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ORIGINAL RESEARCH

Cardiovascular Risks and Outcomes Among Chinese American Immigrants: Insights From the Multi-Ethnic Study of Atherosclerosis

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BACKGROUND: Immigrants experience changes in cardiovascular risk factors and racial disparities in both cardiovascular health prevention and outcomes upon immigration. We aimed to examine cardiovascular risk factors and outcomes among Chinese American immigrants enrolled in the MESA (Multi-Ethnic Study of Atherosclerosis) cohort.

METHODS AND RESULTS: We analyzed data from 746 Chinese American immigrants in the MESA study with a median follow-up period of 17.8 years. The mean age of the cohort was 62.3 years, with 52.7% being women. Kaplan–Meier curves and Cox proportional hazards models were used to assess the association of immigration history, geographic location, biomarkers, and cardiac imaging parameters with cardiovascular risk factors and cardiovascular outcomes. The Cox hazards models were adjusted for known family history of heart disease, education level, sex, diabetes, hypertension, age, and body mass index. Although immigration history categorized as earlier (<20 years) versus later (≥20 years) showed no association with cardiovascular outcomes, the duration of residence in the United States emerged as a strong predictor for an increased risk of cardiovascular disease death (hazard ratio 1.39 [95% CI, 1.07–1.8]; P=0.012). All-cause mortality differed significantly between the Chinese immigrants from Los Angeles and those from Chicago, with higher survival probability in Chicago (log-rank test, P=0.018). Furthermore, elevated levels of N-terminal pro-brain natriuretic peptide levels, left ventricular mass, and coronary artery calcium scores were associated with the risk of cardiovascular disease among Chinese immigrants.

CONCLUSIONS: Within the MESA cohort, the duration of residence and geographic location were associated with the risk of cardiovascular disease outcomes among Chinese immigrants.

Key Words: biomarkers ■ cardiovascular risks ■ Chinese Americans ■ coronary artery calcium ■ immigration

Human migration in an increasingly global community offers opportunities to explore health disparities between immigrant and host nation populations, as well as variations in risk factors among diverse immigrant groups.[1–3] Immigrant populations often encounter distinct environmental risk factors and adopt different health behaviors in their host countries compared with the populations residing in their countries of origin.[4,5] The association between cardiovascular risks and immigration has been well documented in prior research.[6–10] However, despite revealing the importance to reduce cardiovascular risks among

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CLINICAL PERSPECTIVE

What Is New?

- We found an association of the duration of residence in the United States and geographic location with an elevated risk of cardiovascular disease death and all-cause mortality, respectively, among Chinese immigrants in the MESA study (Multi-Ethnic Study of Atherosclerosis) over a median follow-up of 17.8 years.
- Elevated levels of N-terminal pro-brain natriuretic peptide, left ventricular mass, and coronary artery calcium scores were associated with increased risks of cardiovascular outcomes among Chinese immigrants in the MESA cohort.

What Are the Clinical Implications?

- Cardiovascular risks and health outcomes among immigrants may be influenced by the length of immigration history and geographic location. The recognition of the association of the length of immigration history with cardiovascular disease death may indicate the benefit of early intervention of cardiovascular risk factors in improving cardiovascular health among immigrant populations.
- Further investigation into ethnic-selective biomarkers and imaging parameters could offer valuable insights for developing more targeted cardiovascular risk monitoring and reduction strategies. This approach has the potential to make a significant impact on public health.

Nonstandard Abbreviations and Acronyms

hs-cTnT	high-sensitivity cardiac troponin T
MESA	Multi-Ethnic Study of Atherosclerosis

immigrants, these studies often encounter limitations such as cross-sectional or retrospective designs, or the low incidence of cardiovascular events within short follow-up periods.[6–10] To gain a deeper understanding of how immigration history impacts cardiovascular risks, comprehensive characterization of participants in prospective cohort studies with extended follow-up periods is required to provide further insights into the mechanisms underlying structural and functional disparities in cardiovascular health among immigrant populations.

In the United States, disparities in cardiovascular disease (CVD) morbidity and mortality persist among various racial and ethnic groups.[11,12] Scientific statements from the American Heart Association have been issued to advocate for equity and reduce cardiovascular health disparities among African Americans[13] and Hispanics.[14] More recently, in May 2023, a parallel statement was released by the American Heart Association for Asian Americans.[15] The Asian American population is expected to become the largest immigrant group by 2050.[15] Emphasizing the urgency, this 2023 statement highlights the need for future clinical and public health research initiatives dedicated to understanding and addressing the distinctive health concerns prevalent in the Asian American population. Indeed, the National Heart, Lung, and Blood Institute recently launched an epidemiological cohort study in August 2023 named the MOSAAIC (Multi-ethnic Observational Study in American Asian and Pacific Islander Communities), which focuses on the cardiovascular health of Asian Americans, Native Hawaiians, or Pacific Islanders.[16] MOSAAIC aims to build on the valuable insights obtained from previous studies that were designed to improve cardiovascular health and reduce health disparities among different racial groups.[16]

Recent findings within the MESA (Multi-Ethnic Study of Atherosclerosis) population[17,18] have shown that socioeconomic status significantly impacts all-cause and CVD mortality across these 4 groups.[19] In addition, further adjustment for immigration history beyond socioeconomic status can modify the observed racial and ethnic disparities in CVD events and CVD mortality.[19]

Chinese participants enrolled in the MESA study between 2000 and 2002 were predominantly immigrants.[17,18] Therefore, while we anticipate the results of the MOSAAIC study in the coming years, the MESA study, spanning from 2000 to 2018, offers a unique opportunity to investigate the long-term effects of immigration on cardiovascular health and examine the cardiovascular health trajectory among Chinese immigrants in a prospective cohort study over nearly 2 decades. In this report, we aimed to determine the relationship between baseline CVD risk factors, CVD events, and mortality with immigration history and geographic location within the Chinese population enrolled in the MESA cohort. In addition, we investigated the association of baseline biomarkers and advanced cardiac imaging parameters with CVD and mortality among Chinese American participants.

