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# Affect regulation and mortality risk: The role of allostatic load

Short title: Affect regulation, allostatic load, and mortality

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***Open science:*** This study was not preregistered. MIDUS data are publicly available and can be accessed at https://www.icpsr.umich.edu/web/ICPSR/series/203; and analysis code is available upon request from the first author.

**Keywords:** emotion regulation, mortality, allostatic load, coping, coping variability, anger

**Abstract**

**Objective:** Although growing evidence indicates that distinct affect regulation strategies (e.g., positive reappraisal, anger suppression) predict mortality risk, the biological processes involved remain understudied. We investigated the association of various affect regulation exposures with mortality risk while examining the role of allostatic load. **Method:** In 2004-2006, 1,941 participants from the Midlife in the United States longitudinal study completed validated scales assessing use of nine general and emotion-specific regulatory strategies (e.g., denial, anger expression). A standard deviation-based algorithm was also used to characterize how flexibly participants regulate their affect (lower, moderate, or greater variability). Participants further provided data on relevant covariates and 24 allostatic load biomarkers (e.g., cortisol, glucose). Cox regressions modeled hazard ratios (HRs) and 95% confidence intervals (CI) examined associations of affect regulation variables and all-cause mortality risk until 2022. The confounding, mediating, and moderating role of allostatic load was examined in subsequent models. **Results:** In fully-adjusted models, only greater vs. lower affect regulation variability

(HR=1.54; 95%CI=1.11-2.14) significantly predicted a higher mortality risk. Associations were relatively unchanged with further inclusion of allostatic load in models and allostatic load did not mediate affect regulation-mortality relationships. Yet, when evaluating moderation effects, greater vs. lower and moderate variability as well as denial were marginally or significantly related to higher mortality risk among adults with lower allostatic load only. **Conclusions:** Allostatic load may modify rather than confound or mediate the association between some dimensions of affect regulation and mortality risk. Future work should evaluate the potential roles of allostatic load among diverse samples.

**Abbreviations:** adjusted hazard ratio (AHR), body mass index (BMI), cardiovascular disease (CVD), Coping Orientation to Problems Experienced (COPE), C-reactive protein (CRP), dehydroepiandrosterone sulfate (DHEAS), diastolic blood pressure (DBP), general educational development (GED), glycosylated hemoglobin (HbA1c), high-density lipoprotein (HDL), Interleukin 6 (IL-6), low-density lipoprotein (LDL), Midlife in the United States (MIDUS), National Death Index (NDI), root mean squared successive differences (RMSSD), self-administered questionnaire (SAQ), Soluble Intercellular Adhesion Molecule-1 (sICAM-1), standard deviation (SD), The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), systolic blood pressure (SBP), waist-to-hip ratio (WHR).

## Introduction

Available evidence shows that both psychological distress (e.g., depression (1), posttraumatic stress disorder (2)) and psychological well-being (e.g., optimism (3), purpose in life (4)) are associated with mortality risk. Recent theoretical models further suggest that overarching psychosocial processes, such as coping and emotion regulation, may have downstream effects on long-term physical health and longevity, in part via biological and behavioral mechanisms (5–7). To date, empirical studies testing this hypothesis have been informed either by the coping (8) or the emotion regulation (9) framework. While informative, this focus has impeded the direct comparison of their respective associations with mortality within the same sample. Moreover, most of this research considered potential behavioral factors involved (e.g., smoking) when evaluating the association of coping or emotion regulation with mortality risk. To date, less attention has been devoted to the possible roles biological factors play in the aforementioned relationships.

## Coping Strategies and Mortality Risk

Coping strategies, described broadly as "cognitive and behavioral efforts to master, reduce, or tolerate the internal and/or external demands" (8), may be categorized as generally adaptive or maladaptive based on the direction of their associations with health outcomes. For example, meta-analytic findings showed that greater use of planning to cope with stressors and positive reinterpretation, which are strategies typically deemed adaptive, is associated with better physical and psychological functioning (10–12). In contrast, greater self-blame and avoidance, which are usually viewed as maladaptive, are related to poorer physical and psychological functioning (10–12).

In the context of mortality specifically, existing results are somewhat mixed. The Japan Multi-institutional Collaborative Cohort Study followed a group of 79,580 middle-aged adults over 8 years and found that various strategies typically considered adaptive were associated with lower mortality risk, beyond demographic, health status, and behavioral covariates (13). Specifically, emotional expression was related to lower mortality risk among both men and women. In addition, emotional support-seeking predicted lower mortality risk for women only while positive reappraisal and problem solving appeared beneficial for longevity only for men. In contrast, a study of 743 older men from the Veterans Affairs Normative Aging Study showed that greater use of strategies typically deemed adaptive, such as positive action, social coping, and spiritual coping, were each related to *higher* mortality risk over 27 years, after adjusting for relevant covariates (14). Lastly, results from the Black Women's Health Study showed no relation between spiritual coping and lower mortality risk over 8 years among 36,613 participants, in models controlling for a wide array of demographic, health status, behavioral, and psychosocial factors (15).

Although these inconsistent findings may be due to methodological differences (e.g., populations under study, sample sizes), it may also reflect that some strategies are not inherently adaptive or maladaptive, but perhaps depend on situation or context. A suggestive example can be found in the Japan Multi-institutional Collaborative Cohort Study investigation mentioned above. Disengagement, which is usually considered a maladaptive strategy, was related to *lower* mortality risk among women who reported using this strategy "sometimes" relative to "never" (13), hinting to some health benefits with a sporadic use of this strategy, perhaps reflecting a selective use depending on the situation. Accordingly, there is increasing recognition that the adaptive aspects of these strategies may depend on the situation or context (16,17). Thus, optimal

use of strategies might instead be best described via *coping flexibility*. Coping flexibility has been often operationalized by numerical variability – that is, the number and frequency of strategies employed, ranging from lower to greater to indicate less to more variability (16). Emerging work has shown that coping variability is in fact related to long-term health outcomes, including changes in lifespan, beyond demographic, health status, and behavioral covariates (18,19).

**Emotion Regulation and Mortality Risk**

Adjacent to coping strategies, emotion regulation describes how individuals experience and express their emotions (9). Emotion-specific strategies can also be categorized as adaptive or maladaptive depending on their associations with mental and physical health outcomes (6,20). While the conceptual model of emotion regulation relates to various emotions, most existing physical health research has focused on the regulation of anger specifically. For instance, the Tecumseh Community Health Study included 696 adults who reported how they would regulate their anger in hypothetical unfair anger-provoking situations and were recoded as expressing (deemed adaptive) or suppressing (deemed maladaptive) their angry feelings (21). Over the 17-year follow-up, greater anger suppression predicted higher all-cause and cardiovascular (CVD) mortality risk, respectively, beyond demographic and health status covariates. In another study, 17,352 men from the Health Professionals Follow-Up Study reported how often they use an aggressive form of expression to regulate anger, viewed as maladaptive (e.g., screaming, insulting, and slamming doors) (22). Findings revealed that higher anger expression was related to greater cancer, but not all-cause or CVD, mortality risk over the 20-year follow-up. Some studies also considered general suppression (i.e., not related to a specific emotion) and found, for

example, that greater emotion suppression predicted higher all-cause, CVD, and cancer mortality risk among 729 adults over a 12-year period (23).

While research on the role of coping and emotion regulation, respectively, in mortality risk continues to develop, much of this work has occurred in parallel with one another rather than jointly. This is in part due to the conceptual differences between these two psychological processes; namely, a focus on responses to stressors (coping) versus emotions (emotion regulation). Despite these differences, coping and emotion regulation share many conceptual and measurement similarities (17,24,25), recently encouraging researchers to consider them together under the broader affect regulation framework (26). Embracing this recent framework would widen the repertoire of available measures (24) that can be considered in relation to mortality within the same sample. This approach would also enable the comparison of estimates to determine, among others, whether emotion-specific strategies (e.g., anger expression) have a stronger predictive value than general strategies (e.g., positive reappraisal).

**Possible Roles of Allostatic Load**

Prior research on the coping/emotion regulation-mortality linkage has considered certain biological markers, mostly self-reported chronic conditions (e.g., cancer, diabetes), body mass index, and blood pressure (13,14,21,22). However, objective and more comprehensive measures of physiological functioning exist and should be considered. Among those, allostatic load is an index of biomarkers representing dysregulations in the autonomic, neuroendocrine, metabolic, and immune systems unfolding from prolonged exposure to stress (27–30).

