Marital Status, Marital Quality, and Atherosclerotic Burden in Postmenopausal Women

LINDA C. GALLO, PHD, WENDY M. TROXEL, MS, LEWIS H. KULLER, MD, DRPH, KIM SUTTON-TYRRELL, DRPH, DANIEL EDMUNDOWICZ, MD, AND KAREN A. MATTHEWS, PHD

Summary: Marriage confers health benefits for men, but the evidence for women is less consistent. Inconsistent findings may be attributed, in part, to the confounding of marital status and marital quality. **Objectives:** The authors examined whether women in satisfying marriages evidence lesser atherosclerosis relative to women in low-satisfying marriages and relative to unmarried women. **Materials and Methods:** Three hundred ninety-three women from the Healthy Women Study participated in this study. Marital status and quality were assessed at baseline when women were premenopausal. Cardiovascular risk factors were also assessed at baseline to determine potential mediators. Markers of atherosclerotic burden—B-Mode ultrasound measures of intima-media thickness and plaque in the carotid arteries and electron beam computed tomography assessments of calcification in the aorta and coronary arteries—were performed, on average, 11 years and 14 years later, respectively. A subset of women underwent a second ultrasound scan approximately 3 years after their first scan. **Results:** Women in satisfying marriages had the least atherosclerosis in the carotid arteries and aorta, especially relative to those in low-satisfying marriages. Women in satisfying marriages also tended to show less rapid progression of carotid atherosclerosis relative to women in low-satisfying marriages. Women who did not have a partner had intermediate levels of atherosclerosis. Risk factors measured at baseline contributed to the differences between the satisfied and low-satisfied groups, but not those between the satisfied and unmarried groups. **Conclusions:** High-quality marriages may protect against cardiovascular disease for women. Studies concerning marriage and cardiovascular health in women should, therefore, concurrently examine marital quality and marital status. **Key words:** atherosclerosis, calcification, marriage, stress, ultrasound.

BMI = body mass index; **DBP** = diastolic blood pressure; **CHD** = coronary heart disease; **CI** = confidence interval; **EBCT** = electron beam computed tomography; **HDL-c** = high-density lipoprotein cholesterol; **HT** = hormone therapy; **HWS** = healthy women study; **IMT** = intima-media thickness; **LDL-c** = low-density lipoprotein cholesterol; **MI** = myocardial infarction; **OR** = odds ratio; **PP** = pulse pressure; **SBP** = systolic blood pressure.

INTRODUCTION

Previous research suggests that being married exerts a health-protective effect for men; the evidence for women has been less consistent (1,2). However, several lines of research support the idea that being married should confer health benefits for men and women. First, marriage may protect against the well-documented risks associated with social isolation (3). Second, the positive involvement and active influence of a spouse may promote health-enhancing behaviors and deter health-damaging behaviors (4,5). Finally, marriage may affect health indirectly, by increasing socioeconomic resources, particularly for women (6).

Given these assertions, why have some previous studies failed to identify salutary effects of marriage for women (1,2)? We hypothesize that inconsistent findings may reflect the convention of grouping together all marriages, irrespective of quality. That is, in studies concerning marital status, the positive effects of "healthy" marriages may be obscured by the marked, negative influence of discordant marriages. This assertion may be particularly relevant for women, who show greater emotional and physiological stress responses to martial conflict when compared with men (7).

To date, only limited research has pursued the effects of marital relationship quality on cardiovascular health. In a recent study, marital distress predicted poorer prognosis (ie, cardiac death, acute myocardial infarction [MI], revascularization) in women recovering from MI or unstable angina (8). In another recent study, marital quality predicted survival time in congestive heart failure patients, somewhat more strongly in women than in men (9). Helgeson (10) found that men who reported disclosing to their wives were less vulnerable to event recurrence after MI, relative to men who did not disclose to their wives. The effect was nonsignificant in women, possibly consequential to low power. Hence, preliminary evidence suggests that marital quality influences outcomes in male and female coronary heart disease (CHD) patients.

In contrast, marital quality did not predict incident CHD in an initially healthy community sample (11). However, the outcome included angina, which is a poor predictor of coronary atherosclerosis in women (12). To our knowledge, this was the only previous study to examine marital relationship quality as a predictor of CHD incidence, rather than outcomes in patient populations.

Despite the lack of evidence, marital relationship quality would in theory influence the development of atherosclerosis by altering exposure to stress. Acute and chronic stresses are believed to hasten atherosclerosis by influencing hemodynamic and neuroendocrine responses and clotting processes (13). Consistently, laboratory studies have shown that marital conflict leads to increases in blood pressure and heart rate, stress hormones, and alterations in immune functioning (14–16), often with heightened and/or prolonged responses in women when compared with men (7). Over time, these physiological responses could affect resting blood pressure levels

From SDSU/UCSD Joint Doctoral Program in Clinical Psychology, San Diego State University (L.C.G.), the Department of Psychology (W.M.T.), and the Graduate School of Public Health (L.H.K., K.S.T), University of Pittsburgh, and the Departments of Psychiatry (K.A.M.) and Medicine (D.E.), University of Pittsburgh School of Medicine, Pittsburgh, PA.

Address correspondence and reprint requests to: Karen A. Matthews, Department of Psychiatry, University of Pittsburgh School of Medicine, 3811 O'Hara Street, Pittsburgh, PA 15213.

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(17–19) and metabolic risk factors, such as elevations in plasma lipids (20,21) and glucose (22–24). Marital distress could also affect CHD risk indirectly, by increasing exposure to behavioral and psychosocial risk factors (7, 25). Conversely, being in a harmonious marriage could protect against atherosclerosis by increasing material and social support resources, thereby buffering the pathogenic consequences of stress (26). Happy marriages may also facilitate health-promoting behaviors (27) and enhance psychological adjustment (28). These findings suggest that individuals in supportive marriages should experience a health advantage relative to those without a partner and relative to persons in distressed marriages.

In support of these assertions, previous analyses from the Healthy Women Study (HWS) showed that women in highly satisfying marriages had lower levels of behavioral, biological, and psychosocial cardiovascular risk factors measured on multiple occasions across approximately 13 years when compared with women in less satisfying relationships and when compared with unmarried women (29). In specific cases, women in satisfying marriages also showed less atherogenic risk factor trajectories (ie, within person changes) across time. These results demonstrate the usefulness of examining marital status and quality concurrently to assess the salubrious effects of supportive relationships in women.