METHODS

Study Population

The MESA study, which was initiated in July 2000, is a longitudinal cohort study aimed at investigating the characteristics and risk factors associated with subclinical CVD and its progression to clinically overt CVD among 4 self-identified racial and ethnic groups (non-Hispanic White, Black, Hispanic, and

Chinese participants) across 6 field centers in the United States.[17,20] Between 2000 and 2002 (Exam 1), the MESA cohort enrolled 6814 men and women aged 45 to 84 years with no clinical history of CVD. Subsequently, participants underwent additional clinical evaluation and blood sample collection at Exam 2 (2002–2004), Exam 3 (2004–2005), Exam 4 (2005–2007), Exam 5 (2010–2011), and Exam 6 (2016–2018). A total of 802 Chinese Americans were recruited from 2 field centers: Los Angeles, CA and Chicago, IL.

All participants in the MESA study provided written informed consent for their participation, and the study protocol received approval from the institutional review boards of each participating center. Comprehensive information on the study protocol is accessible on the MESA website (https://www.mesa-nhlbi.org).

Demographic and Clinical Characteristics

Demographic information including details such as age, sex, and level of education, along with CVD risk factors and comprehensive clinical characteristics, were obtained as previously reported.[17,19] At baseline, participants reported their duration of residence in the United States.

Nearly half of Chinese immigrants in the United States reside in California and New York, while Illinois harbors the largest Chinese American population in the Midwest.[15] The majority of Chinese participants in the MESA study are immigrants located in Los Angeles, CA and Chicago, IL. Examining immigration history, the second and more recent wave of Chinese immigrants occurred with the establishment of a temporary skilled worker program in the 1970s.[15]

Since the MESA study started the initial enrollment in 2000, we categorized Chinese participants in the MESA study into 2 groups to reflect the earlier wave of immigration and the subsequent, more recent waves of Chinese immigrants, based on their duration of residence in the United States: after immigration: foreign-born participants with <20 years of residence in the United States (later immigrants) and foreign-born participants with ≥20 years of residence (earlier immigrants) in the United States. In addition, we stratified Chinese participants based on their geographic locations (Los Angeles versus Chicago) to assess the potential impact of host country geography on immigrant cardiovascular health.

Height and weight measurements were conducted utilizing a stadiometer and a balance beam scale, with participants in bare feet and lightweight attire. Body mass index was calculated by dividing weight (in kilograms) by the square of height (in meters). The dietary assessment utilized a self-administered, 120-item food frequency questionnaire. The questionnaire was previously used for assessment of dietary patterns among White, Black, and Hispanic participants, and was adapted to incorporate questions related to Chinese cuisine.[21,22]

The diet metric consists of 5 dietary factors: intake of fruits and vegetables, fish, sodium, sugar-sweetened beverages, and fiber-rich whole grains. Each factor has a specific recommended intake (eg, ≥4.5 cups of fruits and vegetables per day). Participants meeting 0 to 1 of the criteria were categorized as having a poor diet, those meeting 2 to 3 criteria as having an intermediate diet, and those meeting 4 to 5 criteria as having an ideal diet. Physical activity levels were evaluated through a semiquantitative survey derived from the Typical Week Physical Activity Survey as described previously.[23] Diabetes was characterized by either a fasting plasma glucose level ≥126 mg/dL or the use of antidiabetic medications.[24] Hypertension was defined as a systolic blood pressure ≥140 mm Hg and/or a diastolic blood pressure ≥90 mm Hg, or the utilization of antihypertensive medications.

Biomarker Measurements

Levels of high-sensitivity cardiac troponin T (hs-cTnT) and amino-terminal B-type natriuretic peptide (NT-proBNP) were measured in blood samples collected from participants at MESA Exam 1 (2000–2002).[25,26] In brief, hs-cTnT levels were accessed using 250 mL aliquots of stored ethylenediaminetetraacetic acid plasma samples, processed with the Cobas e601 system (Roche Diagnostics, Indianapolis, IN) at the University of Maryland.[25] The interassay coefficients of variation for measurements in the MESA cohort were documented to be 3.6% at 28 ng/L and 2.0% at 2154 ng/L, with 3 ng/L as the lowest reported value.[25] NT-proBNP levels were determined through a highly sensitive and specific Elecsys electrochemiluminescence immunoassay involving the application of the double-antibody sandwich method (Roche Diagnostics) at the University of California, San Diego.[27] The intra- and interassay coefficients of variation were reported at different NT-proBNP levels: 2.7% and 3.2% at 175 pg/mL, 2.4% and 2.9% at 355 pg/mL, 1.9% and 2.6% at 1068 pg/mL, and 1.8% and 2.3% at 4962 pg/mL, respectively.[27]

Cardiac Imaging Parameter Measurements

Cardiovascular magnetic resonance imaging was conducted during Exam 1 following the established protocol as previously described.[28–30] Briefly, MESA participants without contraindications underwent cardiovascular magnetic resonance exams utilizing 1.5 T scanners equipped with a 6-channel phased-array surface coil positioned both anteriorly and posteriorly, coupled with ECG gating. Fast gradient-echo cine magnetic resonance imaging pulse sequences were

performed to evaluate left ventricular (LV) functions, dimensions, and myocardial mass.

Cardiac computed tomography (CT) scanning protocols to assess coronary artery calcium (CAC) were reported previously.[31–33] CAC was measured using either cardiac-gated electron-beam CT scanners at 3 field centers or multidetector CT at 3 other field centers. Each participant underwent 2 consecutive CT scans. All CT images were independently analyzed at a central reading center located in the Los Angeles Biomedical Research Institute at Harbor–University of California Los Angeles Medical Center (Torrance, CA). CAC scores from baseline CT were calculated from the average of 2 scans utilizing the Agatston method after being adjusted with a standard calcium phantom. Both interobserver and intraobserver agreements were very high (κ=0.93 and 0.90, respectively).

