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ORIGINAL RESEARCH

Association of Social Network Characteristics With Cardiovascular Health and Coronary Artery Calcium in South Asian Adults in the United States: The MASALA Cohort Study

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BACKGROUND: South Asian adults have worse cardiovascular health (CVH) and more coronary artery calcium compared with other race/ethnicities. The impact of the social environment has not been examined as a potential driver of CVH or coronary artery calcium in this population. We evaluated associations of social network characteristics with CVH and coronary artery calcium in South Asian American adults to inform strategies for CVH promotion in this at-risk population.

METHODS AND RESULTS: Using data from the MASALA (Mediators of Atherosclerosis in South Asians Living in America) cohort study, multinomial and multivariable logistic regression were used to evaluate associations of participant social network size and density, proportion of network who are kin or South Asian ethnicity and reported health of participant's identified social network members ("alters"), with participant CVH and presence of coronary artery calcium. The 699 MASALA participants included were mean age 59.2 (SD, 9.2) years and 42.9% women. After adjustment, a 1-person larger social network size was associated with 13% higher odds of ideal CVH (odds ratio [OR], 1.13; 95% CI, 1.01–1.27). Reporting an alter with high blood pressure was associated with lower odds of ideal CVH (OR, 0.51; 95% CI, 0.29–0.88), and reporting an alter with high cholesterol was associated with lower odds of ideal CVH (OR, 0.54; 95% CI, 0.30–0.94).

CONCLUSIONS: Social network characteristics are associated with CVH in South Asian American adults. Engaging social networks may help promote CVH in this population.

Key Words: cardiovascular health ■ prevention ■ social determinants of health ■ social networks ■ South Asian

People of South Asian ancestry are at higher risk for atherosclerotic cardiovascular disease (CVD) compared with other race/ethnic groups, including White and other Asian populations.[1,2] The cause for CVD disparities in South Asian adults is likely multifactorial. Worse traditional cardiovascular health (CVH) factors like blood pressure and blood glucose, and suboptimal individual cardiovascular health behaviors such as eating pattern and physical activity, account for only a portion of the elevated CVD risk in South Asian adults.[3–7] Identifying unique sociocultural determinants of CVH in this group may provide important targets for enhanced clinical and community-based prevention, particularly as previous declines in CVD-related morbidity and mortality have recently stalled in the United States.[8]

Social determinants are increasingly recognized as contributors to CVH.[9] Personal social networks have

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CLINICAL PERSPECTIVE

What Is New?

- Social network size and the health of social network members are associated with cardiovascular health in South Asian American participants of the MASALA (Mediators of Atherosclerosis in South Asians Living in America) study.

What Are the Clinical Implications?

- Clinical cardiovascular disease prevention may benefit from incorporating social network members into cardiovascular health promotion strategies in the South Asian American population.

Nonstandard Abbreviations and Acronyms

CVH	cardiovascular health
MASALA	Mediators of Atherosclerosis in South Asians Living in America

been linked to the spread of chronic non-communicable disease,[10] health behavior adoption,[11] and interpersonal social support.[12] Growing evidence suggests that elements of cardiovascular risk—such as unhealthful eating patterns, poor levels of physical activity, diabetes mellitus, and obesity—may be influenced by the networks of people with whom has social contact.[10,13–15] Local personal one networks may influence CVH by altering biomarkers and shaping health behaviors across the lifespan.[16] For example, recent data in US South Asian people show that having a social network member who exercises, or who is an exercise partner, is associated with as much as 500 more metabolic equivalent of task-minutes/week of moderate-to-vigorous levels of physical activity.[14]

Social network influences on health outcomes may be of particular importance in the South Asian diaspora in the United States, whose social networks have been characterized as relatively large, family-centered, and dense.[17] Therefore, we evaluated the association of social network characteristics, and the association of health status of social network members, with CVH and coronary artery calcium (CAC) in South Asian American adults, which may inform targeted approaches for effective CVD prevention in this population.

METHODS

Participants

Participants for the present analysis were enrolled in the MASALA (Mediators of Atherosclerosis in South Asians Living in America) study, a community-based cohort of 906 South Asian adults, aged 40 to 84 years and free of CVD upon initial enrollment, who resided in the San Francisco or Chicago metropolitan areas.[18] Eligibility criteria additionally included ability speak English, Hindi, or Urdu. Exclusion criteria included self-reported diagnosis of a heart attack, stroke, transient ischemic attack, heart failure, angina, use of nitroglycerin, a history of cardiovascular procedures, prevalent atrial fibrillation, active treatment for cancer, life expectancy <5 years because of a serious medical condition, impaired cognition, plans to move out of the study region in the 5 years subsequent to enrollment, and residence in or on a waiting list for a nursing home. Further details of recruitment and baseline measurements have been published.[18] The study data collection timeline is shown in Figure. The MASALA study protocols were approved by the institutional review boards at Northwestern University and University of California San Francisco. All participants provided written informed consent. Requests to access the data set from qualified researchers trained in human subject confidentiality may be sent to the MASALA study coordinating center at www.masalastudy.org.

