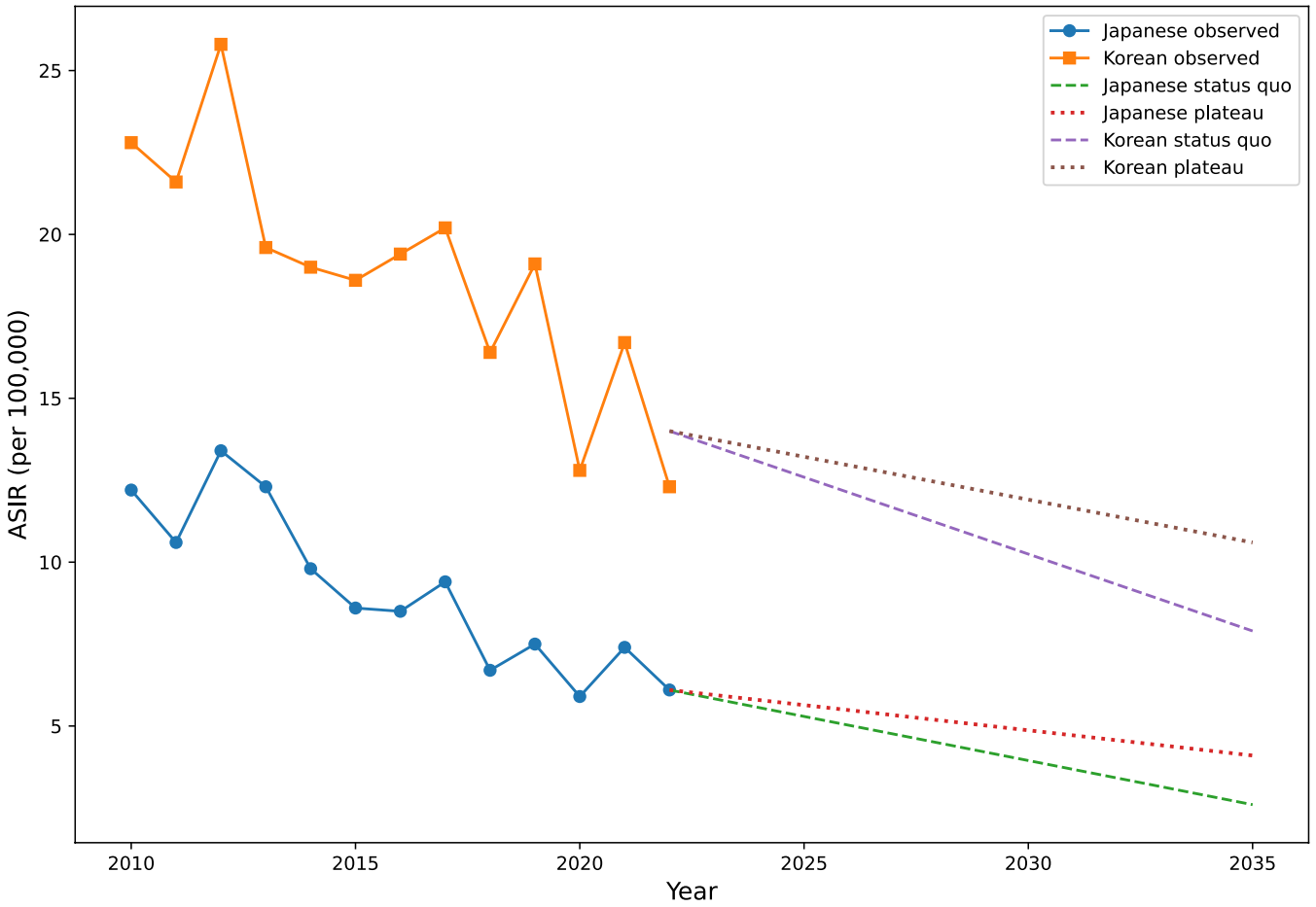


**FIGURE 3** | Observed and scenario-based extrapolation of age-adjusted gastric cancer incidence in California, 2010–2035. Age-adjusted incidence rates (per 100,000) among Korean and Japanese populations are shown. Solid lines represent observed incidence from 2010 to 2022, derived from state cancer registry data and standardized to the 2000 U.S. standard population. Dashed and dotted lines represent conditional, scenario-based extrapolations through 2035. Two scenarios are presented as follows: (1) Continuation of the full Joinpoint-estimated annual percent change (APC) observed during 2010–2022; and (2) partial attenuation, assuming 50% of the observed APC from 2022 onward. Extrapolations were anchored to the model-fitted age-standardized incidence rate (ASIR) in 2022 derived from the log-linear Joinpoint model.

capture the substantial heterogeneity observed across high-risk populations. In this context, subgroup-specific analyses, such as those presented here, are necessary to identify and characterize disparities that may be obscured in aggregate estimates.