CVD Events, All-Cause Mortality, and Cardiovascular Death Outcomes

MESA participants were followed for a median period of 17.8 years to observe CVD events, all-cause mortality, and cardiovascular death.[19] In addition to baseline and 5 follow-up exams, the MESA cohort participants or their family members were contacted by telephone every 9 to 12 months during the follow-up period.[17,34] A telephone interviewer gathered information on interim hospital admissions, cardiovascular outpatient diagnoses and procedures, and deaths. Further details were collected through cohort clinic visits, participant-initiated contacts, and medical record data abstraction. Adjudication of outcomes was conducted by a central committee consisting of physicians.

We designated CVD events, all-cause mortality, and cardiovascular death as the primary outcomes for analysis, as previously described.[19] CVD events include myocardial infarction, stroke, resuscitated cardiac arrest, angina, or death caused by stroke, coronary heart disease, or another cause related to atherosclerotic or cardiovascular disease. Myocardial infarction diagnosis was based on assessment of symptoms, ECGs, and cardiac biomarker levels. Stroke events were adjudicated by 2 of 3 vascular neurologists, who evaluated symptoms, clinical signs, and imaging results.[35] CVD death was defined as a death where the cause was cardiovascular-related and occurred within 30 days of diagnosis of hard CVD.

Statistical Analysis

Baseline characteristics, including demographics, CVD risk factors, clinical features, LV function, and biomarker levels, were summarized using median values with interquartile ranges or frequencies (%), and were compared using either Wilcoxon tests or χ^2 tests, respectively. Kaplan–Meier curves were used to depict the survival curves of fatal and nonfatal CVD, all-cause mortality, and CVD death, categorized based on immigration history (<20 years versus ≥20 years of residence in the United States) or geographic location (Los Angeles versus Chicago). Additionally, log-rank tests were conducted to assess the statistical significance of differences in survival curves.

Adjusted Cox proportional hazards models were used to estimate the association of 3 primary outcomes, CVD events, all-cause mortality, and CVD death, with demographic and CVD risk factor variables. Two sets of models were considered with the primary predictors: (1) time in the United States as either binary (<20 years versus ≥20 years of residence in the United States) or continuous (years in the United States) and (2) geographic location. Separate models were included to consider the association between each of the secondary predictors (levels of hs-cTnT and NT-proBNP, LV function, and CAC scores) with the outcomes of interest. For hs-cTnT values below the 3 ng/L limit of detection, a value of 2.99 ng/L was imputed. In models including the CAC score, the Agatston score was log-transformed. All models were adjusted for known family history of heart disease, education level, sex, diabetes, hypertension, age, and body mass index. We considered adjusting for health insurance coverage, but because it was not a significant predictor in any of the models, nor did it change the significance of the predictors of interest, it was not included. Martingale residuals were plotted against each continuous predictor to verify linearity. The proportional hazards assumption was checked by testing whether the

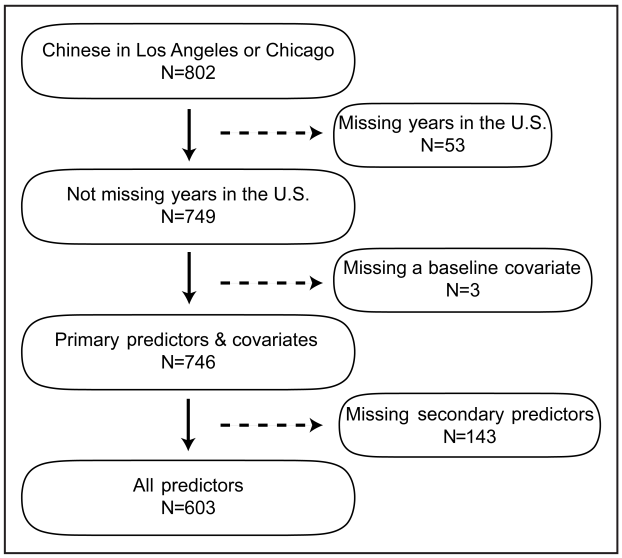

Figure 1. Study flow chart.
The flow chart illustrates the inclusion and exclusion criteria for Chinese American participants from the MESA study, based on the availability of data on years of residence in the United States, covariates, biomarker levels, and imaging parameters. MESA indicates Multi-Ethnic Study of Atherosclerosis.

Table 1. Comparison of the Group Living in the United States for Less Than 20 Years (384 Participants) and the Group Living in the United States for 20 Years or More (362 Participants)