Measurement of Social Network Characteristics

Between 2014 and 2018, MASALA study participants were invited to participate in an ancillary study during which personal social network characteristics were measured, the methods for which have previously been described.[17] Briefly, social network characteristics were measured in a standard "egocentric" approach, which evaluated both the relationships between study participants and their social network members ("alters"), as well as characteristics of alters as reported by the study participant. Data were captured via surveys administered by trained interviewers in English, Hindi, or Urdu. Interviewers asked participants to list alters using a name generator tool previously used in the General Social Survey[19] and the National Social Life, Health, and Aging Project's social networks module,[20] which asks participants to identify up to 10 people with whom they discuss "important matters." This approach identified social network "confidants" who could potentially exert social influence and normative pressure.[21,22]

In-depth name interpreter items collected information on the first five alters consistent with the General Social Survey and National Social Life, Health, and Aging Project approach. Specifically, once the first five alters were named by the participant and recorded, the interviewer asked a series of questions about each named alter individually. These questions sought to characterize the type of relationship with that alter (eg,

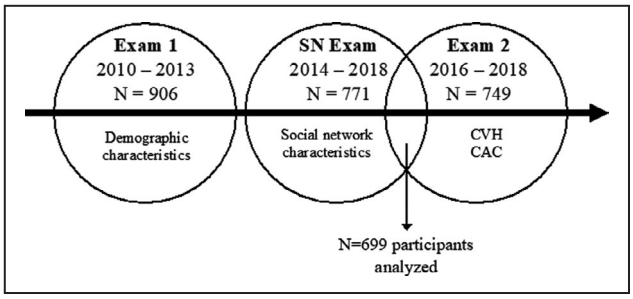

Figure 1. MASALA (Mediators of Atherosclerosis in South Asians Living in America) study timeline.
MASALA study exam visits, and the timeline of variables measured for the present analysis, are displayed. CAC indicates coronary artery calcium; CVH, cardiovascular health; and SN, social network.

spouse, friend), sociodemographic characteristics of that network member (eg, South Asian versus other ethnicity), health status of that alter (ie, if they had a history of heart disease, stroke, high blood pressure, diabetes mellitus, or high cholesterol), and connections that alter may have with other named social network members, in addition to other characteristics.[17] For example, social network-focused questions included: “In the last 12 months, how often did you eat with (alter name)?” “How do you mostly communicate with (alter name)?” and “How often do you talk to (alter name) about your general health?” Volume of contact with alters was measured as the sum across five alters of the annual estimated number of days in contact with each alter. Proximity with alters was assessed as the count of social network members living in the same home; living in the same neighborhood, town, or state; or living out-of-state or out-of-country.

Table 1 summarizes definitions of social network characteristics that were evaluated as primary independent variables in the present study, including social network size, social network density, proportion of kin in the social network, and proportion of social network who are South Asian. In addition, the participant-reported presence of any alter with a health condition (specifically, cardiovascular disease defined as either heart disease or stroke, high blood pressure, diabetes mellitus, or high cholesterol) was evaluated as a primary independent variable. Secondary analyses of alter health status subcategorized network members into types of relationship: spouse, related kin (ie, parent, child, sibling, or niece/nephew), unrelated kin (ie, parent-in-law, other in-law, or other relative), or non-kin (ie, friend, neighbor, co-worker, boss, religious official, or doctor). Since the "other relative" designation did not specify familial versus non-familial relationships, this identification was listed in the "Unrelated Kin" category. Other available relationship type options were not included in subcategory definitions because no participant selected them (eg, stepchild).

Measurement of Cardiovascular Health, Coronary Artery Calcium, and Covariates

CVH as a primary dependent variable was defined using the American Heart Association’s Life’s Simple 7 criteria with definitions previously used in the MASALA study.[23] CVH health factors and behaviors were identified from MASALA Exam 2.[24] Points were assigned to "poor" (0 points), "intermediate" (1 point), or "ideal" (2 points) levels of diet quality (accounting for cultural differences in dietary intake by using the Study of Health Assessment and Risk in Ethnic Groups food

Table 1. Definitions of Social Network Characteristics

Social Network Characteristic (Independent Variable)	Definition	Association Modeled in Statistical Analysis
Social network size	No. of people listed by participant in his/her social network	Odds of outcome associated with a 1-person larger social network
Social network density	Degree of connectedness between a participant’s social network members, ranging from 0 to 1.0 where 1.0 indicates a fully dense social network in which all identified network members have a social relationship with all other network members. Calculated as[17]: Density=(AC, actual number of connections between members of a social network)/(PC, potential number of connections between members of a social network) Where PC=[(number of network members)×(number of network members−1)]/2	Odds of outcome associated with a 10% higher social network density
Proportion of kin in network	Proportion of network members to whom study participants are related	Odds of outcome associated with a 10% higher proportion of kin in network
Proportion of network who are South Asian	Proportion of network members who are of South Asian ethnicity	Odds of outcome associated with a 10% higher proportion of network who are South Asian ethnicity