THE CURRENT STUDY

The current study used indicators of marital status and quality to examine whether women in highly satisfying marital relationships exhibit lower atherosclerotic burden when compared with unmarried women (ie, single, divorced, or widowed) and women in less satisfying marital relationships. We explored this association during middle age and the climacteric, when women's risk for CHD increases substantially. In addition, we used state-of-the art methods for assessing atherosclerotic burden at presymptomatic stages. Objective, presymptomatic indicators of atherosclerosis provide an advantage over clinical CHD outcomes in terms of specificity and sensitivity. Many asymptomatic individuals have significant atherosclerosis, (30) and many with clinically debilitating angina, particularly women, have no underlying occlusion (12). By quantifying atherosclerosis before the appearance of symptoms, these measures also reduce the possible reverse impact of poor cardiovascular health on marital quality.

We examined atherosclerotic burden in the carotid arteries through carotid ultrasound and in the coronary arteries and aorta through electron beam computed tomography (EBCT). We also examined atherosclerotic progression in the carotid arteries, in a subset of women who underwent two ultrasound scans. We hypothesized that women in satisfying marriages would exhibit lower levels of atherosclerosis across sites and a slower progression of atherosclerosis in the carotid arteries, relative to married women with lower marital satisfaction and to unmarried women. Based on previous research concerning the probable routes through which being unmarried or being in a distressed marriage would lead to worse health outcomes, relative to being in a supportive relationship, we also examined whether cardiovascular risk factors assessed at baseline, including blood pressure, metabolic risk factors, and behavioral and psychosocial risk factors, mediated the associations between marital grouping and atherosclerotic burden.

MATERIALS AND METHODS

Design of the Healthy Women Study

Detailed accounts of the HWS procedures are presented elsewhere (31,32). In brief, 541 premenopausal women were recruited from Allegheny County, PA between 1983 and 1985. Eligibility criteria included age 42 to 50, menstrual bleeding within the last 3-month, no surgical menopause, diastolic blood pressure (DBP) less than 100 mm Hg, no use of hormone therapy (HT), and no medications known to influence risk factors. Eighty-nine percent of the 2405 women contacted by telephone agreed to screening, and 901 women were deemed eligible. Sixty-percent (541) of eligible women agreed to participate. Over 90% of participants were white, in part because of the proportion of minorities in Allegheny County and, in part, because relatively more black women did not meet the eligibility criteria. Women attended a baseline visit and a series of postmenopausal visits. The current study includes 393 women (ie, 72.6% of the HWS cohort) who participated in at least one scanning procedure and who provided information about their marital status and quality at baseline. Three women were excluded because they specified their marital status as "other" and three were excluded because they indicated "married" status but did not complete the satisfaction measure.

The subsample of women included in the current analyses was similar to the remainder of eligible women in the overall sample, in terms of biological, psychosocial, and demographic characteristics, with the following exceptions: women who were not included in the current study had significantly higher levels of SBP and were younger, relative to women who were in the current sample ($p < 0.05$). In addition, relative to whites, a larger proportion of blacks did not have measures of atherosclerosis ($p < 0.05$). When considering the full cohort, women in the different marital status/satisfaction categories did not vary in the likelihood of having atherosclerosis scans.

Measurement of Marital Status and Quality

Women with divorced ($N = 42$), separated, ($N = 8$), widowed ($N = 15$), or single ($N = 29$) marital status at baseline formed the unmarried group ($N = 94$). Two hundred ninety-nine women reported marriage at baseline. These women completed a seven-item measure of relationship quality at baseline and 3 years later, which assessed their overall satisfaction with the following: amount of time spent together, communication, sexual activity, agreement on financial matters, and similarity of interests, lifestyle, and temperament. All items were assessed on a 4-point Likert scale and were summed to yield an overall satisfaction score ($\alpha = 0.87$), with higher scores indicating greater marital satisfaction. Overall, most women described their marriages in positive terms, and the distribution of scores was negatively skewed and kurtotic. Based on the shape of the distribution, women with scores in the lower third of the distribution at baseline were placed in a "low-satisfied" group ($N = 92$) and women who scored in the upper two-thirds of the distribution comprised a "satisfied group" (ie, after a clustering of high scores, the distribution began to flatten out and decrease gradually at this point). Scores on the marital satisfaction scale were highly stable across the first 3 years of the study, r (297) = 0.75. In addition, although the marital satisfaction measure was not administered at later clinic visits, scores on a single item assessing overall happiness with the marital relationship, on a 3-point scale, were moderately stable between baseline and the visit closest in time to the atherosclerosis scans, r (268) = 0.50. Marital status also tended to be stable across time, although the groups did differ in the likelihood of showing a marital status change between baseline and the visit closest in time to the scans, $N = 372$, χ^2 (2) = 20.63, $p < 0.001$. The satisfied group was least likely to show a marital status change (7.1%, $N = 14$, with 8 widowed, 1 divorced, and 1 "other"), followed by the low-satisfied group (15.1%, $N = 13$, with 6 widowed, 1 divorced, and 1 "single", and 5 "other"), and the unmarried group (27%, $N = 24$, with 15 married or remarried, 9 living with a partner, and 5 "other"). Twenty-one women had missing data for marital status at the fifth and eighth postmenopausal visits (ie, those closest in time to the atherosclerotic scans).

Participant Characteristics and Risk Factors

Participant characteristics assessed at baseline included age (years), ethnicity (365 whites and 28 nonwhites), and education (109 with high school degree or less, 84 with some college, 102 with a 4-year degree, or 98 with an advanced degree). Risk factors assessed at baseline included systolic and diastolic blood pressure (SBP and DBP, the average of two random-zero muddler readings), pulse pressure (PP) (SBP–DBP, averaged across the two readings), high-density lipoprotein cholesterol (HDL-c) and low-density lipoprotein cholesterol (LDL-c), triglycerides, fasting glucose, fasting insulin, body mass index (BMI), alcohol intake (average grams per day), historical or current smoking, and exercise (measured through the Paffenberger measure of energy expended in leisure activity during the past week) (33). In addition, we examined psychosocial risk factors assessed at baseline, including depressive symptoms (ie, the Beck Depression Inventory) (34), trait anger and anxiety (ie, the Spielberger Trait Scales) (35), and perceived social support (ie, the appraisal support subscale of the Interpersonal Support Evaluation List) (36). Finally, we examined use of HT and medications that would affect cardiovascular risk factors (digitalis, antihypertension and hyperlipidemia medications, insulin or related, and other "heart medication") reported at the time of the scans.