Variable	<20 y	≥20 y	*P* value
Age at exam 1	64 (53.75–71.25)	62 (55–70)	0.429
Body mass index (kg)/(m^2)	23.4 (21.38–25.72)	24 (22.02–26.42)	0.00373 (**)
Exam 1 pack-y of cigarette smoking	15.2 (4.725–27.67)	13 (3.525–30)	0.587
Moderate and vigorous physical activity total (Met-min/wk M-Su)	2350 (1170–4519)	2840 (1577–5182)	0.00286 (**)
Total cholesterol:HDL cholesterol ratio	3.94 (3.268–4.751)	4.02 (3.255–4.765)	0.54
Any lipid-lowering medication			
No	329 (86%)	310 (86%)	1
Yes	55 (14%)	52 (14%)	
Cardiovascular health factor: diet			
Poor	117 (30%)	114 (31%)	0.824
Not poor	267 (70%)	248 (69%)	
Cigarette smoking status			
0: Never	294 (77%)	271 (75%)	0.473
1: Former	66 (17%)	73 (20%)	
2: Current	24 (6.2%)	18 (5%)	
Diabetes			
No	334 (87%)	314 (87%)	1
Yes	50 (13%)	48 (13%)	
Dyslipidemia defined by total cholesterol:HDL cholesterol ratio exceeding 5			
No	310 (81%)	289 (80%)	0.83
Yes	74 (19%)	73 (20%)	
Education			
Less than high school	98 (26%)	93 (26%)	<0.001 (***)
High school graduate	160 (42%)	116 (32%)	
College	99 (26%)	71 (20%)	
Graduate school	27 (7%)	82 (23%)	
Sex			
0: Female	210 (55%)	183 (51%)	0.29
1: Male	174 (45%)	179 (49%)	
Has health insurance			
No	336 (88%)	315 (87%)	0.93
Yes	48 (12%)	47 (13%)	
HMG-CoA reductase inhibitors (statins)			
No	241 (63%)	224 (62%)	0.863
Yes	143 (37%)	138 (38%)	
Hypertension by JNC VI (1997) criteria			
No health insurance	116 (30%)	27 (7.5%)	<0.001 (***)
Has health insurance	268 (70%)	335 (93%)	
Known family history of heart disease			
No	315 (82%)	296 (82%)	1
Yes	69 (18%)	66 (18%)	
Site			
Chicago	94 (24%)	181 (50%)	<0.001 (***)
Los Angeles	290 (76%)	181 (50%)	

(*Continued*)

Table 1. Continued

Variable	<20 y	≥20 y	*P* value
Measurements			
LV end-diastolic mass (g) using Fgre MRI pulse sequence	117 (99.66–138.7)	122 (101.6–144.2)	0.0961
LV end-systolic volume (mL) using Fgre MRI pulse sequence	28.5 (23.04–37.74)	29.3 (23.58–36.02)	0.807
LV end-diastolic volume (mL) using Fgre MRI pulse sequence	106 (94.03–123.3)	108 (94.74–124.6)	0.525
LV ejection fraction (%) using Fgre MRI pulse sequence	73 (68.45–76.42)	73 (68.68–76.41)	0.69
LV stroke volume (mL) using Fgre MRI pulse sequence	78.6 (67.7–87.51)	79 (69.04–89.48)	0.469
Exam 1: high-sensitivity cardiac troponin-T (pg/mL)	3.34 (2.99–5.34)	3.61 (2.99–5.76)	0.129
Exam 1: NT-proBNP (pg/mL)	48.6 (21.28–96.88)	42.4 (17.18–85.95)	0.17
Mean: Agatston calcium score, phantom-adjusted	0.468 (0–67.94)	1.64 (0, 65–13)	0.696

Reported *P* values are from a 2-sided Wilcoxon test for the continuous variables and a χ^2 test of independence for categorical variables. (*) denotes *P* value ≤0.05, (**) denotes *P* value ≤0.01, and (***) denotes *P* value ≤0.001.

Fgre indicates fast gradient-echo; HDL, high-density lipoprotein; HMG-CoA, hydroxymethyl glutaryl coenzyme A; JNC VI, the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; LV, left ventricular; M-Su, Monday through Sunday; and NT-proBNP, N-terminal pro-B-type natriuretic peptide.

Schoenfeld residuals vary with time. We considered an alpha level of 0.05 for statistical testing. R version 4.3.2 was used for all statistical analyses.

RESULTS

Out of the 802 Chinese Americans (11.8% of MESA participants) recruited from Los Angeles and Chicago field centers in the MESA study, a total of 746 participants were included in the analysis. The exclusion criteria involved removing participants with missing years in the United States and 30 US-born individuals, resulting in the exclusion of 53 participants, as illustrated in Figure 1. Furthermore, 3 additional participants were excluded due to missing baseline covariates. In the secondary predictor analysis, 143 participants were excluded due to missing biomarker levels or imaging parameters.

The mean age of the cohort was 62.3 years and 52.7% were women. Table 1 presents the baseline demographic characteristics, cardiovascular risk factors, and clinical features, stratified by the immigration history (<20 years versus ≥20 years of residence in the United States). A comparison between earlier immigrants with ≥20 years of residence and later immigrants with <20 years of residence revealed that earlier immigrants tended to exhibit higher body mass index (24 [22.02–26.42] versus 23.4 [21.38–25.72], *P*=0.004), engage in more physical activity (moderate and vigorous physical activity metabolic equivalent (MET)-minutes per week: 2840 (1577–5182) versus 2350 (1170–4519), *P*=0.003), and have a higher level of education, particularly in graduate school (*P* <0.001). Notably, 76% of the later immigrants were in Los Angeles, while 24% were in Chicago (*P* <0.001). Earlier immigrants were distributed evenly in both geographic locations, with 50% in Los Angeles and 50% in Chicago. No significant differences were observed in age, sex, diet, cigarette smoking, diabetes, dyslipidemia, hypertension, statin administration, and known family history of heart disease, as well as LV stroke volume and LV ejection fraction. Next, we examined the relationship between geographic location and cardiovascular health among Chinese immigrants in the MESA population (Table 2). Compared with those living in Los Angeles, immigrants in Chicago demonstrated higher levels of physical activity (3330 [1770–6390] MET-minutes per week versus 2280 [1151–3982], *P* <0.001) and education (*P* <0.001).

Over a median period of 17.8 years from Exam 1 to Exam 6, Chinese immigrant participants experienced 120 CVD events (14.9% of the participants), 53 cases of CVD death (6.6% of the participants), and 181 cases of all-cause mortality (22.5% of the participants). Although the Kaplan–Meier curve of CVD events suggested a slightly higher CVD incidence in earlier immigrants compared with later immigrants (11.6% versus 8.3%) (Figure 2), log-rank tests demonstrated no significant differences in Kaplan–Meier survival curves of CVD events, all-cause mortality, and CVD death between earlier and later immigrants (*P* >0.05). When considering geographic location, immigrants in Chicago appeared to have lower all-cause mortality (18.2% versus 25.5%) and CVD death (5.5% versus 7.6%) than immigrants in Los Angeles on Kaplan–Meier curves (Figure 3). However, only all-cause mortality demonstrated a statistically significant difference based on the log-rank test (*P*=0.018).