AC indicates actual number of connections; and PC, potential number of connections.

frequency questionnaire validated for use in South Asian patients,[25] which evaluated fruit and vegetable intake, fish intake, fiber-to-carbohydrate ratio, sugar-sweetened beverage intake, and sodium intake), physical activity (measured by metabolic equivalents tasks of intentional exercise activities in the Typical Week's Activity Survey[26]), smoking (self-report assessed by questionnaire[18]), body mass index (weight as measured on a standard balance-beam or digital scale, height measured with stadiometer), blood pressure (measured while seated using an automated blood pressure monitor, calculating the average of the past 2 of 3 seated readings), and fasting total cholesterol and glucose.[18] Participants were asked to bring current medications to the study interview, from which use of blood pressure, lipid, and glucose-lowering mediations was recorded.[18] Scores for individual CVH components were then summed to obtain a total CVH score ranging from 0 to 14, with higher scores indicating better CVH, or greater achievement of the Life's Simple 7 criteria. For primary analyses, CVH was categorized as poor (score 0–6), intermediate (7–9), and ideal (10–14).

CAC at Exam 2 as a primary dependent variable was quantified with gated cardiac computed tomography imaging. CAC was quantified with Agatston scores for each of the four major coronary arteries, and the summed score was used.[27] For primary analyses, CAC was operationalized having any CAC (score >0) versus having no CAC (score=0). Participant age was obtained via questionnaire from Exam 2. Demographic characteristics, including sex, education (less than college, versus some college, or more), income (<$75 000 per year versus ≥$75 000 per year), country of birth (US-born versus born outside the United States), length of residence in the United States (years), marital status (married/cohabitating versus not married/cohabitating), and self-reported English fluency (speaks English well or very well, versus fairly well, poorly, or not at all) were obtained via standard questionnaire during the Exam 1 interview.[18,24]

Statistical Analysis

Levels of independent variables, dependent variables, and covariates are reported overall and by sex, as mean (SD) or median (25th–75th percentile interquartile range). Categorical variables are reported as number (percentage). Differences in variables between women and men were compared using Wilcoxon-Mann-Whitney tests for continuous variables and Chi-Square tests for categorical variables.

Multinomial logistic regression was used to evaluate the associations between social network characteristics and ideal or intermediate CVH relative to poor CVH. Multiple logistic regression was used to evaluate the association between social network characteristics and presence of non-zero CAC relative to CAC=0 in the index participant. Odds ratios (ORs) from regression models represent the odds of intermediate or ideal CVH (versus poor CVH as referent) or any CAC (versus CAC=0) for a 1-unit increase in social network size, or a 0.10-unit (10%) increase in social network density, proportion of kin in network, and proportion of South Asian patients in network. Regression models were assessed sequentially: first unadjusted, next adjusted for age and sex, and finally additionally adjusted for study site, education, family income, social network alter count (ie, number of alters enumerated in the questionnaire, in models where social network size was not the primarily independent variable), and statin use and CVH (for CAC models).

In primary analyses, multinomial logistic regression was also used to evaluate the association between participant-reported alter health status (ie, prevalent cardiovascular disease, high blood pressure, diabetes mellitus, or high cholesterol) and participant ideal or intermediate CVH relative to poor CVH. Multiple logistic regression was used to evaluate the associations between alter health status and presence of any CAC relative to CAC=0. ORs from these regression models represent the odds of intermediate or ideal CVH (compared with poor CVH) or any CAC (compared with CAC=0) that was associated with the presence of any alter with the specified CVH condition. Secondary exploratory analyses evaluated the association of spouse, related kin, unrelated kin, or non-kin alter with a specified prevalent CVH condition with participant CVH or CAC. Regression models were assessed sequentially: first unadjusted, next adjusted for age and sex, and finally additionally adjusted for study site, education, income, social network alter count, and proportion of kin in network, and statin use and CVH (in CAC analysis).

Interaction terms for an interaction of social network characteristics or alter health status with participant sex were assessed and were not statistically significant (results not shown), so primary analyses were not stratified by sex. Egocentric networks were independent of one another and thus do not violate assumptions of independent observations required in regression models. A 2-sided $P<0.05$ defined statistical significance. Analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC) between August 2019 and July 2020.