B-Mode Ultrasound

B-Mode ultrasound scans of carotid artery intima-media-thickness (IMT) and focal plaque formed one measure of atherosclerotic burden. These indicators have been prospectively linked with increased risk of stroke and MI (37–38). Women attending their 5- or 8-year postmenopausal visits were invited to participate in the ultrasound scan between 1994 and 1998 ($N = 376$ for the current study). On average, women were age 58.59 years (SD = 2.03) at the time of the scan, which occurred an average of 10.89 years (SD = 1.52) after the baseline. Carotid measurements were obtained using a scanner equipped with a 5-MHz array-imaging probe. To determine the reproducibility of IMT and plaque scores, five participants underwent two ultrasound examinations within 1-week; intraclass correlations were 0.86 for IMT and 0.96 for plaque index. A sonographer scanned the right and left common artery, carotid bulb, and the first 1.5 cm of the internal and external carotid arteries. Trained readers measured the average IMT across 1-cm segments of the near and far walls of the distal common carotid artery, the far wall of the carotid bulb, and the internal carotid artery on both the right and left sides. An overall measure of IMT, in millimeters, was calculated by averaging measures from each location. Plaque scores were obtained from the images of the proximal common artery, distal common artery, carotid bulb, internal carotid artery, and external carotid artery. Plaque was defined as a discrete area of hyperechogenicity and/or a focal protrusion into the lumen of the vessel. Summary scores were computed across the right and left carotid arteries for an overall measure of focal plaque. The distribution of plaque index scores was positively skewed with many women having scores of 0 (48% and 42% at the first and second time points) or 1 (22% and 27% at the first and second time points). Plaque index was, therefore, dichotomized, so that one group comprised women with scores of 0 or 1 ($N = 275$) and a second comprised women with scores of 2 or greater ($N = 101$).

A subset of women ($N = 206$) have undergone a second ultrasound scan on average 3 years (SD = 0.73) after the first scan. Follow-up ultrasound scans were suspended during the course of the study so that financial resources could be devoted to calcification measures. Changes in IMT (ie, second IMT–first IMT) and plaque index (ie, movement from the 0 or 1 group to the 2 or higher group) were examined to assess whether relationship grouping predicted atherosclerotic progression.

Electron Beam Computed Tomography

EBCT assessments of aortic and coronary calcification formed additional measures of atherosclerotic burden. EBCT measures of coronary calcification relate closely to degree of atherosclerosis observed on pathologic study (39,40) and angiography (41,42), and the extent of coronary (43,44) and aortic calcification (45,46) predicts coronary morbidity and mortality. Aortic calcification may be a particularly useful early marker for disease in women, because these measures do not show pronounced gender differences, unlike the coronary arteries (47). The EBCT scan was added to the protocol in 1997, for women returning for their 5- or 8-year postmenopausal visits ($N = 334$ for the current study). On average, women were age 61.9 years (SD = 1.72) at the time of the EBCT scan, which occurred 14.3 years (SD = 1.10) after the baseline. A trained technician used a densitometric program from the Imatron C150 scanner to derive calcium scores for both the coronary arteries and the aorta (48). The first pass focused on the coronary arteries from the aortic root to the apex of the heart, and recorded 30 to 40 contiguous 3-mm thick transverse images during maximal breath-holding. The second pass imaged 6-mm contiguous segments of the aorta from the aortic arch to the iliac bifurcation. Electrocardiograph triggering was used, so that each 100-ms exposure was derived from the same phase of the cardiac cycle (60% of the RR interval). Examination of scores from 40 subjects indicated high reproducibility, with intraclass correlations of 0.99 and 0.98, for the coronary and aortic scores, respectively (49). None of the women who have obtained an EBCT scan were symptomatic for coronary heart disease.

The distributions of scores for aortic and coronary calcification were extremely positively skewed, with many women having scores of 0 (54% and 26% for coronary and aortic calcification, respectively). Guidelines suggest that asymptomatic individuals with high coronary calcification relative to a sex- and age-matched comparison group are likely to be at elevated risk for CHD (50). For example, a recent meta-analysis of studies examining coronary calcification in asymptomatic populations found that individuals with scores above the group median had a risk of MI or coronary death of 4.2-times that of scores below the median (95% confidence interval: 1.6–11.3) (51). Given the low level of calcification in the current sample, we created coronary calcification groups consisting of individuals with scores in the top quintile for the sample (ie, ≥ 56, $N = 66$) and individuals with scores in the remainder of the distribution ($N = 268$). Similarly, we created two aortic calcification groups consisting of individuals with scores in the top quintile of the distribution (ie, ≥ 592, $N = 64$) and individuals with scores in the remainder of the distribution ($N = 259$). A consistent grouping scheme was used in two previous studies from the HWS (52,53).

Statistical Analyses

Differences in participant characteristics and risk factors at baseline according to marital status/quality grouping were tested with chi-square analyses for categorical variables and analyses of variance (ANOVAs), with Fisher's least significant difference test for follow-up comparisons, for continuous variables. Variables with substantially skewed distributions were log-transformed before analysis to normalize the distributions. In addition, outliers at least 3 standard deviations from the mean were removed from the analysis for fasting glucose, because the distribution remained skewed after transformation and because inclusion of these outliers substantially altered the analysis.

Hierarchical linear regression analyses tested the associations between marital grouping and IMT or change in IMT, and hierarchical logistic regression analyses tested the associations between marital grouping and plaque, change in plaque, and aortic and coronary calcification. Age at the time of the scan was entered first into the equation, followed by marital status/quality grouping represented by two dummy codes that compared married women with higher marital satisfaction to: (1) married women with low satisfaction and (2) unmarried women. Analyses for change in carotid atherosclerosis also controlled for time between scans and first scan measurements at the initial regression step.

To evaluate whether the effects of marital status/quality grouping were explained (ie, mediated) by other risk factors, analyses revealing statistically significant effects for the marital grouping effect were followed with mediation analyses, using the procedures outlined by Baron and Kenny (54) and Baron, Kenny, and Kashy (55). The initial steps for testing mediation involve examining if a potential mediator relates: (1) to the predictor (ie, marital grouping) and (2) to the outcome (ie, IMT, plaque, aortic or coronary calcification, or IMT or plaque changes). To examine variables related to the outcome, we performed hierarchical regression analyses in which age was always entered at the first step (and for atherosclerotic progression, time between scans and outcome at scan 1), followed by all biological, behavioral, and psychosocial risk factor variables that were at least marginally related to the marital grouping (ie, at $p < 0.1$, as determined through ANOVAs and chi-square analyses). By identifying potential mediators through a single analysis, we sought to limit the analysis to those risk factors that were independently predictive of the outcome to reduce the number of variables and the effect of multicollinearity in the final models. The analyses testing for mediators included PP rather than SBP and DBP, because SBP and DBP were highly correlated ($r = 0.72$), and because PP was a stronger predictor of all outcomes than was either individual measure. We also included ethnicity in these analyses, given marital group differences on this variable (Table 1).

