Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Disrupting the path to cardiovascular disease: Stress-related coping and onset of hypertension and obesity

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ARTICLE INFO

Keywords:
Coping skills
Coping variability
Emotion regulation
Hypertension
Obesity
Stress

ABSTRACT

Objective: Accumulating research suggests stress-related coping contributes to cardiovascular disease risk, but its association with upstream cardiometabolic conditions remains unexplored. We examined whether coping strategies generally deemed adaptive (e.g., acceptance) and maladaptive (e.g., self-blame), as well as variability in their use (reflecting attempts to find the best strategies for managing stressors) predict risk of developing hypertension and obesity.

Methods: Women (N = 26,126) from the Nurses' Health Study II cohort reported use of eight coping strategies in 2001. Coping variability was operationalized using a standard deviation-based algorithm and considered categorically (i.e., lower, moderate, greater levels) to assess non-linear effects. Until 2019, hypertension status was self-reported and obesity was derived from height and updated weight information. Cox regression models, controlling for baseline demographic, health-related, and behavioral factors, estimated hazard ratios (HR) and 95% confidence intervals (CI). Potential effect modification by age, menopausal status, and neighborhood socioeconomic status (SES) was evaluated.

Results: In the overall sample, many coping strategies were associated with increased risk of new onset obesity (e.g., per 1-SD increase in behavioral disengagement adjusting for demographic and health-related covariates: HR = 1.08, 95CI% = 1.05-1.11), but not hypertension. Greater versus lower variability levels were related to 8-10% lower risk of developing obesity and hypertension, respectively. Associations were generally comparable across age, menopausal status, and neighborhood SES subgroups.

Conclusions: Stress-related coping strategies and variability in their use were associated with risk of developing obesity and hypertension among women. Future intervention research may consider how women manage stressors to lower risk of conditions that affect lifelong cardiovascular health.

1. Introduction

Success in efforts to decrease cardiovascular disease (CVD) rates have been noted over past decades (Martin et al., 2024). Yet, recent trends show troubling reversals and increasing incidence rates, and CVD continues to be the leading cause of death among U.S. women (Martin et al., 2024). Targeting upstream CVD risk factors like hypertension and obesity has been a focus of recent clinical efforts in preventive cardiology, a specialty that argues that preventing such conditions will likely have high impact on improving and maintaining cardiovascular health (German et al., 2022). Moreover, the prevalence of hypertension and obesity have been increasing among women relative to men, especially in postmenopausal women (Rajendran et al., 2023; Hetherington et al., 2024). Thus, identifying shared modifiable determinants of cardiometabolic conditions that lead to CVD, especially among women, is critical. To this end, the American Heart Association (Levine et al., 2021) and the Lancet Commission on the emotional determinants of health (Larson et al., 2020) have encouraged the study of upstream psychological factors that may promote health, including the response to and capacity to manage stressors (Levine et al., 2021). However, to our

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https://doi.org/10.1016/j.socscimed.2026.119213
Received 27 August 2025; Received in revised form 17 March 2026; Accepted 18 March 2026
Available online 19 March 2026

knowledge, no study has specifically examined if the ways women cope with stressors are associated with the development of cardiometabolic conditions like hypertension and obesity that increase risk of developing CVD.

Examining coping processes among women is warranted because they are frequently exposed to psychosocial stressors (Ebong et al., 2024). Among those, nurses are of particular interest because their profession is characterized by a significant amount of work-related stress, partly explained by high demands and workload, often accompanied by lower autonomy and recognition (Khamisa et al., 2013). Stress-related coping has been broadly defined as ways to manage stressful experiences and their potentially detrimental impacts. In prior work, several coping processes have been investigated, including coping *strategies* and *variability* in the use of these strategies. Coping strategies are usually characterized as adaptive (e.g., seeking social support, planning) or maladaptive (e.g., denial, disengagement) based on their observed impact on mental and physical health (Carver et al., 1989; Penley et al., 2002; Kato, 2015). Coping variability refers to the patterning in use of coping strategies when managing diverse stressors, as indicated by the extent to which individuals will consistently favor one strategy over others regardless of the nature of the stressor, use several strategies similarly, or alternate between different strategies within a repertoire of strategies, which presumably mirrors their attempts to find the best strategy for a given situation (Cheng et al., 2014).

The role of such coping processes in risk of developing new onset hypertension or obesity among women, and in nurses in particular, remains unexplored in longitudinal studies. Yet, prior empirical research among initially CVD-free individuals suggests that greater use of certain adaptive strategies and, to a lesser extent, maladaptive strategies predict future risk of diabetes (Ng et al., 2024a) and CVD (Nagayoshi et al., 2023; Roohafza et al., 2022; Svensson et al., 2016) in expected directions. One theoretical model that further provides support for examining this research question is the allostatic load model (McEwen, 2000; Parker et al., 2022), which posit that the body adapts to stressors by activating various physiological systems, including cardiovascular and metabolic processes. Allostatic load, that is the wear and tear on these systems, occurs when such stress responses are too frequent or intense – responses that are modulated partly by how one copes with stressors.

Hence, the current longitudinal study examined if eight individual coping strategies and variability in their use were each related to risk of developing hypertension or obesity, separately, across 18 years of follow-up, in female nurses from the Nurses' Health Study II (NHSII). Based on prior findings (Ng et al., 2024a; Nagayoshi et al., 2023; Roohafza et al., 2022; Svensson et al., 2016), we hypothesized that likelihood of developing each condition is lower with greater use of adaptive strategies (e.g., emotional support) and higher with greater use of maladaptive strategies (e.g., denial). We also examined the association of coping variability with risk of developing each condition. Based on prior studies on coping variability in relation to longevity (Trudel-Fitzgerald, 2024a) and health behaviors (Trudel-Fitzgerald et al., 2025) in NHSII, we posited that greater and moderate (versus lower) variability levels would be related to lower risk of developing both conditions.