Table 2. Comparison of the Group Recruited From Chicago (275 Participants) and the Group Recruited From Los Angeles (471 Participants)

Variable	Chicago	Los Angeles	*P* value
Age at exam 1	63 (53.5–70)	63 (55– 71)	0.546
Body mass index (kg)/(m^2)	23.7 (21.76–25.77)	23.7 (21.67–26.17)	0.739
Exam 1 pack-y of cigarette smoking	12.8 (1.438–32)	15 (6–26)	0.374
Moderate and vigorous physical activity total (Met-min/wk M-Su)	3330 (1770–6390)	2280 (1151–3982)	<0.001 (***)
Total cholesterol:HDL cholesterol ratio	4 (3.176–4.756)	3.98 (3.293–4.758)	0.307
Any lipid-lowering medication			
No	238 (87%)	401 (85%)	0.674
Yes	37 (13%)	70 (15%)	
Cardiovascular health factor: diet			
Poor	81 (29%)	150 (32%)	0.549
Not poor	194 (71%)	321 (68%)	
Cigarette smoking status			
0: Never	211 (77%)	354 (75%)	0.0911
1: Former	55 (20%)	84 (18%)	
2: Current	9 (3.3%)	33 (7%)	
Diabetes			
No	247 (90%)	401 (85%)	0.0867
Yes	28 (10%)	70 (15%)	
Dyslipidemia defined by total cholesterol: HDL cholesterol ratio exceeding 5.			
No	222 (81%)	377 (80%)	0.895
Yes	53 (19%)	94 (20%)	
Education			
Less than high school	50 (18%)	141 (30%)	<0.001 (***)
High school graduate	96 (35%)	180 (38%)	
College	62 (23%)	108 (23%)	
Graduate school	67 (24%)	42 (8.9%)	
Sex			
0: Female	151 (55%)	242 (51%)	0.392
1: Male	124 (45%)	229 (49%)	
Has health insurance			
No	241 (88%)	410 (87%)	0.906
Yes	34 (12%)	61 (13%)	
HMG-CoA reductase inhibitors (statins)			
No	179 (65%)	286 (61%)	0.267
Yes	96 (35%)	185 (39%)	
Hypertension by JNC VI (1997) criteria			
No health insurance	27 (9.8%)	116 (25%)	<0.001 (***)
Has health insurance	248 (90%)	355 (75%)	
Known family history of heart disease			
No	215 (78%)	396 (84%)	0.055
Yes	60 (22%)	75 (16%)	
Years in the United States			
<20 y	94 (34%)	290 (62%)	<0.001 (***)
≥20 y	181 (66%)	181 (38%)	
Measurements			
LV end-diastolic mass (g) using Fgre MRI pulse sequence	120 (101.9–137.9)	118 (99.84–142.8)	0.733
LV end-systolic volume (mL) using Fgre MRI pulse sequence	27.7 (22.1–35.09)	29.7 (23.62–37.32)	0.0681

(*Continued*)

Table 2. Continued

Variable	Chicago	Los Angeles	*P* value
LV end-diastolic volume (mL) using Fgre MRI pulse sequence	105 (93.64–120.7)	109 (94.66–125)	0.19
LV ejection fraction (%) using Fgre MRI pulse sequence	73.5 (69.39–76.63)	72.5 (68.35–76.08)	0.0641
LV stroke volume (mL) using Fgre MRI pulse sequence	78.1 (67.72–86.77)	78.8 (68.28–89.3)	0.481
Exam 1: high-sensitivity cardiac troponin-T (pg/mL)	3.3 (2.99–5.665)	3.57 (2.99–5.485)	0.519
Exam 1: NT-proBNP (pg/mL)	49.5 (23.37–96.74)	43.2 (16.81–87.4)	0.0408 (*)
Mean: Agatston calcium score, phantom-adjusted	0 (0, 52.57)	2.57 (0, 71.61)	0.27

Reported *P* values are from a 2-sided Wilcoxon test for the continuous variables and a χ^2 test of independence for categorical variables. (*) denotes *P* value ≤0.05, (**) denotes *P* value ≤0.01, and (***) denotes *P* value ≤0.001.

Fgre indicates fast gradient-echo; HDL, high-density lipoprotein; HMG-CoA, hydroxymethyl glutaryl coenzyme A; JNC VI, the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; LV, left ventricular; M-Su, Monday through Sunday; and NT-proBNP, N-terminal pro-B-type natriuretic peptide.

Cox proportional hazards models for 3 primary outcomes (CVD events, all-cause mortality, and CVD death) are shown in Table 3. The Cox models were adjusted with years of residence in the United States treated as a continuous variable. Due to the limited sample size and event incidence, we opted for utilizing years of residence as a continuous variable instead of a dichotomized variable reflecting immigration history. Years of residence showed a strong association with CVD death (hazard ratio [HR] 1.39 [1.07–1.8]; *P*=0.012), but no significant association was observed with CVD events and all-cause mortality. In all 3 models, age and diabetes exhibited significant associations with the primary outcomes (*P* <0.001), while a family history of heart disease demonstrated a significant association only with CVD death (*P* <0.05). Geographic location emerged as a significant predictor for CVD death (HR 2.29 [1.1–4.76]; *P*=0.026), JNC VI, the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure with participants in Chicago exhibiting lower CVD death. Furthermore, incorporating physical activity and energy consumption as adjustable variables in all the models did not significantly affect the association analysis.