### 4.2 | Early-Life Exposure and Long Latency as a Primary Explanatory Framework

The persistence of gastric cancer risk across Asian subgroups is most parsimoniously explained by early-life exposure coupled with long disease latency. Gastric carcinogenesis is a slow, multistep process often initiated early in life through chronic *Helicobacter pylori* infection, dietary exposures, and sustained inflammatory injury, with malignant transformation occurring many years or decades later [23–25]. Within this context, migration represents an inflection point along an already established risk trajectory rather than a reset of cumulative exposure.

Consistent with this pattern, populations originating from historically high-incidence countries, most notably Korea and Japan, continued to exhibit elevated age-adjusted gastric cancer incidence in the United States, with persistently higher rates among Korean populations and variation across other subgroups. Although Asian subgroups differed substantially in nativity composition and duration of residence in the United States, these differences did not fully account for the observed subgroup-level disparities. Differences in nativity composition provide additional population-level context for divergence between Japanese and Korean populations in the United States, with Japanese populations including a larger U.S.-born and long-term resident component (Table 4). In particular, the relatively lower incidence observed among Japanese populations in the United States may reflect their longer history of migration and a higher proportion of U.S.-born or long-term resident individuals, consistent with greater cumulative exposure to a low-incidence environment over the life course. While these data do not permit causal inference at the individual level, they are compatible with attenuation of risk associated with longer cumulative residence in a low-incidence setting.

At the same time, these patterns are unlikely to be explained by migration-related exposure alone. Although the observed patterns are consistent with a life-course and migration-informed framework, these subgroup differences likely reflect a broader

set of unmeasured contributors beyond migration history alone. In particular, variation in early-life acquisition and persistence of *Helicobacter pylori* infection, including differences in prevalence, strain virulence, and prior detection and eradication, may play a central role in shaping risk trajectories across populations. Socioeconomic and environmental conditions across the life course, such as childhood crowding, sanitation, and dietary exposures, may further influence cumulative risk. In addition, differences in access to health care, utilization of diagnostic services, and prior endoscopic or preventive interventions before and after migration may affect both underlying disease burden and the likelihood of detection. These factors were not directly modeled in the present analysis and should be considered when interpreting the observed incidence, which likely reflects the combined influence of multiple intersecting exposures rather than a single determinant.

### 4.3 | Scenario-Based Extrapolation Highlights Sensitivity of Future Burden to Trend Assumptions

Scenario-based extrapolation to 2035 extends these observations by illustrating how conclusions about future burden depend on assumptions about trend persistence. When recent Joinpoint-estimated declines were continued unchanged, projected incidence decreased through 2035 among Korean and Japanese populations in California. However, under a conservative plateau scenario reflecting attenuation of recent declines, projected incidence remained substantially higher, particularly among Korean populations, whose absolute rates remained elevated despite continued decline (Figure 3).

These conditional extrapolations are not forecasts; rather, they demonstrate that even statistically significant historical declines may not translate into low future burden if trend momentum slows. The results underscore that reliance on historical declines alone can underestimate future prevention needs among high-risk populations and reinforce the relevance of migration- and life-course–informed approaches to planning.

### 4.4 | Implications for Risk Stratification and Prevention Policy

Taken together, these findings underscore a central tension between how gastric cancer risk is accumulated across the life course and how prevention strategies are currently operationalized in low-incidence settings. In the United States, prevention frameworks are largely organized around age-based thresholds and current residence, reflecting an implicit assumption that risk is acquired relatively late and converges toward host-country norms [7]. For diseases characterized by early-life exposure and long latency, such approaches may incompletely capture meaningful variation in population risk.

This study does not seek to define screening eligibility criteria or propose specific duration-of-residence thresholds. Rather, it highlights an opportunity to more explicitly incorporate exposure timing, origin-country risk, and cumulative life-course context into risk assessment. A migration-informed framework would complement existing approaches by integrating pragmatic proxies, such as early-life residence in high-incidence regions and origin-country incidence, alongside traditional demographic factors, thereby improving alignment between epidemiologic risk and prevention strategies.

The distinction between crude and age-adjusted incidence further illustrates the relevance of this perspective. Crude incidence reflects the health-system burden experienced by populations, whereas age-adjusted incidence facilitates comparison of underlying susceptibility across groups with differing age structures. Migration influences both dimensions simultaneously. Prevention strategies that attend to only one metric risk overlooking either near-term clinical burden or longer-term exposure-related risk.

Importantly, age-adjusted incidence rates, while essential for population-level comparisons, can understate the magnitude of risk faced by older adults, who are the population in whom cancer screening decisions are actually made. Prior California-based analyses have shown that among individuals aged 50 years and older, gastric cancer incidence among Asian populations is approximately seven-fold higher than among non-Hispanic Whites, and exceeds fourteen-fold among Korean populations, corresponding to absolute incidence rates greater than 40 per 100,000 [26]. These age-specific risks are comparable to, or exceed, thresholds that motivate organized screening for other cancers in high-risk populations.