2. Methods

2.1. Participants

The NHSII is an ongoing cohort study launched in 1989 among 116,429 female nurses aged 25-42 years. Participants complete biennial questionnaires on lifestyle, medical history, and newly diagnosed conditions, with response rates of >85% across cycles (Bao et al., 2016). The coping measure was administered in 2001, which constitutes the current baseline, as part of a substudy on violence exposure in a subset of participants (n = 68,360). Exclusions, mainly due to prevalent cases of or missing data on hypertension or obesity at baseline, led to an analytic sample of 26,126 (Suppl. Fig. 1). Notably, participants with either hypertension or obesity or missing items on the variables used to derive condition status at the 2001 baseline were excluded from the analytic sample, in order to conduct hypertension and obesity onset analyses in the same analytic sample, which allows direct comparison of estimates. Furthermore, because a 2-year lag was introduced to mitigate concerns about reverse causation, whereby underlying cardiometabolic processes related to hypertension and obesity may influence the experience or report of psychological experiences like stress-related coping processes (Schaare et al., 2023; Tyrrell et al., 2019), participants with prevalent hypertension or obesity or missing items in 2003 were also excluded. Eligible versus non-eligible participants based on their completion of the coping items specifically were notably similar (Suppl. Table 1). The study protocol was approved by the IRBs of the Brigham & Women's Hospital/Harvard T.H. Chan School of Public Health (#1999P003389), the Université du Québec à Trois-Rivières (#CERPPE-22-04-10.05) and the CIUSSS de l'Est-de-l'Île-de-Montréal (#2022-2968).

2.2. Measures

Coping. Details about the coping measure and the dispositional coping variability construct are provided in **Suppl. Text 1**.

How individuals *typically* cope with stressful events, as a dispositional style, was measured once in 2001 using a modified version of the validated self-report 60-item Coping Orientation to Problems Experienced (COPE) inventory (Carver et al., 1989). This version includes 8 subscales representing commonly used coping strategies. Four subscales reflect strategies deemed adaptive: Active Coping, Use of Emotional Support, Acceptance, and Religion; another 4 subscales capture strategies deemed maladaptive: Denial, Behavioral Disengagement, Focus on & Venting of Emotions, and Self-Blame (Carver et al., 1989). Each subscale includes two items rated on a scale from 0 = "*Not at all*" to 3 = "*A lot*" that were combined to derive a score ranging from 0 (less frequent use) to 6 (more frequent use). Continuous scores from each subscale were standardized using *z*-scores to ease comparisons with prior work. Participants with missing data on any item were excluded.

Following recent work (Ng et al., 2024a; Trudel-Fitzgerald, 2022, 2024a; Blanke et al., 2020), we used this single assessment to derive the dispositional Between-Strategy Index ($SD_{between}$) that captures the variability one *typically* has in use of their coping strategies. This $SD_{between}$ reflects the amount of variation in the frequency of use of the eight coping strategies (Blanke et al., 2020). Individuals with higher variability levels display frequency scores that are highly uneven across the eight coping strategies; thus, they are more likely to select and rely one or a few strategies only and fail to use others when managing stressors. Conversely, those with lower variability levels display frequency scores that are highly similar across the eight coping strategies; thus, they are more likely to use all or nearly all strategies to a similar extent across situations. Lastly, individuals scoring in the moderate range display frequency scores that are only moderately uneven across the eight coping strategies; thus, they tend to use most or all strategies but to varying extent depending on the strategy, perhaps reflecting efforts to find the best fit or prioritize a given strategy for a given context (Blanke et al., 2020). Thus, moderate (vs. greater or lower) variability is conceptualized as the most flexible way of coping with stressors. Accordingly, prior work has shown that lower and higher variability levels, relative to moderate levels, are related to poorer psychological health and longevity (Trudel-Fitzgerald, 2022; Dixon-Gordon et al., 2015). To investigate potential discontinuity effects (Cheng et al., 2014), we created tertiles of the dispositional Between-Strategy Index score (lower, moderate, greater levels). Mean strategy use score was also adjusted in all models with coping variability to reflect that participants with consistently low or high mean strategy scores are unable to show high levels of variability due to floor or ceiling effects (Trudel-Fitzgerald, 2022, 2024a; Blanke et al., 2020).

Cardiometabolic conditions. Hypertension status and body weight were self-reported on each biennial questionnaire (i.e., every 2 years) until 2019, the last available follow-up assessment for these endpoints, for a total follow-up period of 18 years. Height was self-reported in 1989 at the inception of NHSII. Such self-reported health measures have been found reliable and valid when compared with physical measures and medical records (Kim et al., 2014; Okura et al., 2004), including among health professionals like nurses (Bao et al., 2016; Colditz et al., 1986; Rimm et al., 1990). New onset hypertension was identified when women indicated receiving a new diagnosis of high blood pressure or initiating use of hypertensive medication since the prior biennial questionnaire. Participants were classified as having new onset obesity if the calculation of their BMI, using self-reported height and weight, reached $\geq$30 kg/m^2 since the prior biennial questionnaire. Overall stability of hypertension and obesity statuses across the seven follow-up assessments, from 2005 to 2019, is fairly high (intra-class correlation coefficients: hypertension = 0.64, 95%CI = 0.64-0.64; obesity = 0.70, 95% CI = 0.69-0.70).

Covariates. Relevant demographic, health-related, and behavioral factors were self-reported at the 2001 baseline, unless otherwise noted. Demographic factors, which could confound the associations of coping with hypertension or obesity, respectively, included age (continuous), race/ethnicity (Non-Hispanic White, underrepresented individuals [combining Asian, Black, Native American, and Hawaiian to ensure sufficient statistical power]; reported in 1989), neighborhood SES using census tract income data (continuous; of note, no relevant individual-level SES information was available), and marital status (married/in a relationship, divorced/separated/widowed). Health-related factors, as considered as potential confounders, included postmenopausal status (yes, no) and family history of cardiometabolic diseases, including heart disease, stroke, and diabetes (yes, no).

Behavioral factors may confound but also mediate the associations of interest, or even be coping strategies themselves (e.g., sleeping longer to avoid facing a stressor) (Mezuk et al., 2017; Park et al., 2014). To ensure that, at a minimum, they do not confound the associations of interest, we controlled for baseline levels of physical activity, diet quality, alcohol and tobacco consumption, and sleep duration at baseline. Physical activity was measured with a validated questionnaire, which showed high correlations with activity reported on past-week activities recalls and 7-day activity diaries (Wolf et al., 1994), from which total MET-hours/week was derived (continuous). Women reported their current smoking status (current, former, or never smoker), which prior work has found to be highly correlated with toenail nicotine levels in female nurses (Al-Delaimy et al., 2002). Sleep was characterized with a single item querying duration (i.e., $\leq$6, 7-8, $\geq$9 h), which has been found to be highly correlated with sleep diaries information among female nurses (Patel et al., 2004).

