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UNIVERSITY OF CALIFORNIA
Los Angeles

Measurement of Psychosocial Resources,
Allostatic Load, and Their Relations

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy in
Psychology

By

Joshua Fredrick Wiley

2015
ABSTRACT OF THE DISSERTATION

Measurement of Psychosocial Resources, Allostatic Load, and Their Relations

By

Joshua Fredrick Wiley

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2015

Professor Annette Louise Stanton, Chair

Background: The present four studies aimed to develop comprehensive, succinct measures of psychosocial resources and system-wide physiological dysregulation (allostatic load) and integrate these into a conceptual model, a modified form of the Reserve Capacity Model (Gallo & Matthews, 2003), to characterize how socioeconomic status, stress, psychosocial factors, mood, physiology, and health behaviors contribute to health outcomes.

Methods: Identification of factors underlying psychosocial resources was conducted in four independent samples in which a range of psychological and social resources were measured. A systematic review of psychosocial resources and allostatic load was conducted by retrieving all articles with "allostasis" or "allostatic load"
in the title, abstract, or keywords from major databases. An allostatic load factor was examined using data from the large Midlife in the United States (MIDUS) study, which was also used for the final study linking SES, psychosocial resources, health behaviors, allostatic load, and a health outcome.

**Results:** In the first study, two factors, psychological and social resources, provided the best fit to all the psychosocial resources assessed. In Study 2, evidence of a common factor, allostatic load, underlying 23 biomarkers in MIDUS emerged, although there was also evidence of unique system-specific factors. In the systematic review of psychosocial resources and AL, results were mixed, with some studies finding null effects, and others finding significant positive or negative effects of psychosocial resources on allostatic load. In a fourth study testing the modified Reserve Capacity Model, results largely supported the model’s predictions. SES was associated with better health outcomes indirectly via lower allostatic load, lower negative mood, and higher physical activity. These associations were themselves linked to SES via psychological resources and major stressful life events. Psychological resources were associated with higher physical activity, but not directly to allostatic load or health outcomes, and social resources had no association independent of psychological resources.

**Conclusions:** Psychological resources, social resources, and allostatic load form coherent constructs. Psychosocial resources appear more strongly associated with health behaviors than directly to allostatic load or health outcomes. Results generally supported the modified Reserve Capacity Model, suggesting it is a useful conceptual framework to guide future research.
The dissertation of Joshua Fredrick Wiley is approved.

Julienne E. Bower

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2015
# TABLE OF CONTENTS

ABSTRACT OF THE DISSERTATION ................................................................. II

TABLE OF CONTENTS .................................................................................. V

LIST OF FIGURES ......................................................................................... VIII

LIST OF TABLES .......................................................................................... IX

ACKNOWLEDGEMENTS .............................................................................. X

VITA ................................................................................................................ XII

GENERAL INTRODUCTION ........................................................................... 1

REFERENCES ............................................................................................... 3

PAPER 1: A TALE OF TWO RESOURCES: PSYCHOLOGICAL AND SOCIAL RESOURCES ARE DISTINCT FACTORS AND ARE RELATED TO PSYCHOLOGICAL HEALTH ................................................................. 4

ABSTRACT .................................................................................................... 6

INTRODUCTION ............................................................................................ 7

METHOD ....................................................................................................... 11

RESULTS ...................................................................................................... 15

DISCUSSION .................................................................................................. 17

REFERENCES ............................................................................................... 22

SUPPLEMENTARY MATERIAL ....................................................................... 31

PAPER 2: MODELING MULTISYSTEM PHYSIOLOGICAL DYSREGULATION .... 35
PAPER 3: RELATIONS OF PSYCHOSOCIAL RESOURCES WITH ALLOSTATIC LOAD: A SYSTEMATIC REVIEW .......................................................... 58

ABSTRACT ................................................................................................................. 59
INTRODUCTION .......................................................................................................... 61
METHODS .................................................................................................................. 65
RESULTS ...................................................................................................................... 68
DISCUSSION ............................................................................................................... 77
REFERENCES ............................................................................................................. 84