Following Baron and Kenny (54), variables that related both to marital grouping and to the outcome, at $p < 0.1$, were then included in an analysis that regressed the outcome on marital grouping and potential mediators simultaneously. Degree of mediation was evaluated by comparing the unstandardized regression coefficients for the marital group contrasts from the analyses that did and did not include the possible mediators. A reduction in a regression coefficient of at least 1.65 of its standard error was considered evidence of mediation (56).

For all analyses, missing data were excluded on an analysis-specific, pair-wise basis. Minor differences in degrees of freedom therefore occur across analyses. We used $p < 0.05$ as the criterion for statistical significance and $p < 0.10$ as the criterion for marginal significance.

RESULTS

Participant Characteristics and Risk Factors According to Marital Status/Quality Grouping

Table 1 summarizes the marital status/quality group differences in sociodemographic characteristics. The groups differed significantly on ethnicity; the satisfied group was least likely and the unmarried group was most likely to report nonwhite ethnicity.

Differences in baseline risk factors are also shown in Table 1. The marital groups differed significantly on PP, HDL-c, LDL-c, fasting glucose, and fasting insulin, and on all psychosocial factors measured at baseline, and marginally on measures of SBP and exercise during leisure activity. Pairwise contrasts showed that the low-satisfied group had lower levels of HDL-c, exercise, and higher PP when compared with the satisfied group and lower HDL-c, exercise, and higher LDL-c, SBP, fasting glucose, and insulin when compared with the unmarried group. The low-satisfied group also reported higher depression, anxiety, anger, and lower social support when compared with the satisfied group, and higher anxiety, anger, and lower support than the unmarried group. The

TABLE 1. Participant Characteristics at Baseline as a Function of Marital Status and Quality

Participant Characteristic	Satisfied (n = 207)	Low Satisfaction (n = 92)	Unmarried (n = 94)	Statistical Test
Categorical Variables	% of group (n)	% of group (n)	% of group (n)	Chi-Square
Nonwhite Ethnicity	3.9 (8)	9.8 (9)	11.7 (11)	$\chi^2(2) = 7.28$*
Education				
≤ 12 years	24.6 (51)	37.0 (34)	25.5 (24)	
Some college	22.2 (46)	18.5 (17)	22.3 (21)	$\chi^2(6) = 8.31$
College graduate	24.2 (50)	27.2 (25)	28.7 (27)	
Advanced degree	29.0 (60)	17.4 (16)	23.4 (22)	
Ever smoked	51.9 (107)	61.5 (56)	62.0 (57)	$\chi^2(2) = 3.80$
HT (time of scans)	52.9 (108)	48.4 (44)	41.5 (39)	$\chi^2(2) = 3.40$
Medication (time of scans)	19.4 (39)	24.4 (22)	24.4 (22)	$\chi^2(2) = 1.42$
Continuous Variables	M (SD)	M (SD)	M (SD)	ANOVA
Age (y)	47.70 (1.59)	47.65 (1.58)	47.64 (1.60)	F (2,390) = 0.06
SBP (mm Hg)	107.74_{ab} (10.65)	110.39_{a} (13.72)	106.61_{b} (11.77)	F (2,390) = 2.63#
DBP (mm Hg)	72.61 (7.70)	72.04 (8.58)	70.49 (8.11)	F (2,390) = 2.23
PP (mm Hg)	35.13_{a} (7.72)	38.35_{b} (8.80)	36.12_{ab} (8.63)	F (2,390) = 4.90*
HDL-c (mg/dl)	60.73_{a} (12.92)	56.90_{b} (14.25)	61.18_{a} (14.89)	F (2,388) = 2.98#
LDL-c (mg/dl)	108.50_{ab} (27.54)	111.75_{a} (29.51)	96.28_{b} (108.36)	F (2,388) = 2.68#
Triglycerides (mg/dl)	78.96_{a} (44.45)	90.08_{b} (49.58)	79.44_{a} (49.45)	F (2,388) = 3.12*
Fasting glucose (mg/dl)	86.92_{a} (9.71)	88.18_{a} (9.00)	84.36_{b} (8.97)	F (2,383) = 4.13*
Fasting insulin (mg/dl)	7.88_{ab} (5.28)	8.64_{b} (4.69)	7.19_{a} (4.56)	F (2,386) = 3.18*
BMI† (kg/m^2)	24.60 (4.26)	25.18 (4.52)	24.02 (4.76)	F (2,390) = 2.13
Exercise (kcals past week)	1583.14_{a} (1597.62)	1389.06_{b} (2016.48)	1465.11_{a} (1928.95)	F (2,389) = 2.63#
Alcohol (grams per day)	7.88 (9.16)	9.08 (10.30)	9.66 (12.09)	F (2,390) = 0.97
Depression	3.27_{a} (3.33)	5.80_{b} (5.50)	5.31_{b} (5.07)	F (2,390) = 12.78***
Trait anxiety	16.28_{a} (3.89)	20.01_{b} (5.92)	18.00_{c} (5.07)	F (2,390) = 20.42***
Trait anger	17.45_{a} (4.32)	18.91_{b} (4.78)	18.48_{a} (4.43)	F (2,390) = 4.01*
Perceived social support	8.34_{a} (1.78)	6.58_{b} (2.46)	7.86_{a} (2.34)	F (2,389) = 20.80***

Means with common subscripts do not differ at $p < .05$ according to Fisher's LSD test.
* $p < .05$, # $p < .1$, *** $p < .001$.

unmarried group showed lower fasting glucose, insulin, and higher anxiety and depression when compared with the satisfied group.

Relationships Among Measures of Subclinical Atherosclerosis

Spearman correlation calculations indicated that plaque and IMT were highly correlated at both the first, r (373)= 0.45, and second assessment, r (204) = 0.56, both $p < 0.001$. In contrast, the correlation between aortic and coronary calcification was lower but significant, r (323) = 0.29, $p < 0.001$. The cross-sectional association between IMT and aortic calcification was r (303) = 0.25, $p < 0.001$, as was the correlation between aortic calcification and plaque r (306) = 0.25, $p < 0.001$. Coronary calcification showed a low correlation with both IMT, r (314) = 0.09, not significant, and plaque, r (317) = 0.10, $p < 0.10$.

