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# Social Support, Social Network Size, Social Strain, Stressful Life Events, and Coronary Heart Disease in Women With Type 2 Diabetes: A Cohort Study Based on the Women's Health Initiative

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## OBJECTIVE

**We studied associations between social support, social network size, social strain, or stressful life events and risk of coronary heart disease (CHD) in postmenopausal women with type 2 diabetes.**

## RESEARCH DESIGN AND METHODS

**From the Women's Health Initiative, 5,262 postmenopausal women with type 2 diabetes at baseline were included. Cox proportional hazards regression models adjusted for demographics, depressive symptoms, anthropometric variables, and lifestyle factors were used to examine associations between social factors and CHD.**

## RESULTS

**A total of 672 case subjects with CHD were observed during an average 12.79 (SD 6.29) years of follow-up. There was a significant linear trend toward higher risk of CHD as the number of stressful life events increased (*P* for trend = 0.01; hazard ratio [HR] [95% CI] for the third and fourth quartiles compared with first quartile: 1.27 [1.03–1.56] and 1.30 [1.04–1.64]). Being married or in an intimate relationship was related to decreased risk of CHD (HR 0.82 [95% CI 0.69–0.97]).**

## CONCLUSIONS

**Among postmenopausal women with type 2 diabetes, higher levels of stressful life events were associated with higher risk of CHD. Experience of stressful life events might be considered as a risk factor for CHD among women with type 2 diabetes.**

Diabetes is one of the most common chronic diseases globally. Currently, 415 million people worldwide have diabetes, which is expected to increase to 615 million by 2040 (1). Type 2 diabetes accounts for around 90% of all diabetes (1). The major threats to the health of people with type 2 diabetes are associated conditions, such as cardiovascular diseases (CVDs), retinopathy, nephropathy, and neuropathy.

CVD, especially coronary heart disease (CHD), is one of the leading causes of mortality from type 2 diabetes (2). Findings from a meta-analysis of 102 prospective studies showed that people with diabetes have twice the risk of CHD compared with those without diabetes (3). Lifestyle factors (e.g., physical inactivity, smoking,

unhealthy diet, and alcohol consumption), metabolic factors (e.g., hypertension and obesity), and psychosocial factors (e.g., depression) have been identified as potential risk factors for CVD among people with type 2 diabetes (3). Self-management of blood glucose is vital for the prevention of CVD in people with type 2 diabetes (4). Postmenopausal women with type 2 diabetes have a higher risk of CVD and worse prognosis after a CVD event compared with men with type 2 diabetes (5), suggesting a particular need to better understand risk factors for CVD in women.

Social epidemiological research and theory suggest the importance of social relationship factors in health outcomes. For example, Berkman et al. (6) proposed a causal process of social relationships on biopsychosocial components of health through several mechanisms, including provision of social support, social influence, social engagement and attachment, and access to resources and material goods. According to the stress-buffering hypothesis (7), social support and social network moderate the association between stress and health outcomes. According to the stress-exacerbating hypothesis, social strain moderates the association between stress and health outcomes. Social strain and stressful life events are the negative aspects of social relationships (6) and had been recognized as the risk factors for CHD in the general population. In terms of buffering factors, larger social network size was found to be related to lower all-cause mortality risk among older adults with diabetes (8). Earlier cross-sectional studies among people with type 2 diabetes showed that a smaller social network was related to higher risk of CVD (9). No significant associations were observed between social support and risk factors for CVD, such as hypertension and smoking, in one cross-sectional study (10). Positive associations between social support or social network and the self-management of diabetes were reported in other studies (11–14). Associations of social relationship variables with CHD among people with diabetes have not been examined prospectively.

The theoretical framework of this study is based on the stress-buffering and stress-exacerbating hypotheses, which involve testing both noninteraction (main effects) and interaction models. In general, the noninteraction model will test the main effects of stress, social support, social network, and social strain on health outcomes. The interaction models will test the stress-buffering hypothesis (interaction between social support or social network and stressful life events) and stress-exacerbating hypothesis (interaction between social strain and stressful life events). This large-scale epidemiological study will be based on data from the Women's Health Initiative (WHI). Specifically, to test the stress-buffering hypothesis, the following question will be answered in the current study: does social support or social network moderate the association between stressful life events and the occurrence of CHD? To test the stress-exacerbating hypothesis, this study will answer: does social strain moderate the association between stressful life events and the risk of CHD?