APPENDIX 1. FREQUENCY OF USE OF EACH BIOMARKER ACROSS THE 25 STUDIES .... 108
APPENDIX 2. PLOT OF THE MEANS OF ALLOSTATIC LOAD AGAINST THE MEANS OF VARIOUS
PSYCHOSOCIAL VARIABLES FOR EACH OF THE 10 OCCUPATIONAL GROUPS. ............... 109

PAPER 4: TESTING A MODIFIED RESERVE CAPACITY MODEL WITH SES,
PSYCHOSOCIAL RESOURCES, AND ALLOSTATIC LOAD IN THE MIDLIFE IN THE
UNITED STATES STUDY ............................................................................................... 110

ABSTRACT ................................................................................................................. 111
INTRODUCTION .......................................................................................................... 113
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHODS</td>
<td>119</td>
</tr>
<tr>
<td>RESULTS</td>
<td>126</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>130</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>136</td>
</tr>
<tr>
<td>GENERAL DISCUSSION</td>
<td>153</td>
</tr>
<tr>
<td>GENERAL LIMITATIONS</td>
<td>155</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>155</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>156</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

PAPER 1

Figure 1. Final Structural Models ........................................................................ 30

PAPER 2

Figure 1 Biomarkers ............................................................................................ 56
Figure 2. Sample diagrams .................................................................................. 57

PAPER 3

Figure 1. Flow chart ............................................................................................ 107

PAPER 4

Figure 1. Hypothesized model ........................................................................... 151
Figure 2. Final study model ................................................................................ 152
LIST OF TABLES

PAPER 1

Table 1. Fit Statistics ........................................................................................................ 29

Supplementary Tables

Table 1. Descriptive Statistics for Sample 1 ................................................................. 31
Table 2. Descriptive Statistics for Sample 2 ................................................................. 32
Table 3. Descriptive Statistics for Sample 3 ................................................................. 33
Table 4. Descriptive Statistics for Sample 4 ................................................................. 34

PAPER 2

Table 1. Descriptive statistics ......................................................................................... 54
Table 2. Model Fit Statistics ......................................................................................... 55

PAPER 3

Table 1. Quality Assessment Scoring .............................................................................. 91
Table 2. Quality of Study Assessment ........................................................................... 92
Table 3. Sample Recruitment and Settings .................................................................... 93
Table 4. Study Characteristics ....................................................................................... 95
Table 5. Measures of Allostatic Load .......................................................................... 98
Table 6. Summary of Results for Psychological Resources ........................................... 99
Table 7. Summary of Results for Social Resources ..................................................... 103

PAPER 4

Table 1. Means and Correlations ............................................................................... 149
Table 2. Path estimates ............................................................................................... 150
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VITA

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GENERAL INTRODUCTION

Psychosocial resources (PSRs) are a diverse set of psychological (e.g., optimism) and social (e.g., perceived emotional support) constructs that promote psychological and physical health or can be drawn on to cope with and buffer the deleterious health effects of stress (Taylor & Broffman, 2011). Despite the common health promoting role of resources, consensus exists on neither which specific resources should be assessed nor how they should be measured in research. Further, although PSRs are theoretically related to both psychological and physical health, the bulk of the research has focused on psychological health outcomes. In the present research, we focus on the aggregate level to investigate the relations between PSRs and physical health. We operationalize broad PSRs by investigating a factor model for a variety of specific resources. We operationalize broad physical health using allostatic load (AL), an objectively measured, multisystem index created from biomarkers.

Manuscript 1 comprises four samples (women and men prior to biopsy to detect ocular melanoma; women and men after treatment of ocular melanoma; women treated for breast cancer; healthy undergraduates) who completed various measures of PSRs. We explore the factor structure of PSRs and investigate whether multiple specific resources can be aggregated into a general psychosocial resource factor or separate psychological and social resource factors.

