GYNECOLOGY

Multiparity is associated with poorer cardiovascular health among women from the Multi-Ethnic Study of Atherosclerosis

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BACKGROUND: Multiparity is associated with a greater risk of incident cardiovascular disease. However, the relationship of parity with cardiovascular health, as measured by the American Heart Association Life's Simple 7 metrics, is uncertain.

OBJECTIVE: We aimed to examine the association between parity and ideal cardiovascular health among 3430 women, aged 45—84 years, free of clinical cardiovascular disease enrolled in the Multi-Ethnic Study of Atherosclerosis.

STUDY DESIGN: The Multi-Ethnic Study of Atherosclerosis is a prospective cohort study that recruited middle-aged to older women and men from 6 centers in the United States between 2000 and 2002. The study population comprised 38% White, 28% Black, 23% Hispanic, and 11% Chinese American subjects. Parity (total number of live births) was self-reported and categorized as 0, 1—2, 3—4 and ≥5. The Life's Simple 7 metrics, defined according to American Heart Association criteria, include health behaviors (smoking, physical activity, body mass index, diet) and health factors (blood pressure, total cholesterol, and blood glucose). We categorized each metric into ideal (2 points), intermediate (1 point), and poor (0 points). A total cardiovascular health score of 0—8 was considered inadequate; 9—10, average; and 11—14, optimal. We used multinomial logistic regression to examine the cross-sectional association between parity and the cardiovascular health score, adjusted for sociodemographics, field site, hormone therapy, and menopause.

RESULTS: The mean (standard deviation) age was 62 (10) years. The mean (standard deviation) cardiovascular health score was lower with higher parity (8.9 [2.3], 8.7 [2.3], 8.5 [2.2], and 7.8 [2.0] for 0, 1—2, 3—4, and ≥5 live births, respectively). In comparison to inadequate cardiovascular health scores, the adjusted odds of average cardiovascular health scores were significantly lower for all parity categories relative to nulliparity (prevalence odds ratios [OR] for parity of 1—2, 0.64 [95% confidence interval 0.49—0.83]; 3—4, 0.65 [0.49—0.86]; ≥5, 0.64 [0.45—0.91]). Women with ≥5 live births had a lower prevalence of optimal cardiovascular health scores (OR 0.50 [0.30—0.83]). In the fully adjusted models, the association between parity and each Life's Simple 7 metric was only statistically significant for body mass index. Women with ≥5 live births had lower prevalence of ideal body mass index (OR 0.52 [0.35—0.80]). In addition, the test for interaction showed that the association between parity and cardiovascular health was not modified by race/ethnicity (P = .81 for average cardiovascular health scores and P = .20 for optimal cardiovascular health scores).

CONCLUSION: Multiparity was associated with poorer cardiovascular health, especially for women with ≥5 live births. More research is required to explore the mechanisms by which parity may worsen cardiovascular health.

Key words: ideal cardiovascular health metrics, Life's Simple 7, live births, parity, pregnancy

The burden of cardiovascular disease (CVD) among women is substantial, with 1 in 3 women dying from CVD globally.[1,2] In the United States, approximately 48 million women aged ≥20 years had CVD between 2011 and 2014, accounting for 36% of the total female population.[3] The normal physiologic changes occurring during pregnancy (for example, changes in lipids, glucose, and weight), and additional stressors (such as endothelial dysfunction, inflammation, and hemostatic processes),[4,5] may lead to an increased risk of incident CVD later in life. Prior studies have reported that both a history of nulliparity (0 live births)[6] and high parity (≥4 live births)[7] are associated with an increased risk of CVD.[6,7] However, other studies have reported different results.[8,9]

With the introduction of the concept of ideal cardiovascular health (CVH) measured by the Life's Simple 7 (LS7) metrics, the American Heart Association emphasizes primordial prevention of CVD risk factors as a means to decrease the CVD burden in the general population.[10] A person is considered to be in ideal CVH if they meet the ideal requirements for each LS7 metric.[10] Numerous studies have documented ideal CVH is inversely related to the incidence of CVD.[11,12] However, only 1 of these studies has explored the association between parity and ideal CVH.[13] Furthermore, it is not known if parity is more strongly associated with any of the individual LS7 metrics (ie, smoking, physical activity, body mass index [BMI], diet, total cholesterol, blood pressure, blood glucose). Lastly, it is unclear if there are racial/ethnic differences in CVH related to parity. Thus, the aim of this study is to determine if parity is associated with ideal CVH among women in the Multi-Ethnic Study of Atherosclerosis (MESA). A secondary aim is to assess for interactions by race/ethnicity. We hypothesized that multiparity will be associated with poorer CVH irrespective of race/ethnicity.

AJOG at a Glance

Why was this study conducted?
To examine the relationship between parity and ideal cardiovascular health, as measured by the American Heart Association's Life's Simple 7 metrics.

Key findings
Multiparity was associated with poorer cardiovascular health in middle or late adulthood, particularly among women with ≥5 live births.

What does this add to what is known?
This study emphasizes the importance of primordial prevention of cardiovascular disease risk factors as a strategy to improve cardiovascular health among women, a shift from disease prevention to promotion of cardiovascular wellness.

Methods

Study population

MESA is a longitudinal study that recruited 6814 women and men between the ages of 45 and 84 years from 6 centers (Baltimore, MD; Chicago, IL; Forsyth County, NC; Los Angeles, CA; New York, NY; and St Paul, MN) between the years 2000 and 2002.[14] The MESA study population was 38% White, 28% Black, 23% Hispanic, and 11% Chinese American. Participants did not have a history of clinical CVD at the time of enrollment. The institutional review boards of each recruitment center approved the study protocol, and all participants gave informed consent. Data were collected from standardized questionnaires, physical examination findings, and fasting laboratory blood draw. A total of 3430 women were included in this cross-sectional analysis from the baseline examination, after the exclusion of men (n = 3213) and participants without complete information on parity (n = 2) and the LS7 metrics (n = 169).