We examined the association of baseline levels of biomarkers, specifically hs-cTnT and NT-proBNP, and imaging parameters, including LV mass and LV ejection fraction measured by cardiovascular magnetic resonance, along with CAC scores assessed by cardiac CT, with the 3 primary outcomes among Chinese participants. Surprisingly, elevated baseline levels of hs-cTnT did not show any significant association with an increased risk for any of the primary outcomes (Table S1). In contrast, higher levels of NT-proBNP at baseline emerged as a strong predictor for both CVD events (HR 1.24 [1.04–1.48]; *P*=0.017) and all-cause mortality (HR 1.27 [1.14–1.41]; *P* <0.001), although no significant association was observed with CVD death (Table S2). Similarly, while there was no significant association between LV ejection fraction with any of the 3 primary outcomes (Table S3), LV mass demonstrated an association with both CVD events (HR 1.58 [1.1–2.27]; *P*=0.014) and all-cause mortality (HR 1.39 [1.07–1.8]; *P*=0.013), but not for CVD death (Table S4). Furthermore, CAC scores were significantly associated with both CVD events (HR 1.6 [1.25– 2.04]; *P* <0.001) and CVD death (HR 1.63 [1.19–2.24]; *P*=0.0026), but they did not exhibit a significant association with all-cause mortality (Table S5).

DISCUSSION

Our findings provide several insights into cardiovascular health among Chinese immigrants in the United States, as observed within the MESA study cohort. Over a median follow-up of 17.8 years, the duration of residence in the United States and geographic location, specifically Los Angeles versus Chicago, were associated with an elevated risk of CVD death and all-cause mortality among Chinese immigrants, respectively. Elevated levels of NT-proBNP, LV mass, and CAC scores were associated with increased risks of cardiovascular outcomes.

Earlier immigrants tended to engage in more physical activity and had higher levels of education and elevated body mass index compared with later immigrants. However, these differences were not independently associated with the 3 primary cardiovascular outcomes of CVD events, all-cause mortality, and CVD death. Similarly, immigrants in Chicago were also observed to have higher levels of physical activity and education, and interestingly, lower all-cause mortality than immigrants in Los Angeles. The influence of geographic location on all-cause mortality among Chinese immigrants requires further investigation. It is conceivable that state-specific geographic characteristics such as geographic disparities in mortality and life expectancy may play a role. A recent analysis of the Mortality Disparities in American Communities data set indicates that state-specific features of migration

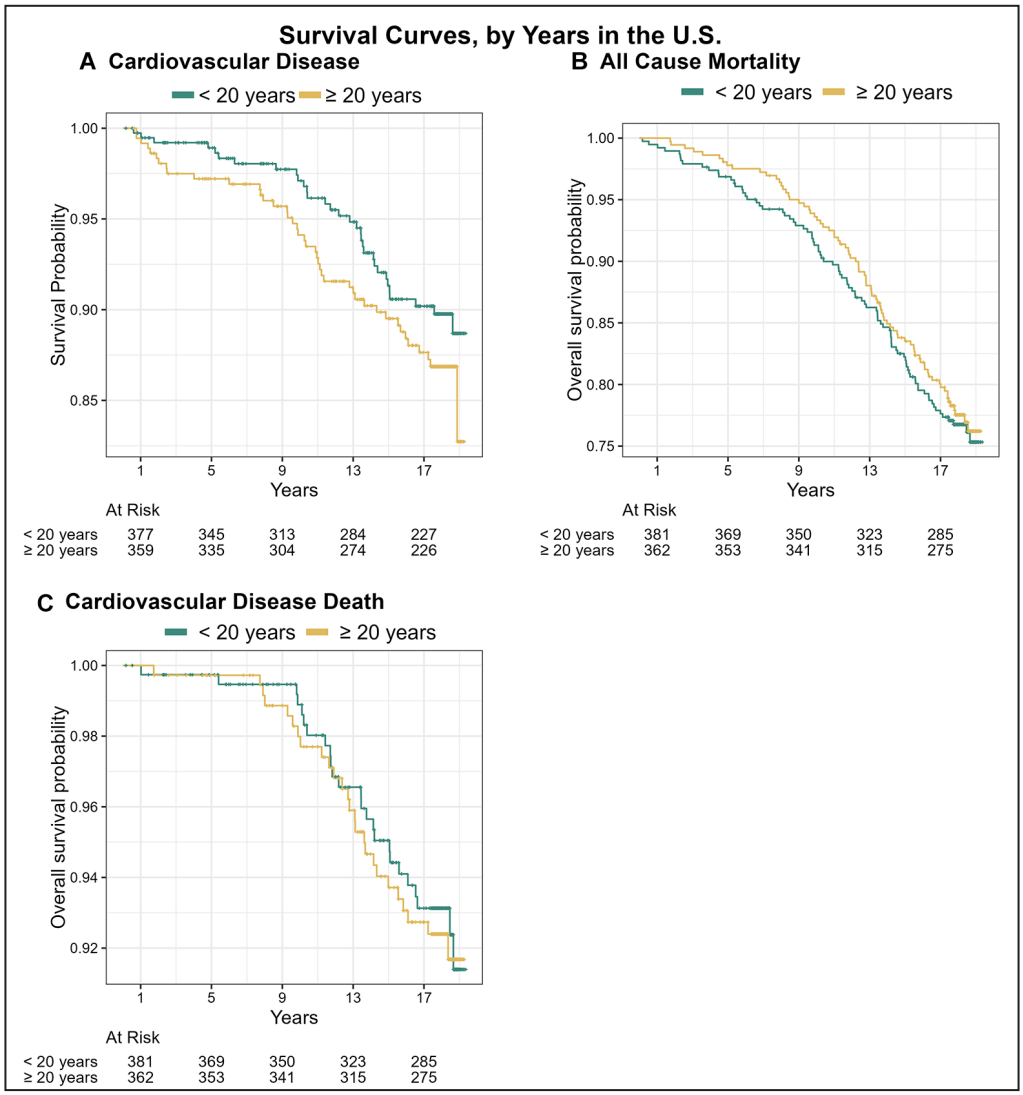

Figure 2. Kaplan–Meier curves by immigration categories (<20 years vs ≥20 years) for (A) cardiovascular disease, (B) all-cause mortality, and (C) cardiovascular disease death.
The number at risk at each time point is listed below the graph.

might be associated with geographic disparities in mortality outcomes in the United States.[36] However, foreign-born individuals were excluded from the migration analysis,[36] leaving room for additional research to explore the impact of geographic location on all-cause mortality among immigrants.