RESULTS

Characteristics of the 699 participants included in analyses are shown in Table 2. Characteristics

Table 2. MASALA Participant and Social Network Member Characteristics at Exam 2, 2014 to 2018

	Overall (N=699)	Women (n=300)	Men (n=399)	*P* Value
Age (y), mean (SD)	59.2 (9.2)	57.8 (8.5)	60.3 (9.5)	<0.01
Education (some college or more), n (%)	659 (94.3)	274 (91.3)	385 (96.5)	<0.01
Family income ($75k or greater), n (%)	527 (77.5)	227 (78.3)	300 (76.9)	0.88
Years in the United States, mean (SD)	27.2 (11.0)	26.2 (11.1)	27.9 (10.9)	0.06
US born, n (%)	19 (2.7)	10 (3.3)	9 (2.2)	0.48
English speaker, n (%)	621 (88.8)	256 (85.3)	365 (91.5)	0.01
Married/cohabitating, n (%)	632 (90.4)	251 (83.7)	381 (95.5)	<0.01
CAC score, median (IQR)	8.0 (0–140.3)	0 (0–15.6)	55.1 (0–306.6)	<0.01
Score=0, n (%)	296 (42.4)	195 (65.0)	101 (25.3)	<0.01
Score >0, n (%)	403 (57.7)	105 (35.0)	298 (74.7)	
CVH score, mean (SD)	8.9 (1.9)	9.4 (1.8)	8.5 (1.9)	<0.01
Poor (score, 0–6), n (%)	67 (9.9)	18 (6.1)	49 (12.7)	<0.01
Intermediate (score, 7–9), n (%)	336 (49.6)	125 (42.7)	211 (54.8)	
Ideal (score, 10–14), n (%)	275 (40.6)	150 (51.2)	125 (32.5)	
Smoking (current/former), n (%)	124 (17.8)	11 (3.7)	113 (28.3)	<0.01
Body mass index (kg/m^2), mean (SD)	26.5 (4.0)	26.6 (4.3)	26.4 (3.8)	0.29
Exercise (MET-min/wk), median (IQR)	1207.5 (465.0–2145.0)	1155.0 (442.5–2100.0)	1260.0 (472.5–2190.0)	0.58
Daily calorie intake (kcal/d), mean (SD)	1617.0 (506.8)	1529.9 (441.0)	1682.5 (542.5)	<0.01
Systolic blood pressure, mean (SD)	128.3 (17.0)	124.6 (18.1)	131.1 (15.5)	<0.01
Diastolic blood pressure, mean (SD)	75.7 (9.9)	73.6 (10.4)	77.3 (9.1)	<0.01
Total cholesterol (mg/dL), mean (SD)	187.1 (41.0)	198.3 (37.3)	178.8 (41.7)	<0.01
HDL cholesterol (mg/dL), median (IQR)	48.0 (40.0–59.0)	55.0 (46.0–66.0)	45.0 (37.0–52.0)	<0.01
LDL cholesterol (mg/dL), mean (SD)	111.1 (35.8)	116.3 (33.9)	107.2 (36.7)	<0.01
Fasting blood glucose (mg/dL), mean (SD)	109.3 (23.6)	103.4 (18.1)	113.7 (26.1)	<0.01
Statin use, n (%)	219 (31.3)	67 (22.3)	152 (38.1)	<0.01
Social network size, mean (SD)	5.6 (2.6)	5.8 (2.6)	5.4 (2.6)	0.04
Social network density (scale 0–1, 1=fully dense), mean (SD)	0.79 (0.26)	0.78 (0.27)	0.80 (0.25)	0.23
Proportion of kin in network (scale 0–1, 1=all kin), mean (SD)	0.72 (0.28)	0.72 (0.27)	0.71 (0.28)	0.84
Proportion of South Asian in network (scale 0–1, 1=all SA), mean (SD)	0.88 (0.23)	0.89 (0.21)	0.87 (0.25)	0.49
Alter health status				
Any alter with CVD, n (%)	133 (19.0)	58 (19.3)	75 (18.8)	0.86
Any alter with high blood pressure, n (%)	333 (47.6)	167 (55.7)	166 (41.6)	<0.01
Any alter with diabetes mellitus, n (%)	382 (40.3)	135 (45.0)	147 (36.8)	0.03
Any alter with high cholesterol, n (%)	297 (42.5)	143 (47.7)	154 (38.6)	0.02

Data reported for all individuals who had social network data and coronary artery calcium data from Exam 2 available (n=699). Percentages are reported by accounting for missing data, so all participants may not be included in denominator. CAC indicates coronary artery calcium; CVD, cardiovascular disease (composed of heart disease and/or stroke); CVH, cardiovascular health; HDL, high-density lipoprotein; IQR, interquartile range (25th–75th percentile); LDL, low-density lipoprotein; MASALA, Mediators of Atherosclerosis in South Asians Living in America; MET, metabolic equivalent of task; and SA, South Asian.