Existing studies, while sparse, suggest that general affect regulation strategies (e.g., disengagement), emotion-specific regulation strategies (e.g., anger control), and affect regulation variability levels are cross-sectionally (31,32) and longitudinally associated with allostatic load

(33). In parallel, allostatic load has been identified as a robust predictor of mortality risk by a recent systematic review and meta-analysis (34). Given these temporal associations, allostatic load may represent a biological mechanism on the pathway (mediator) linking affect regulation to mortality risk. Alternatively, allostatic load has been found to predict various indicators of psychological functioning later on (35,36). This suggests that this biological index may confound the association of affect regulation with mortality risk. Lastly, broader empirical evidence shows that the role of psychological functioning (e.g., psychological distress, psychological well-being) in long-term physical health outcomes varies in magnitude depending on whether individuals are initially healthy (from the general population) versus already suffering from a chronic condition (from a medical sample) (37,38). Given these differences in magnitude, it is plausible that affect regulation's role in mortality risk differs based on whether individuals are more or less physically healthy. In other words, the comprehensive physiological index of allostatic load may modify (moderate) this association. To our knowledge, no research to date has sought to assess thoroughly allostatic load's possible roles in the affect regulation-mortality risk association.

**The Present Study**

The current research aimed to examine associations of affect regulation indicators (i.e., general and emotion-specific strategies, and variability in their use) and all-cause mortality, while considering potential roles of allostatic load in these relationships, using 18 years of follow-up data available from the Midlife in the United States Study (MIDUS). Although previous research did examine associations of coping strategies and variability in their use with lifespan also using MIDUS (18), the current work is novel in three distinct ways. First, the two studies adopted a different statistical analytic approach: the present one modeled proportional hazard ratio whereas the prior one modeled predicted changes in lifespan. While these two

outcomes leverage mortality data, the current study yields mortality risk whereas the prior one yields percent changes in lifespan, which are two distinct metrics. Second, the two studies relied on distinct conceptual and theoretical grounds: while the prior one was based on the pioneering coping framework (8,39), the current one is based on the recently introduced affect regulation framework (26), which acknowledges the conceptual and measurement overlap between coping and emotion regulation. As a result, unlike the prior study, the current one considered emotion regulation measures aside from coping ones. Third, and perhaps most importantly, the first study aimed to determine the presence of an association between psychological functioning and a longevity outcome, whereas the current study went a step further by seeking to unravel the roles biological processes may play in such association, through an in-depth examination of allostatic load's roles in the affect regulation-mortality linkage.

Based on prior work examining relationships between affect regulation strategies and mortality risk (13,21,23), we hypothesized that strategies typically deemed adaptive would be associated with lower mortality risk, while strategies usually seen as maladaptive would be associated with higher mortality risk. We posited no *a priori* hypothesis for the associations between affect regulation variability and mortality given the limited prior evidence in this area. Within these associations, we also explored without *a priori* hypotheses allostatic load as a potential 1) confounder, influencing both the affect regulation exposures and the mortality outcome; 2) mediator, relating the affect regulation exposures to the mortality outcome; and 3) moderator, modifying the affect regulation-mortality association (Figure 1).

## Method

### Study Sample

The present study used data from MIDUS, a national cohort study of noninstitutionalized English-speaking adults between the ages of 25-74 at baseline, recruited through random-digit-dialing. MIDUS data is publicly available and can be accessed at https://www.icpsr.umich.edu/web/ICPSR/series/203; analysis code is available upon request from the first author. The current study followed the STROBE standards.

MIDUS participants were interviewed first in 1995-1996 (MIDUSI, N=7,108) and then again in 2004-2006 (MIDUSII, N=4,963; 70% response rate from MIDUSI). At each time point, participants completed a phone interview and self-administered questionnaire (SAQ) via mail. At MIDUSII (2004-2006), participants also completed comprehensive biological assessments, medical histories, and an additional SAQ. To supplement the original MIDUS sample, additional participants were included in the MIDUS Refresher Project (N=4,085; 2011-2015) and completed the same assessments as MIDUSII participants. The MIDUS study was approved by the Institutional Review Board at all participating centers, and written informed consent was obtained from all participants. Data were linked to all-cause mortality from the National Death Index, with follow-up into 2022. The current study sample (N=1,941) includes all respondents with data on all affect regulation variables (2004-2006) and allostatic load (2004-2009) at MIDUSII and follow-up mortality data (Figure S1, Supplemental Digital Content 1, http://links.lww.com/PSYMED/B77 ). Any missing data on covariates used from MIDUSII were imputed using multiple imputation, with virtually all sociodemographic, health, and behavioral covariate missingness ranging from 0.10% to 9.60%.

**Measures**

*Affect Regulation.* At MIDUSII, participants completed a modified version of the 60-item Coping Orientation to Problems Experienced (COPE) Inventory (40), which describes how someone generally handles stressful events. The modified COPE Inventory includes 24 items, separated into 6 subscales representing distinct coping strategies. Three strategies are typically deemed as adaptive: Positive Reinterpretation & Growth (e.g. "I look for something good in what is happening"), Active Coping (e.g. "I take direct action to get around the problem"), and Planning (e.g. "I try to come up with a strategy about what to do"), while the other three are typically deemed as maladaptive: Focus on & Venting of Emotions (e.g. "I feel a lot of emotional distress and find myself expressing those feelings a lot"), Denial (e.g. "I pretend that it hasn't really happened", and Behavioral Disengagement (e.g. "I give up trying to reach my goal"). These strategies have been categorized by the direction of their association with psychological distress and well-being in prior work (10–12).

Item scores were rated on a scale from (1) *A lot* to (4) *Not at all* for each subscale, which were consequently summed and reverse-coded to create a total score for each subscale ranging from 4 to 16, such that higher scores indicating the strategy was used more frequently. All strategies had acceptable-to-high internal consistency (MIDUSII; Cronbach alpha, $\alpha$=0.72-0.81; Table S1, Supplemental Digital Content 1, http://links.lww.com/PSYMED/B77 ) and were consistent over 10 years when compared to scores obtained at MIDUSIII (most Pearson correlations, $r$=0.48-0.67; Table S1). Subscale scores were computed for participants with valid data on at least half of the items, per MIDUS recommendations (41). For items with remaining missing values, the mean value of completed items was then used. Scores from each strategy

were standardized using z-scores to facilitate comparison with results obtained from other affect regulation exposures in the current study and those observed in previous studies.

Using the following algorithm based on prior research (18,19,42,43), we created a dispositional Between-Strategy Index, or the affect regulation variability score, using information from the COPE subscales:

$$SD_{(\text{between})\text{i}} = \sqrt{\frac{1}{L-1} \times \sum_{s=1}^{L} \left(x_{si} - M_{(between)i}\right)^2}$$

where $x_{si}$ corresponds to the value of strategy *s* of individual *i* for the total number of strategies *L*. As previously mentioned, *affect regulation variability* describes how participants may alter their coping strategy approach based on the situation. Participants that use the same strategies across situations at equal frequency (displaying high evenness in scores across strategies) are categorized as having lower variability, while participants that use some strategies frequently and rarely use others (displaying high unevenness in scores across strategies) are categorized as having greater variability. Participants with moderate variability are likely to engage in several strategies with varied frequencies (displaying moderate unevenness in scores across strategies), possibly reflecting an effort to find the best strategy for each situation. To examine possible non-linear associations with allostatic load, following previous studies (18,19,42) the affect regulation variability score was divided into tertiles (lower, moderate, and greater) (16,43). Mean strategy use score was also adjusted for in all models with affect regulation 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 (18,19,42).