Assessment of cardiovascular health

The CVH score is the dependent variable of this study derived from the components of the LS7 metrics, which consists of 4 health behaviors (smoking, physical activity, BMI, diet) and 3 health factors (total cholesterol, blood pressure, blood glucose).[10] According to the American Heart Association, ideal CVH is defined as nonsmoking, physical activity at goal levels, BMI <25 kg/m², and a healthy

diet consistent with the Dietary Approaches to Stop Hypertension guideline, in addition to the nonuse of medications to achieve total cholesterol <200 mg/dL, blood pressure <120/<80 mm Hg, and fasting blood glucose <100 mg/dL.[10] Smoking status was self-reported with 3 categories: nonsmokers (participants who never smoked or quit >12 months ago), former smokers (participants who quit within past 12 months), and current smokers.[10] Physical activity was measured using a self-report survey instrument modified from the Cross-Cultural Activity Participation Study.[15] The survey has 28 questions on time and frequency of activities during a week in the previous month. The questions were used to estimate the total minutes of moderate and vigorous exercise.[16] BMI was expressed in kg/m² and was calculated from the weight and height measurements.

A validated food frequency questionnaire with 120 items was employed in the assessment of diet. The questionnaire was modified from the Insulin Resistance Atherosclerosis Study instrument.[17,18] A healthy diet included 5 items: fruits and vegetables, fish, whole grains, intake of sodium <1500 mg per day, and sugar-sweetened beverages ≤450 kcal (36 oz) per week.[10] Three blood pressure readings were taken from each participant in a seated position after 5 minutes of rest. The average value of the second and third readings were recorded. Total cholesterol and blood glucose measurements were obtained from 12-hour fasting blood samples.

The definition of the LS7 metrics and their categories (poor, intermediate, and ideal)[10] are presented in Supplemental Table 1 (Appendix). Points were assigned to each category, where 0 indicates poor; 1, intermediate; and 2, ideal. The points from the 7 metrics were then summed to give a total CVH score (dependent variable) that ranged from 0 to 14.[19] As previously reported, CVH scores of 0–8 were considered inadequate; 9–10, average; and 11–14, optimal.[12,16,20,21]

Assessment of parity

Parity is the independent variable of this study. Parity was self-reported and defined as the total number of live births. We used a previously defined algorithm for the gravidity and parity assessment in MESA.[22] According to prior studies,[23] the validity of self-report for parity vs chart review is very high (kappa 0.93–0.98). As per prior studies,[24,25] we categorized parity as 0, 1–2, 3–4, and ≥5, and 0 (nulliparity) was the reference category.

Assessment of covariates

Age, race/ethnicity, education, income, health insurance, marital status, MESA field site, menopause status, and current use of hormone therapy were the covariates included in this study. Age ranged from 45 to 84 years (continuous), but we considered 2 categories, <65 and ≥65 years, in stratified analyses. Race/ethnicity was categorized as White, Black, Hispanic, or Chinese-American. Education had 9 categories, but was dichotomized as ≥ bachelor's degree and < bachelor's degree in stratified analyses. Income had 13 categories, but was dichotomized as ≥$40,000 and <$40,000 for stratified analyses. Menopause status was defined using a previously described algorithm and categorized as "Yes" and "No."[26] Marital status was categorized as married, widowed, divorced, separated, and never married. Health insurance and current use of hormone therapy were categorized as "Yes" and "No."

Statistical analyses

The baseline characteristics of the study participants were reported by parity

categories. Continuous variables were presented as means with standard deviation (SD) while categorical variables were presented as frequencies with percentages. We used the ANOVA and χ^2 tests to compare the differences between continuous and categorical variables, respectively. We also reported the proportions for each of the LS7 metrics by parity categories.

Multinomial logistic regression models were used to examine the association between parity (independent variable) and the CVH score categories (dependent variable) in the total cohort. Three separate regression models were fitted. Model 1 was unadjusted. Model 2 was adjusted for sociodemographic factors (age [continuous], race/ethnicity [4 categories], education [9 categories], income [13 categories], health insurance status [yes/no], marital status [5 categories], and MESA field site [6 categories]). We adjusted for education and income using the original 9 and 13 categories collected at baseline to minimize residual confounding. Model 3 was additionally adjusted for current use of hormone therapy (yes/no) and menopause (yes/no). Prevalence odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for the CVH score categories across the categories of parity. The reference groups were 0 live births (nulliparity) for parity and the inadequate score for the CVH score. In addition, the associations between parity and each of the individual LS7 metrics were examined by comparing the intermediate and ideal categories of the respective metrics to the poor category. We also examined the association between parity and the number of LS7 metrics in the "ideal" category, reporting prevalence ORs and 95% CIs. Participants with 2, 3, 4, 5, and 6−7 ideal metrics were compared to those with 0−1 ideal metrics.

We examined the interaction of parity with race/ethnicity using the likelihood ratio χ^2 test, by including interaction terms in model 3. We performed this analysis to assess if race/ethnicity is an effect modifier of the relationship between parity and CVH. Given a priori interest in racial/ethnic and sociodemographic

differences, we presented results stratified by race/ethnicity, age, education, and health insurance status regardless if a significant interaction was found (presented in Supplemental Tables 4, 5 and 7. In supplemental analyses, we also explored results stratified by gravidity instead of parity. Lastly, we calculated predicted probabilities of achieving CVH scores by parity categories. All analyses were performed using STATA version 15.0 (StataCorp LP, College Station, TX).

Results

Among women in our study population (n = 3430), the mean (SD) age was 62 (10) years and 18% were nulliparous, 39% had 1−2 live births, 19% had 3−4 live births, and 13% had ≥5 live births. The baseline characteristics of study participants varied by parity categories, as illustrated in Table 1. Women with ≥5 live births were more likely to be Hispanic or have less than a bachelor's degree or earn <$40,000 annually or have a higher systolic blood pressure or higher fasting blood glucose. These women were also less likely to be physically active.

The mean (SD) for the CVH score was lower with higher parity, as follows: 8.9 (2.3), 8.7 (2.3), 8.5 (2.2), and 7.8 (2.0) for 0, 1−2, 3−4, and ≥5 live births, respectively (P < .001) (Supplemental Table 2). The distribution of the CVH scores within parity categories for the total cohort and stratified by race/ethnicity are presented in the Figure and Supplemental Figures, respectively. The proportion of women with optimal CVH scores (11−14 points) was lower with higher parity.

The associations between parity and CVH score categories in the overall study population are presented in Table 2. After adjustment for sociodemographic characteristics, MESA field site, current use of hormone therapy, and menopause status (model 3), women with 1−2, 3−4, and ≥5 live births had lower prevalence of average CVH scores (9−10 points) compared to women with 0 live births (prevalence OR for 1−2 live births, 0.64 [95% CI, 0.49−0.83]; 3−4, 0.65 [0.49−0.86]; ≥5, 0.64 [0.45−0.91]). In addition, multiparity was associated

with lower prevalence of optimal CVH scores, although the association was only statistically significant for women with ≥5 live births (prevalence OR 0.50 [95% CI, 0.30−0.83]).