In the second manuscript, we compare alternative models of the factor structure underlying biomarkers of seven biological systems to examine whether the results are consistent with allostatic load theory and to create an AL index.
In the third manuscript, a systematic review of research of PSRs and AL was conducted to investigate the strength of evidence for a relationship between PSRs and AL. Studies that included a multi-system index of AL and any PSR were included. In order to not miss studies, PSRs were defined generally and included studies that measured both resources (e.g., social integration and connection) and lack of resources (e.g., social isolation).

The final manuscript draws on the results from Manuscript 1 to create psychological and social resource factors in data from MIDUS and from Manuscript 2 to create a single measure of AL. These are combined along with other measures in MIDUS to test a modified version of the Reserve Capacity Model (Gallo & Matthews, 2003; Matthews & Gallo, 2011). In light of the important role of PSRs as moderators identified in Manuscript 3, sex was examined as a potential moderator of the pathways in the integrative model in Manuscript 4.

The studies evaluate optimal ways to use measures of multiple psychosocial resources and biomarkers. These methods may be applied in many other research contexts, such as studies investigating the relations between psychosocial resources and psychological adjustment, or stress and allostatic load. These studies will also illuminate the overall relation and magnitude of effect between a comprehensive assessment of PSRs and AL, an objective measure of physical health.
References


PAPER 1: A TALE OF TWO RESOURCES: PSYCHOLOGICAL AND SOCIAL RESOURCES ARE DISTINCT FACTORS AND ARE RELATED TO PSYCHOLOGICAL HEALTH

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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Abstract

Extensive research addresses the roles of psychosocial resources (PSRs; e.g., optimism, social support) in health. Most researchers examine individual PSRs or PSR sets. Using data from four samples \((N = 615)\), we tested whether PSRs could be synthesized using a one-factor (psychosocial) or two-factor (psychological, social) model. A two-factor model provided excellent fit. Meta-analytically combining the samples, psychological resources correlated \(r = -.50\) and \(r = .51\), and social resources correlated \(r = -.32\) and \(r = .28\) \((p < .001)\) with negative and positive indicators of psychological health, respectively. Assessing multiple resources and modeling them using two factors or composites is recommended in future research.

**Keywords:** resources, perceived control, optimism, social support, protective factors
Introduction

Psychosocial resources are defined as “individual differences and social relationships that have beneficial effects on mental and physical health outcomes” (p. 1; Taylor and Broffman, 2011). Individual resources such as self-esteem (Hu and Ai, 2014), hope (Hirsch and Sirois, 2014), optimism (de Moor et al., 2006), and social support (Brand et al., 2014) are commonly examined in health psychology research as predictors, moderators, and mediators of effects on psychological and physical health. For example, from January 2009 through July 2014, 111 of 722 articles published in the Journal of Health Psychology included an examination of at least one psychosocial resource. Researchers frequently assess multiple individual resources (e.g., Applebaum et al., 2014; He et al., 2014). Although several major theories conceptualize psychosocial resources (PSRs) as a constellation (e.g., Hobfoll, 1989; Taylor and Armor, 1996), most scales designed to measure them focus on one specific resource (see the Conservation of Resources Evaluation scale for an exception; Hobfoll et al., 1991). In light of theories conceptualizing psychosocial resources as a cluster and of frequent empirical work assessing multiple resources, the present article aims to evaluate whether measures of commonly used psychosocial resources can be analyzed as one or two factors rather than using each resource individually. We also examine associations between the psychosocial resource factor(s) and measures of psychological health.

Psychosocial Resources and Psychological Health

Taylor and Broffman (2011) comprehensively reviewed the most studied psychosocial resource constructs and the evidence relating them to psychological and physical health.
physical health. An attractive aspect of PSRs is that they both theoretically promote good health and help buffer the deleterious effects of distress and disease. This observation is evidenced in the breadth of outcomes associated with PSRs, from emotional well-being and stress responses to recovery from surgery and mortality (Taylor and Broffman, 2011). Due to their broad effects on psychological health, psychosocial resources are particularly relevant to health psychology research on adjustment to stress and disease. The present study examines an array of resources including multiple domains of social support, optimism, mastery, hope, and self-esteem, all of which are individually associated with psychological health.