Marital Status/Quality and Carotid IMT

A hierarchical linear regression analysis tested the hypothesis that women with higher marital satisfaction would have lower IMT than women in low-satisfying marriages and unmarried women. As shown in Table 2, the marital status/quality variables accounted for a significant amount of variance in average IMT at the first scan, after controlling for age. The low-satisfaction group (M = 0.81 mm, SD = 0.13) had significantly greater average IMT when compared with the satisfied group (M = 0.77 mm, SD=0.10), but not compared with the unmarried group (M = 0.78 mm, SD=0.13). Figure 1A shows the average IMT for each marital status/quality group.

Given the identification of a significant effect of marital grouping on carotid IMT, we performed mediation analyses to see whether measured risk factors explained the observed association. The analysis that regressed first IMT on age and all risk factors related to marital grouping (ie, PP, LDL-c, HDL-c, triglycerides, fasting glucose, fasting insulin, exercise, all psychosocial variables, and also race/ethnicity), showed that only PP and triglycerides independently predicted IMT, and therefore were considered possible mediators. As depicted in Table 2, the overall marital grouping effect was attenuated to nonsignificance in the analysis that controlled for these risk factors but the satisfied versus dissatisfied contrast remained marginally significant. Both PP (β = 0.23) and triglycerides (β = 0.24) represented significant predictors of IMT at the final model step. Comparing the unstandardized regression coefficient for the satisfied versus low-satisfied contrast in the uncontrolled analysis to that in the controlled analysis, the final criterion for mediation (ie, a reduction of 1.65 SE, or 0.025) was not met. Thus, PP and triglycerides only partially explained the difference in IMT between the low-satisfaction and satisfied group.

Next, we examined change in IMT (N = 201) as a marker of atherosclerotic progression, controlling for age and IMT at first scan and time between scans. Relationship grouping only marginally predicted IMT change. The satisfied versus low-satisfied contrast was significant, but the satisfied versus unmarried contrast was not. As shown in Figure 1B, average

TABLE 2. Summary of the Hierarchical Linear Regression Analyses Examining the Association Between Marital Grouping and Carotid IMT and Marital Grouping and Change in IMT

Step	Variables Entered	B (SE)	β	ΔR^2 Block	F-Change
Average carotid IMT at scan 1, adjusted for age (N = 373)					
1.	Age (years at time of carotid scan)	.007 (.003)	.128*	.014	F (1,371) = 5.15*
2.	Marital Group			.020	F (2,369) = 3.91*
	Satisfied (0) vs. Low-Satisfied (1)	.042 (.015)	.151**		
	Satisfied (0) vs. Unmarried (1)	.013 (.015)	.048		
Average carotid IMT at scan 1, adjusted for age and potential mediators (N = 371)					
1.	Age	.005 (.003)	.091#	.014	F (1,369) = 5.14*
2.	Potential Mediators			.118	F (2,367) = 24.93***
	PP (mm Hg)	.003 (.001)	.225*		
	Triglycerides (mg/dl)	.144 (.030)	.235*		
3.	Marital Group			.007	
	Satisfied (0) vs. Low-Satisfied (1)	.024 (.014)	.088#		F (3,365) = 1.52
	Satisfied (0) vs. Unmarried (1)	.013 (.014)	.047		
3-y change in carotid IMT, adjusted for age and average IMT at first scan and time between scans (N = 200)					
1.	Age and IMT at first scan, time between scans			.220	F (3,198) = 18.61***
2.	Marital Group			.019	F (2,196) = 2.41#
	Satisfied (0) vs. Low-Satisfied (1)	.022 (.011)	.132*		
	Satisfied (0) vs. Unmarried (1)	–.003 (.011)	–.017		

* $p < .5$, ** $p < .05$, # $p < .01$, *** $p < .001$.
All coefficients and standard errors are from final model steps.

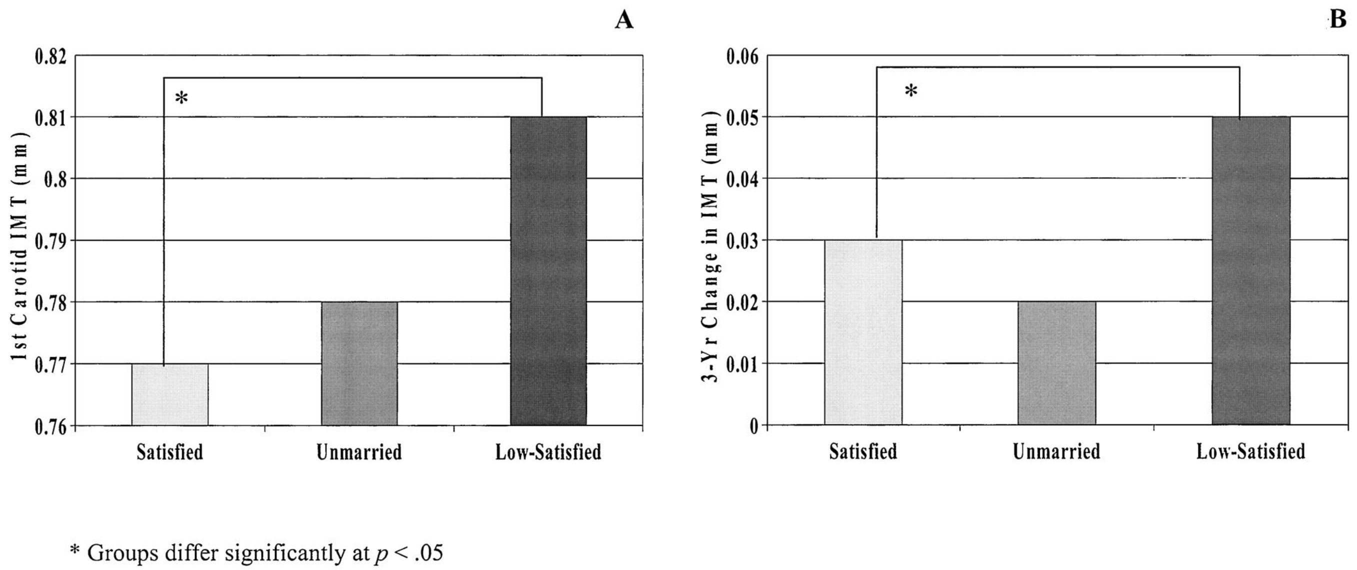

Figure 1. **A:** Average IMT (in mm) according to marital status/quality grouping at the first scan (N = 372). **B:** Average change in IMT (in mm) across 3 years (N = 203) according to marital status/quality grouping.