The distribution of each of the LS7 metrics by parity categories is shown in Supplemental Table 2, and the adjusted associations between parity and each of the LS7 metrics are presented in Tables 3 and 4. We did not find any associations of the metrics of diet, smoking, and total cholesterol with parity. For the metrics of physical activity, blood pressure, and glucose, there was a graded association between parity and the LS7 metrics, where multiparity was associated with lower prevalence of intermediate or ideal metrics; however, these associations were not statistically significant in the fully adjusted model. However, for BMI, this graded association was seen even in adjusted analyses, where women with ≥5 live births had lower prevalence of ideal BMI (prevalence OR 0.52 [0.35−0.80], Table 3, model 3). In adjusted models, we did not find a statistically significant association between parity and the number of LS7 metrics in the "ideal" category, as shown in Supplemental Table 3.

The test for interaction showed that the association between parity and CVH was not modified by race/ethnicity (P = .81 for average scores and P = .20 for optimal scores). The associations between parity and CVH score categories stratified by race/ethnicity are shown in Supplemental Tables 4 and 5. In the fully adjusted stratified analysis, White women with ≥5 live births had lower prevalence of optimal scores (prevalence OR 0.23 [0.09−0.63]), while Hispanic women with 3−4 live births had lower prevalence of optimal scores (prevalence OR 0.29 [0.10−0.82]). The predicted probabilities of CVH scores by parity categories showed that women with ≥5 live births had highest probability for achieving inadequate scores (margin 0.53 [0.47−0.59]) and the lowest probability for achieving optimal scores (margin 0.11 [0.08−0.15]) (Supplemental Table 6). The associations of parity and CVH scores stratified by age,

TABLE 1
Characteristics of study participants by parity

	Total (3430)	0 (627)	1−2 (1349)	3−4 (644)	≥5 (453)	P value
Age, mean (SD), y	62 (10)	60 (11)	60 (10)	63 (10)	68 (9)	<.001
Age, y						
<65, n (%)	1972 (57)	395 (63)	895 (66)	541 (54)	141 (31)	<.001
≥65, n (%)	1458 (43)	232 (37)	454 (34)	460 (46)	312 (69)	
Race/ethnicity						
White, n (%)	1320 (38)	314 (50)	538 (40)	362 (36)	106 (23)	
Chinese American, n (%)	409 (12)	39 (6)	176 (13)	143 (14)	51 (11)	<.001
Black, n (%)	957 (28)	194 (31)	410 (30)	245 (24)	108 (24)	
Hispanic, n (%)	744 (22)	80 (13)	225 (17)	251 (25)	188 (42)	
Education						
≥ Bachelor's degree, n (%)	1044 (30)	326 (52)	455 (34)	235 (23)	28 (6)	<.001
< Bachelor's degree, n (%)	2386 (70)	301 (48)	894 (66)	766 (77)	425 (94)	
Income						
≥$40,000, n (%)	1453 (42)	322 (51)	658 (49)	397 (40)	76 (17)	<.001
<$40,000, n (%)	1977 (58)	305 (49)	691 (51)	604 (60)	377 (83)	
Health insurance, n (%)						
Yes	3123 (91)	597 (95)	1,230 (91)	916 (92)	380 (84)	<.001
No	307 (9)	30 (5)	119 (9)	85 (8)	73 (16)	
Menopause status, n (%)						
Yes	2933 (86)	497 (79)	1112 (82)	890 (89)	434 (96)	<.001
No	497 (14)	130 (21)	237 (18)	111 (11)	19 (4)	
Hormone therapy (postmenopause), n (%)						
Current user	986 (32)	182 (34)	412 (35)	297 (32)	95 (22)	<.001
Noncurrent user	2104 (68)	357 (66)	780 (65)	629 (68)	338 (78)	
LS7 metrics[a]						
Current smoking, n (%)	398 (12)	79 (13)	176 (13)	98 (10)	45 (10)	.11
Body mass index (kg/m^2)	29 (6)	28 (6)	28 (6)	29 (6)	30 (6)	<.001
Physical activity (MET-min/week)	342 (515)	359 (479)	356 (528)	357 (561)	244 (396)	<.001
Healthy diet score (0−5)	1.7 (0.9)	1.7 (0.9)	1.7 (0.9)	1.7 (0.9)	1.6 (0.8)	.23
Total cholesterol (mg/dL)	200 (36)	199 (35)	200 (36)	199 (35)	199 (37)	.97
Systolic blood pressure (mm Hg)	127 (23)	124 (23)	125 (23)	128 (23)	134 (24)	<.001
Diastolic blood pressure (mm Hg)	69 (10)	69 (10)	69 (10)	69 (10)	69 (10)	.22
Fasting blood glucose (mg/dL)	95 (28)	90 (22)	94 (26)	96 (31)	101 (31)	<.001
CVH score, n (%)						
Inadequate	1614 (47)	240 (38)	612 (45)	483 (48)	279 (62)	
Average	1118 (33)	228 (36)	424 (31)	327 (33)	139 (31)	<.001
Optimal	698 (20)	159 (25)	313 (23)	191 (19)	35 (8)	

CVH, cardiovascular health; *LS7*, Life's Simple 7; *MET*, metabolic equivalent of task; *SD*, standard deviation.

[a] Mean (SD) of LS7 metrics are shown with the exception of smoking.

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education, and health insurance status are presented in Supplemental Table 7. The associations of gravidity and CVH are presented in Supplemental Table 8 and show similar patterns to parity.

Discussion
Principal findings
In this multiethnic community-based cohort of women free of CVD at baseline, we found that after taking into consideration sociodemographic characteristics (age, race/ethnicity, education, income, health insurance, marital status), MESA field site, current use of hormone therapy, and menopause status, women with a history of 1–2, 3–4, and ≥5 live births had lower prevalence of average CVH scores compared to women with 0 live births. In addition, women with ≥5 live births had lower prevalence of optimal CVH scores compared to women with 0 live births. Women with a history of ≥5 live births also had lower prevalence of ideal BMI.