When interpreted alongside the present findings, these data clarify that seemingly modest age-adjusted rates mask substantial age-specific risk concentration. In practice, prevention and screening are applied to age-defined populations, not to age-standardized averages. A migration-informed framework that considers early-life exposure and age-specific risk therefore provides a more clinically relevant representation of gastric cancer burden than age-adjusted incidence alone.

### 4.5 | Aggregated Race Categories Obscure Prevention-Relevant Heterogeneity

Standard cancer surveillance in the United States relies on broad racial and ethnic categories that are limited in their ability to capture exposure-relevant risk for gastric cancer. Aggregation under "Non-Hispanic Asian or Pacific Islander" consistently obscures substantial heterogeneity across Asian subgroups. When disaggregated, age-adjusted gastric cancer incidence differed by approximately two to three-fold across Chinese, Japanese, Korean, and Vietnamese populations, with substantially larger differences observed in age-specific analyses and in comparisons with non-Hispanic Whites. These differences were not explained by age structure alone and persisted across crude and age-adjusted estimates.

Variation in nativity composition further illustrates why race alone is an imprecise proxy for exposure history, as populations differed markedly in early-life residence and cumulative exposure to high-incidence environments. Together, these findings demonstrate that migration history captures dimensions of gastric cancer risk not well represented by conventional race-based categories and provide a conceptual basis for interpreting contemporary incidence patterns.

## 5 | Limitations

This analysis has several limitations. First, it is descriptive and population-based, relying on aggregated incidence estimates rather than individual-level data; causal effects of age at migration, duration of residence, or specific exposures cannot be directly estimated.

Second, Asian subgroup denominators derived from race-based ACS classifications are imperfect proxies for early-life exposure history and may attenuate observed between-group differences. Because these classifications assign individuals to mutually exclusive categories, multiracial individuals are not included in subgroup-specific estimates; as the proportion of multiracial individuals increases in U.S. populations, this approach may modestly underestimate gastric cancer incidence within some Asian-American subgroups. Sensitivity analyses using ancestry-based denominators yielded consistent age-adjusted patterns, supporting the robustness of the central findings while highlighting structural limitations of race-based cancer surveillance constructs.

Third, nativity composition and duration of residence were assessed at the population level and could not be linked to individual cancer outcomes. In addition, statistical power to detect joinpoints may be limited in smaller subgroups with low annual case counts; accordingly, subgroup-specific trend estimates should be interpreted with caution. Projections were anchored to the model-fitted 2022 incidence to ensure consistency with the estimated log-linear trend; however, as with all scenario-based extrapolations, results remain sensitive to modeling assumptions and should not be interpreted as forecasts. Finally, origin-country incidence estimates drawn from global sources are subject to variation in registry completeness and diagnostic practices and are intended to provide contextual anchoring rather than precise comparators.

The lack of statistical significance in some subgroup analyses, particularly in New York, may reflect reduced statistical power due to smaller population size and lower case counts. Approaches such as pooled analyses or Bayesian smoothing may improve precision in low-volume settings and warrant future investigation.

## 6 | Conclusion

Migration-associated variation in gastric cancer risk remains detectable and prevention-relevant in contemporary U.S. populations. Despite significant declines in incidence in some settings, Asian subgroups originating from historically high-incidence regions continue to exhibit persistent, though declining, differences in risk in California and New York, with no clear evidence of risk equilibration following migration. By integrating formal trend analysis with conditional, scenario-based extrapolation, this study demonstrates that inferences about future incidence are sensitive to assumptions about trend persistence and that historical declines alone may be insufficient for prevention planning. Together, these findings support a migration-informed approach to gastric cancer prevention that incorporates early-life exposure, origin-country risk, and cumulative life-course context, and represents an important step toward prevention strategies that are more precise, equitable, and aligned with contemporary epidemiologic realities.

### Author Contributions

**Chul S. Hyun:** conceptualization, investigation, writing – original draft, methodology, validation, writing – review and editing, formal analysis, project administration, data curation, supervision, resources. **Rong Wang:** conceptualization, investigation, methodology, validation, software, formal analysis, data curation, writing – review and editing. **Sung Hwi Hong:** investigation, methodology, formal analysis, resources. **Xuehong Zhang:** resources, writing – review and editing, validation. **Jae Il Shin:** investigation, writing – review and editing, project administration, resources.

### Disclosure

The content of this manuscript is the sole responsibility of the authors and does not necessarily represent the official views of the National Cancer Institute, the U.S. Census Bureau, or any affiliated institutions.

### Conflicts of Interest

Rong Wang reports institutional research funding from Flatiron Health. The other authors declare no conflicts of interest.

### Data Availability Statement

The data analyzed in this study are derived from publicly available and restricted-access sources under the data usage and sharing policies. Cancer incidence data are available through the National Cancer Institute's SEER Program and participating state cancer registries. Population denominator data are available from the U.S. Census Bureau's American Community Survey, Public Use Microdata Sample (PUMS). Further data supporting the findings of this study are available from the corresponding author upon reasonable request.

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**Supporting Information**

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Age-adjusted gastric cancer incidence trends in New York by race/ethnicity, 2010–2022.