## RESEARCH DESIGN AND METHODS

### Study Design and Settings

This was a cohort study based on postmenopausal women with type 2 diabetes from the WHI. The WHI included three separate but overlapping clinical trials (CTs) and an observational study (OS) investigating the major causes of morbidity and mortality among postmenopausal women (15). The study is described in greater detail elsewhere (16–20). Briefly, 161,808 postmenopausal women aged 50–79 years were recruited from 40 clinical centers throughout the United States between 1993 and 1998. Women were enrolled into one or more of three CTs, including a hormone therapy trial, dietary modification trial, and calcium and vitamin D supplementation trial, or an OS. Participants in the OS included 93,676 women who were screened for the CT but were ineligible or unwilling to participate in the WHI CT or were recruited through a direct invitation for the OS. The WHI main study ended on 31 March 2005 with a closeout date for data collection on 8 April 2005. Overall, 82.4% of participants in the CT and 72.9% of participants in the OS consented to join the first Extension Study and were additionally followed from 2005 to 2010. There were 85.2% of women in the CT and 88.2% of women in the OS component from the first Extension Study who consented to join the second Extension Study (2010–2020) for additional follow-up. Non-Latina white women and younger women were more likely to consent to extension studies. The study was approved by Institutional Review Boards at all 40 clinical centers and at the coordinating center. All participants provided written informed consent.

### Participants

The inclusion criterion was women with type 2 diabetes at the baseline of WHI. According to baseline measurement using a validated definition for type 2 diabetes (21), a participant was considered to have type 2 diabetes if she answered "yes" to the question, "Did a doctor ever say that you had sugar diabetes or high blood sugar when you were not pregnant?," was diagnosed after 21 years of age, and had not been hospitalized for diabetic coma. The exclusion criteria were women who had CVD, cancer, or missing information on the main exposures at baseline.

### Variables

#### *Exposures*

Based on previously validated measurements collected at baseline, social support (22), social network size (23), social strain (24), and stressful life events (25) were the main exposure variables and were analyzed separately to test our hypotheses:

Social support: Social support was constructed based on nine questions regarding how often participants could access each type of support (22). Items are shown in Supplementary Table 1*A*. Subscales of social support were constructed from different questions and included emotional/information support, affection support, tangible support, and positive social interaction (Supplementary Table 1*B*). Five-point scales (range from 1, none of the time, to 5, all of the time) were used for each answer. The total scale score ranged from 9 to 45, with a higher score representing greater social support.

Social network size: Information on the components of social network (i.e., being married or in an intimate relationship, club ties, religious ties, and number of first-degree relatives) was collected. A social network size index was developed based on these components (23). Scores on the index ranged from 0 to 5, with 1 point each for marital status (married/in an intimate relationship vs. not), club ties (attended clubs/lodges/groups last month; yes vs. no), religious ties (yes vs. no), and 0–2 points based on the tertile of ties to supportive

relatives (0 points for <5 ties, 1 point for 5–7 ties, and 2 points for >7 ties).

Social strain: Social strain is a construct based on four items selected from the original seven-item scale developed by Antonucci et al. (24) (Supplementary Table 2). Each item is coded from 1 (none) to 5 (all), with the total score ranging from 4 to 20 and higher scores indicating greater social strain.

Stressful life events: Eleven items were used to assess stressful life events that occurred in the year prior to WHI baseline (25) (Supplementary Table 3). The responses were: no/did not occur; yes, and it upset me but not too much; yes, it upset me moderately (medium); and yes, it upset me very much. The total score ranges from 0 to 33, with higher scores representing greater number and severity of upsetting events.

#### *Outcomes*

The primary outcome was first occurrence of CHD during WHI follow-up. The occurrence of CHD was defined as first occurrence of clinical myocardial infarction (MI), definite silent MI, or death due to definite CHD or possible CHD. Outcomes were adjudicated by physicians following diagnostic standards for CT and OS through 2010 (26). From 2010, cardiovascular outcomes were adjudicated by physicians for the subset that included all former hormone trial participants and all African American and Hispanic participants.