Comparison to prior research
A previous meta-analysis including 10 cohorts and over 3 million women found an increased risk of incident CVD events associated with parity (compared to nulliparity) in a nonlinear dose-dependent fashion.[6] The reasons for this greater CVD risk associated with parity are uncertain, but several potential biologic mechanisms have been proposed, including unfavorable changes in lipids, glucose, and weight with each pregnancy, as well as endothelial dysfunction and inflammatory and hemostatic processes.[4,5] Few studies have examined the association of parity with markers of cardiovascular wellness, which was the aim of the present study. The findings of our study are comparable to those of a prior cross-sectional study that examined the cumulative effect of reproductive factors including parity on ideal CVH among postmenopausal Chinese women.[13] In that study, participants with more than 3 children (compared with women with 3 children or fewer) were less likely to have better CVH. After adjusting for age, these women had lower prevalence of 2, 3, 4, 5, and 6–7 ideal metrics (prevalence

FIGURE
Distribution of cardiovascular health scores within parity categories
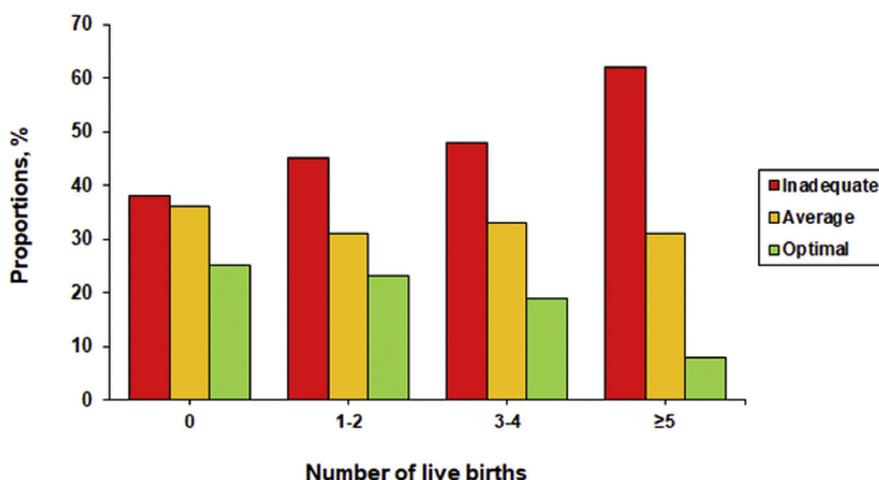
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TABLE 2
Association between parity and cardiovascular health

	CVH score	
	Average vs Inadequate	Optimal vs Inadequate
Parity	OR (95% CI)	
Model 1: Unadjusted		
0	1 (reference)	1 (reference)
1—2	0.73 (0.59—0.91)[a]	0.77 (0.61—0.98)[a]
3—4	0.71 (0.57—0.90)[a]	0.60 (0.46—0.78)[a]
≥5	0.52 (0.40—0.69)[a]	0.19 (0.13—0.28)[a]
Model 2: Adjusted		
0	1 (reference)	1 (reference)
1—2	0.68 (0.52—0.87)[a]	0.82 (0.61—1.11)
3—4	0.70 (0.53—0.92)[a]	0.79 (0.57—1.10)
≥5	0.69 (0.49—0.95)[a]	0.48 (0.29—0.77)[a]
Model 3: Adjusted		
0	1 (reference)	1 (reference)
1—2	0.64 (0.49—0.83)[a]	0.84 (0.61—1.17)
3—4	0.65 (0.49—0.86)[a]	0.75 (0.53—1.08)
≥5	0.64 (0.45—0.91)[a]	0.50 (0.30—0.83)[a]

Model 2: adjusted for sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for Model 2 variables + current use of hormone therapy and menopause status. No statistically significant interaction for parity with race/ethnicity (P = .81 for average scores, P = .20 for optimal scores). N for models 1 & 2 = 3430; N for model 3 = 3090.

CI, confidence interval; CVH, cardiovascular health; OR, odds ratio.

[a] Statistically significant (P<.05).
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TABLE 3
Association between parity and Life's Simple 7 metrics (health behaviors)

Parity	Smoking		Body mass index		Physical activity		Diet	
	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor
	OR (95% CI)		OR (95% CI)		OR (95% CI)		OR (95% CI)	
Model 1: Unadjusted								
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1.62 (0.58,4.51)	0.95 (0.72,1.27)	1.06 (0.84,1.34)	0.89 (0.71,1.12)	0.96 (0.71,1.29)	0.92 (0.72,1.17)	1.07 (0.88,1.30)	0.88 (0.41,1.86)
3—4	1.45 (0.47,4.50)	1.33 (0.97,1.82)	1.04 (0.81,1.32)	0.76 (0.60,0.97)[a]	0.67 (0.49,0.92)[a]	0.72 (0.56,0.92)[a]	1.15 (0.90,1.36)	1.34 (0.64,2.81)
≥5	1.05 (0.24,4.62)	1.31 (0.89,1.93)	0.77 (0.58,1.03)	0.41 (0.30,0.56)[a]	0.65 (0.46,0.93)[a]	0.49 (0.37,0.66)[a]	1.01 (0.78,1.29)	0.63 (0.21,1.84)
Model 2: Adjusted								
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1.60 (0.52,4.89)	0.90 (0.65,1.25)	0.98 (0.75,1.27)	0.90 (0.68,1.19)	1.10 (0.79,1.53)	1.04 (0.79,1.37)	0.98 (0.78,1.23)	0.69 (0.30,1.55)
3—4	1.43 (0.40,5.04)	1.16 (0.80,1.68)	0.86 (0.65,1.15)	0.74 (0.54,1.00)	0.85 (0.60,1.22)	0.95 (0.71,1.27)	1.00 (0.79,1.28)	1.08 (0.48,2.47)
≥5	0.81 (0.15,4.42)	0.97 (0.61,1.55)	0.61 (0.43,0.86)[a]	0.49 (0.33,0.73)[a]	0.96 (0.62,1.47)	0.91 (0.64,1.29)	0.98 (0.72,1.33)	0.66 (0.20,2.23)
Model 3: Adjusted								
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1.44 (0.40,5.16)	0.88 (0.62,1.26)	1.01 (0.76,1.33)	0.94 (0.70,1.28)	1.11 (0.78,1.59)	1.00 (0.74,1.34)	1.02 (0.80,1.30)	0.63 (0.27,1.44)
3—4	1.52 (0.38,6.04)	1.06 (0.72,1.58)	0.89 (0.66,1.20)	0.77 (0.55,1.07)	0.79 (0.54,1.16)	0.89 (0.65,1.22)	1.03 (0.80,1.34)	1.07 (0.46,2.46)
≥5	0.80 (0.13,4.92)	0.89 (0.55,1.45)	0.65 (0.45,0.93)[a]	0.52 (0.35,0.80)[a]	1.00 (0.64,1.57)	0.89 (0.61,1.28)	1.00 (0.73,1.38)	0.63 (0.18,2.14)

Model 2: adjusted for sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for Model 2 variables + current use of hormone therapy and menopause status. OR were rounded up to 2 decimal places; N for models 1 & 2 = 3430; N for model 3 = 3090.