To measure the use of emotion-specific regulatory strategies, participants completed the validated Spielberger Anger Expression Inventory at MIDUSII (44). This inventory included 8

items that capture subscales on anger expression and suppression, respectively, and 4 items on anger control (e.g., Anger expression: “In general, when I feel angry or furious I lose my temper”; Anger suppression: “I keep things in”; Anger Control: “I control my temper”). Participants responded on a scale from (1) *Almost never* to (4) *Almost always*. At baseline, these strategies had moderate-to-high internal consistency (MIDUSII; α=0.53-0.81; Table S1, Supplemental Digital Content 1, http://links.lww.com/PSYMED/B77 ) and were also relatively stable over 10 years, when compared with those obtained at MIDUSIII (*r*=0.44-0.58; Table S1), thus supporting the dispositional nature of these strategies. As per MIDUS recommendations (41), each subscale score was computed by summing across all items for which there were no, or only one missing value, such that higher scores indicated greater frequency of use. In cases with only one missing value, mean substitution was used. As with general affect regulation strategies, scores from each anger subscale were standardized using z-scores to facilitate comparison with results obtained from other affect regulation exposures in the current study and those observed in previous studies.

*All-Cause Mortality.* Confirmed deaths of any cause were obtained via linked records through 2022 from the National Death Index (NDI), and via longitudinal sample maintenance by the MIDUS Administrative Core. In the current study, follow-up time was calculated as the time period between the MIDUSII interview and date of death according to the NDI for participants who had died, or between the MIDUSII interview and censoring date of December 31, 2022 for participants without confirmed deaths. Participants with deaths attributed to accidental causes were excluded from analyses.

*Covariates.* Information on various covariates was collected at analytic baseline (MIDUSII). Potential confounders of the associations between affect regulation and all-cause

mortality included age (continuous), biological sex (male, female), racial minority status (White, underrepresented individuals [Black and/or African American, Native American or Aleutian Islander, Asian or Pacific Islander, Other, Multiracial]), marital status (married/living with partner, separated/widowed/divorced, never married), income ($0-24,999, $25,000-44,999, $45,000-74,999, $75,000-200,000), highest level of education (less than high school/general educational development (GED), high school diploma/GED, some college/Bachelor's degree or higher), prevalent/history of heart disease (yes, no), and prevalent/history of cancer (yes, no).

Health behaviors were theorized as potential confounders or mediators of the associations between affect regulation and all-cause mortality. Health behaviors included physical activity, smoking status, and alcohol consumption. Physical activity was measured with many items capturing season- and situation-specific moderate-to-vigorous physical activity (employment, leisure, and chores) (33). Active participants were moderately or vigorously active at least once per week in both summer and winter, from any situation. Smoking status was measured using two items asking whether the participant (i) had ever smoked or (ii) currently smoke. A participant that responded "no" to the first item were classified as a "never smoker", a participant that responded "yes" to the first and "no" to the second were classified as a "former smoker", and participants that responded "yes" to both items were classified as "current smokers". Alcohol consumption was ascertained via one item that asked participants how many drinks they would typically drink per day during the time they drank the most. In accordance with public health guidelines on chronic disease prevention and other empirical evidence (45,46), moderate drinkers were defined as females who reported more than zero but less than or equal to one drink per day, and males who reported more than zero but less than or equal to two drinks per day. Heavy drinkers were defined as females who reported more than two drinks and males who

reported more than three drinks per day. Non-drinkers were defined as those that did not report drinking. Alcohol consumption was categorized into two categories, moderate drinkers, considered to be more favorable, and heavy/no drinkers, representing less favorable alcohol consumption level (45,46).

As described earlier, allostatic load may either confound, moderate, or mediate the association of affect regulation with all-cause mortality. Although there are different ways to conceptualize allostatic load (47–49), we followed the widely used approach in the literature of a summary score of biomarker indicators for which participant values fall in high-risk ranges. These are commonly sample-derived high-risk quartiles or, less commonly, values which exceed an established clinical criterion (e.g., systolic blood pressure of 140 mmHg or greater). Quartile cutpoints are often used to ensure similar scoring criteria across biomarkers as established clinical criteria are not available for many of the biomarkers utilized in allostatic load indices. The system-level summary score used in MIDUS addresses the large, but unequal number, of biomarker indicators for different physiological regulatory systems available in MIDUS, thus minimizing outsized influence of some systems in the allostatic load score as a consequence of greater representation (50). These biomarkers are justified as a count-based approach following several review articles (47,51–53). We also elected to utilize this scoring approach to ensure comparability across MIDUS results (32,50,54,55).

While rare, studies comparing different methods of scoring allostatic load typically find a similar pattern of associations between allostatic load and predictor or outcome variables of interest across different scoring techniques including the system-based approach used in MIDUS (48,56). Factor-based assessments of biomarkers from other cohort studies also suggest that biomarker indicators of different physiological systems adequately represent each physiological

system (30,57). That being said, similar assessments in MIDUS are an important aim of future research, as is the robustness of observed associations utilizing difference scoring strategies.

Likewise, a very limited number of studies allow assessment of the stability of allostatic load scores and, to our knowledge, none have a second assessment within a time frame that would be appropriate for assessment of test-retest reliability. A few studies have examined predictors and outcomes of *change* in allostatic load scores over longer follow-up periods, but published data do not provide stability estimates (58–61). It is worth noting that increases in allostatic load over time are associated with characteristics also linked to higher levels of allostatic load in cross-sectional investigations (e.g., lower socioeconomic status (58)); such increases in allostatic load further predict health outcomes (e.g., incident cardiovascular disease and mortality (59–61)) that are also associated with higher allostatic load from a single assessment, hence somewhat lowering concerns about allostatic load's temporal instability.

In the current study, a continuous, sex-specific allostatic load score was created using 24 biomarkers representing 7 physiological domains collected at MIDUSII: Sympathetic Nervous System (epinephrine, norepinephrine), Parasympathetic Nervous System (low frequency spectral power, high frequency spectral power, SDRR, RMSSD), Hypothalamic Pituitary Adrenal Axis (DHEAS, Cortisol), Inflammation (CRP, IL-6, fibrinogen, sE-Selectin, sICAM-1), Cardiovascular (resting SBP, resting DBP, resting heart rate), Glucose Metabolism (HbA1c, fasting glucose, insulin resistance), and Lipid Metabolism (BMI, WHR, triglycerides, HDL cholesterol, LDL cholesterol). Details on the collection of these biomarkers can be accessed as part of the MIDUS Biomarker Project documentation: https://www.icpsr.umich.edu/web/NACDA/studies/29282/datadocumentation. In summary, fasting blood samples were collected from participants and shipped on dry ice to the MIDUS

Biocare Lab. Fresh whole blood samples were then assayed for hemoglobin A1C, while frozen serum and plasma were assayed for several markers, including cardiovascular markers, hormone markers, inflammation markers, creatinine, and glucose metabolism markers. A 12-hour overnight urine sample was collected from each participant during their hospital stay visit, and then assayed at the MIDUS Biocare lab for neuroendocrine markers, corticosteroids, and creatinine. Also at this visit, a clinician or trained staff member completed a physical exam to measure vital signs (e.g. blood pressure, heart rate).

Based on previous work showing that the distribution of these biomarkers differs by sex (62–64), sex-specific quartile cut-offs were used for each biomarker, to separate participants into high/low categories. For participants with valid data on at least half of the biomarkers in the domain, the proportion of biomarkers categorized as high was calculated. The proportions of the domains were then summed to create a continuous total allostatic load score ranging from 0-7, following prior work (55). When evaluated as a potential confounder or mediator, allostatic load was considered continuously. For analyses testing allostatic load as an effect modifier, the continuous score was dichotomized with participants in the highest quartile coded as having "higher allostatic load" (n=484), and participants in the lower three quartiles coded as having "lower allostatic load" (n=1457) (62).

Of note, allostatic load was fairly stable over 10 years among participants who had available biomarker data on both time points (n=602). Specifically, at MIDUSII when participants were 52 years old on average, the allostatic load mean score was 1.37(SD=0.72), while at MIDUSIII, when participants were 61 years old on average, the allostatic load mean score was 1.42(SD=0.73) (correlation between MIDUSII and MIDUSIII allostatic load scores, $r$=0.40; Table S1, Supplemental Digital Content 1, http://links.lww.com/PSYMED/B77 ). It is

worth recalling here that the few investigations of change in allostatic load over many years within the same participants did not provide estimates of time 1 and time 2 correlations in scores (58–61), which prevent any comparison with the current descriptive results. Yet, an examination of sex-specific allostatic load scores as a function of age in the representative Canadian Health Measures Survey showed less than a 1-point difference (on a 0-to-11-point range) between individuals aged 50 and 60 (65), which is consistent with the relative stability of this index over a decade observed herein.