#### *Covariates*

We considered the following potential confounders: baseline age, race/ethnicity (American Indian or Alaska Native, Asian or Pacific Islander, black or African American, Hispanic/Latina, non-Hispanic white, or other), educational level (high school or less, some college/technical training, college or some postcollege, and master's level or higher), family income (<$20,000, $20,000–34,999, $35,000–49,999, $50,000–74,999, $75,000–99,999, $100,000–149,999, and ≥$150,000), study cohort (participation in OS or CT and different treatment assignments for all three CTs), hypertension (never, untreated, or treated), a history of high cholesterol requiring pills (no or yes), and a family history of MI; depressive symptoms were assessed using the eight-item Burnam scale, resulting in a composite scale ranging from 0 to 1; scores were categorized into none, mild, or moderate based on previously established cut points of 0.009 and 0.06 (27). Additional covariates included physical activity (assessed as total energy expenditure from recreational physical activity and classified as <5, 5 to <10, 10 to <20, 20 to <30, or ≥30 metabolic equivalent [MET] values/week), smoking history (never, former, or current), alcohol consumption (nondrinker, past drinker, current and less than one drink per week, current and one to seven drinks per week, current and at least seven drinks per week, or current and less than one drink per month), BMI (established by clinical height/weight assessment), waist-to-hip ratio (WHR), and healthy eating index (HEI)-2005 score (quartile) obtained from the Food Frequency Questionnaire. HEI-2005 is a measure of diet quality that assesses conformance to the 2005 dietary guidelines for Americans (28).

### Statistical Analysis

Both descriptive and inferential statistical analyses were performed. Each constructed exposure variable was categorized into quartiles. We also analyzed the scores on the components of social support as mentioned above. Means and SDs were used to describe baseline continuous variables, and frequencies and proportions were presented for categorical variables. Differences by exposure variables were evaluated using ANOVA for continuous variables and $\chi^2$ tests for categorical variables. We used Cox proportional hazards models to evaluate associations between each of the main exposures and the occurrence of CHD, with results presented as hazard ratios (HRs) and 95% CIs. Survival time was calculated as the duration from the date of enrollment until the first occurrence of CHD, date of death, or 31 March 2018, whichever occurred first. In the multivariable models, we adjusted for potential covariates listed above in progressively adjusted models. In model 1, we adjusted for age, ethnicity, education, family income, family history of MI, hypertension, history of high cholesterol requiring pills, and study cohort (CT or OS and different assignments for CTs). In the second model, we adjusted additionally for depressive symptoms. Depressive symptoms are common among people with type 2 diabetes (29). These were shown to be related to the social support (30) and the occurrence of complications in diabetes (31). The third model additionally adjusted for major modifiable lifestyle factors including BMI, WHR, dietary quality, physical activity, smoking history, and alcohol consumption. Trend analyses were performed by entering the original scales of the main exposure variables as continuous variables in the models. To test the stress-buffering and stress-exacerbating hypotheses, interaction terms between social support or social network or social strain and stressful life events were added to the models. *P* values were two-sided and considered significant at values <0.05. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

## RESULTS

Based on our inclusion and exclusion criteria, 9,303 women with type 2 diabetes at the baseline of WHI were first identified. Among these 9,303 women, we excluded 2,498 women who had CVD at baseline, 962 women who had cancer (except nonmelanoma skin cancer) at baseline, and 581 women with missing information on the main exposures. Thus, the current study included 5,262 women with type 2 diabetes.

There were 672 case subjects with CHD during a mean follow-up of 12.79 (SD 6.29) years. Table 1 shows the baseline characteristics of the study population according to the occurrence of CHD. Compared with women with type 2 diabetes who did not develop CHD, women who developed CHD were older, had lower levels of education, had lower income, less often reported minority racial background, had lower total energy expenditure from recreational physical activity (MET-h per week), had greater WHR, had more family history of MI, and had more hypertension (all $P < 0.05$). There were no significant differences in HEI, BMI, smoking history, alcohol consumption, history of high cholesterol requiring pills, or depressive symptoms between women who did or did not develop CHD.