IMT changes for the groups were as follows: satisfied, M = 0.03 mm, SD = 0.06; low-satisfied, M = 0.05 mm, SD=0.08; unmarried, M = 0.02 mm, SD = 0.09. The average percentage changes of IMT from initial examinations were as follows: 4.88% (SD = 8.47) for satisfied; 6.69% (SD = 9.00) for low-satisfied; and 3.14% (SD = 10.54) for unmarried.

Marital Status/Quality and Carotid Focal Plaque

A hierarchical logistic regression analysis tested the hypothesis that women in satisfying marriages would have lower odds of a plaque score of 2 or higher when compared with women in low-satisfying marriages or to unmarried women (N = 376). As shown in Table 3, the relationship grouping variables significantly predicted plaque group. The low-satisfied group was significantly more likely (34.1% of group), and the unmarried group was marginally more likely (31.5% of group) to have a score of 2 or higher when compared with the satisfied group (21.6% of group). Figure 2A shows the percentage of each marital status/quality group with a plaque score of 2 or higher at the first scan.

TABLE 3. Summary of the Hierarchical Logistic Regression Analyses Predicting Carotid Plaque and Change in Carotid Plaque According to Marital Grouping

Step	Variables Entered	B (SE)	OR	95% CI	ΔR^2 Block	Chi-Square
Odds of plaque score ≥ 2 at scan 1, adjusted for age (N = 376)						
1.	Age (y at time of carotid scan)	0.016 (0.058)	1.02	0.91, 1.14	0.000	$\chi^2(1) = 0.00$
2.	Marital group					
	Satisfied (0) vs. low satisfaction (1)	0.636 (0.284)	1.90*	1.08, 3.30	0.024	$\chi^2(2) = 6.16$*
	Satisfied (0) vs. unmarried (1)	0.517 (0.287)	1.68#	0.96, 2.94		
Odds of plaque score ≥ 2 at scan 1, adjusted for age and possible mediators (N = 374)						
1.	Age	–0.013 (0.060)	0.99	0.88, 1.11	0.000	$\chi^2(1) = 0.00$
2.	Possible mediators				0.091	$\chi^2(3) = 24.29$***
	PP (mm Hg)	0.032 (0.015)	1.03*	1.00, 1.07		
	Triglycerides (mg/dl)	0.007 (0.003)	5.73**	1.59, 20.67		
	LDL-c (mg/dl)	0.010 (0.004)	1.01*	1.00, 1.02		
3.	Marital group					$\chi^2(2) = 4.67$#
	Satisfied (0) vs. low satisfaction (1)	0.434 (0.299)	1.52	0.85, 2.73	0.017	
	Satisfied (0) vs. unmarried (1)	0.592 (0.299)	1.83*	1.02, 3.29		
Odds of increasing plaque score group at 3-y follow-up, adjusted for age and plaque score at first scan and time between scans (N = 206)						
1.	Age and plaque score at first scan, time between scans				0.038	$\chi^2(3) = 3.93$
2.	Marital group				0.031	$\chi^2(2) = 3.25$
	Satisfied (0) vs. low satisfaction (1)	0.972 (0.537)	2.64#	0.92, 7.58		
	Satisfied (0) vs. unmarried (1)	0.469 (0.606)	1.60	0.49, 5.24		

* $p < .05$, # $p < .1$, *** $p < .001$.
All coefficients and standard errors are from final model steps.

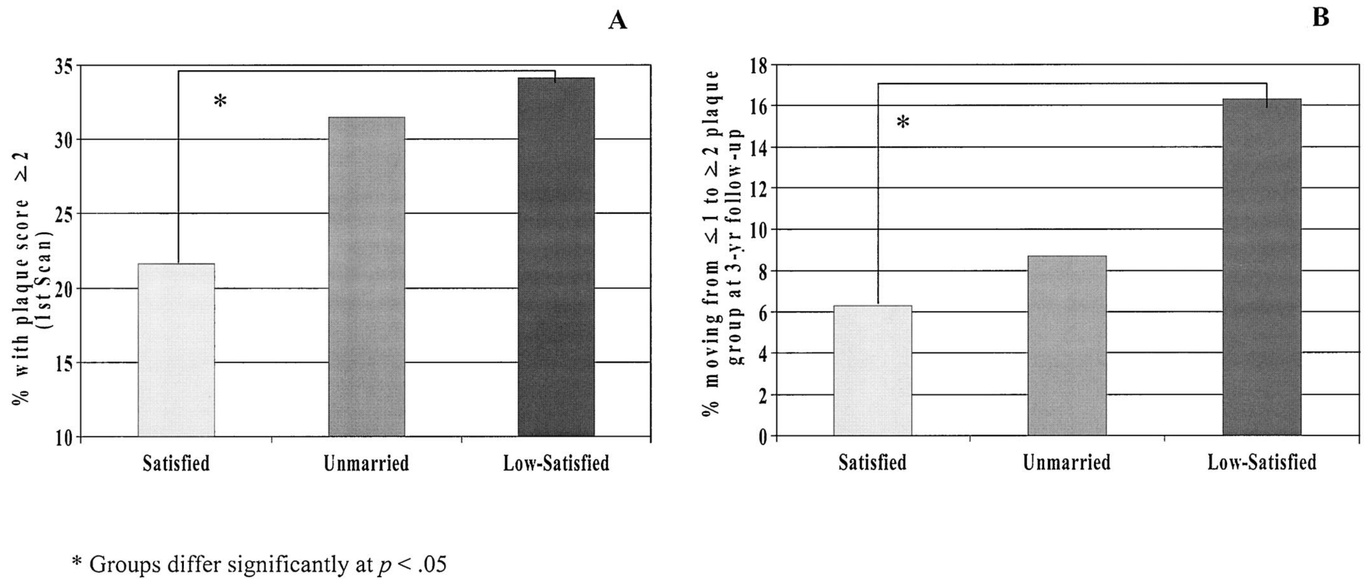

Figure 2. **A:** Percent of each marital status/quality group with a plaque score of two or higher at the first scan ($N = 376$). **B:** Percent of each group showing an increase in plaque score from 0 or 1 to 2 or higher.