CI, confidence interval; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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TABLE 4
Association between parity and Life's Simple 7 metrics (health factors)

Parity	Total cholesterol		Blood pressure		Blood glucose	
	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Model 1: Unadjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1–2	1.11 (0.84,1.46)	0.99 (0.75,1.30)	0.80 (0.62,1.03)	0.89 (0.71,1.11)	0.85 (0.53,1.36)	0.63 (0.43,0.91)[a]
3–4	1.27 (0.94,1.70)	1.03 (0.77,1.38)	0.76 (0.59,0.98)[a]	0.65 (0.52,0.83)[a]	0.85 (0.53,1.38)	0.56 (0.38,0.83)[a]
≥5	0.88 (0.62,1.24)	0.82 (0.58,1.15)	0.68 (0.50,0.92)[a]	0.37 (0.28,0.50)[a]	0.85 (0.51,1.42)	0.32 (0.21,0.48)[a]
Model 2: Adjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1–2	1.02 (0.74,1.39)	0.88 (0.65,1.20)	0.91 (0.69,1.21)	1.05 (0.80,1.40)	0.81 (0.48,1.34)	0.63 (0.42,0.96)[a]
3–4	1.19 (0.85,1.67)	1.04 (0.74,1.46)	0.96 (0.71,1.30)	0.99 (0.73,1.34)	0.89 (0.52,1.53)	0.71 (0.46,1.10)
≥5	0.99 (0.66,1.50)	1.09 (0.72,1.65)	1.13 (0.79,1.62)	0.95 (0.65,1.41)	1.06 (0.58,1.94)	0.70 (0.42,1.14)
Model 3: Adjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1–2	0.94 (0.68,1.30)	0.87 (0.63,1.21)	0.96 (0.72,1.30)	1.04 (0.77,1.40)	0.78 (0.46,1.34)	0.59 (0.38,0.92)[a]
3–4	1.11 (0.78,1.58)	1.01 (0.70,1.44)	0.99 (0.73,1.36)	0.95 (0.69,1.31)	0.87 (0.49,1.54)	0.66 (0.42,1.05)
≥5	0.92 (0.60,1.42)	1.04 (0.68,1.60)	1.13 (0.78,1.65)	0.95 (0.64,1.42)	1.04 (0.55,1.95)	0.68 (0.40,1.14)

Model 2: adjusted for sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for Model 2 variables + current use of hormone therapy and menopause status. OR were rounded up to 2 decimal places; N for models 1 & 2 = 3430; N for model 3 = 3090.

CI, confidence interval; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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OR 0.72 [0.62–0.82], 0.66 [0.58–0.76], 0.62 [0.52–0.68], 0.56 [0.48–0.66], and 0.42 [0.38–0.56]), respectively, compared to 0–1 ideal metric. Additionally, the odds of meeting the ideal criteria for BMI and physical activity were 24% and 34% lower, respectively, among these women.

Possible mechanisms

The main finding of our study in a multiethnic cohort showed that women with a history of greater number of live births were more likely to have worse CVH when assessed in mid- to later adulthood. For example, women with a history of multiparity had lower prevalence of ideal BMI later in life. This finding can be explained by several physiological changes that occur during pregnancy and persist many years

postpartum.[27,28] These changes include insulin resistance,[29] hormonal alterations (such as decreased estrogen levels) caused by fewer ovulatory cycles,[30] and the excessive accumulation of adipose tissue.[31] Behavioral and lifestyle changes during pregnancy, such as reduction in physical activity levels[32] and increase in caloric intake, may also contribute to higher BMI.[33] Patterns of weight gain in early and mid-adulthood have been shown to track into later adulthood and are associated with increased CVD risk.[34]

In our unadjusted models, we observed a worse physical activity profile among multiparous women, although upon adjustment for covariates the association was not significant. Pregnancy often leads to a reduction in physical activity, particularly vigorous activities

such as sports and exercise.[32] Post-pregnancy, owing to the time demands allocated to their caregiver roles, mothers may have fewer opportunities to meet the American Heart Association recommended exercise levels, and again these behavioral patterns can track long-term. Studies have found that younger women are less physically active, on average, compared to similarly aged men.[35] As life events such as having children are associated with reduction in physical activity levels in women,[36] better strategies are needed to promote the maintenance of physical activity during these vulnerable life transitions.

We also observed lower prevalence of ideal blood pressure levels with a higher number of live births in our unadjusted models. Prior studies have documented that parity is inversely correlated with

blood pressure levels.[37–39] Additionally, in the unadjusted models, women with a higher number of live births had lower prevalence of ideal blood glucose levels. Adjusting for covariates showed women with ≥5 live births were still less likely to have ideal glucose levels, although the association was not statistically significant. These results are consistent with a meta-analysis of 7 cohort studies[40] (pooled total of over 9000 cases and approximately 290,000 participants) that reported women with ≥5 live births had a 42% increased risk of incident type 2 diabetes mellitus compared to those with 0 or 1 live birth.[40] During a normal pregnancy, insulin levels rise, and there is an increased resistance of peripheral tissues to insulin caused by the antagonistic effects of hormones secreted during pregnancy, such as estrogen, progesterone, chorionic somatomammotropin, and corticosteroids.[41] Significantly increased insulin resistance during pregnancy presenting as gestational diabetes is associated with greater risk of later-life type 2 diabetes and maternal CVD.[42] Unfortunately, there was insufficient data collection from MESA participants regarding a history of gestational diabetes, preeclampsia, or preterm delivery, so we could not examine these adverse pregnancy outcomes in our analyses.