Dietary information was reported in 2003 with the 131 item Food Frequency Questionnaire, which has high reproducibility and validity when compared with 1-week diet records over a one-year period (Yuan et al., 2017). Diet scores were derived from the Alternative Healthy Eating Index (AHEI), a revised version from the U.S. Department of Agriculture Healthy Eating Index (McCullough et al., 2002) and incorporate: higher intake of vegetables, fruit, whole grains, nuts and legumes, long-chain (n-3) fatty acids, polyunsaturated fats; lower intake of sugar-sweetened beverages and fruit juice, red/processed meat, saturated fats, sodium. The conventional score for each dietary component ranges from 0 (worst dietary behavior) to 10 (optimal dietary behavior), and then scores were summed, yielding a continuous total score ranging from 0 to 100. Reported alcohol consumption frequency (e.g., beer, wine, liquor) in 2003 was used categorically (0/drink per day, >0 to <2 drinks/day, $\geq$2 drinks/day) to account for potential protective effects on cardiovascular outcomes related to moderate consumption (Mostofsky et al., 2016; Krittanawong et al., 2022). Participants with missing data on any items assessing covariates were excluded.

2.3. Statistical analysis

Descriptive statistics. All statistical analyses were conducted using SAS v9.4. We first calculated the means and standard deviation (SD) or frequencies for each covariate within the analytic sample (N = 26,126) and across coping variability levels. We then computed Pearson and Spearman correlations across the scores of the eight COPE subscales and three variability levels to evaluate the associations between individual strategies and with the variability scores.

Primary models. Cox proportional hazards regression models were used to assess the hazard ratios (HR) and 95% confidence intervals (CI) of hypertension and obesity, separately, from 2001 analytic baseline to new onset of hypertension/obesity, end of follow-up (June 2019), or death, whichever came first. The relationship of coping variables with onset of each condition was examined in four sets of nested models. Specifically, analyses progressively accounted for age (Model 1), + demographics (Model 2), + health-related factors (core Model 3). Because behavioral factors can play various roles in the associations of interest, they were then added to all other covariates in an exploratory model (Model 4); we entered them simultaneously to account for their shared variance and have a better sense of their respective unique effects in the coping-cardiometabolic health linkage. Individual coping strategies were considered continuously [standardized; per 1-SD], while coping variability was used categorically (lower, moderate, higher levels; examining all possible contrasts). We also performed a sensitivity analysis for the primary models to assess robustness of the results when using multiple imputation (n = 5 datasets) rather than participants' exclusion to handle missing data on covariates, which ranged from 0.0% to 7.7% across variables. All analyses were lagged for 2 years, to reduce concerns about potential reverse causation.

Secondary models. We performed three sets of secondary analyses. First, unadjusted Kaplan-Meier curves were implemented to depict the relation of coping exposures with hypertension and obesity incidence, respectively. Second, to quantify the influence of unmeasured confounders, we calculated the E-value, defined as the minimum strength of association that an unmeasured confounder would need to have with both exposure and outcome to fully explain an observed association (VanderWeele et al., 2017; Mathur et al., 2018). Third, based on prior evidence showing age-, menopausal- and socioeconomic-related disparities in coping and cardiometabolic health (Ebong et al., 2024; Mezuk et al., 2017; Brennan et al., 2012; Broni et al., 2022; El et al., 2020; Endalifer et al., 2020), we included interaction terms of each continuous coping strategy with age (median-split; <45 years old vs. $\geq$45 years old), postmenopausal status (yes, no), and neighborhood SES (median-split; <\$65,000 vs. $\geq$\$65,000) subgroups, separately, in distinct Cox models with each outcome, while adjusting for all demographic and health-related variables (core Model 3). If interaction terms were statistically significant, we then conducted stratified analyses to evaluate the association of individual coping strategies with hypertension and obesity onset, separately, in each age, postmenopausal, and neighborhood SES subgroups using Model 3.

3. Results

3.1. Baseline characteristics

Table 1 shows descriptive statistics in the total analytic sample (N = 26,126) and stratified by coping variability levels. At study baseline, women were on average 45.9 years (SD = 4.6) and lived in a neighborhood with average neighborhood SES of \$68K (\$25K); most were non-Hispanic White (96.5%) and married/in a relationship (83.3%). Over a fifth of participants were post-menopausal (22.2%) and half had a family history of cardiometabolic diseases (50.0%); most reported favorable health behaviors, including sleeping 7-8 h/day (69.9%), being a never smoker (68.1%), and consuming >0 and < 2 alcoholic drinks/day (64.6%). Characteristics were remarkably similar

Table 1
Distribution of baseline covariates in the overall sample and according to coping variability levels[a] in 2001.

	Total (n = 26,126)	Coping variability levels: Lower (n = 8665)	Moderate (n = 8917)	Greater (n = 8544)
Demographic factors				
Age, M(SD)	45.9 (4.6)	45.9 (4.6)	45.8 (4.6)	46.0 (4.6)
Non-Hispanic White[b], %	96.5	96.2	96.5	96.7
Married/in a relationship, %	83.3	82.2	83.9	83.9
Census tract income in thousands of dollars, M(SD)	68 (25)	68 (24)	68 (24)	69 (25)
Health-related factors				
Family history of CMD, %	50.0	51.3	49.0	49.8
Postmenopausal status, %	22.2	22.7	21.4	22.6
Behavioral factors				
Smoking status				
never smoker, %	68.1	66.0	68.7	69.5
former smoker, %	24.8	25.4	24.3	24.6
current smoker, %	7.2	8.6	6.9	6.0
Sleep duration				
≤6 h/day, %	25.1	27.6	24.4	23.2
7-8 h/day, %	69.9	67.9	70.7	71.2
≥9 h/day, %	5.0	4.5	4.8	5.7
Alcohol consumption				
no drinks/day, %	31.5	29.8	30.5	34.4
>0 and < 2 drinks/day, %	64.6	66.4	65.5	61.9
≥2 drinks/day, %	3.8	3.8	4.0	3.7
Physical activity (MET-hours/week), M(SD)	24.1 (28.1)	22.5 (27.5)	24.3 (27.7)	25.5 (29.2)
AHEI diet quality score, M(SD)	52.5 (12.3)	51.6 (12.1)	52.7 (12.4)	53.3 (12.5)

Notes. Values are means (SD) for continuous variables and percentages for categorical variables. Values of polytomous variables may not sum to 100% due to rounding.
AHEI=Alternative Healthy Eating Index; CMD = cardiometabolic diseases (i.e., heart disease, diabetes, and stroke).
[a] There were too many (i.e., 8) individual coping strategies assessed to present covariates' distribution by each of them.
[b] Because the Non-White category represents only 3.55% of the total sample, its subcategories – namely Asian (1.38%), Hispanic (1.25%), Black (0.52%), Native American (0.31%), and Hawaiian (0.09%) – were too small and could not be studied separately.

across coping variability levels, although women displaying greater coping variability levels were slightly less likely to be short sleepers (≤6 h/night) and more likely to be alcohol abstinent.