Table 2 shows the results of Cox proportional hazards models on the main effect of social support, social network size, social strain, and stressful life events on the risk of CHD in women with type 2 diabetes. Only the main association between stressful life events and risk

**Table 1—Baseline characteristics of participants by the occurrence of CHD**

| | CHD | |
|---|---|---|
| | No | Yes |
| Age at baseline (years)* | 4,590 (63.5 [6.8]) | 672 (65.8 [6.7]) |
| Family income | | |
| Missing | 312 (6.8) | 41 (6.1) |
| <$20,000 | 1,126 (24.5) | 211 (31.4) |
| $20,000–34,999 | 1,187 (25.9) | 190 (28.3) |
| $35,000–49,999 | 864 (18.8) | 112 (16.7) |
| $50,000–74,999 | 684 (14.9) | 76 (11.3) |
| $75,000–99,999 | 248 (5.4) | 24 (3.6) |
| $100,000–149,999 | 117 (2.5) | 15 (2.2) |
| ≥$150,000 | 52 (1.1) | 3 (0.4) |
| Ethnicity | | |
| Missing | 13(0.3) | 2 (0.3) |
| American Indian or Alaskan Native | 47 (1.0) | 5 (0.7) |
| Asian or Pacific Islander | 229 (5.0) | 20 (3.0) |
| Black or African American | 929 (20.2) | 125 (18.6) |
| Hispanic/Latino | 324 (7.1) | 20 (3.0) |
| White (not of Hispanic origin) | 2,980 (64.9) | 492 (73.2) |
| Other | 68 (1.5) | 8 (1.2) |
| Educational levels | | |
| Missing | 34 (0.7) | 1 (0.1) |
| High school diploma or less | 1,401 (30.5) | 236 (35.1) |
| Some college or technical training | 1,814 (39.5) | 252 (37.5) |
| College graduate or some postcollege | 763 (16.6) | 103 (15.3) |
| Master's degree or higher | 578 (12.6) | 80 (11.9) |
| BMI (kg/m$^2$)* | 4,562 (31.9 [6.7]) | 668 (32.4 [6.7]) |
| WHR* | 4,572 (0.87 [0.08]) | 669 (0.88 [0.079]) |
| Total HEI-2005 score* | 4,590 (68.2 [10.6]) | 671 (67.5 [10.2]) |
| Total energy expenditure from recreational physical activity (MET-h/week)* | 4,391 (9.7 [12.0]) | 627 (8.2 [11.4]) |
| Smoking habit | | |
| Missing | 64 (1.4) | 15 (2.2) |
| Never smoked | 2,424 (52.8) | 335 (49.9) |
| Past smoker | 1,810 (39.4) | 269 (40.0) |
| Current smoker | 292 (6.4) | 53 (7.9) |
| Alcohol consumption | | |
| Missing | 39 (0.8) | 9 (1.3) |
| Nondrinker | 783 (17.1) | 127 (18.9) |
| Past drinker | 1,721 (37.5) | 258 (38.4) |
| <1 drink/month | 636 (13.9) | 98 (14.6) |
| <1 drink/week | 760 (16.6) | 98 (14.6) |
| 1 to <7 drinks/week | 480 (10.5) | 63 (9.4) |
| ≥7 drinks/week | 171 (3.7) | 19 (2.8) |
| Relative had MI | | |
| Missing | 296 (6.4) | 37 (5.5) |
| No | 1,983 (43.2) | 238 (35.4) |
| Yes | 2,311 (50.3) | 397 (59.1) |
| Depressive symptoms | | |
| None | 3,266 (71.2) | 487 (72.5) |
| Mild | 680 (14.8) | 91 (13.5) |
| Moderate | 644 (14.0) | 94 (14.0) |
| High cholesterol requiring pills ever | | |
| Missing | 270 (5.9) | 54 (8.0) |
| No | 3,352 (73.0) | 466 (69.3) |
| Yes | 968 (21.1) | 152 (22.6) |
| Hypertension | | |
| Missing | 263 (5.7) | 57 (8.5) |
| Never hypertensive | 1,780 (38.8) | 208 (31.0) |
| Untreated hypertensive | 433 (9.4) | 74 (11.0) |
| Treated hypertensive | 2,114 (46.1) | 333 (49.6) |

Data are *n* (%) unless otherwise indicated. *Total number (mean [SD]).

of CHD was statistically significant in models 1–3. In model 1, women in the third and fourth quartiles of stressful life events had significantly increased risk for CHD compared with women in the lowest quartile (HRs [95% CI] were 1.28 [1.05–1.57] and 1.33 [1.07–1.66], respectively). In model 2, similar increased risks of CHD were observed for the third and fourth quartiles versus the lowest quartile (HRs [95% CI] were 1.29 [1.05–1.59] and 1.34 [1.07–1.69], respectively). In model 3, the HRs remained significant (HRs [95% CI] were 1.27 [1.03–1.56] and 1.30 [1.04–1.64], respectively). The third quartile of social network size had significantly lower risk of CHD compared with the lowest quartile in models 1, 2, and 3 (HRs [95% CI] were 0.73 [0.57–0.93], 0.73 [0.58–0.93], and 0.76 [0.59–0.97], respectively). The HRs (95% CI) for the fourth quartile of social network size in these three models were 0.84 (0.66–1.06), 0.84 (0.66–1.07), and 0.88 (0.69–1.12), respectively. No significant associations between social support and social strain and risk of CHD were observed in any models.