of social network members are summarized in Table S1. Participants were on average, aged 59.2 (SD, 9.2) years, and 42.9% were women. Participants were 3% US-born, immigrant participants lived in the United States on average 27 (11) years, 90% of participants were married/cohabitating, and 89% of participants spoke English well or very well. Compared with men, women had larger social network size (6 [SD, 3] people in women versus 5 [SD, 3] people in men, *P*=0.04), and social network density, proportion of kin in network, and proportion of South Asian in network were similar. Women had a higher frequency of reporting an alter with high blood pressure (55.7% versus 41.6% in men, *P*<0.01), diabetes mellitus (45.0% versus 36.8%, *P*=0.03), or high cholesterol (47.7% versus 38.6%, *P*=0.02) but not cardiovascular disease (19.3% versus 18.8%, *P*=0.86). CVH score was higher (more favorable) in women (9.4 [1.8])

Table 3. Adjusted Associations of Social Network Structural Characteristics With Coronary Artery Calcium and Cardiovascular Health in MASALA Participants

Cardiovascular Health (CVH Score)	OR (95% CI)	*P* Value	Coronary Artery Calcium	OR (95% CI)	*P* Value
Social network size					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	1.09 (0.97–1.21)	0.14	CAC >0 vs CAC=0	0.95 (0.87–1.02)	0.16
Ideal (10–14) vs poor	1.13 (1.01–1.27)	0.04			
Social network density					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	1.08 (0.97–1.19)	0.17	CAC >0 vs CAC=0	1.00 (0.92–1.08)	0.92
Ideal (10–14) vs poor	1.07 (0.96–1.19)	0.21			
Proportion of social network who are kin					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	0.99 (0.90–1.10)	0.91	CAC >0 vs CAC=0	1.02 (0.95–1.10)	0.54
Ideal (10–14) vs poor	1.00 (0.91–1.11)	0.96			
Proportion of social network who are South Asian ethnicity					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	1.03 (0.92–1.16)	0.58	CAC >0 vs CAC=0	1.06 (0.98–1.16)	0.15
Ideal (10–14) vs poor	1.01 (0.90–1.13)	0.91			

Adjusted for participant age, sex, study site, education, income, statin use (in coronary artery calcium analyses), cardiovascular health (in coronary artery calcium analyses), and social network alter count (where social network size is not the main predictor). Odds ratios represent the odds of the presence of any coronary artery calcium (vs coronary artery calcium=0), or the odds of ideal or intermediate cardiovascular health (vs poor cardiovascular health), for a 1-unit increase in social network size, for a 0.10-unit (10%) increase in social network density, proportion of kin in network, and proportion of South Asian ethnicity in network. CAC indicates coronary artery calcium; CVH, cardiovascular health; MASALA, Mediators of Atherosclerosis in South Asians Living in America; and OR, odds ratio.

compared with men (8.5 [1.9], *P*<0.01), and they had a lower frequency of any CAC (57.7%) compared with men (74.7%, *P*<0.01).

The association between social network characteristics and CVH and CAC are listed in Table 3. Overall, a 1-person increase in social network size was associated with 13% higher odds of ideal versus poor CVH (OR, 1.13; 95% CI, 1.01–1.27; *P*=0.04). No statistically significant associations were observed between social network density, proportion of kin in network, or proportion of South Asian in network and CVH. Similarly, no statistically significant associations were observed between social network characteristics and CAC.

The association of alter health status with participant CVH and CAC are shown in Table 4. Reporting an alter with high blood pressure was associated with 50% lower odds of intermediate CVH (OR, 0.50; 95% CI, 0.28–0.87; *P*=0.02) and 49% lower odds of ideal CVH (OR, 0.51; 95% CI, 0.29–0.88; *P*=0.02) in the participant, relative to poor CVH. Similarly, reporting an alter with high cholesterol was associated with 46% lower odds of ideal CVH (OR, 0.54; 95% CI, 0.30–0.94; *P*=0.03) versus poor CVH. No statistically significant associations between alter health status and CAC were observed. In secondary analyses (Tables S2 and S3), associations between alter health status and participant CVH were predominantly for alters who are related kin.

DISCUSSION

In this analysis we observed that a larger social network size among US South Asian adults was associated with higher odds of ideal CVH. We also found that the presence of a social network member with high blood pressure or cholesterol was associated with lower odds of intermediate or ideal CVH. These findings suggest that the size of social networks and the health of social network members may influence the CVH of South Asian adults in the United States, and address gaps in CVD prevention research to understand how social networks may influence CVH and CVD risk in this population.

Prior research has indicated that health status may be influenced by interactions with social network members, including for smoking,[28] diabetes mellitus,[15,29] and obesity.[10] Associations between social networks and health status may operate through mechanisms such as presence of social support as a facilitator of healthful behaviors, health information sharing between members of a social network either verbally or through digital communication, or shared behaviors that promote or detract from health.[30–32] Notably, such associations—including those we observed—may potentially be attributable to homophily (ie, the tendency for people with similar health status to be socially connected).