Additional descriptive statistics support the independent nature of coping exposures and their examination separately. As shown in Suppl. Table 2**,** while nearly all coping strategies were significantly correlated with one another, the magnitude of these associations was overall small-to-moderate ($|r| = .01$ to 0.34) with adaptive versus maladaptive coping strategies inversely correlated. Moreover, lower variability levels were correlated with less frequent use of adaptive strategies (e.g., active coping, acceptance, use of emotional support) and more frequent use of maladaptive strategies (e.g., denial, behavioral disengagement). Correlation patterns were in inverse directions for greater variability levels (i.e., more frequent use of adaptive strategies and less frequent use of maladaptive strategies). Most coefficients between moderate variability levels and (mal)adaptive strategies were around the null.

3.2. Associations of coping with hypertension and obesity incidence

Over the 18-year follow-up period, 7019 (26.9%) and 3855 (14.8%) women developed hypertension and obesity, respectively. Table 2 reports associations of baseline coping exposures with risk of developing hypertension. In age-adjusted models (Model 1), most adaptive and maladaptive strategies were unrelated to risk of developing hypertension, except for using religion (HR = 0.97, 95%CI = 0.95-0.995), behavioral disengagement (HR = 1.02, 95%CI = 1.0002-1.05), and self-blame (HR = 1.03, 95%CI = 1.01-1.06). All estimates were similar after further progressive adjustment for demographics (Model 2) and health-related factors (core Model 3) and were slightly attenuated with behavioral factors (Exploratory Model 4; $HR_{religion}$ = 0.96, 95% CI = 0.94-0.99, $HR_{behavioral\ disengagement}$ = 1.02, 95%CI = 0.995-1.04, $HR_{self\text{-}blame}$ = 1.03, 95%CI = 1.01-1.05). However, variability in coping strategies used was more strongly related to risk of developing hypertension. Specifically, when compared to women with lower variability levels, those with greater variability levels had a 10% lower hypertension risk in the age-adjusted model (HR = 0.90, 95%CI = 0.85-0.96). The estimate was robust to additional control for demographic factors (HR = 0.91, 95%CI = 0.85-0.96) and health-related factors (HR = 0.91, 95%CI = 0.86-0.97), but the CI became slightly wider when further adding behavioral factors (HR = 0.94, 95%CI = 0.89-1.002). Similar patterns were obtained when contrasting greater to moderate variability levels, and no clear difference was evident when contrasting moderate to lower levels. Among behavioral covariates, all were significantly associated with hypertension onset (e.g., in model 4 using religion as the exposure: $HR_{physical\ activity}$ = 0.998, 95%CI = 0.998-0.99945; HR_{diet} = 0.99, 95%CI = 0.99-0.99; $HR \geq_{2\ drinks/day\ vs.\ abstinence}$ = 1.73, 95%CI = 1.56-1.93; $HR_{former\ vs.\ never\ smokers}$ = 1.15, 95%CI = 1.09-1.22; $HR_{current\ vs.\ never\ smokers}$ = 1.27, 95%CI = 1.17-1.38; $HR \leq_{6\ h\ vs.\ 7\text{-}8h/night}$ = 1.15, 95%CI = 1.09-1.21). Fig. 1 shows the unadjusted Kaplan-Meier curves for hypertension incidence in relation to coping variability levels.

Several coping strategies were associated with increased risk of developing obesity, as shown in Table 3. For example, in age-adjusted models, every 1-SD increase in active coping was associated with a 5% (HR = 0.95, 95%CI = 0.92-0.98) lower risk of developing obesity over the 18-year follow-up period, whereas each 1-SD increase in denial, behavioral disengagement, and self-blame were related to a 4% (HR = 1.04, 95%CI = 1.01-1.07), 9% (HR = 1.09, 95%CI = 1.06-1.12), and 5% (HR = 1.05, 95%CI = 1.01-1.08) respectively higher risk. When further controlling for demographic and health-related factors, associations remained evident (e.g., Model 3: $HR_{active\ coping}$ = 0.96, 95% CI = 0.93-0.99; $HR_{behavioral\ disengagement}$ = 1.08, 95%CI = 1.05-1.11), but somewhat attenuated when adding behavioral factors (e.g., Model 4: $HR_{active\ coping}$ = 0.98, 95%CI = 0.95-1.01; $HR_{behavioral\ disengagement}$ = 1.05, 95%CI = 1.02-1.09). Both moderate and greater (versus lower) variability levels were associated with a 9-11% reduced obesity risk in age-adjusted models (Model 1: $HR_{moderate\ versus\ lower}$ = 0.91, 95%CI = 0.84-0.98; $HR_{greater\ versus\ lower}$ = 0.89, 95% CI = 0.82-0.96); estimates were robust to subsequent inclusion of demographic and health-related factors, but attenuated after further including behavioral factors (e.g., Model 4: $HR_{moderate\ versus\ lower}$ = 0.95, 95%CI = 0.88-1.03; $HR_{greater\ versus\ lower}$ = 0.95, 95%CI = 0.87-1.02). Compared to moderate variability levels, greater levels were unrelated to risk of developing obesity across nested models. All behavioral covariates except alcohol consumption were significantly associated with obesity onset (e.g., in model 4 using active coping as the exposure: $HR_{physical\ activity}$ = 0.99, 95%CI = 0.99-0.99; HR_{diet} = 0.995, 95% CI = 0.99-0.997; $HR_{former\ vs.\ never\ smokers}$ = 1.18, 95%CI = 1.09-1.27; $HR_{current\ vs.\ never\ smokers}$ = 1.47, 95%CI = 1.32-1.64; $HR \leq_{6\ h\ vs.\ 7\text{-}8h/night}$ = 1.23, 95%CI = 1.15-1.32). Unadjusted Kaplan-Meier curves for obesity incidence in relation to coping variability levels are shown in Fig. 2. For both hypertension and obesity sensitivity analyses, results were nearly identical when using multiple imputation instead of

Table 2
Risk of developing hypertension up to 2019 associated with the adoption of coping individual strategies and variability levels in 2001.