Table 3 presents the main effect of components of social network size and the risk of CHD in women with type 2 diabetes. Being married or in an intimate relationship was related to decreased risk of CHD compared with not being married or in an intimate relationship in models 1, 2, and 3 (HRs [95% CI] were 0.80 [0.67–0.95], 0.81 [0.68–0.96], and 0.82 [0.69–0.97], respectively). There were no significant associations between other components and the risk of CHD. To further examine the specific role of stressful life events in the context of other social variables, we further tested the changes of the effect estimate of associations between stressful life events and the risk of CHD in women with type 2 diabetes by adding social support, social network size, or social strain to model 3. However, the effect estimates remained the same for these analyses.

Table 4 shows the main effect of subscales of social support and the associated risk of CHD in women with type 2 diabetes. Compared with women with type 2 diabetes who reported "none of the time" to the affection support subscale item "someone to love you and make you feel wanted," women who reported some level of support such as "a little of the time" to "all of the time" had a lower risk of CHD.

In our analysis of interaction models, we did not find an interaction between stressful life events and social support (interaction term $P = 0.27$). Similarly, no interactions were observed between stressful life events and social network size ($P = 0.14$). No interactions were observed between stressful life events and social strain ($P = 0.88$).

## CONCLUSIONS

In this cohort study among postmenopausal women with type 2 diabetes who participated in the WHI, higher levels of

**Table 2—Associations between social support, social network, social strain, and stressful life events and risk of CHD in women with type 2 diabetes**

| | Number of cases | Model 1[1] | Model 2[2] | Model 3[3] |
|---|---|---|---|---|
| Social support[4] | | | | |
| Q1 | 192 | Reference | Reference | Reference |
| Q2 | 160 | 0.95 (0.77–1.18) | 0.96 (0.77–1.19) | 0.99 (0.80–1.23) |
| Q3 | 186 | 0.97 (0.79–1.19) | 0.98 (0.79–1.21) | 1.02 (0.82–1.26) |
| Q4 | 134 | 0.93 (0.74–1.17) | 0.94 (0.74–1.19) | 1.00 (0.79–1.26) |
| *P* for trend | | 0.23 | 0.29 | 0.68 |
| Social network size[4] | | | | |
| Q1 | 116 | Reference | Reference | Reference |
| Q2 | 192 | 0.96 (0.76–1.21) | 0.96 (0.76–1.21) | 0.97 (0.77–1.23) |
| Q3 | 173 | 0.73 (0.57–0.93) | 0.73 (0.58–0.93) | 0.76 (0.59–0.97) |
| Q4 | 191 | 0.84 (0.66–1.06) | 0.84 (0.66–1.07) | 0.88 (0.69–1.12) |
| *P* for trend | | 0.03 | 0.03 | 0.11 |
| Social strain[4] | | | | |
| Q1 | 175 | Reference | Reference | Reference |
| Q2 | 192 | 1.11 (0.90–1.37) | 1.11 (0.90–1.37) | 1.09 (0.88–1.35) |
| Q3 | 141 | 1.02 (0.81–1.28) | 1.01 (0.80–1.26) | 0.99 (0.78–1.24) |
| Q4 | 164 | 1.09 (0.87–1.36) | 1.07 (0.86–1.34) | 1.00 (0.79–1.25) |
| *P* for trend | | 0.41 | 0.51 | 0.96 |
| Stressful life events[4] | | | | |
| Q1 | 164 | Reference | Reference | Reference |
| Q2 | 84 | 1.00 (0.77–1.30) | 1.00 (0.77–1.31) | 0.97 (0.74–1.28) |
| Q3 | 239 | 1.28 (1.05–1.57) | 1.29 (1.05–1.59) | 1.27 (1.03–1.56) |
| Q4 | 185 | 1.33 (1.07–1.66) | 1.34 (1.07–1.69) | 1.30 (1.04–1.64) |
| *P* for trend | | 0.01 | <0.001 | 0.01 |