When years of residence in the United States were treated as a continuous variable, the duration of residence showed a significant association with CVD death. Previous work based on the MESA study showed that, in comparison to White participants, Chinese participants exhibited a 21% lower all-cause mortality, a pattern that persisted even after adjusting for demographics, socioeconomic status, lifestyle, and psychosocial factors and clinical risk factors.[19] However, the association of Chinese ethnicity with lower all-cause mortality over White participants was attenuated and became nonsignificant after adjustment by immigration history.[19] New immigrants exhibited faster declines in cardiovascular health than older immigrants and American-born individuals over 10 years.[8] Our analysis demonstrates that during the 17.8 years of follow-up, a longer duration of residence in the United States was associated with an increased risk of CVD death in Chinese immigrants. This observation further supports the impetus for early secondary prevention and risk reduction strategies of CVD[37] among Chinese immigrants to improve survival.

To the best of our knowledge, our study represents the first comprehensive analysis of the application of biomarkers and advanced imaging parameters in predicting cardiovascular outcomes among Chinese Americans. While hs-cTnT levels and LV ejection fraction were not associated with any of the 3 primary outcomes, NT-proBNP levels and LV mass emerged as significant predictors of CVD events and all-cause

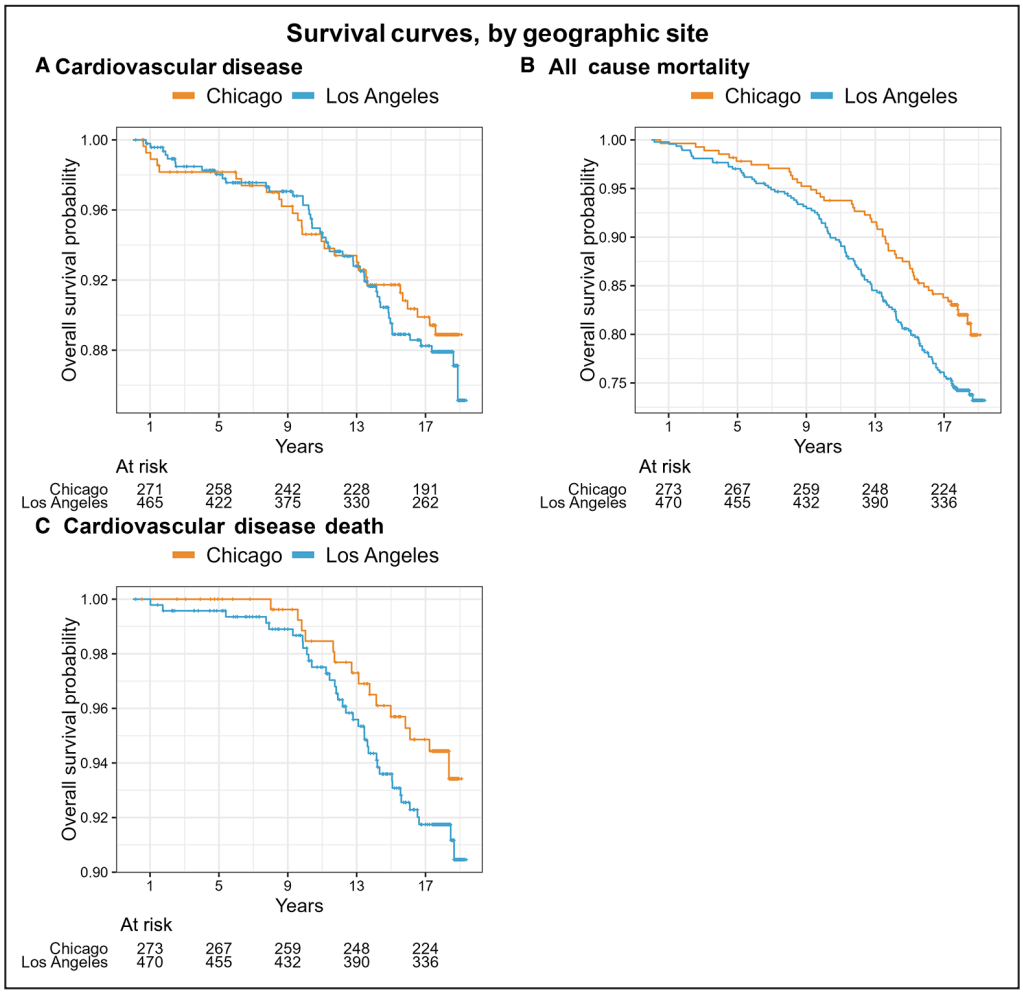

Figure 3. Kaplan–Meier curves by geographic locations (Chicago vs Los Angeles) for (A) cardiovascular disease, (B) all-cause mortality, and (C) cardiovascular disease death.
The number at risk at each time point is listed below the graph.

mortality. In addition, CAC scores were found to be predictive of the risk of CVD events and CVD death. NT-proBNP levels and LV remodeling reflected by LV mass have been shown to provide incremental predictive values for incident symptomatic heart failure.[27] We were not able to specifically test their association with incident heart failure due to the low incidence of heart failure among Chinese participants. The CARDIA (Coronary Artery Risk Development in Young Adults) study indicates that cumulative exposure to individual risk factors in early life may have varying effects on different ethnicities.[38] For instance, hypertension disproportionately affects Black patients, and elevated low-density lipoprotein levels have greater significance for White patients. The diverse distribution of cardiovascular events and related cardiovascular health disparities among different ethnicities in the United States reported previously[12,19,32,38] emphasizes the need for further research on ethnic-selective biomarkers and imaging parameters. This could guide more tailored cardiovascular risk reduction strategies and potentially have a significant impact on public health.