	Model 1: Age HR (95% CI)	Model 2: Demographics HR (95% CI)	Core Model 3: Model 2 + health-related factors HR (95% CI)	Exploratory Model 4: Model 3 + behavioral factors HR (95% CI)	E-values (using Model 3 estimates)
Individual coping strategies (per *1-SD increase)*					
Active Coping	0.98 (0.96, 1.00)§	0.98 (0.96, 1.00)	0.98 (0.96, 1.01)	1.00 (0.97, 1.02)	
Acceptance	0.99 (0.97, 1.02)	0.99 (0.97, 1.01)	0.99 (0.97, 1.01)	0.99 (0.97, 1.02)	
Religion	0.97 (0.95, 0.995)*	0.96 (0.94, 0.99)**	0.96 (0.94, 0.99)**	0.99 (0.96, 1.01)	1.20
Use of Emotional Support	1.00 (0.97, 1.02)	1.00 (0.98, 1.02)	1.00 (0.98, 1.02)	1.01 (0.99, 1.04)	
Focus on & Venting of Emotions	0.99 (0.96, 1.01)	0.99 (0.97, 1.01)	0.99 (0.96, 1.01)	0.99 (0.96, 1.01)	
Denial	1.02 (0.998, 1.04)§	1.02 (0.997, 1.04)§	1.02 (0.996, 1.04)	1.01 (0.99, 1.03)	
Behavioral Disengagement	1.02 (1.0002, 1.05)*	1.02 (0.998, 1.04)§	1.02 (0.995, 1.04)	1.01 (0.99, 1.03)	
Self-Blame	1.03 (1.01, 1.06)*	1.03 (1.01, 1.06)**	1.03 (1.01, 1.05)*	1.02 (0.99, 1.04)	1.17
Variability in coping strategies used					
Moderate versus lower variability	0.96 (0.91, 1.02)	0.97 (0.91, 1.02)	0.97 (0.92, 1.03)	0.99 (0.94, 1.05)	
Greater versus lower variability	0.90 (0.85, 0.96)***	0.91 (0.85, 0.96)***	0.91 (0.86, 0.97)**	0.94 (0.89, 1.002)§	1.34
Greater versus moderate variability	0.94 (0.88, 0.99)*	0.94 (0.89, 0.996)*	0.94 (0.89, 0.995)*	0.95 (0.90, 1.01)§	1.26

Notes. N = 26,126, n_{events} = 7019 (number of events per variability levels: lower = 2421, moderate = 2399, greater = 2199).
§$p \le 0.10$; *$p \le 0.05$; **$p \le 0.01$; ***$p \le 0.001$. CI = confidence interval, HR = hazard ratio, SD = standard deviation.
The first four individual coping strategies are typically considered more adaptive whereas the last four strategies are typically deemed less adaptive. Although individual coping strategies and coping variability levels are presented in the same table, they represent distinct analyses.
Model 1 adjusted for age. Model 2 adjusted for age, race/ethnicity, marital status, and census tract income. Model 3 (core) adjusted for Model 2 and family history of cardiometabolic diseases and postmenopausal status. Model 4 (exploratory) adjusted for Model 3 as well as smoking, sleep, alcohol consumption, physical activity, and diet quality. All coping variability models further adjusted for mean of all individual coping strategies.

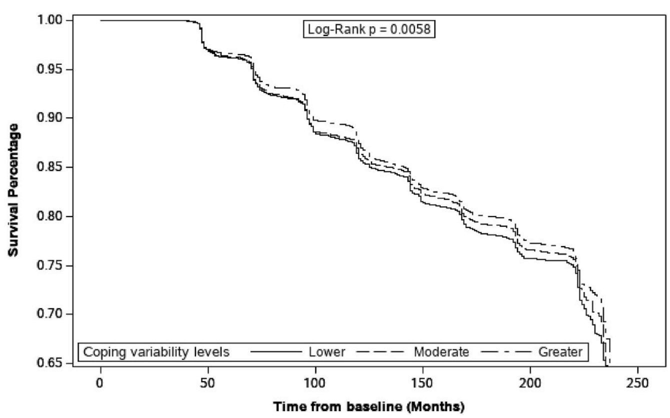

Fig. 1. Unadjusted Kaplan-Meier curves for hypertension incidence up to 2019 in relation to coping variability levels in 2001.

participants' exclusion to handle covariate missingness. Only the associations of onset of obesity with denial and self-blame use, respectively, were attenuated and no longer statistically significant, likely due to their initial small magnitude. For example, in the primary models, findings with complete-case were: HR_{denial} = 1.03, 95%CI = 1.001-1.06; $HR_{self\text{-}blame}$ = 1.04, 95%CI = 1.004-1.07 and with multiple imputation were: HR_{denial} = 1.02, 95%CI = 0.99-1.05; $HR_{self\text{-}blame}$ = 1.02, 95%CI = 0.996-1.05.

3.3. Potential residual confounding

Tables 2 and 3 also report E-values obtained for each association, after adjusting for demographics and health-related factors (Model 3). Coefficients vary from 1.17 to 1.34 in hypertension models and from 1.17 to 1.36 in obesity models. These values suggest that the observed estimates could be explained away only by an unmeasured confounder that was related, beyond the measured covariates, to both coping exposures and the cardiometabolic conditions with a risk ratio (E-value) of 1.17- to 1.36-fold each.

3.4. Differences by age, postmenopausal status, and neighborhood SES

No interaction terms between coping strategies and any of the potential effect modifiers reached statistical significance in models evaluating risk of developing obesity. In models assessing hypertension onset, many interaction terms were marginally significant at $p < .10$, and one reached the statistically significant threshold of $p < .05$ (i.e., active coping*neighborhood SES, $p = 0.01$). Related stratified analyses using core Model 3 showed that greater use of active coping was related to lower risk of developing hypertension among higher versus lower neighborhood SES women ($HR_{<\$65,000}$ = 1.01, 95%CI = 0.98-1.04, $HR_{\geq\$65,000}$ = 0.95, 95%CI = 0.92-0.98).