**Statistical Analyses**

All analyses were conducted with SAS, version 9.4. First, descriptive statistics of the study sample were calculated. Percentages are presented for categorical variables, and means and standard deviations (SD) are presented for continuous variables.

*Primary models.* Cox proportional hazards regression models were constructed to examine associations between each standardized affect regulation variable and risk of all-cause mortality. Relevant covariates were added to each model in blocks. Model 1 was adjusted for age only, and Model 2 additionally adjusted for other sociodemographic characteristics (biological sex, racial minority status, marital status, education). Model 3, our core model, also included health conditions (heart disease, cancer). Given that health behaviors may be either confounders, intermediate pathways, or affect regulation strategies themselves (i.e., someone may smoke to handle anxiety due to stressor exposure) (6,66,67), physical activity, smoking, and alcohol consumption were then included in an exploratory Model 4. Model 5 additionally adjusted for allostatic load at baseline, to assess its confounding role. These same nested models were also constructed to examine associations between categorical affect regulation variability levels and

all-cause mortality, looking at all possible contrasts (i.e., moderate vs. lower, greater vs. lower, greater vs. moderate).

*Secondary models.* If the inclusion of allostatic load in Model 5 described above altered the strength of the association between affect regulation and mortality risk found in Model 4, hence suggesting that allostatic load may lie on the pathway, causal mediation analysis techniques were conducted using a Cox proportional hazard framework. These models estimate the natural direct effect of affect regulation strategies on mortality risk over 18 years of follow-up, and the natural indirect effect mediated through allostatic load measured at baseline, while taking into account exposure*mediator interactions, if any (68–70). To assess effect modification by allostatic load levels, interaction terms between each affect regulation variable and allostatic load (e.g., continuous denial*dichotomized allostatic load [highest quartile vs. else]) were included to core Model 3 described above. If interaction terms were statistically or marginally significant at the $p<0.05$ or $p<0.10$ level, respectively, stratified models were then constructed.

## Results

### Descriptive Statistics

Table 1 presents descriptive characteristics of the study sample. On average, participants were middle-aged (M=53.29 years; SD=12.47), with a similar representation of males and females. Most were White (80.71%) and married/living with a partner (65.20%), while approximately half attended some college or more (48.27%) and had incomes equal or over $25,000 (52.00%). The vast majority did not have a history/prevalent heart disease (90.73%) or cancer (88.43%), and about half to three-quarters of the sample were physically active (55.62%), never or past smokers (83.46%), and moderate alcohol drinkers (67.18%).

**Primary Analyses**

Over 18 years of follow-up, 268 deaths were ascertained. Table 2 first presents results from Cox regression models examining associations between general affect regulation strategies and mortality risk. In age-adjusted models, 1-SD increase in focusing on and venting of emotion was marginally related to a lower mortality risk (Model 1, adjusted hazard ratio, AHR=0.85; 95% confidence interval, CI=0.77-1.01). This association was attenuated to the null when adding sociodemographic characteristics (Model 2, AHR=0.91; 95%CI=0.79-1.05). In contrast, 1-SD increase in behavioral disengagement was marginally related to a higher mortality risk in an age-adjusted model (Model 1, AHR=1.12; 95%CI=0.98-1.28). This association remained marginally significant with the progressive inclusion of demographics, health status, and health behaviors (Model 4, AHR=1.15; 95%CI=0.99-1.33). Other general regulatory strategies were unrelated to mortality risk. In all these models, estimates remained nearly identical after further including allostatic load (Model 5).

Results pertaining to affect regulation variability are also reported in Table 2. Greater vs. lower levels (AHR=1.56; 95%CI=1.14-2.14) and greater vs. moderate levels (AHR=1.30; 95%CI=0.96-1.76) were related to a significantly or marginally higher mortality risk in age-adjusted models. Both associations were robust to further adjustment for all covariates (Model 4, $AHR_{\text{greater vs. lower levels}}$=1.54; 95%CI=1.11-2.14; $AHR_{\text{greater vs. moderate levels}}$=1.32; 95%CI=0.97-1.80), and estimates were remarkably robust to additional control for allostatic load (Model 5). When compared to lower variability levels, moderate levels were not significantly related to mortality risk.

Lastly, Table 2 shows that emotion-specific regulatory strategies were overall unrelated to all-cause mortality throughout models progressively adjusting for covariates. However, a marginal association between a 1-SD increase in anger expression and a lower mortality risk was obtained when adjusting for health conditions and health behaviors (Model 4, AHR=0.90; 95%CI=0.79-1.02), which did not change after including allostatic load (Model 5).

**Secondary Analyses**

Because estimates remained notably similar between Model 4 and Model 5 (i.e., after further statistical adjustment for allostatic load), there was no indication that allostatic load could lie on the pathway relating affect regulation exposure and mortality. Thus, causal mediation models were not performed. However, tests for interaction assessing effect modification by allostatic load using core Model 3 were statistically or marginally significant for denial ($p$=0.04) and affect regulation variability (greater vs. lower [$p$=0.08], greater vs. moderate [$p$=0.07]). Findings from related stratified analyses are presented in Table S2, , Supplemental Digital Content 1, http://links.lww.com/PSYMED/B77 . Greater vs. lower affect regulation variability was related to higher mortality risk among adults with lower but not higher levels of allostatic load, beyond control for all covariates (Model 4, AHR=1.84; 95%CI=1.24-2.75). Likewise, greater vs. moderate variability and 1-SD increase in denial appeared to be related to higher mortality risk among adults with lower allostatic load only, but these associations failed to reach statistical significance (Model 4: $AHR_{\text{greater vs. moderate variability}}$=1.46; 95%CI=0.96-2.20; $AHR_{\text{denial}}$=1.12; 95%CI=0.96-1.32).

**Discussion**

To our knowledge, this is the first study to investigate the association between various affect regulation exposures and all-cause mortality risk, while thoroughly considering the role of allostatic load. Using 18 years of follow-up data, results showed that behavioral disengagement, greater vs. lower affect regulation variability, and greater vs. moderate affect regulation variability were related to a significant or marginally higher mortality risk, whereas anger expression was related to a marginally lower risk. These associations were observed beyond statistical control for sociodemographic, health status, and behavioral covariates. When further controlling for allostatic load, estimates were remarkably robust, suggesting that this biological index does not confound the affect regulation-mortality association. Subsequent analyses suggested that allostatic load might be an effect modifier (moderator) rather than a mediator of the affect regulation-mortality relationship. Indeed, interaction terms between affect regulation exposures and allostatic load levels were marginally or statistically significant for denial, as well as greater vs. moderate and lower affect regulation variability levels. Subsequent stratified analyses revealed that greater vs. lower affect regulation variability was associated with significantly higher mortality risk only among adults with lower levels of allostatic load. While estimates failed to reach statistical significance, greater vs. moderate affect regulation variability and greater use of denial also appeared to be related to a higher mortality risk at lower allostatic load levels only.

**Affect Regulation and Mortality Risk**

The detrimental role of behavioral disengagement in mortality risk is consistent with results from previous work that also found higher mortality risk with greater use of maladaptive strategies (21–23). While it appears inconsistent with other results suggesting a protective effect of behavioral disengagement in mortality risk (13), such discrepancy may be due to the population

under study (Japanese vs. American adults) as some cultural differences in the association of affect regulation with physical health has been noted elsewhere (71). Likewise, in the present study, general adaptive strategies like positive reinterpretation and planning were unrelated to mortality risk, which is aligned with findings obtained among American adults (15) but inverse to other past results observed in Japanese adults (13).

Interestingly, associations for greater vs. lower variability were observed, and greater vs. moderate variability approached statistical significance, hinting to a dose-response relationship between affect regulation variability and mortality risk, where more variability leads to worst health outcomes. Displaying a certain level of variability in the use of regulatory strategies is thought as being favorable, because it suggests that individuals are seeking to find the best strategy for each situation. However, it is plausible that too much variability can become detrimental, because such high unevenness in scores across strategies might reflect a more rigid way of regulating affect, such as always implementing the same one or two strategies regardless of the situation. To our knowledge, no prior study has used affect regulation variability indices in relation to mortality risk specifically. Yet, these results align with those of previous work focused on variability and changes in lifespan within MIDUS, which showed that greater vs. moderate variability was associated with up to 15% shorter lives (18). Note that the present analysis found significant associations for greater vs. lower variability that the previous lifespan paper did not. Although both these studies used MIDUS data, it is possible that the additional four years of mortality data our study leverages and the different sample size (N=4398 vs. N=1941 in the current study) explain the discordance in results.