Table 4. Adjusted Association of Alter Health Status With Cardiovascular Health and Coronary Artery Calcium in MASALA Participants

Cardiovascular Health (CVH Score)	OR (95% CI)	*P* Value	Coronary Artery Calcium	OR (95% CI)	*P* Value
Any alter with cardiovascular disease					
Poor (0–6)	Ref.		CAC=0	Ref.	
Intermediate (7–9) vs poor	0.62 (0.33–1.16)	0.13	CAC >0 vs CAC=0	0.96 (0.57–1.62)	0.89
Ideal (10–14) vs poor	0.72 (0.37–1.39)	0.32			
Any alter with high blood pressure					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	0.50 (0.28–0.87)	0.02	CAC >0 vs CAC=0	1.05 (0.70–1.57)	0.81
Ideal (10–14) vs poor	0.51 (0.29–0.88)	0.02			
Any alter with diabetes mellitus					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	0.87 (0.50–1.51)	0.62	CAC >0 vs CAC=0	0.83 (0.55–1.24)	0.35
Ideal (10–14) vs poor	0.85 (0.48–1.50)	0.57			
Any alter with high cholesterol					
Poor (0–6)	Ref.		CAC=0	*Ref.*	
Intermediate (7–9) vs poor	0.73 (0.42–1.25)	0.24	CAC >0 vs CAC=0	1.40 (0.93–2.11)	0.11
Ideal (10–14) vs poor	0.54 (0.30–0.94)	0.03			

Adjusted for participant age, sex, study site, education, income, statin use (in coronary artery calcium analyses), cardiovascular health (in coronary artery calcium analyses), and social network alter count (where social network size is not the main predictor). Odds ratios represent the odds of the presence of any coronary artery calcium (vs coronary artery calcium=0), or the odds of ideal or intermediate cardiovascular health (vs poor cardiovascular health), associated with the presence (vs absence) of any alter reported to have the specified health condition. CAC indicates coronary artery calcium; CVH, cardiovascular health; MASALA, Mediators of Atherosclerosis in South Asians Living in America; and OR, odds ratio.

Our exploratory analyses suggest that associations between alter CVH status and worse participant CVH occur predominantly in social network members who are kin, which could in part reflect shared genetic risk, but also may be attributable to shared cardiovascular health behaviors such as suboptimal eating patterns or non-participation in physical activity among kin. Though the available sample size precludes robust quantitative evaluation of differences in social network characteristics across generational cohorts and participants were predominantly first generation immigrants, recent mixed-methods analysis in MASALA showed that positive role modeling and support from adult children facilitate favorable health behaviors in South Asian American immigrants, which supports a potential intergenerational effect of social networks on CVH.[33]

Our finding that social network size is positively associated with ideal CVH may indicate that in this population a larger social network provides enhanced social support or opportunities for information or behavior sharing. In a 2019 report from the MASALA cohort, having social network members who exercised or were exercise partners was associated with ≈200 to 500 more metabolic equivalent of task-minutes/week of moderate-to-vigorous leisure time physical activity.[14] A similar association has also been observed in Latino populations in the United States.[34] However, despite large social network size similar to that of Latino immigrant populations in the United States and larger than non-immigrant populations,[17] South Asian populations have a higher burden of CVD and worse CVH compared with other race/ethnic groups,[1] indicating that social network influences alone likely do not account for this disproportionate CVD burden.

Because these data are cross-sectional, causality of the observed associations cannot be directly inferred, and these results should be seen as hypothesis generating. For instance, our evaluation of CAC is a surrogate for coronary artery disease and does not necessarily identify high-grade or vulnerable angiographic lesions, so further investigation of how social network characteristics may influence cardiovascular risk factors and ultimately be associated with coronary heart disease events is warranted. Longitudinal follow-up for cardiovascular risk factor changes and cardiovascular disease events in MASALA is ongoing and may be able to address this limitation in the future. Our findings are further limited by sample size, which limits power to detect associations. Additionally, the health status of alters is reported by MASALA participants themselves, so may be subject to recall bias. It is also possible that some of our findings were observed because of chance in the context of multiple comparisons. Alter proximity may influence health outcomes, however, we were not able to account for proximity of alters in this analysis since proximity is measured at the alter level, whereas our predictor

variables are operationalized at the MASALA participant level. Future directions will evaluate the influence of alter health accounting for alter proximity. Finally, the associations we observed are most representative of the South Asian American population in the communities studied. Our findings may not be generalizable to all South Asian adults in different areas of the United States or in South Asia. Nevertheless, the associations we observed between social network characteristics and individuals' CVH may inform the incorporation of social networks in interventions to promote CVH and prevent atherosclerotic CVD in South Asian American adults.