4. Discussion

This study examined whether strategies women generally use to cope with stressors and the variability in the use of such strategies were associated with risk of developing either hypertension or obesity over 18 years. Overall, results adjusting for key demographic and health status covariates indicated that individual coping strategies were not clearly associated with risk of developing hypertension in the entire sample. However, greater use of active coping was related to 4% lower risk of developing obesity, whereas greater use of denial, behavioral disengagement, and self-blame were related to 3-8% higher such risk. Moreover, coping variability levels, which generally reflect attempts to find the best coping strategy for a given stressor, were associated with new onset of each condition, whereby greater (vs. lower) variability levels were significantly related to 8-10% lower hazard of developing hypertension and obesity, separately. Although these estimates may appear relatively modest, they could in fact be conservative as this study assessed onset of these cardiometabolic conditions starting when women were already at midlife. Besides, estimates were only slightly smaller in magnitude to the hazards incurred by traditional risk factors like diet quality in the current analytic sample (e.g., in age-adjusted models predicting new onset hypertension [$HR_{per\ 1\text{-}SD\ increase\ in\ diet\ quality}$ = 0.87,

Table 3
Risk of developing obesity up to 2019 associated with the adoption of coping individual strategies and variability levels in 2001.

	Model 1: Age HR (95% CI)	Model 2: Demographics HR (95% CI)	Core Model 3: Model 2 + health-related factors HR (95% CI)	Exploratory Model 4: Model 3 + behavioral factors HR (95% CI)	E-values (using Model 3 estimates)
Individual coping strategies (per 1-SD increase)					
Active Coping	0.95 (0.92, 0.98)***	0.96 (0.93, 0.99)**	0.96 (0.93, 0.99)**	0.98 (0.95, 1.01)	1.20
Acceptance	1.00 (0.97, 1.03)	0.99 (0.96, 1.02)	0.99 (0.96, 1.02)	0.99 (0.96, 1.03)	
Religion	0.98 (0.95, 1.01)	0.97 (0.93, 0.996)*	0.96 (0.93, 0.995)*	0.98 (0.94, 1.01)	1.20
Use of Emotional Support	1.00 (0.97, 1.03)	1.00 (0.97, 1.03)	1.00 (0.97, 1.04)	1.03 (0.99, 1.06)	
Focus on & Venting of Emotions	1.02 (0.99, 1.05)	1.03 (0.99, 1.06)	1.03 (0.99, 1.06)	1.03 (1.00, 1.06)§	
Denial	1.04 (1.01, 1.07)*	1.03 (1.002, 1.07)*	1.03 (1.001, 1.06)*	1.02 (0.99, 1.05)	1.17
Behavioral Disengagement	1.09 (1.06, 1.12)***	1.08 (1.05, 1.11)***	1.08 (1.05, 1.11)***	1.05 (1.02, 1.09)***	1.30
Self-Blame	1.05 (1.01, 1.08)**	1.04 (1.01, 1.07)*	1.04 (1.004, 1.07)*	1.02 (0.99, 1.05)	1.20
Variability in coping strategies used					
Moderate versus lower variability	0.91 (0.84, 0.98)**	0.92 (0.85, 0.99)*	0.92 (0.85, 0.995)*	0.95 (0.88, 1.03)	1.31
Greater versus lower variability	0.89 (0.82, 0.96)**	0.90 (0.83, 0.97)**	0.90 (0.83, 0.98)**	0.95 (0.87, 1.02)	1.36
Greater versus moderate variability	0.98 (0.90, 1.06)	0.98 (0.90, 1.06)	0.98 (0.90, 1.06)	1.00 (0.92, 1.08)	

Notes. N = 26,126, n_{events} = 3855 (number of events per variability levels: lower = 1360, moderate = 1280, greater = 1215).
§$p \leq 0.10$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$. CI = confidence interval, HR = hazard ratio, SD = standard deviation.
The first four individual coping strategies are typically considered more adaptive whereas the last four strategies are typically deemed less adaptive. Although individual coping strategies and coping variability levels are presented in the same table, they represent distinct analyses.
Model 1 adjusted for age. Model 2 adjusted for age, race/ethnicity, marital status, and census tract income. Model 3 (core) adjusted for Model 2 and family history of cardiometabolic diseases and postmenopausal status. Model 4 (exploratory) adjusted for Model 3 as well as smoking, sleep, alcohol consumption, physical activity, and diet quality. All coping variability models further adjusted for mean of all individual coping strategies.

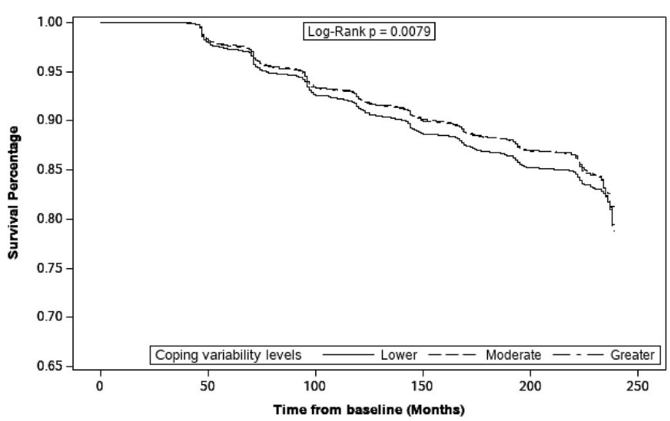

Fig. 2. Unadjusted Kaplan-Meier curves for obesity incidence up to 2019 in relation to coping variability levels in 2001.

95%CI = 0.85-0.89] and new onset obesity [$HR_{per\ 1\text{-}SD\ increase\ in\ diet\ quality}$ = 0.86, 95%CI = 0.84-0.89]). Lastly, E-values suggested that residual unmeasured confounding was unlikely to be substantial, at least for moderate and greater (vs. lower) variability levels.

4.1. Distinct associations of coping strategies with new onset of either hypertension or obesity

The fact that certain but not all individual coping strategies were related to our cardiometabolic endpoints is consistent with prior empirical research on coping strategies and future risk of diabetes (Ng et al., 2024a) and CVD (Nagayoshi et al., 2023; Roohafza et al., 2022; Svensson et al., 2016). However, the presence of associations mainly with obesity relative to hypertension appears at first unexpected. In fact, both conditions share some common underlying processes that can affect them, including sleep disruptions and lack of physical activity, as well as increased sympathetic nervous system activity (German et al., 2022; Akanji, 2024); they have also been identified as having some of the most impactful effects on cardiovascular health (German et al., 2022). These divergent results may reflect outcome-specificity for certain stress-related coping exposures. In line with this possibility, a meta-analysis conducted among 47,000 adults showed that higher levels of job strain – a work-related stressor that is frequently encountered by nurses (Khamisa et al., 2013) – was associated with higher obesity but not hypertension incidence, beyond age, sex, and socioeconomic covariates (Nyberg et al., 2013). It may be that stress-related processes like coping have a greater impact on short-term blood pressure fluctuations, an effect that has been observed in many experimental studies (Tyra et al., 2024; Chida et al., 2010), than whether individuals develop hypertension over the life course.