Data are HR (95% CI) unless otherwise indicated. [1]Adjusted for age at baseline, race/ethnicity (American Indian or Alaska Native, Asian or Pacific Islander, black or African American, Hispanic/Latino, non-Hispanic white, and other), education (high school or less, some college/technical training, college or some postcollege, and master's degree or higher), family income (<$20,000, $20,000–34,999, $35,000–49,999, $50,000–74,999, $75,000–99,999, $100,000–149,999, and ≥$150,000), family history of MI (no or yes), hypertension (never, untreated, or treated), a history of high cholesterol requiring pills ever (no or yes), and different study cohorts (participation in OS or CTs and different treatment assignments for all three CTs). [2]Further adjusted for depressive symptoms. [3]Further adjusted for BMI, WHR, smoking (never, former, or current), alcohol intake (nondrinker, past drinker, current and <7 drinks/week, or current and ≥7 drinks/week), physical activity (<5, 5 to <10, 10 to <20, 20 to <30, or ≥30 MET-h/week), and quality of diet (quartile). [4]Q1, Q2, Q3, and Q4 for each exposure represent first, second, third, and fourth quartile, respectively.

stressful life events were associated with higher risk of CHD. The third quartile of social network size was associated with a lower risk of CHD. No main effects of social support or social strain on the risk of CHD were found. One component of social network size—being married or in an intimate relationship—was associated with lower risk of CHD. There was no evidence for stress-buffering effects by social support or social network or a stress-exacerbating effect by social strain.

To the best of our knowledge, this is the first study on the associations between social support, social network size, social strain, and stressful life events and the risk of CHD in postmenopausal women with type 2 diabetes. An earlier study based on the general population in the WHI found that diabetes might be a mediator for associations of both stressful life events and social strain with CHD (32). Earlier studies among people with diabetes were cross-sectional in design with relatively small sample sizes and focused on only one social relationship variable. One cross-sectional study based on 797 individuals with diabetes in the Maastricht Study found that smaller social network size was associated with increased risk of CVD (9).

Our interaction tests did not support the stress-buffering and stress-exacerbating hypotheses. There could be several possible reasons for this. First, social support or social strain may, in fact, not buffer or exacerbate stress as we measured. There are different forms of social support. Each form of social support might be specifically useful in buffering certain types of stressful events (7). For example, economic support from a friend may be effective in the situation of temporary unemployment, but not effective in the situation of loss of a pet. Second, stressful life events, social support, social network size, and social strain were all measured at baseline; we did not capture changes over time that may affect the outcome.

The observed associations between recent stressful life events and risk of CHD might operate through different mechanisms. Stressful life events in the past year at baseline may increase the risk of CHD through inflammation and endothelia dysfunction due to the stress-induced dysregulation of the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis (33,34). Stressful life events could be related to less involvement in diabetes care programs (35). The higher level of stressful life events was significantly associated with increased risk of CHD in all three models. The effect estimates in model 3 that controlled for lifestyle factors, such as dietary quality and physical activity, were similar to the results in models 1 and 3. This indicates that stressful life events were related to increased risk of CHD independent of health behaviors among women with type 2 diabetes. It is possible that psychophysiological factors associated with exposure to a stressful life event, beyond the event itself, may be a mechanism affecting CHD risk in these women, and this should be further evaluated in future research. This may be relevant given that the measure of stressful life events used in WHI not only reflected exposure to different types of events (e.g., exposure to physical abuse, spouse died) but also the degree of emotional distress (e.g., the event "upset me very much") associated with the event. Interestingly, larger social network size was significantly associated with lower risk of CHD in models 1 and 2, but not in model 3, in which there was additional adjustment for lifestyle factors. This result indicates that health behaviors, such as physical activity and healthy diet, might be mediators of the associations between social network size and risk of CHD.