Implications

In summary, our study showed that a higher number of live births was associated with poorer CVH, an established risk for developing CVD.[10] This study adds to the growing literature that emphasizes the use of primordial prevention of CVD risk factors as a strategy to reduce the burden of CVD, a shift from disease prevention to promotion of cardiovascular wellness.[10,43,44] Primordial prevention of CVD risk factors is especially important among women, given the poorer cardiovascular outcomes observed in women compared to men.[45] The metabolic processes occurring during pregnancy, such as changes in lipids, glucose, and weight, may partly explain the increased burden of CVD among multiparous women later in life.[4,5]

Many younger women who do not regularly seek health care may do so during pregnancy; thus the time surrounding a pregnancy can represent an opportunity to reinforce healthy lifestyle habits such as regular physical activity, healthy diet, and maintenance of a normal BMI. Our findings, in addition to those of previous studies, highlight the importance of increasing awareness of CVD prevention among women and also the implementation of policies that encourage efforts to decrease considerably the morbidity and mortality of CVD among women.[45]

Strengths and limitations

This study has many strengths, which include the evaluation of an ethnically diverse group of women and the standardized methodology for data collection. However, the following limitations should be taken into consideration in the interpretation of our findings. First, causal inferences cannot be drawn because of the observational study design. Second, recall bias may have been introduced through the use of self-report questionnaires for data collection on smoking, physical activity, and diet. Third, CVH status was measured at the baseline examination when the women were mid-to-older age (mean age was 62 years) and thus may not be representative of the past or future CVH status of participants. Information regarding women's CVH at the time of their pregnancies was not available. Fourth, data were not available in MESA for variables such as birth spacing and breastfeeding, which may also influence the association between parity and CVH. Fifth, diet was only assessed at the baseline examination, so we could not examine change in CVH score over longitudinal MESA follow-up. Lastly, MESA did not collect data on parity among men, so we could not assess this relationship in men to rule out residual confounding by sociodemographic factors.

Conclusion

We found that women with a history of multiparity had a lower prevalence of favorable CVH in middle to later

adulthood. Future studies should be conducted to examine the implications of our findings, including exploring the mechanisms by which multiparity contributes to poor CVH and studying whether targeted preventive interventions geared towards women at the time of pregnancy can improve their CVH later in life. ∎

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Appendix

SUPPLEMENTARY TABLE 1
Definition of the Life's Simple 7 metrics

LS7 metrics	Points	Definition
Smoking	0	Current smoker
	1	Former smoker, quit $\leq$12 months ago
	2	Never smoker or quit >12 months ago
Body mass index	0	$\geq$30 kg/m^2
	1	25.0—29.99 kg/m^2
	2	<25.0 kg/m^2
Physical activity	0	No exercise
	1	1—149 min of moderate exercise or 1—74 min of vigorous exercise/week
	2	150+ min of moderate exercise or 75+ min of vigorous exercise/week
Diet	0	0—1 components of healthy diet
	1	2—3 components of healthy diet
	2	4—5 components of healthy diet
Total cholesterol	0	$\geq$240 mg/dL
	1	200—239 mg/dL or treated to <200 mg/dL
	2	<200 mg/dL, unmedicated
Blood pressure	0	SBP $\geq$140 mm Hg or DBP $\geq$90 mm Hg
	1	SBP 120—139 mm Hg or DBP 80—89 mm Hg or treated to <120/80 mm Hg
	2	<120/80 mm Hg, unmedicated
Blood glucose	0	$\geq$126 mg/dL fasting
	1	100—125 mg/dL fasting or treated to <100 mg/dL
	2	<100 mg/dL fasting, unmedicated

Adapted from Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. Circulation 2010;121:586—613; and from Unger E, Diez-Roux AV, Lloyd-Jones DM, et al. Association of neighborhood characteristics with cardiovascular health in the multi-ethnic study of atherosclerosis. Circ Cardiovasc Qual Outcomes 2014;7:524—31.

DBP, diastolic blood pressure; *LS7*, Life's Simple 7; *SBP*, systolic blood pressure.

Poor = 0 points; Intermediate = 1 point; Ideal = 2 points.

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SUPPLEMENTARY TABLE 2
Distribution of Life's Simple 7 metrics by parity

Parity	Total (n=3430)	0 (n=627)	1—2 (n=1349)	3—4 (n=644)	≥5 (n=453)	P value
Total CVH score, mean (SD)	8.6 (2.2)	8.9 (2.3)	8.7 (2.3)	8.5 (2.2)	7.8 (2.0)	<.001
LS7 metrics, n (%)						
Smoking						
Poor	398 (12)	79 (13)	176 (13)	98 (10)	45 (10)	
Intermediate	35 (1)	5 (1)	18 (1)	9 (1)	3 (1)	.11
Ideal	2997 (87)	543 (87)	1155 (86)	894 (89)	405 (89)	
Body mass index						
Poor	1220 (36)	206 (33)	452 (34)	355 (35)	207 (46)	
Intermediate	1161 (34)	197 (31)	459 (34)	352 (35)	153 (34)	<.001
Ideal	1049 (31)	224 (36)	438 (32)	294 (29)	93 (21)	
Physical activity						
Poor	833 (24)	128 (20)	292 (22)	266 (27)	147 (32)	
Intermediate	678 (20)	127 (20)	278 (21)	178 (18)	95 (21)	<.001
Ideal	1919 (56)	372 (59)	779 (58)	557 (56)	211 (47)	
Diet						
Poor	1286 (37)	243 (39)	504 (37)	363 (36)	176 (39)	
Intermediate	2086 (61)	373 (59)	825 (61)	616 (62)	272 (60)	.67
Ideal	58 (2)	11 (2)	20 (1)	22 (2)	5 (1)	
Total cholesterol						
Poor	560 (16)	105 (17)	218 (16)	150 (15)	87 (19)	
Intermediate	1413 (41)	242 (39)	557 (41)	438 (44)	176 (39)	.25
Ideal	1457 (42)	280 (45)	574 (43)	413 (41)	190 (42)	
Blood pressure						
Poor	1342 (39)	207 (33)	494 (37)	415 (41)	226 (50)	
Intermediate	864 (25)	167 (27)	319 (24)	254 (25)	124 (27)	<.001
Ideal	1224 (36)	253 (40)	536 (40)	332 (33)	103 (23)	
Blood glucose						
Poor	334 (10)	39 (6)	125 (9)	101 (10)	69 (15)	
Intermediate	431 (13)	58 (9)	158 (12)	128 (13)	87 (19)	<.001
Ideal	2665 (78)	530 (85)	1066 (79)	772 (77)	297 (66)	

Percentages were rounded up to whole numbers.