However, because other findings have shown that various psychosocial determinants are associated with both conditions (Eleazu et al., 2025; Azizi et al., 2024), alternative explanations may be needed. One of these may be that hypertension is widespread and largely depends on age. Or it may be that the coping-hypertension association differs depending on the subpopulation. In fact, when evaluating whether associations of coping strategies with hypertension and obesity incidence differ by age, postmenopausal, and neighborhood SES subgroups, findings revealed some differences across these subgroups in relation to hypertension only. Among differences that reached statistical significance, a protective association of active coping with risk of developing hypertension was noted only among women with a higher neighborhood SES. This result may reflect that women who live in poorer neighborhoods can face barriers (e.g., limited access to psychosocial services, time poverty due to excessive domestic labor) to learning this coping strategy or implementing it effectively (Felix et al., 2019), in turn making active coping less potent with regards to hypertension onset in this subpopulation. It is unclear, however, why such processes were not also evident in relation to onset of obesity in this sample of midlife participants. Future work should verify whether such effect modification exists for both conditions earlier in life.

Alternatively, our divergent results in the associations of specific coping strategies and new onset of hypertension or obesity may suggest that variability in the use of coping strategies, rather than the strategies themselves, may be the coping process that confers the greatest benefit.

Indeed, coping variability was associated with both outcomes in our sample. This suggests that the extent to which individuals favor one or a few strategies over others, which presumably mirrors their attempts to find the best strategy for a given situation, may be more protective than the impact of single (adaptive) strategies themselves. Such results have important practical implications. For instance, recent clinical approaches that aim to promote flexible and favorable coping processes, such as transdiagnostic (Sauer-Zavala et al., 2021) and mindfulness (Gu et al., 2015) psychotherapies, could potentially contribute to better cardiometabolic health over time beyond their established positive impact on common mental health outcomes (Carlucci et al., 2021; Dou et al., 2025). In fact, recent reviews of studies conducted in various populations indicate that improving the ways individuals manage stress via mindfulness interventions may lead to better health outcomes, including improvements in blood pressure and body weight indices (Geiger et al., 2023; Carriere et al., 2018).

4.2. Behavioral, biological, and psychological mechanisms

Various underlying mechanisms could explain the role of coping strategies and variability in their use in risk of developing obesity and hypertension. From a behavioral standpoint, prior conceptual and theoretical models in social epidemiology and health psychology posit that health behaviors lie on the pathway linking psychological factors, including coping processes, to cardiometabolic endpoints (Epel et al., 2018; Trudel-Fitzgerald et al., 2024b; Cohen et al., 2016). Supporting this premise is the attenuation of most, albeit not all, estimates for coping-related exposures when additionally controlling for smoking status, physical activity frequency, diet quality, alcohol consumption, and sleep duration in the current study. Indeed, all these behavioral covariates were significantly associated with both of our cardiometabolic outcomes, except alcohol consumption in obesity models, suggesting common underlying behavioral pathways across these two conditions. It is worth noting, however, that the role of health behaviors in coping-health outcome relationships is complex, as health behaviors can be confounders, mediators, or coping strategies themselves (Mezuk et al., 2017; Park et al., 2014). For instance, individuals may turn to food as a distracting or comforting coping strategy in the face of stressors, leading to a cycle of emotional eating and weight gain (Segal et al., 2025), which can increase obesity risk. In the current study with participants in the NHSII, health behaviors are queried as habitual habits rather than stress-related strategies (e.g., “Do you smoke cigarettes regularly now?” vs. “Do you smoke to relieve tension?”). Thus, future work is warranted to determine whether associations observed between coping and risk of developing either hypertension or obesity is similarly explained by habitual vs. stress-related health behaviors.

From a biological standpoint, prior conceptual models further postulated several physiological processes that could explain how stress-related coping “gets under the skin" (Epel et al., 2018; Trudel-Fitzgerald et al., 2024b; Cohen et al., 2016). Such processes include allostatic load, an index reflecting poorer functioning of the autonomic, neuroendocrine, metabolic, and immune systems that is influenced by varied indicators of stress (Magan et al., 2025; Mauss et al., 2021; Finlay et al., 2022) and is an established predictor of cardiovascular disease and mortality (Parker et al., 2022; Guidi et al., 2021; Evans et al., 2025). Accordingly, a prior longitudinal study conducted among midlife and older adults showed that greater vs. moderate coping variability levels were related to lower allostatic load over 10 years (Ng et al., 2024b). Interestingly, this prior study did not find evidence for an association between single coping strategies and allostatic load, mirroring our results that coping variability may be more health-beneficial than single strategies. Such evidence further raises the possibility that allostatic load is a potential underlying mechanism specific to coping variability. Per the allostatic load model, displaying greater levels of coping variability possibly promotes more favorable stress appraisals, less intense subsystem activation, and quicker physiologic recovery following stressors relative to lower variability levels that presumably reflect more rigidity in the use of any single coping strategies. Other processes associated with poorer cardiometabolic health, including carotid intima media thickness and cardiovascular reactivity, have also been associated with greater use of avoidant coping strategies like denial (Schwerdtfeger et al., 2015) and of repression (Howard et al., 2017).

From a psychological standpoint, adaptive coping processes may contribute to more favorable cardiometabolic outcomes because they promote greater psychological resilience to stressors. In fact, several authors have recently argued that stress-related coping is a key mechanism of psychological resilience (Trudel-Fitzgerald, 2024c; Troy et al., 2023; Bonanno, 2021). Accordingly, emerging research conducted in a male-only sample suggests that lower compared to higher resilience was associated with greater hypertension risk over time (Crump et al., 2016). To our knowledge, no longitudinal study has evaluated the role of psychological resilience in relation to obesity onset specifically, but prospective research on related constructs shows that higher psychological resilience is related to a healthier body weight (Nishimi et al., 2022) as well as lower risk of cardiometabolic diseases like diabetes and all-cause mortality (Nishimi et al., 2023; Hahad et al., 2025).