Future work to contextualize and leverage these findings should acknowledge the intersectionality of social determinants of health by recognizing the complex interrelation of social and structural health determinants that may operate at individual and community levels.[35] Though our analysis of social network characteristics adjusted for determinants such as income and education as independent covariates, these factors may interact dynamically with social network characteristics. Multilevel modeling approaches may help demonstrate the intersection of social context and social networks with other social determinants in the production of health inequalities.[36] Future approaches in development and implementation of interventions may consider social network influences in the context of an individual or community's social and structural environment.

Practically, potentially effective social network interventions for health behavior change may leverage existing networks, establish new network ties, disrupt harmful network relationships, or educate individuals about the potential influences of their health behaviors on their network members.[37] Social network engagement for CVH promotion in the South Asian American population may include increasing personal social connections or engaging alters in diet or physical activity interventions to promote healthful shared behaviors. In the context of clinical assessment of social determinants of health, collecting data on patient social networks and social isolation in clinical settings may also inform and enhance clinical care, for South Asian individuals and other groups.[38] Implementation of CVH interventions that incorporate social networks for health promotion and behavior change may be further enhanced by adapting evidence-based practices in other health conditions, such as for mental health, HIV, and smoking.[37,39] Research in those conditions have demonstrated that enhancing social support, facilitating social exchange, and leveraging key individuals who have large numbers of social ties (therefore, higher influence potential) may lead to favorable behavior change. Ultimately, the observed associations of social network characteristics with CVH in MASALA cohort participants inform the pursuit of health promotion strategies that engage social networks to enhance CVD prevention in this risk-enhanced population.

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Supplementary Material

Tables S1–S3

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SUPPLEMENTAL MATERIAL

Table S1. Characteristics of alters of MASALA participants.

	Overall N = 699	**Women N = 300**	**Men N = 399**
Age of alters, years, mean (SD)	49.9 (9.0)	49.5 (9.1)	50.2 (8.9)
Frequency of contact, contact-days/year, mean (SD)	1074 (388)	1134 (382)	1030 (388)
Alter physical proximity, N*			
Living in the same home	874	365	508
Living in the same neighborhood, town, state	1417	625	789
Living out-of-state or out-of-country	687	316	370
Participant-alter relationship, N*			
Spouse	566	208	358
Ex-spouse	1	1	0
Parent	140	74	66
Parent-in-law	19	8	11
Child	620	343	277
Sibling	374	170	204
Niece/Nephew	19	12	7
Other in-law	189	99	90
Other relative	58	30	28
Friend	707	379	328
Neighbor	12	4	8
Co-Worker	141	101	40
Boss/Manager	18	16	2
Religious official	4	3	1
Other	10	6	4

*****Percentages are not calculated since a MASALA participant may list multiple alters of the same physical location or type (e.g., one participant may list two alters who live in the same home, or three children in their social network); accordingly, alter location and type frequencies may be larger than the number of MASALA participants.

Table S2. Frequency of alters with cardiovascular health conditions in MASALA participants.

	Overall N = 699	**Women N = 300**	**Men N = 399**	**P**
Spouse				
With CVD, N (%)	34 (4.9)	26 (8.7)	8 (2.0)	<0.01
With high blood pressure, N (%)	146 (20.9)	76 (25.3)	70 (17.5)	0.01
With diabetes, N (%)	121 (17.3)	63 (21.0)	58 (14.5)	0.03
With high cholesterol, N (%)	138 (19.7)	76 (25.3)	62 (15.5)	<0.01
Related kin				
With CVD, N (%)	50 (7.2)	24 (8.0)	26 (6.5)	0.45
With high blood pressure, N (%)	134 (19.2)	71 (23.7)	63 (15.8)	0.01
With diabetes, N (%)	93 (13.3)	50 (16.7)	43 (10.8)	0.02
With high cholesterol, N (%)	109 (15.6)	54 (18.0)	55 (13.8)	0.13
Unrelated kin				
With CVD, N (%)	15 (2.2)	3 (1.0)	12 (3.0)	0.07
With high blood pressure, N (%)	39 (5.6)	19 (6.3)	20 (5.0)	0.45
With diabetes, N (%)	39 (5.6)	13 (4.3)	26 (6.5)	0.21
With high cholesterol, N (%)	31 (4.4)	11 (3.7)	20 (5.0)	0.39
Non-kin				
With CVD, N (%)	44 (6.3)	10 (3.3)	34 (8.5)	0.01
With high blood pressure, N (%)	101 (14.5)	44 (14.7)	57 (14.3)	0.89
With diabetes, N (%)	90 (12.9)	36 (12.0)	54 (13.5)	0.55
With high cholesterol, N (%)	102 (14.6)	40 (13.3)	62 (15.5)	0.41

Data presented are frequencies of having at least one alter type with the specified health condition, e.g. "frequency of having any related kin with diabetes."

Table S3. Adjusted association of alter health status with cardiovascular health and coronary artery calcium, by alter type.