In respect to emotion-specific results, our findings align with other results that indicated anger expression was not clearly related to all-cause mortality among midlife US men (22). Our

findings deviate, however, from other work led in the US that suggested anger suppression, and emotion suppression more broadly, is related to higher all-cause mortality risk (21,23). Methodological differences, such as the use of hypothetical vignettes (21) and general rather than emotion-specific suppression items (23), may contribute to these divergent findings.

**The Role of Allostatic Load**

Many of these prior studies have considered various biological markers as potential confounders, such as high blood pressure, high cholesterol, and body mass index (13,14,21,22). None of them, to our knowledge, have yet examined allostatic load, which is a more holistic measure of biological stress (27,28,72). Our results showed that associations were very robust to further control for allostatic load, suggesting that this comprehensive biological index does not play a major confounding role in the affect regulation-mortality associations. Future research should pursue the study of other comprehensive biological measures (e.g., the mitochondrial health index (73)) that may confound the association of affect regulation with mortality risk.

The results of our study did not provide evidence for the role of allostatic load as a mechanistic pathway (mediator) either. Other biological mechanisms at play on the pathway between affect regulation and mortality may be explored, such as the gut microbiome (74). However, testing of interaction terms between affect regulation and allostatic load revealed marginally or statistically significant terms for planning, denial, greater vs. lower variability, and greater vs. moderate variability, implying a modifying (moderating) role of allostatic load. When stratifying by the top quartile of allostatic load score, clear effect modification was observed for greater vs. lower variability, whereby associations between these affect regulation indicators and increased mortality risk were observed only among adults with lower allostatic load. These findings suggest that among adults who already have high levels of biological wear-and-tear, the

way they handle stressors and regulate their emotions may not be sufficient to influence their mortality risk. Such results are consistent with broader empirical evidence suggesting that certain psychosocial factors (e.g., depression) are more strongly associated with long-term health outcomes among initially-healthy populations relative to medical samples (37,38).

**Limitations and Strengths**

We acknowledge several limitations to our study. First, the MIDUSII and the MIDUS Refresher subsamples with biomarker data are mainly composed of White, relatively well-educated, and healthy individuals (e.g., low levels of heart disease and cancer). Thus, conducting the same analyses in a more diverse population could reveal existing linkages between affect regulation, allostatic load, and mortality that were not observed in the current study. Moreover, the current affect regulation measures do not capture the nature (e.g., controllable vs. uncontrollable) or the intensity/persistence (e.g., acute vs. chronic) of stressors, which may influence which regulatory strategies are used. However, prior findings on the coping-health relationship have indicated similar results when specific stressors were imposed by researchers (e.g., all participants reported their coping strategies when facing an exam) and when participants selected stressors (10). Besides, MIDUSII collected only anger-specific measures, meaning our study could not focus on the regulation of other emotions (e.g., sadness, fear) and, in turn, derive an emotion-specific variability score. Lastly, with respect to possible mediation patterns, data collection of affect regulation and allostatic load at MIDUSII partly overlapped (affect regulation: 2004-2006; allostatic load: 2004-2009), meaning we did not have ideal temporality when considering allostatic load as a mediator. However, allostatic load was fairly stable over a 10-year period, between MIDUSII and MIDUSIII. Thus, it is unlikely that an assessment of allostatic load a few

years after the affect regulation exposure at MIDUSII, which would have enabled optimal temporality to test mediation, might have led to drastically different conclusions.

In respect to strengths, we used a longitudinal, prospective data source with 18 years of follow-up, strengthening our ability to make conclusions about the long-term impact of affect regulation on mortality risk. Allostatic load was measured via objective biomarkers, and validated scales were used to measure affect regulation strategies. The use of coping variability also helped move away from the dichotomy of adaptive vs. maladaptive strategies, to help create a more comprehensive view of affect regulation. This study also investigated several potential roles of allostatic load within the associations between affect regulation and mortality risk, to better disentangle its possible confounding, mediating, and effect modifying influence.

**Conclusions**

Overall, some indicators of affect regulation – including the use of strategies like behavioral disengagement and denial, as well as the display of greater variability levels – may predict mortality risk over 18 years of follow-up, especially among adults who do not exhibit dysregulations in their autonomic, neuroendocrine, metabolic, and immune systems. These findings also indicate that other general strategies (e.g., positive reinterpretation, planning) and emotion-specific strategies (e.g., anger suppression) were not clearly related to mortality risk. As these null results are at times opposite to those obtained in other populations (e.g., Japanese adults), subsequent studies should pay particular attention to potential cultural differences in the affect regulation-mortality linkage. In our study, allostatic load did not appear to lie on the pathway connecting affect regulation to mortality risk. Therefore, future basic research should seek to identify other holistic biological mechanistic pathways of the affect regulation-mortality

relationship. In parallel, our findings suggest that interventions studies aiming to improve affect regulation strategies to foster longer lives may be most beneficial for healthier adults.

**References**


1. Wei J, Hou R, Zhang X, Xu H, Xie L, Chandrasekar EK, et al. The association of late-life depression with all-cause and cardiovascular mortality among community-dwelling older adults: systematic review and meta-analysis. Br J Psychiatry. 2019 Aug;215(2):449–55.

2. Nilaweera D, Phyo AZZ, Teshale AB, Htun HL, Wrigglesworth J, Gurvich C, et al. Lifetime posttraumatic stress disorder as a predictor of mortality: a systematic review and meta-analysis. BMC Psychiatry. 2023 Apr 10;23(1):229.

3. Rozanski A, Bavishi C, Kubzansky LD, Cohen R. Association of Optimism With Cardiovascular Events and All-Cause Mortality: A Systematic Review and Meta-analysis. JAMA Network Open. 2019 Sep 27;2(9):e1912200.

4. Cohen R, Bavishi C, Rozanski A. Purpose in Life and Its Relationship to All-Cause Mortality and Cardiovascular Events: A Meta-Analysis. Psychosomatic Medicine [Internet]. 2016;78(2).

5. Epel ES, Crosswell AD, Mayer SE, Prather AA, Slavich GM, Puterman E, et al. More than a feeling: A unified view of stress measurement for population science. Frontiers in Neuroendocrinology. 2018 Apr;49:146–69.

6. Trudel-Fitzgerald C, Guimond AJ, Kubzansky LD. Emotion regulation and cardiovascular health. In: B Q Ford & J J Gross (Eds), Handbook of Emotion Regulation (3rd ed). Guilford Press; 2024.

7. Trudel-Fitzgerald C, Qureshi F, Appleton AA, Kubzansky LD. A healthy mix of emotions: underlying biological pathways linking emotions to physical health. Current opinion in behavioral sciences. 2017;15:16–21.

8. Folkman S. Personal control and stress and coping processes: a theoretical analysis. J Pers Soc Psychol. 1984 Apr;46(4):839–52.

9. Gross JJ. Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. J Pers Soc Psychol. 1998 Jan;74(1):224–37.

10. Penley JA, Tomaka J, Wiebe JS. The Association of Coping to Physical and Psychological Health Outcomes: A Meta-Analytic Review. Journal of Behavioral Medicine. 2002;53.

11. Kato T. Frequently Used Coping Scales: A Meta-Analysis. Stress Health. 2015 Oct;31(4):315–23.

12. Hoyt MA, Llave K, Wang AWT, Darabos K, Diaz KG, Hoch M, et al. The utility of coping through emotional approach: A meta-analysis. Health Psychology. 2024;43(6):397–417.

13. Nagayoshi M, Takeuchi K, Tamada Y, Kato Y, Kubo Y, Okada R, et al. Sex-specific Relationship Between Stress Coping Strategies and All-cause Mortality: Japan Multi-

Institutional Collaborative Cohort Study. Journal of Epidemiology. 2023 May 5;33(5):236–45.

14. Marino VR, Trudel-Fitzgerald C, Aldwin CM, Spiro A III, Lee LO. The Costs of Coping: Long-Term Mortality Risk in Aging Men. The Journals of Gerontology: Series B. 2024 Apr 1;79(4):gbae011.