Of the variables related to marital grouping at baseline, PP, LDL, and triglycerides predicted plaque index group in a hierarchical logistic regression analysis (controlling for age at the first step). As shown in Table 3, control for these risk factors attenuated the overall relationship group effect to marginal significance. In addition, the contrast comparing satisfied to low-satisfied married women became nonsignificant, whereas the contrast comparing the satisfied to unmarried groups became stronger and statistically significant. Triglycerides, LDL-c, and PP all predicted plaque group at the final model step. The final criteria for mediation—ie, a reduction of 1.65 SE in the regression coefficient—was not met for the satisfied versus low-satisfied contrast. Thus, the baseline risk factors contributed to, but did not explain, the higher plaque scores of women in low-satisfied marriages. Control for risk factors heightened the contrast comparing the satisfied to unmarried groups.

Progression of carotid plaque was next examined ($N = 206$). A hierarchical logistic regression analysis predicted the odds of a 2-point or greater increase in plaque score ($N = 22$). As shown in Table 3, after controlling for age, time between scans, and plaque score at time 1, the relationship grouping variables did not significantly predict plaque change. The low-satisfied group was marginally more likely to have an increase of at least 2 when compared with the satisfied group, but the unmarried group did not differ from the satisfied group. As shown in Figure 2B, the percentages of each group moving from the low to higher plaque group were 7.2, 18.4, and 10.9 for the satisfied, low-satisfied, and unmarried groups, respectively.

Marital Status/Quality and Aortic Calcification

A hierarchical logistic regression analysis tested the hypothesis that women in satisfying marriages would have lower odds of having an aortic calcification score in the top quintile of the sample distribution when compared with women in low-satisfying marriages and to unmarried women ($N = 323$). As shown in Table 4, the relationship grouping variables significantly predicted aortic calcification group. The satisfied group (15.1% of group) was significantly less likely to have an aortic calcification score in the top quintile when compared with the low-satisfied group (28.8%), but not the unmarried group (21.8%). Figure 3 shows the proportion of each marital group with an aortic calcification score in the upper quintile of the distribution.

Of the risk factor variables related to marital grouping, only LDL and PP represented significant, independent predictors of aortic calcification in the stepwise logistic regression analysis testing for potential mediators. As shown in Table 4, at the final model step of the controlled analysis, the overall effect of marital grouping remained statistically significant, as did the contrast comparing satisfied to low-satisfied participants. Further, the reduction in size of the regression coefficients did not meet criteria for mediation. Further, the contrast comparing the satisfied to unmarried group became stronger and statistically significant. LDL was also a significant predictor at the final model step, whereas PP was not. Thus, the risk factors related to both aortic calcification and marital grouping did not mediate their association.

Marital Status/Quality and Coronary Calcification

The marital variables did not predict the odds of having a coronary calcification score in the upper quintile of the distribution, as shown in Table 4 ($N = 334$), and neither the satisfied versus low-satisfied nor the satisfied versus unmarried contrast was statistically significant. The percentages of each group having coronary calcification scores in the upper quintile is shown in Figure 3.

TABLE 4. Summary of the Hierarchical Logistic Regression Analyses Predicting Aortic and Coronary Calcification According to Marital Grouping

Step	Variables Entered	B (SE)	OR	95% CI	ΔR^2 Block	Chi-Square
Odds of aortic calcification score in top quintile, adjusted for age (N = 323)						
1.	Age (y at time of EBCT)	0.231 (0.085)	1.26	1.03, 1.44	0.029	$\chi^2(1) = 5.99$*
2.	Marital group				0.037	$\chi^2(2) = 7.67$*
	Satisfied (0) vs. low satisfaction (1)	0.925 (0.343)	2.52**	1.29, 4.94		
	Satisfied (0) vs. unmarried (1)	0.564 (0.354)	1.76	0.88, 3.52		
Odds of aortic calcification score in top quintile, adjusted for age and possible mediators (N = 321)						
1.	Age (y at time of EBCT)	0.214 (0.092)	1.24*	1.04, 1.08	0.028	$\chi^2(1) = 5.67$*
2.	Possible mediators				0.114	$\chi^2(2) = 24.18$*
	Pulse pressure (mm Hg)	0.026 (0.017)	1.03	0.99, 1.06		
	LDL-c (mg/dl)	0.022 (0.005)	1.02*	1.01, 1.03		
3.	Marital group				0.032	$\chi^2(2) = 7.23$*
	Satisfied (0) vs. low satisfaction (1)	0.865 (0.365)	2.38*	1.16, 4.86		
	Satisfied (0) vs. unmarried (1)	0.769 (0.376)	2.16*	1.03, 4.51		
Odds of coronary calcification score in top quintile, adjusted for age (N = 334)						
	Age (y at time of EBCT)	0.096 (0.081)	1.09	0.93, 1.28	0.006	$\chi^2(1) = 1.19$
	Marital group				0.003	$\chi^2(2) = 0.74$
	Satisfied (0) vs. low satisfaction (1)	0.250 (0.339)	1.28	0.66, 2.50		
	Satisfied (0) vs. unmarried (1)	0.226 (0.338)	1.25	0.65, 2.43		

All coefficients and standard errors are from final model steps.
# $p < .1$, * $p < .05$, *** $p < .001$.