Study Limitations

The MESA study comprised mainly immigrant Chinese participants from Los Angeles and Chicago, with an average age of 62.3 years. This demographic may not accurately represent the broader Chinese population in these 2 communities. Geographic comparison of Chinese immigrants located in Los Angeles and Chicago may be subject to residual confounding factors. Asian immigrants display significant heterogeneity in CVD risk factors across diverse subgroups.[2] It is important to recognize that our findings may not be generalizable to all Chinese communities in the US American-born Chinese and non-Chinese Asian American populations.[8] In addition, we were not able

Table 3. Cox Model Results, Time in the United States as Continuous Covariate

Variable	CVD		All-cause mortality		CVD death	
	Hazard ratio (CI)	*P* value	Hazard ratio (CI)	*P* value	Hazard ratio (CI)	*P* value
Primary predictor: years in the United States						
Years in the United States (continuous)	1.17 (0.93–1.48)	0.18	1.12 (0.96– 1.31)	0.14	1.39 (1.07– 1.8)	0.012 (*)
Primary predictor: geographic location						
Los Angeles (reference: Chicago)	1.05 (0.61–1.8)	0.87	1.4 (0.96–2.05)	0.081	2.29 (1.1–4.76)	0.026 (*)
Family history of heart disease						
Known family history of heart disease	1.49 (0.84–2.65)	0.17	1.18 (0.79–1.77)	0.43	2.29 (1.18–4.47)	0.015 (*)
Education level (reference: less than High School)						
High school graduate	0.85 (0.47–1.51)	0.57	0.67 (0.46–0.99)	0.044 (*)	0.62 (0.3–1.3)	0.2
College	0.56 (0.25–1.25)	0.16	0.92 (0.6–1.41)	0.69	1.03 (0.46–2.3)	0.94
Graduate school	1.29 (0.63–2.66)	0.49	0.65 (0.36–1.17)	0.15	1.01 (0.39–2.63)	0.98
Sex						
Male	1.24 (0.72–2.14)	0.44	1.26 (0.87–1.82)	0.22	1.3 (0.65–2.58)	0.46
Diet (reference: not poor)						
Poor diet	0.92 (0.53–1.61)	0.77	0.8 (0.56–1.13)	0.2	1.01 (0.53–1.93)	0.98
Diabetes status						
Has diabetes	2.8 (1.67–4.71)	<0.001 (***)	1.6 (1.08–2.35)	0.018 (*)	3.16 (1.64–6.1)	<0.001 (***)
Hypertension						
Hypertension by JNC VI (1997) criteria	1.42 (0.86–2.35)	0.17	1.19 (0.86–1.65)	0.29	1.75 (0.94–3.27)	0.077
Continuous predictors						
Age	2.22 (1.63–3.01)	<0.001 (***)	3.13 (2.54–3.87)	<0.001 (***)	5.19 (3.26–8.26)	<0.001 (***)
BMI	1.08 (0.85–1.37)	0.53	1.04 (0.88–1.22)	0.66	0.99 (0.72–1.36)	0.95
Pack-y of cigarette smoking	1.04 (0.85–1.26)	0.72	0.89 (0.76–1.04)	0.15	0.73 (0.52–1.04)	0.085
Dyslipidemia	0.63 (0.31–1.26)	0.19	1.15 (0.77–1.71)	0.5	0.72 (0.31–1.64)	0.43

(*) denotes *P* value ≤0.05, (**) denotes *P* value ≤0.01, and (***) denotes *P* value ≤0.001.

BMI indicates body mass index; CVD, cardiovascular disease; and JNC VI, the Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.

to directly assess variations in CVD risk factors and mortality between Chinese Americans and native Chinese.[39–41] It is plausible that cardiovascular health trends in the country of origin might have undergone significant changes among individuals who immigrated at different periods (earlier versus later immigrants) before arriving in the United States.

In the MESA study, earlier immigrants and later immigrants had similar ages (62.5±9.603 versus 63±10.81 years old) at the initial enrollment. Therefore, earlier immigrants tended to arrive in the host country at a younger age and might have been quicker to adopt different health behaviors compared with later immigrants, who immigrated at older ages. Furthermore, the average age of the MESA Chinese participants free of CVD at the baseline was 62.3±10.3 years old, and they were more likely to be healthier than the general Chinese American population in the United States.

CONCLUSIONS

The present study provides novel insight into understanding the cardiovascular health and outcomes among Chinese Americans from an immigration perspective. Among the MESA Chinese immigrant population free of clinically overt CVD at baseline, immigration history categorized as earlier (<20 years) versus later (≥20 years) did not have a significant association with cardiovascular outcomes. However, the years of residence in the United States was associated with an increased risk of CVD death. Geographic locations (Los Angeles versus Chicago) significantly impacted all-cause mortality among Chinese immigrants. Moreover, elevated NT-proBNP levels, LV mass, and CAC scores were associated with higher risk of cardiovascular events among Chinese immigrants. Further studies such as MOSAAIC[16] with a larger and more representative sample size of Asian participants are

essential to gain a comprehensive understanding of CVD risk factors and health disparities within the Asian American populations in the United States. This will contribute to a more accurate understanding of cardiovascular health outcomes among the diverse Asian American population.[15]

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Disclosures

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Supplemental Material

Tables S1–S5

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