We did not find significant associations among social support, social strain, and risk of CHD in women with type 2 diabetes. However, the third quartile of social network size was associated with lower risk of CHD. We speculate that this moderate level of network size may offer beneficial support, as opposed to lower or higher levels of support that may

**Table 3—Associations between components of social network and risk of CHD in women with type 2 diabetes**

| | Number of cases | Model 1[1] | Model 2[2] | Model 3[3] |
|---|---|---|---|---|
| Married/in an intimate relationship | | | | |
| No | 489 | Reference | Reference | Reference |
| Yes | 624 | 0.80 (0.67–0.95) | 0.81 (0.68–0.96) | 0.82 (0.69–0.97) |
| Attended clubs/lodges/groups last month | | | | |
| None | 513 | Reference | Reference | Reference |
| ≥1 | 600 | 1.01 (0.86–1.19) | 1.01 (0.86–1.19) | 1.04 (0.88–1.23) |
| Times attending religious services/church during the past month | | | | |
| None | 368 | Reference | Reference | Reference |
| ≥1 | 745 | 0.89 (0.75–1.05) | 0.88 (0.75–1.04) | 0.90 (0.76–1.07) |
| Number of relatives | | | | |
| <5 | 402 | Reference | Reference | Reference |
| 5–8 | 268 | 1.00 (0.82–1.21) | 1.01 (0.83–1.23) | 1.01 (0.83–1.23) |
| >8 | 443 | 0.90 (0.75–1.09) | 0.93 (0.77–1.11) | 0.92 (0.76–1.11) |
| *P* for trend | | 0.28 | 0.30 | 0.40 |

Data are HR (95% CI) unless otherwise indicated. [1]Adjusted for age at baseline, race/ethnicity (American Indian or Alaska Native, Asian or Pacific Islander, black or African American, Hispanic/Latino, non-Hispanic white, and other), education (high school or less, some college/technical training, college or some postcollege, and master's degree or higher), family history of MI (no or yes), hypertension (never, untreated, or treated), high cholesterol requiring pills ever (no or yes), and different study cohorts (participation in OS or CTs and different treatment assignments for all three CTs). [2]Further adjusted for depressive symptoms. [3]Further adjusted for BMI, WHR, smoking (never, former, or current), alcohol intake (nondrinker, past drinker, current and <7 drinks/week, or current and ≥7 seven drinks/week), physical activity (<5, 5 to <10, 10 to <20, 20 to <30, and ≥30 MET-h/week), and quality of diet (quartile).

reflect either social isolation or heavy social obligations, respectively. In our analysis on the subscales of social support and social network size, we found that being married or in an intimate relationship was related to decreased risk of CHD. The protective effect of marriage has been seen in other cohort studies (36). Being married or in an intimate relationship was related to regular monitoring of blood glucose (37) and maintaining blood glucose targets (38). Spouses and partners could help women with type 2 diabetes with coping and decreasing the distress that is related to diabetes, and it could be that more proximal sources of support (e.g., with whom the woman lives) have a more direct impact on diabetes management than other distal sources of support. Other components of social network size, such as club ties, religious ties, and the numbers of relatives, were not found to be significantly associated with risk of CHD in women with type 2 diabetes. The subscales of social support, including emotional/informational support, affection support, tangible support, and positive social interaction, were not significantly associated with risk of CHD in women with type 2 diabetes.

Our study strengths include the large sample of women with type 2 diabetes and long follow-up period. There was detailed information on social factors and potential confounding factors and adjudicated information on CHD. However, some limitations in our study need to be mentioned. First, the social network size scale used only measures size and does not measure the quality of the social network. Furthermore, it did not include the number of close friends. However, we analyzed social strain, which is an indicator of negative social relationships. By analyzing total social support and specific subscales, including emotional/informational, affection, and tangible and positive social interaction, we were able to evaluate the quality of the social network. Second, exposures and potential confounding factors were measured at WHI baseline. Some misclassification might be caused by lack of examination of changes of these factors during follow-up, which would bias findings toward the null. Third, our study results have limited generalizability because our population consisted solely of postmenopausal women with type 2 diabetes treated with diabetic medications in the United States. We cannot generalize our results to individuals with diabetes treated with only diet and lifestyle modifications. Furthermore, women with significant psychiatric conditions were excluded from WHI. Thus, our results cannot be generalized to postmenopausal women who experienced mental health conditions that may have been exacerbated or triggered by stressful life events. Fourth, the definition of diabetes was based on self-reported information. However, the validity of self-reported diabetes is high according to validation studies in the WHI when comparing self-report with a gold standard based on medical record review and with medication inventories (21,39).