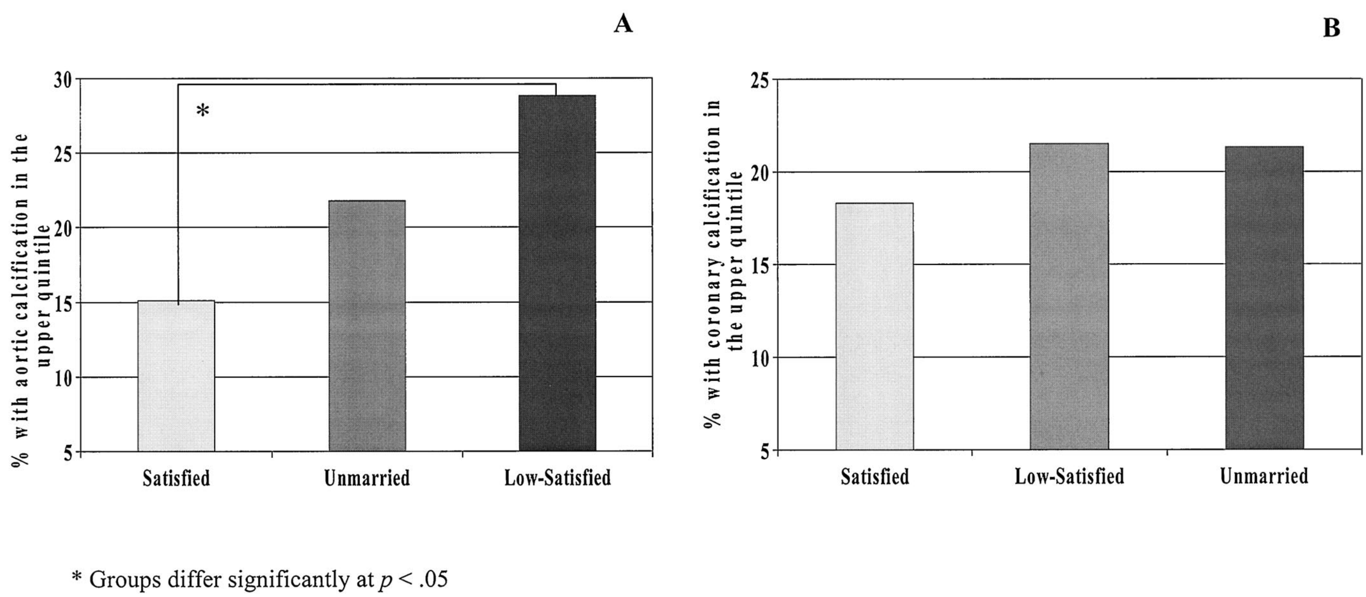

Figure 3. Percent of each marital status/quality group with an aortic **(A)** or coronary **(B)** calcification score in the top quintile of the distribution of scores.

DISCUSSION

A paradox in the marriage literature is that men benefit from being married more than do women, whereas women seem more distressed by low-quality marriages (7). The present study sought to evaluate whether relationship quality and status, examined concurrently, are predictive of post-menopausal women's cardiovascular health. Surprisingly, little data are available on this question with regard to CHD morbidity or mortality. Rather than examining clinical events, which occur after years of exposure to adverse risk factors, the current study evaluated the effect of relationship status and quality early in the disease process, with presymptomatic, objective indicators of atherosclerotic burden. Our analyses showed that women who described their marriages as highly satisfying at a baseline visit had lesser carotid IMTs and less focal plaque measured approximately 11 years later, and they tended to show slower 3-year progression on these indicators when compared with women reporting lower marital satisfaction. Women in satisfying marriages also had higher aortic, but not coronary, calcification scores, assessed approximately

14 years after the baseline, when compared with women in low-satisfying marriages. Unmarried women tended to show intermediate levels of atherosclerosis. Compared with women in satisfying marriages, they tended to have lower levels of carotid plaque and aortic calcification. Thus, in general, the pattern of results confirmed our expectations that satisfying relationships are protective of women's cardiovascular health.

Why were high-quality marriages associated with less atherosclerotic burden? To some extent, the standard cardiovascular risk factors measured at baseline contributed to the differences in atherosclerosis between the satisfied and low-satisfied groups. The low-satisfied group tended to have higher PP, triglycerides, and LDL-c at baseline, and these variables also related to the indicators of atherosclerosis. However, in no case did the variables fully meet established statistical criteria for mediation (55,56), and they explained very little of the effect for aortic calcification. Importantly, the unmarried did not tend to show worse behavioral or biological risk factor profiles at baseline when compared with the other groups, although they did have higher anxiety and depression than the satisfied group. Consistently, control for physical risk factors representing potential mediators did not seem to contribute to the differences between the satisfied and unmarried group. Thus, the observed associations may be due to unmeasured variables associated with happy marriages, such as small physiological responses to psychological challenge, material resources, ability to engage in restorative activities, such as vacations, and availability of a bank of psychological reserves to deal with the inevitable challenges of being older (57).

One question that needs to be addressed is why the associations were stronger for some measures than for others. Although all measures employed have been validated against clinical events, they are thought to reflect somewhat different pathogenic processes and are measured at different sites. Calcification occurs early in plaque development as part of the inflammatory cascade and is regulated in part by a process similar to bone mineralization. Women have calcification in the aorta before the large coronary arteries (45). The effects of risk factors with small effect sizes could therefore be easier to detect for the aortic outcome, because of increased power associated with greater variability observed in our study. IMT measures reflect an adaptation of the vessel wall to risk factors such as hypertension, whereas plaque reflects a focal manifestation of disease that is perhaps initiated through damage to, and subsequent healing of, the endothelium. Thus, it is of interest that the stronger associations are observed for IMT and aortic calcification, which increase earlier in the natural history of atherosclerosis. Perhaps with further progression of atherosclerosis, stronger associations will be obtained with coronary calcification and plaque measurements.

The findings should be interpreted in light of several limitations. First, marital status and quality were measured infrequently and years before the ultrasound and EBCT scan. Multiple, detailed measurements of marital variables across time would have been preferable. However, because of the protracted nature of the atherosclerotic process, the effects of risk factors may occur over a period of years. For example, previous articles concerning this cohort have shown that premenopausal risk factor measurements were strong predictors of later IMT, plaque and calcification—even stronger than risk factors measured closer in time to the scans (58,59).

As in previous research (8–11), marital quality was assessed with a study-specific measure. The seven-item scale used in the current study was shown to be internally consistent and stable in this sample, and some evidence of construct validity may be derived from its correlations with other psychosocial measures (eg, depression, perceived social support). However, future research utilizing validated assessments would allow comparison across studies and integration of findings with prior research concerning marital quality in normative and clinical samples.

Finally, the HWS cohort is more than 90% non-Hispanic white and was healthier and higher in socioeconomic status relative to the general population at the study's inception (31, 32). The sample size is modest, potentially impeding our ability to identify difference between groups—especially for atherosclerotic progression. We were also unable to examine the possible distinct effects of being single, divorced, or widowed, because of small sample sizes. The results suggested that in aggregate, unmarried women showed intermediate levels of atherosclerosis relative to the married and satisfied and married and low-satisfied groups. However, the degree of excess risk displayed by individual women in the group is likely to vary based on factors such as participation in close but nonmarital relationships, the availability of supplementary emotional and material resources, length of time in marriage and quality of marriage before divorce or widowhood, and length of time since the transition to these marital states. Overall, the current findings suggest that additional research with larger and more diverse samples is warranted.

In summary, a marital status/quality grouping predicted atherosclerotic burden during the climacteric transition. Although the effect sizes were small, with marital status/quality explaining only 2% to 4% of the variance across outcomes, the findings suggest that previous studies concerning the salubrious effects of marriage may have produced inconsistent findings because they confounded marital status and quality. That is, perhaps marriage does benefit women's cardiovascular health, -but only if the marriage is harmonious.

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