15. VanderWeele TJ, Yu J, Cozier YC, Wise L, Argentieri MA, Rosenberg L, et al. Attendance at Religious Services, Prayer, Religious Coping, and Religious/Spiritual Identity as Predictors of All-Cause Mortality in the Black Women's Health Study. Am J Epidemiol. 2017 Apr 1;185(7):515–22.

16. Cheng C, Lau HPB, Chan MPS. Coping flexibility and psychological adjustment to stressful life changes: A meta-analytic review. Psychological Bulletin. 2014;140(6):1582–607.

17. Bonanno GA, Burton CL. Regulatory Flexibility: An Individual Differences Perspective on Coping and Emotion Regulation. Perspect Psychol Sci. 2013 Nov 1;8(6):591–612.

18. Trudel-Fitzgerald C, Chen R, Lee LO, Kubzansky LD. Are coping strategies and variability in their use associated with lifespan? Journal of Psychosomatic Research. 2022 Nov 1;162:111035.

19. Trudel-Fitzgerald C, Lee LO, Guimond AJ, Chen R, James P, Koga HK, et al. A long and resilient life: the role of coping strategies and variability in their use in lifespan among women. Anxiety Stress Coping. 2024 Jul;37(4):473–86.

20. Aldao A, Nolen-Hoeksema S, Schweizer S. Emotion-regulation strategies across psychopathology: A meta-analytic review. Clinical Psychology Review. 2010 Mar 1;30(2):217–37.

21. Harburg E, Julius M, Kaciroti N, Gleiberman L, Schork AM. Expressive/Suppressive Anger-Coping Responses, Gender, and Types of Mortality: a 17-Year Follow-Up (Tecumseh, Michigan, 1971-1988). Psychosomatic Medicine. 2003 Jul;65(4):588.

22. Trudel-Fitzgerald C, Reduron LR, Kawachi I, Kubzansky LD. Specificity in associations of anger frequency and expression with different causes of mortality over 20 years. Psychosom Med. 2021 Jun 1;83(5):402–9.

23. Chapman BP, Fiscella K, Kawachi I, Duberstein P, Muennig P. Emotion Suppression and Mortality Risk Over a 12-Year Follow-up. J Psychosom Res. 2013 Oct;75(4):381–5.

24. Trudel-Fitzgerald C, Boucher G, Morin C, Mondragon P, Guimond AJ, Nishimi K, et al. Coping and emotion regulation: A conceptual and measurement scoping review. Canadian Psychology/Psychologie canadienne. 2024;65(3):149.

25. Compas BE, Jaser SS, Dunbar JP, Watson KH, Bettis AH, Gruhn MA, et al. Coping and emotion regulation from childhood to early adulthood: Points of convergence and divergence. Australian Journal of Psychology. 2014 Jun 1;66(2):71–81.

26. Troy AS, Willroth EC, Shallcross AJ, Giuliani NR, Gross JJ, Mauss IB. Psychological Resilience: An Affect-Regulation Framework. Annu Rev Psychol. 2023 Jan 18;74:547–76.

27. McEwen BS, Stellar E. Stress and the individual. Mechanisms leading to disease. Arch Intern Med. 1993 Sep 27;153(18):2093–101.

28. Seeman TE, Singer B, Rowe J, Horwitz R, McEwen BS. Price of adaptation--allostatic load and its health consequences. MacArthur studies of successful aging. Archives of internal medicine [Internet]. 1997 Oct 27 [cited 2024 Aug 12];157(19).

29. Mauss D, Jarczok MN. The streamlined allostatic load index is associated with perceived stress in life – findings from the MIDUS study. Stress. 2021 Jul 4;24(4):404–12.

30. Wiley JF, Gruenewald TL, Karlamangla AS, Seeman TE. Modeling Multisystem Physiological Dysregulation. Psychosom Med. 2016 Apr;78(3):290–301.

31. Fernandez CA, Loucks EB, Arheart KL, Hickson DA, Kohn R, Buka SL, et al. Evaluating the Effects of Coping Style on Allostatic Load, by Sex: The Jackson Heart Study, 2000–2004. Prev Chronic Dis. 2015 Oct 1;12:150166.

32. Zilioli S, Imami L, Ong AD, Lumley MA, Gruenewald T. Discrimination and anger control as pathways linking socioeconomic disadvantage to allostatic load in midlife. Journal of Psychosomatic Research. 2017 Dec 1;103:83–90.

33. Ng AE, Gruenewald T, Juster RP, Trudel-Fitzgerald C. Affect regulation and allostatic load over time. Psychoneuroendocrinology. 2024 Nov 1;169:107163.

34. Parker HW, Abreu AM, Sullivan MC, Vadiveloo MK. Allostatic Load and Mortality: A Systematic Review and Meta-Analysis. American Journal of Preventive Medicine. 2022 Jul 1;63(1):131–40.

35. Guidi J, Lucente M, Sonino N, Fava GA. Allostatic Load and Its Impact on Health: A Systematic Review. Psychother Psychosom. 2021;90(1):11–27.

36. Stephan Y, Sutin AR, Luchetti M, Terracciano A. Allostatic Load and Personality: A 4-Year Longitudinal Study. Psychosom Med. 2016 Apr;78(3):302–10.

37. Chida Y, Steptoe A. Positive psychological well-being and mortality: a quantitative review of prospective observational studies. Psychosomatic medicine. 2008;70(7):741–56.

38. Chida Y, Hamer M, Wardle J, Steptoe A. Do stress-related psychosocial factors contribute to cancer incidence and survival? Nature clinical practice Oncology. 2008;5(8):466–75.

39. Lazarus RS, Folkman S. Stress, appraisal, and coping. Springer publishing company; 1984.

40. Carver CS, Scheier MF, Weintraub JK. Assessing coping strategies: a theoretically based approach. Journal of personality and social psychology. 1989;56(2):267.

41. University of Wisconsin Madison. MIDUS: Midlife in the United States: A national longitudinal study of health & well-being. [Internet]. 2020. Available from: https://www.midus.wisc.edu/

42. Ng AE, Kubzansky LD, Guimond AJ, Trudel-Fitzgerald C. Are there sociodemographic-specific associations of coping with heart disease and diabetes incidence? Health Psychology. 2024.

43. Blanke ES, Brose A, Kalokerinos EK, Erbas Y, Riediger M, Kuppens P. Mix it to fix it: Emotion regulation variability in daily life. Emotion. 2020 Apr;20(3):473–85.

44. Spielberger CD. State-trait anger expression inventory professional manual. Odessa (FL): Psychological Assessment Resources. 1988.

45. Dietary Guidelines for Americans, 2020-2025. 9th ed. U.S. Department of Agriculture and National Insitutes of Health: US Department of Agriculture and US National Institutes of Health; 2020.

46. Sotos-Prieto M, Mattei J, Cook NR, Hu FB, Willett WC, Chiuve SE, et al. Association Between a 20-Year Cardiovascular Disease Risk Score Based on Modifiable Lifestyles and Total and Cause-Specific Mortality Among US Men and Women. J Am Heart Assoc. 2018 Nov 6;7(21):e010052.

47. Beckie TM. A systematic review of allostatic load, health, and health disparities. Biol Res Nurs. 2012 Oct;14(4):311–46.

48. McLoughlin S, Kenny RA, McCrory C. Does the choice of Allostatic Load scoring algorithm matter for predicting age-related health outcomes? Psychoneuroendocrinology. 2020 Oct 1;120:104789.

49. McCrory C, McLoughlin S, Layte R, NiCheallaigh C, O'Halloran AM, Barros H, et al. Towards a consensus definition of allostatic load: a multi-cohort, multi-system, multi-biomarker individual participant data (IPD) meta-analysis. Psychoneuroendocrinology. 2023;153:106117.

50. Gruenewald TL, Karlamangla AS, Hu P, Stein-Merkin S, Crandall C, Koretz B, et al. History of socioeconomic disadvantage and allostatic load in later life. Social Science & Medicine. 2012 Jan;74(1):75–83.

51. Juster RP, McEwen BS, Lupien SJ. Allostatic load biomarkers of chronic stress and impact on health and cognition. Neurosci Biobehav Rev. 2010 Sep;35(1):2–16.

52. Kerr P, Kheloui S, Rossi M, Désilets M, Juster RP. Allostatic load and women's brain health: A systematic review. Front Neuroendocrinol. 2020 Oct;59:100858.