**Table 4—Associations between four subscales of social support and risk of CHD in women with type 2 diabetes**

| | Number of cases | Model 1[1] | Model 2[2] | Model 3[3] |
|---|---|---|---|---|
| Emotional/information support subscale[4] | | | | |
| Q1 | 228 | Reference | Reference | Reference |
| Q2 | 167 | 0.78 (0.64–0.96) | 0.78 (0.64–0.96) | 0.83 (0.68–1.03) |
| Q3 | 110 | 0.98 (0.77–1.24) | 0.97 (0.77–1.23) | 1.02 (0.80–1.30) |
| Q4 | 167 | 0.85 (0.69–1.05) | 0.85 (0.69–1.05) | 0.91 (0.74–1.13) |
| *P* for trend | | 0.11 | 0.15 | 0.45 |
| Affection support subscale[5] | | | | |
| 1 | 46 | Reference | Reference | Reference |
| 2 | 54 | 0.67 (0.45–1.00) | 0.67 (0.45–1.00) | 0.67 (0.45–1.01) |
| 3 | 95 | 0.75 (0.52–1.08) | 0.76 (0.53–1.09) | 0.77 (0.53–1.11) |
| 4 | 161 | 0.74 (0.53–1.04) | 0.75 (0.53–1.05) | 0.76 (0.54–1.08) |
| 5 | 316 | 0.71 (0.51–0.98) | 0.72 (0.52–0.99) | 0.75 (0.54–1.05) |
| *P* for trend | | 0.22 | 0.27 | 0.48 |
| Tangible support subscale[4] | | | | |
| Q1 | 179 | Reference | Reference | Reference |
| Q2 | 182 | 1.00 (0.81–1.24) | 1.01 (0.82–1.24) | 1.01 (0.81–1.24) |
| Q3 | 114 | 1.07 (0.84–1.36) | 1.07 (0.84–1.36) | 1.11 (0.87–1.41) |
| Q4 | 197 | 0.93 (0.76–1.15) | 0.95 (0.77–1.17) | 0.97 (0.78–1.20) |
| *P* for trend | | 0.74 | 0.81 | 0.87 |
| Positive social interaction subscale[4] | | | | |
| Q1 | 190 | Reference | Reference | Reference |
| Q2 | 238 | 1.03 (0.84–1.25) | 1.04 (0.85–1.26) | 1.12 (0.92–1.37) |
| Q3 | 55 | 0.98 (0.72–1.33) | 1.01 (0.74–1.38) | 1.02 (0.74–1.40) |
| Q4 | 189 | 0.93 (0.75–1.14) | 0.94 (0.76–1.16) | 1.00 (0.81–1.24) |
| *P* for trend | | 0.52 | 0.63 | 0.93 |

Data are HR (95% CI) unless otherwise indicated. [1]Adjusted for age at baseline, race/ethnicity (American Indian or Alaska Native, Asian or Pacific Islander, black or African American, Hispanic/Latino, non-Hispanic white, and other), education (high school or less, some college/technical training, college or some postcollege, and master's degree or higher), family history of MI (no or yes), hypertension (never, untreated, or treated), high cholesterol requiring pills ever (no or yes), and different study cohorts (participation in OS or CTs and different treatment assignments for all three CTs). [2]Further adjusted for depressive symptoms. [3]Further adjusted for BMI, WHR, smoking (never, former, or current), alcohol intake (nondrinker, past drinker, current and $<7$ drinks/week, or current and $\geq 7$ drinks/week), physical activity ($<5$, 5 to $<10$, 10 to $<20$, 20 to $<30$, and $\geq 30$ MET-h/week), and quality of diet (quartile). [4]Q1, Q2, Q3, and Q4 for each exposure represent first, second, third, and fourth quartile, respectively. [5]The affection support subscale is based on one question (question 9: someone to love you and make your feel wanted). See Supplementary Table 1*A*.

In conclusion, among postmenopausal women with type 2 diabetes, larger social network size and being married or in an intimate relationship were associated with decreased risk of CHD. A higher level of stressful life events was associated with increased risk of CHD. Our study has some practical implications for targeted diabetic care among postmenopausal women with type 2 diabetes. Women with type 2 diabetes who experience stressful life events might benefit from cognitive and behavioral therapies to better cope with stressful events.

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**Author Contributions.** J.M.J. conceived and designed the study; acquired, managed, analyzed, and interpreted data; and drafted and revised the manuscript. M.H. and J.L. conceived and designed the study, interpreted data, and critically reviewed and revised the manuscript. A.H.S., E.K., K.C.J., C.H.K., L.G., S.La., A.S., S.S.-J., X.L., C.W.C., S.Li., and C.V. interpreted data and critically reviewed and revised the manuscript. J.M.J. and J.L. are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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