CVH, cardiovascular health; *LS7*, Life's Simple 7; *SD*, standard deviation.

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SUPPLEMENTARY TABLE 3
Association between parity and number of ideal metrics (0—7)

Number of ideal metrics

Parity	0—1 (n=254)	2 (n=670)	3 (n=1,019)	4 (n=864)	5 (n=466)	6—7 (n=157)
Model 1: Unadjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1 (reference)	1.08 (0.69,1.68)	1.02 (0.67,1.54)	0.76 (0.50,1.15)	0.90 (0.57,1.40)	0.67 (0.39,1.15)
3—4	1 (reference)	0.95 (0.60,1.51)	0.94 (0.61,1.45)	0.78 (0.50,1.20)	0.61 (0.38,0.98)[a]	0.41 (0.23,0.75)[a]
≥5	1 (reference)	0.95 (0.58,1.55)	0.60 (0.37,0.97)[a]	0.46 (0.28,0.75)[a]	0.18 (0.10,0.32)[a]	0.12 (0.05,0.29)[a]
Model 2: Adjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1 (reference)	1.18 (0.73,1.92)	1.03 (0.65,1.63)	0.75 (0.47,1.19)	0.97 (0.59,1.62)	0.84 (0.45,1.57)
3—4	1 (reference)	1.04 (0.62,1.74)	1.02 (0.63,1.67)	0.89 (0.54,1.46)	0.86 (0.49,1.49)	0.78 (0.39,1.58)
≥5	1 (reference)	1.12 (0.63,2.00)	0.83 (0.47,1.45)	0.85 (0.48,1.52)	0.53 (0.26,1.08)	0.66 (0.23,1.88)
Model 3: Adjusted						
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	1 (reference)	1.23 (0.75,2.05)	0.93 (0.58,1.50)	0.71 (0.44,1.16)	0.95 (0.56,1.63)	0.80 (0.41,1.58)
3—4	1 (reference)	1.07 (0.62,1.83)	0.96 (0.58,1.58)	0.85 (0.50,1.42)	0.81 (0.45,1.44)	0.71 (0.33,1.51)
≥5	1 (reference)	1.13 (0.62,1.83)	0.75 (0.42,1.34)	0.84 (0.46,1.52)	0.50 (0.24,1.05)	0.55 (0.18,1.71)

Model 2: adjusted for sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for Model 2 variables + current use of hormone therapy and menopause status; N for models 1 & 2 = 3430; N for model 3 = 3090.

[a] Statistically significant ($P<.05$).

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SUPPLEMENTARY TABLE 4
Association between parity and cardiovascular health by race/ethnicity

Parity	White, n = 1320		Chinese American, n = 409	
	Average vs Inadequate	Optimal vs Inadequate	Average vs Inadequate	Optimal vs Inadequate
	OR (95% CI)			
Model 1: Unadjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.77 (0.55,1.09)	0.62 (0.43,0.88)[a]	0.87 (0.35,2.18)	2.19 (0.77,6.22)
3—4	0.71 (0.49,1.02)	0.50 (0.34,0.73)[a]	0.50 (0.20,1.24)	0.91 (0.32,2.58)
≥5	0.46 (0.28,0.76)[a]	0.09 (0.04,0.20)[a]	0.65 (0.23,1.84)	0.76 (0.22,2.59)
Model 2: Adjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.76 (0.50,1.15)	0.75 (0.48,1.18)	0.68 (0.21,2.28)	1.78 (0.44,7.18)
3—4	0.73 (0.46,1.15)	0.76 (0.46,1.25)	0.43 (0.13,1.44)	1.01 (0.25,4.12)
≥5	0.57 (0.32,1.03)	0.24 (0.10,0.61)[a]	0.68 (0.17,2.67)	1.41 (0.28,7.15)
Model 3: Adjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.79 (0.51,1.24)	0.89 (0.55,1.44)	0.48 (0.12,1.92)	1.73 (0.34,8.83)
3—4	0.74 (0.46,1.18)	0.83 (0.49,1.40)	0.33 (0.08,1.29)	0.18 (0.18,4.71)
≥5	0.57 (0.31,1.06)	0.23 (0.09,0.63)[a]	0.48 (0.10,2.21)	1.27 (0.20,7.89)

Model 2: adjusted for sociodemographic factors (age, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for model 2 variables + current use of hormone therapy and menopause status. White: N for models 1 & 2 = 1320, model 3 = 1201; Chinese American: N for models 1 & 2 = 409, model 3 = 357.

CVH, cardiovascular health; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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SUPPLEMENTARY TABLE 5
Association between parity and cardiovascular health by race/ethnicity

	Black, n = 957		Hispanic, n=744	
	Average vs Inadequate	Optimal vs Inadequate	Average vs Inadequate	Optimal vs Inadequate
Parity		OR (95% CI)		
Model 1: Unadjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.75 (0.50,1.10)	0.84 (0.49,1.43)	0.43 (0.24,0.76)[a]	0.77 (0.37,1.60)
3—4	0.83 (0.54,1.27)	0.79 (0.43,1.45)	0.48 (0.28,0.84)[a]	0.54 (0.25,1.13)
≥5	0.59 (0.34,1.02)	0.17 (0.05,0.60)[a]	0.41 (0.23,0.73)[a]	0.27 (0.11,0.63)[a]
Model 2: Adjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.80 (0.52,1.23)	0.71 (0.38,1.32)	0.28 (0.14,0.54)[a]	0.56 (0.23,1.36)
3—4	1.04 (0.64,1.69)	0.90 (0.44,1.86)	0.33 (0.17,0.64)[a]	0.42 (0.17,1.06)
≥5	0.78 (0.42,1.45)	0.32 (0.08,1.22)	0.43 (0.22,0.88)[a]	0.45 (0.16,1.28)
Model 3: Adjusted				
0	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1—2	0.77 (0.49,1.21)	0.79 (0.40,1.57)	0.21 (0.10,0.43)[a]	0.39 (0.14,1.09)
3—4	0.95 (0.57,1.58)	1.00 (0.46,2.18)	0.27 (0.13,0.55)[a]	0.29 (0.10,0.82)[a]
≥5	0.74 (0.38,1.41)	0.38 (0.09,1.56)	0.37 (0.18,0.80)[a]	0.42 (0.13,1.30)

Model 2: adjusted for sociodemographic factors (age, education, income, health insurance status, marital status) and MESA site. Model 3: adjusted for model 2 variables + current use of hormone therapy and menopause status. Black: N for models 1 & 2 = 957, model 3 = 870; Hispanic: N for models 1 & 2 = 744, model 3 = 662.