53. Misiak B, Stańczykiewicz B, Pawlak A, Szewczuk-Bogusławska M, Samochowiec J, Samochowiec A, et al. Adverse childhood experiences and low socioeconomic status with

respect to allostatic load in adulthood: A systematic review. Psychoneuroendocrinology. 2022 Feb;136:105602.

54. Piazza JR, Stawski RS, Sheffler JL. Age, Daily Stress Processes, and Allostatic Load: A Longitudinal Study. J Aging Health. 2019 Oct;31(9):1671–91.

55. Podber N, Gruenewald TL. Socioeconomic status, positive experiences, and allostatic load. Health Psychology. 2023 Feb;42(2):82–91.

56. Kezios KL, Suglia SF, Doyle DM, Susser E, Bradwin G, Cirillo P, et al. Comparing different operationalizations of allostatic load measured in mid-life and their patterning by race and cumulative life course socioeconomic status. Psychoneuroendocrinology. 2022 May;139:105689.

57. Seeman T, Gruenewald T, Karlamangla A, Sidney S, Liu K, McEwen B, et al. Modeling multisystem biological risk in young adults: The Coronary Artery Risk Development in Young Adults Study. Am J Hum Biol. 2010 Aug;22(4):463–72.

58. Merkin SS, Karlamangla A, Roux AVD, Shrager S, Seeman TE. Life course socioeconomic status and longitudinal accumulation of allostatic load in adulthood: multi-ethnic study of atherosclerosis. Am J Public Health. 2014 Apr;104(4):e48-55.

59. Hwang AC, Peng LN, Wen YW, Tsai YW, Chang LC, Chiou ST, et al. Predicting all-cause and cause-specific mortality by static and dynamic measurements of allostatic load: a 10-year population-based cohort study in Taiwan. J Am Med Dir Assoc. 2014 Jul;15(7):490–6.

60. Karlamangla AS, Singer BH, Seeman TE. Reduction in allostatic load in older adults is associated with lower all-cause mortality risk: MacArthur studies of successful aging. Psychosom Med. 2006 Jun;68(3):500–7.

61. Li Y, Chen C, Wen Y, Wang X, Zeng Z, Shi H, et al. Impact of baseline and longitudinal allostatic load changes on incident cardiovascular disease and all-cause mortality: A 7-year population-based cohort study in China. J Affect Disord. 2024 Jun 15;355:487–94.

62. Juster RP, Pruessner JC, Desrochers AB, Bourdon O, Durand N, Wan N, et al. Sex and Gender Roles in Relation to Mental Health and Allostatic Load. Psychosom Med. 2016 Sep;78(7):788–804.

63. Juster RP, Moskowitz DS, Lavoie J, D'Antono B. Sex-specific interaction effects of age, occupational status, and workplace stress on psychiatric symptoms and allostatic load among healthy Montreal workers. Stress. 2013 Nov;16(6):616–29.

64. McCrory C, Fiorito G, Ni Cheallaigh C, Polidoro S, Karisola P, Alenius H, et al. How does socio-economic position (SEP) get biologically embedded? A comparison of allostatic load and the epigenetic clock(s). Psychoneuroendocrinology. 2019 Jun;104:64–73.

65. Thomson EM, Kalayci H, Walker M. Cumulative toll of exposure to stressors in Canadians: An allostatic load profile. Health Rep. 2019 Jun 19;30(6):14–21.

66. Park CL, Iacocca MO. A stress and coping perspective on health behaviors: theoretical and methodological considerations. Anxiety, Stress, & Coping. 2014 Mar 4;27(2):123–37.

67. Mezuk B, Abdou CM, Hudson D, Kershaw KN, Rafferty JA, Lee H, et al. "White Box" Epidemiology and the Social Neuroscience of Health Behaviors: The Environmental Affordances Model. Soc Ment Health. 2013 Jul 1;3(2).

68. Valeri L, VanderWeele TJ. Mediation analysis allowing for exposure–mediator interactions and causal interpretation: theoretical assumptions and implementation with SAS and SPSS macros. Psychological methods. 2013;18(2):137.

69. Valeri L, VanderWeele TJ. SAS macro for causal mediation analysis with survival data. Epidemiology. 2015;26(2):e23–4.

70. VanderWeele TJ. Mediation Analysis: A Practitioner's Guide. Annu Rev Public Health. 2016;37:17–32.

71. Kitayama S, Park J, Boylan JM, Miyamoto Y, Levine CS, Markus HR, et al. Anger Expression and Ill-Health in Two Cultures: An Examination of Inflammation and Cardiovascular Risk. Psychol Sci. 2015 Feb;26(2):211–20.

72. McEwen BS. Allostasis and Allostatic Load: Implications for Neuropsychopharmacology. In: Stress and the Brain. Routledge; 2002.

73. Picard M, Juster RP, McEwen BS. Mitochondrial allostatic load puts the "gluc" back in glucocorticoids. Nat Rev Endocrinol. 2014 May;10(5):303–10.

74. Ke S, Guimond AJ, Tworoger SS, Huang T, Chan AT, Liu YY, et al. Gut feelings: associations of emotions and emotion regulation with the gut microbiome in women. Psychol Med. 2023 Nov;53(15):7151–60.

**Figure 1.** Conceptual model of the constructs and relationships under study. Within the associations between affect regulation and mortality risk, allostatic load is evaluated either as a potential confounder (Aim 1), mechanistic pathway (mediator; Aim 2), or effect modifier (moderator; Aim 3). Selected covariates (i.e., sociodemographic characteristics, health conditions, and health behaviors) are mostly conceptualized as confounders.

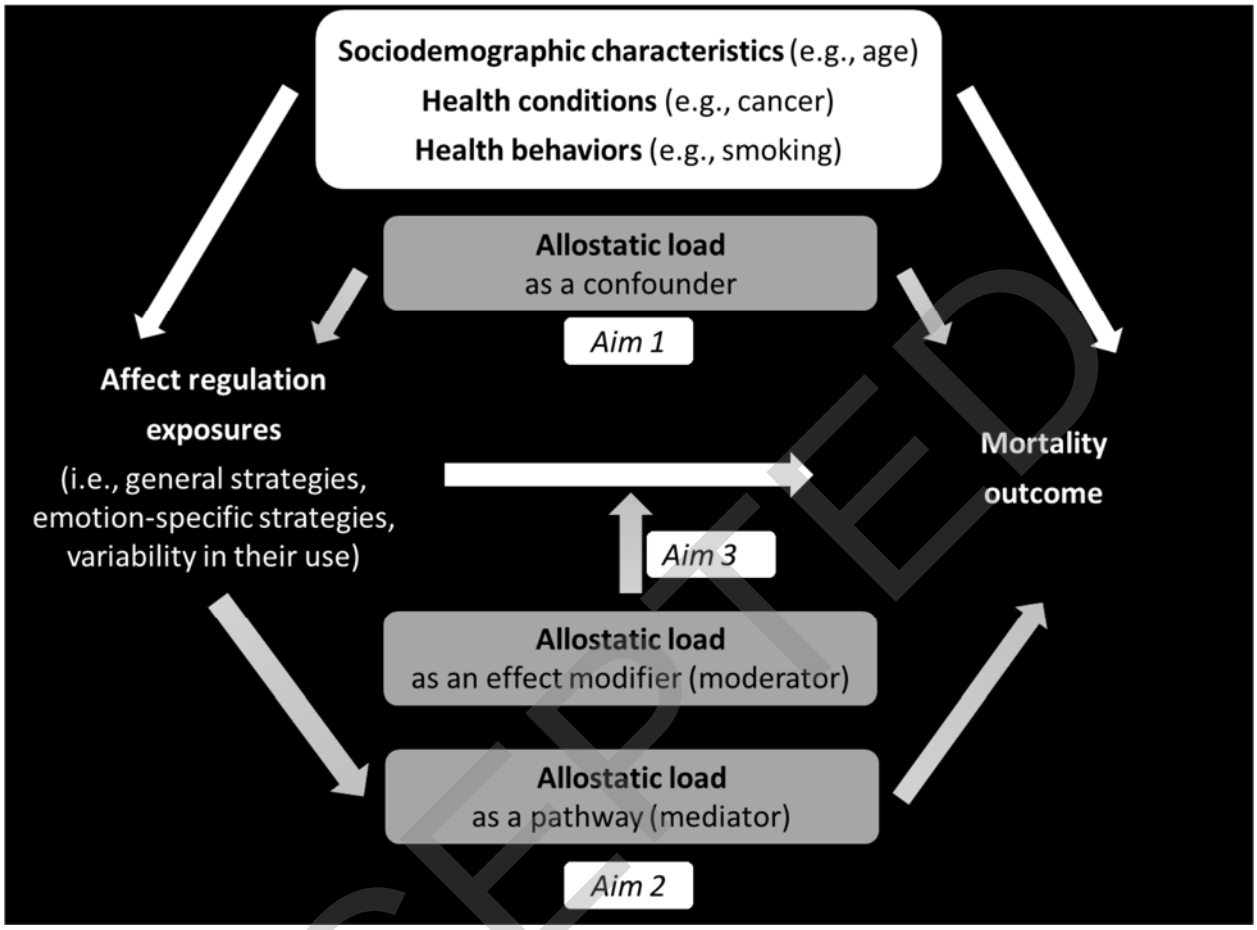

**Table 1.** Descriptive statistics of sociodemographic and health-related covariates, allostatic load, and affect regulation exposures (N=1941).