4.3. Limitations and strengths

This study has some limitations. First, our sample of female nurses was mainly composed of non-Hispanic White individuals. Thus, further research is needed to evaluate if similar associations of stress-related coping with risk of developing hypertension and obesity are evident among minority women or among men. Moreover, individuals who choose to be nurses may be more emotionally resilient than other working women (Williams et al., 2009), which may in fact underestimate the role of coping processes in cardiometabolic health at the population level. Likewise, nurses may be more conscientious about their health (e.g., be more self-disciplined towards lifestyle factors that matter for cardiometabolic health) than women in the general population (Williams et al., 2009; Louwen et al., 2023). Although prior findings on lifestyle factors from occupational cohorts are generally similar to those of the general population (Batty et al., 2014), examining these associations among more diverse occupational and racial/ethnic samples is warranted.

Second, misclassification of hypertension and obesity cases, respectively, may have occurred, despite the fairly high stability of hypertension and obesity statuses suggested by the magnitude of our intraclass correlation coefficients. Relatedly, using a BMI threshold to define obesity has been debated and recent work has acknowledged that obesity is a complex, multifactorial condition that is not fully reflected in the current measure of BMI (Weir et al., 2022; Rubino et al., 2025). However, various alternative indices, including mean weight and waist circumference, increased similarly to BMI between 1999 and 2016 in the U.S. (Fryar et al., 2018) and elsewhere (Endalifer et al., 2020). Moreover, substantial research shows that obesity defined according to BMI thresholds is associated with a wide array of adverse physical health outcomes (Endalifer et al., 2020), notably among female nurses (Hruby et al., 2016). Lastly, findings from the Whitehall II study, a cohort of midlife adults, showed that BMI, waist circumference, and waist-to-height index increased similarly over 10-12 years and that stress-related factors (e.g., psychological distress, relationships conflicts) had, overall, similar associations with each of these indices (Kubera et al., 2017; Kouvonen et al., 2011).

Third, stressors that trigger the use of various coping strategies vary in intensity and chronicity, as well as across participants. Information about these features, which likely drives the selection and implementation of coping strategies and variability in their use, as well as the determination of whether strategies are truly more or less adaptive, was not available in the current study. Yet, previous evidence is reassuring. Using the COPE inventory, prior findings showed moderate-to-high consistency between the dispositional and situational (i.e., across distinct contexts/stressors) versions of the inventory (Carver et al., 1989, 1994). Moreover, other research on variability in the use of such strategies indicated a clear consistency between dispositional between-strategy variability (captured at a single time assessment, as in the current study) and within-strategy variability (captured across multiple daily assessments; meta-analytic $r = 0.47$, $p < 0.001$) (Blanke et al., 2020). In addition, recent work indicated that the association of coping strategies and variability with future allostatic load, an index of physiological dysregulations including blood pressure and BMI, did not vary as a function of psychosocial stress levels reported by midlife adults (Ng et al., 2024b). Likewise, other features related to coping processes themselves were unavailable in the current study. For instance, individuals' appraisal of a given stressor and perceived effectiveness of strategies used are coping components that are distinct from the (mal) adaptive nature of strategies or the variability/flexibility in their use and also included in the allostatic load model (McEwen, 2000; Parker et al., 2022). These components could be important and deserve empirical attention in future health research.

Several strengths are also worth noting. First, we leveraged data from a large and richly characterized sample, using a prospective study design covering over a decade. Further, we considered many coping strategies documented via a validated coping scale and adjusted for a broad range of potential confounders. Lastly, we moved beyond the traditional categorization of adaptive versus maladaptive strategies by assessing if variability in their use was associated with cardiometabolic endpoints over time. Future research should explore alternative modeling approaches, including data-driven methods like latent profile analysis, to characterize individuals' coping processes.

4.4. Conclusion

Altogether, findings indicate that the ways women cope with stressors are associated with risk of developing two cardiometabolic conditions that contribute to lifelong cardiovascular health. In particular, a greater use of strategies deemed adaptive (e.g., active coping), a lower use of strategies viewed as maladaptive (e.g., behavioral disengagement) and, more importantly, an overall greater flexibility in the use of these strategies were related to a reduced hazard of developing obesity or hypertension in this sample of midlife women. Because these associations were observed beyond the influence of traditional sociodemographic and health-related risk factors, future intervention research should consider whether integrating stress-related coping processes to evaluate whether their consideration can potentiate current prevention efforts.

Ethics approval statement

The study protocol was approved by the Institutional Review Boards of the Brigham and Women's Hospital and the Harvard T.H. Chan School of Public Health (#1999P003389), Université du Québec à Trois-Rivières (#CERPPE-22-04-10.05) and Centre Intégré Universitaire de Santé et Services Sociaux de l'Est-de-l'Île-de-Montréal (#2022-2968).

Data statement

Nurses' Health Studies data are not publicly available but can be accessed. Information including the procedures to obtain and access data from the Nurses' Health Studies is described at https://www.nurseshealthstudy.org/researchers (contact email: nhsaccess@channing.harvard.edu); study materials are available at: https://www.nurseshealthstudy.org/participants/questionnaires. Analytic methods will be provided upon request to the first author.

Ethical statement

The study protocol was approved by the IRBs of the Brigham & Women's Hospital/Harvard T.H. Chan School of Public Health (#1999P003389), the Université du Québec à Trois-Rivières (#CERPPE-22-04-10.05) and the CIUSSS de l'Est-de-l'Île-de-Montréal (#2022-2968).

Funding Statement

This work was supported by the National Institutes of Health [grants U01 CA176726 and U01 HL145386] to The Nurses' Health Study II and a PAIR grant from Université du Québec à Trois-Rivières awarded to CTF. CTF also holds the Research Chair on Social Disparities, Stress-Related Coping, and Health from the Université du Québec à Trois-Rivières and received research funds from the Fondation de l'Institut Universitaire en Santé Mentale de Montréal. SZ was supported by salary award from the Lee Kum Sheung Center for Health and Happiness at Harvard T.H. Chan School of Public Health.

CRediT authorship contribution statement

Claudia Trudel-Fitzgerald: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. **Scott G. Smith:** Data curation, Formal analysis, Software, Visualization, Writing – review & editing. **Shuqi Zhang:** Data curation, Formal analysis, Software, Writing – review & editing. **Laura D. Kubzansky:** Methodology, Writing – review & editing.

Acknowledgements

The authors thank the participants and the staff of the Nurses' Health Study at the Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA, for their valuable contributions.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2026.119213.

Data availability

Nurses' Health Studies data are not publicly available but can be accessed. Procedures are described at https://www.nurseshealthstudy.org/researchers.

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