CVH, cardiovascular health; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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SUPPLEMENTARY TABLE 6
Predicted probabilities of cardiovascular health score by parity

	Inadequate	Average	Optimal
Parity	Margin (95% CI)	Margin (95% CI)	Margin (95% CI)
0	0.40 (0.35—0.46)	0.42 (0.37—0.47)	0.17 (0.14—0.21)
1—2	0.49 (0.46—0.53)	0.33 (0.30—0.36)	0.18 (0.15—0.20)
3—4	0.50 (0.46—0.54)	0.34 (0.31—0.37)	0.16 (0.14—0.19)
≥5	0.53 (0.47—0.59)	0.36 (0.30—0.41)	0.11 (0.08—0.15)

CI, confidence interval; *CVH*, cardiovascular health.

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SUPPLEMENTARY TABLE 7
Association between parity and cardiovascular health stratified by age, education, and health insurance

Parity	CVH score	
	Average vs Inadequate	Optimal vs Inadequate
	OR (95% CI)	
Age <65 years		
0	1 (reference)	1 (reference)
1—2	0.59 (0.41—0.85)[a]	0.68 (0.45—1.02)
3—4	0.60 (0.41—0.90)[a]	0.48 (0.30—0.76)[a]
≥5	0.67 (0.39—1.16)	0.36 (0.16—0.81)[a]
Age ≥65 years		
0	1 (reference)	1 (reference)
1—2	0.70 (0.46—1.05)	1.22 (0.66—2.27)
3—4	0.67 (0.44—1.03)	1.37 (0.73—2.57)
≥5	0.63 (0.39—1.01)	0.69 (0.32—1.46)
≥ Bachelor's degree		
0	1 (reference)	1 (reference)
1—2	0.78 (0.50—1.21)	0.78 (0.48—1.28)
3—4	0.74 (0.45—1.24)	0.77 (0.44—1.35)
≥5	0.50 (0.18—1.38)	0.22 (0.05—0.88)[a]
< Bachelor's degree		
0	1 (reference)	1 (reference)
1—2	0.57 (0.40—0.81)[a]	0.95 (0.59—1.52)
3—4	0.60 (0.42—0.86)[a]	0.75 (0.46—1.23)
≥5	0.58 (0.39—0.86)[a]	0.52 (0.29-0.96)
Health insurance: Yes		
0	1 (reference)	1 (reference)
1—2	0.65 (0.49—0.86)[a]	0.91 (0.65—1.28)
3—4	0.67 (0.50—0.90)[a]	0.82 (0.57—1.18)
≥5	0.58 (0.41—0.84)[a]	0.42 (0.24—0.73)[a]
Health insurance: No		
0	1 (reference)	1 (reference)
1—2	0.67 (0.16—2.87)	0.31 (0.05—1.76)
3—4	0.67 (0.14—3.13)	0.28 (0.04—1.85)
≥5	1.71 (0.35—8.23)	2.15 (0.29—15.87)

Model: adjusted for sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status), MESA site, current use of hormone therapy, and menopause status.

CI, confidence interval; *CVH*, cardiovascular health; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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SUPPLEMENTARY TABLE 8
Association between gravidity and cardiovascular health

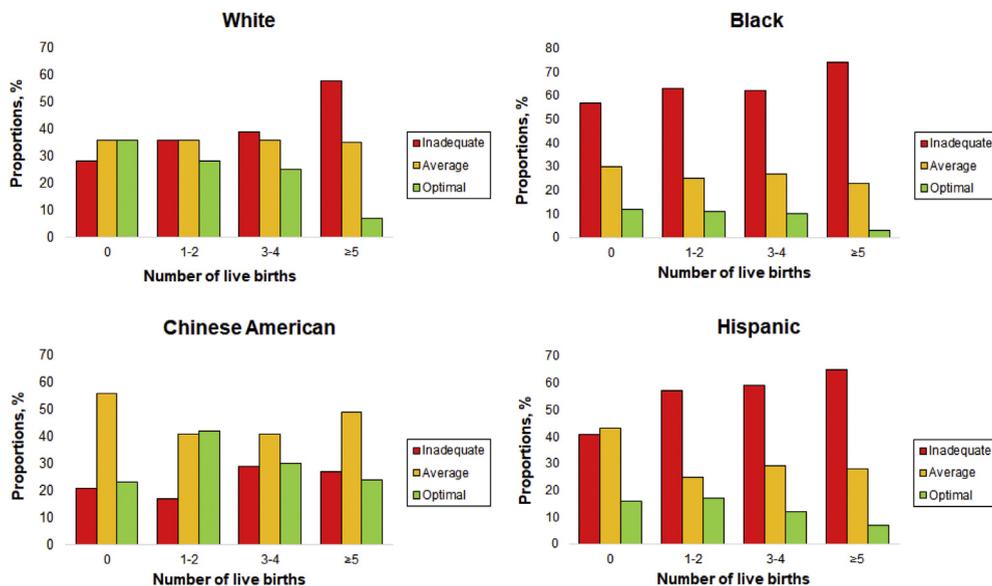|	CVH score	
	Average vs Inadequate	Optimal vs Inadequate
Gravidity	OR (95% CI)	
0	1 (reference)	1 (reference)
1—2	0.76 (0.56—1.04)	0.86 (0.59—1.26)
3—4	0.65 (0.47—0.89)[a]	0.78 (0.53—1.14)
≥5	0.68 (0.48—0.96)[a]	0.70 (0.45—1.08)

Gravidity is defined as the total number of pregnancies. Model: sociodemographic factors (age, race/ethnicity, education, income, health insurance status, marital status), MESA site, current use of hormone therapy, and menopause status.

CI, confidence interval; *CVH*, cardiovascular health; *OR*, odds ratio.

[a] Statistically significant (*P*<.05).

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SUPPLEMENTAL FIGURE
The distribution of cardiovascular health scores within parity categories stratified by race/ethnicity

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