Cardiovascular health (CVH score)			**Coronary artery calcium**		
	OR (95% CI)	P		OR (95% CI)	P
Alter with cardiovascular disease					
Spouse with cardiovascular disease					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	1.02 (0.27 – 3.85)	0.97	CAC > 0 vs. CAC = 0	1.25 (0.50 – 3.16)	0.63
Ideal (10-14) vs. poor	1.26 (0.33 – 4.83)	0.74			
Related kin with cardiovascular disease					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.37 (0.15 – 0.89)	0.03	CAC > 0 vs. CAC = 0	0.95 (0.44 – 2.06)	0.89
Ideal (10-14) vs. poor	0.41 (0.17 – 1.01)	0.05			
Unrelated kin with cardiovascular disease					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.90 (0.17 – 4.69)	0.90	CAC > 0 vs. CAC = 0	5.85 (0.47 – 72.29)	0.17
Ideal (10-14) vs. poor	0.68 (0.11 – 4.18)	0.68			
Non-kin with cardiovascular disease					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.61 (0.22 – 1.68)	0.50	CAC > 0 vs. CAC = 0	0.45 (0.20 – 1.05)	0.06
Ideal (10-14) vs. poor	0.69 (0.24 – 2.01)	0.34			
Alter with high blood pressure					
Spouse with high blood pressure					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.68 (0.38 – 1.28)	0.23	CAC > 0 vs. CAC = 0	1.10 (0.67 – 1.82)	0.70
Ideal (10-14) vs. poor	0.74 (0.39 – 1.41)	0.36			
Related kin with high blood pressure					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.53 (0.28 – 1.00)	0.05	CAC > 0 vs. CAC = 0	0.83 (0.48 – 1.41)	0.48

Ideal (10-14) vs. poor	0.33 (0.17 – 0.66)	<0.01			
Unrelated kin with high blood pressure					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.52 (0.18 – 1.45)	0.21	CAC > 0 vs. CAC = 0	1.83 (0.75 – 4.50)	0.19
Ideal (10-14) vs. poor	0.72 (0.25 – 2.04)	0.53			
Non-kin with high blood pressure					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.76 (0.34 – 1.71)	0.51	CAC > 0 vs. CAC = 0	0.82 (0.46 – 1.49)	0.52
Ideal (10-14) vs. poor	0.85 (0.37 – 1.95)	0.70			
Alter with diabetes					
Spouse with diabetes					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.82 (0.41 – 1.64)	0.57	CAC > 0 vs. CAC = 0	0.96 (0.57 – 1.64)	0.89
Ideal (10-14) vs. poor	1.09 (0.53 – 2.22)	0.82			
Related kin with diabetes					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.90 (0.41 – 2.01)	0.80	CAC > 0 vs. CAC = 0	0.89 (0.49 – 1.62)	0.70
Ideal (10-14) vs. poor	0.72 (0.31 – 1.65)	0.43			
Unrelated kin with diabetes					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.91 (0.32 – 2.63)	0.86	CAC > 0 vs. CAC = 0	1.52 (0.57 – 4.06)	0.40
Ideal (10-14) vs. poor	0.59 (0.19 – 1.87)	0.37			
Non-kin with diabetes					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.97 (0.42 – 2.23)	0.94	CAC > 0 vs. CAC = 0	0.76 (0.41 – 1.42)	0.39
Ideal (10-14) vs. poor	0.71 (0.30 – 1.70)	0.44			
Alter with high cholesterol					
Spouse with high cholesterol					

Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.76 (0.40 – 1.45)	0.41	CAC > 0 vs. CAC = 0	1.41 (0.84 – 2.38)	0.20
Ideal (10-14) vs. poor	0.69 (0.35 – 1.36)	0.28			
Related kin with high cholesterol					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.58 (0.28 – 1.15)	0.11	CAC > 0 vs. CAC = 0	0.70 (0.40 – 1.21)	0.20
Ideal (10-14) vs. poor	0.43 (0.21 – 0.88)	0.02			
Unrelated kin with high cholesterol					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	1.72 (0.37 – 7.98)	0.49	CAC > 0 vs. CAC = 0	1.73 (0.63 – 4.79)	0.29
Ideal (10-14) vs. poor	1.54 (0.31 – 7.53)	0.60			
Non-kin with high cholesterol					
Poor (0-6)	*Ref.*		CAC = 0	*Ref.*	
Intermediate (7-9) vs. poor	0.89 (0.41 – 1.95)	0.77	CAC > 0 vs. CAC = 0	1.70 (0.94 – 3.07)	0.08
Ideal (10-14) vs. poor	0.72 (0.32 – 1.64)	0.44			

Adjusted for participant age, sex, study site, education, income, proportion of kin, statin use (in CAC analysis), CVH (in CAC analysis), and social network alter count. Odds ratios represent the odds of the presence of any CAC (vs. CAC = 0), or the odds of ideal or intermediate cardiovascular health (vs. poor cardiovascular health), associated with the presence (versus absence) of any alter reported to have the specified health condition.