| | Total Sample<br>**M (SD)** | **N (%)** |
|---|---|---|
| **Sociodemographic and health covariates (MIDUSII)** | | |
| Age (Range: 25-83) | 53.29 (12.47) | |
| Sex | | |
| *Male* | | 898 (46.26) |
| *Female* | | 1043 (53.74) |
| Racially underrepresented individuals (N=1,903) | | 367 (19.29) |
| Marital status (N=1,937) | | |
| *Married/Living with Partner* | | 1263 (65.20) |
| *Separated/Widowed/Divorced* | | 417 (21.53) |
| *Never Married* | | 257 (13.27) |
| Education (N=1,939) | | |
| *Less Than High School* | | 434 (22.38) |
| *High School Diploma/GED* | | 569 (29.35) |
| *Some College or More* | | 936 (48.27) |
| Income (N=1,773) | | |
| *$0-24,999* | | 851 (48.00) |
| *$25,000-44,999* | | 317 (17.88) |
| *$45,000-74,999* | | 335 (18.89) |
| *$75,000-200,000* | | 270 (15.23) |
| Prevalent or history of heart disease (N=1910) | | 177 (9.27) |
| Prevalent or history of cancer (N=1936) | | 224 (11.57) |
| Physical activity[a] | | |
| *Active* | | 1069 (55.62) |
| *Inactive* | | 853 (44.38) |
| Smoking (N=404) | | |
| *Never Smoked* | | 548 (39.91) |
| *Past Smoker* | | 598 (43.55) |

| | |
|---|---|
| *Current Smoker* | 227 (16.53) |
| Alcohol consumption[b] | |
| *None or Heavy* | 532 (32.82) |
| *Moderate* | 1089 (67.18) |
| Allostatic load score (Range: 0-7) | 1.38 (0.94) |
| **Affect regulation exposures (MIDUSII)** | |
| General regulatory strategies (Range: 4-16) | |
| *Positive Reinterpretation & Growth* | 12.47 (2.39) |
| *Active Coping* | 12.66 (2.13) |
| *Planning* | 13.18 (2.32) |
| *Focusing on and Venting of Emotion* | 9.20 (2.86) |
| *Denial* | 5.92 (2.23) |
| *Behavioral Disengagement* | 6.79 (2.35) |
| Emotion-specific regulatory strategies | |
| *Anger Expression (Range: 4-32)* | 13.07 (3.38) |
| *Anger Control (Range: 4-16)* | 9.97 (2.24) |
| *Anger Suppression (Range: 4-32)* | 14.99 (4.28) |

*Notes.* These statistic descriptives were conducted before multiple imputation was implemented.

[a] Active=participants indicated they were moderately or vigorously active at least once per week in both summer and winter, from any context (i.e., employment, leisure, and chores); Inactive=participants not classified as Active.

[b] Moderate drinkers=females who reported more than zero but less than or equal to one drink per day, and males who reported more than zero but less than or equal to two drinks per day; Heavy drinkers=females who reported more than two drinks and males who reported more than three drinks per day.

**Table 2.** Cox proportional hazards regressions modeling the associations between affect regulation exposures (MIDUSII; 2004-2006) and all-cause mortality until 2022, N=1941

| | Model 1 | | Model 2 | | Core Model 3 | | Exploratory Model 4 | | Model 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AHR | 95% CI | AHR | 95% CI | AHR | 95% CI | AHR | 95% CI | AHR | 95% CI |
| General regulatory strategies (per 1-SD increase) | | | | | | | | | | |
| *Positive Reinterpretation* | 0.99 | (0.86, 1.13) | 1.02 | (0.88, 1.17) | 1.03 | (0.89, 1.18) | 1.01 | (0.88, 1.16) | 1.01 | (0.88, 1.17) |
| *Active Coping* | 0.99 | (0.87, 1.13) | 0.996 | (0.87, 1.14) | 0.98 | (0.87, 1.14) | 0.99 | (0.86, 1.13) | 0.99 | (0.86, 1.14) |
| *Planning* | 0.98 | (0.86, 1.11) | 0.98 | (0.86, 1.11) | 0.98 | (0.86, 1.11) | 0.97 | (0.86, 1.10) | 0.97 | (0.86, 1.11) |
| *Focusing on & Venting of Emotion* | 0.85 | (0.77, 1.01)§ | 0.91 | (0.79, 1.05) | 0.91 | (0.78, 1.05) | 0.90 | (0.78, 1.05) | 0.91 | (0.78, 1.06) |
| *Denial* | 1.09 | (0.96, 1.23) | 1.08 | (0.94, 1.24) | 1.04 | (0.91, 1.20) | 1.05 | (0.91, 1.21) | 1.05 | (0.91, 1.21) |
| *Behavioral Disengagement* | 1.12 | (0.98, 1.28)§ | 1.14 | (0.99, 1.31)§ | 1.14 | (0.99, 1.31)§ | 1.15 | (0.99, 1.33)§ | 1.15 | (0.996, 1.34)§ |
| Affect regulation variability levels | | | | | | | | | | |
| *Moderate vs. Lower* | 1.20 | (0.90, 1.61) | 1.12 | (0.82, 1.52) | 1.13 | (0.83, 1.55) | 1.17 | (0.85, 1.61) | 1.14 | (0.83, 1.58) |
| *Greater vs. Lower* | 1.56 | (1.14, 2.14)* | 1.56 | (1.14, 2.14)* | 1.51 | (1.10, 2.08)* | 1.54 | (1.11, 2.14)* | 1.52 | (1.10, 2.11)* |
| *Greater vs. Moderate* | 1.30 | (0.96, 1.76)§ | 1.40 | (1.03, 1.90)* | 1.33 | (0.97, 1.83)§ | 1.32 | (0.97, 1.80)§ | 1.33 | (0.97, 1.82)§ |
| Emotion-specific regulatory strategies (per 1-SD increase) | | | | | | | | | | |
| *Anger Expression* | 0.93 | (0.82, 1.05) | 0.93 | (0.83, 1.05) | 0.90 | (0.80, 1.02)§ | 0.90 | (0.79, 1.02)§ | 0.90 | (0.80, 1.02)§ |
| *Anger Control* | 1.07 | (0.95, 1.20) | 1.08 | (0.96, 1.22) | 1.10 | (0.97, 1.25) | 1.10 | (0.96, 1.25) | 1.10 | (0.97, 1.25) |
| *Anger Suppression* | 1.09 | (0.95, 1.24) | 1.06 | (0.92, 1.22) | 1.03 | (0.89, 1.19) | 1.04 | (0.89, 1.20) | 1.04 | (0.90, 1.21) |

§ $p \leq .10$; * $p \leq .05$; AHR=adjusted hazard ratio, CI=confidence interval.
Model 1: age adjusted
Model 2: Model 1 + sex, race, marital status, income, and education at baseline (MIDUSII)
Model 3: Model 2 + prevalent/history of heart disease and cancer at baseline (MIDUSII)
Model 4: Model 3 + physical activity, smoking, and alcohol consumption at baseline (MIDUSII)
Model 5: Model 4 + allostatic load at baseline (MIDUSII)
Note: All affect regulation variability analyses are additionally adjusted for the mean strategy score.