Social support entails the perception of being cared for and having assistance available if needed and is tied to declines in depressive symptoms and distress and improved adjustment in individuals with chronic disease (for an overview, see Stanton et al., 2007). Dispositional optimism (the enduring tendency to hold positive expectancies about one’s future; Scheier et al., 1994) is related cross-sectionally and prospectively to depressive symptoms, distress, and life satisfaction (Carver et al., 2010). The benefits of optimism are observed in diverse contexts including acute and chronic stress, medical experiences, and academic situations.

Like social support and optimism, hope (having the agency or motivation, the “will”, to pursue goals; and perceiving pathways to one’s goals, the “ways”; Snyder et al., 1991) is associated with psychological health, prospectively predicting lower levels of depression and negative affect and higher positive affect (e.g., Michael and Snyder, 2005; Arnau et al., 2007). Mastery is a more specific measure of agency and personal control than optimism and hope, targeting an internal locus of control and the perceived
ability to achieve goals (Pearlin and Schooler, 1978). Mastery is linked to psychological health (e.g., Taylor and Stanton, 2007) and lower depressive symptoms (e.g., Mausbach et al., 2007). Finally, dispositional self-esteem captures stable, favorable self-perceptions. Self-esteem is associated with lower depressive symptoms (Hu and Ai, 2014); a meta-analysis demonstrated stronger effects from self-esteem to subsequent depression than the reverse (Sowislo and Orth, 2013).

**Psychosocial Resources as a Constellation**

Psychosocial resources comprise numerous constructs, which tend to be correlated moderately. For example, a meta-analysis of optimism and hope found moderate to strong correlations of each with other psychosocial resources including self-esteem, self-efficacy, and social support (Alarcon et al., 2013). An earlier review of the literature on PSRs and health also noted the intercorrelations among resources; the authors suggested that researchers should examine a PSR profile or constellation (Taylor and Seeman, 1999).

Although it is theoretically attractive to capture the effects of a constellation of resources, including many variables complicates analyses and interpretation. Saphire-Bernstein et al. (2011) summarized resources using a single factor for the psychological resources of mastery, optimism, and self-esteem; however, most studies that include multiple resources have used them individually (e.g., Applebaum et al., 2014; He et al., 2014), perhaps because there are few empirical studies that demonstrate a sound methodological approach for summarizing and better utilizing diverse psychosocial resources. Such a method may encourage researchers to apply Taylor and Seeman's (1999) notion of measuring a constellation of resources.
The Present Study

The first aim was to test whether a constellation of psychosocial resource measures can be summarized using one or two factors. To maximize the generalizability of results to contexts relevant in health psychology, we tested psychosocial resource factors in four distinct populations representing a range of health status: healthy undergraduates, patients referred for diagnosis of eye cancer, women who were undergoing or had completed treatment for breast cancer, and eye cancer survivors. The specific resource indicators vary across the samples, and we hypothesized that if psychological and social resources are broad constructs, the specific scales used should not change the overall one- or two-factor structure.

The second aim was to examine whether different measures of psychosocial resources share a common core or have distinct, unique relations with psychological health outcomes. This is in light of the extensive theoretical work linking psychosocial resources to health outcomes, such as the reserve capacity model (Gallo and Matthews, 2003) where resources buffer the effects of stress on health outcomes, and Taylor and Stanton’s (2007) model in which coping resources such as social support and optimism contribute to neural and behavioral processes and ultimately psychological and physical health. To test the second aim, we embedded the measurement models identified from our first aim into a larger structural equation model and correlated the psychosocial resources factors with indicators of psychological health. To increase generalizability of outcomes, we incorporated different indicators of both negative (e.g., depressive symptoms) and positive (e.g., positive affect) psychological health. We included both positive and negative indicators of
psychological health because prior research has demonstrated unique patterns of results for each (e.g., Watson, 1988). We hypothesized that individuals who score high on psychological or social resources would report lower negative and higher positive psychological adjustment.

Method

In each of the four study samples, participants completed measures of psychosocial resources and negative and positive psychological health as part of the original study's protocol. Psychosocial resources were scored so that higher values indicate more resources. All studies were conducted at UCLA and approved by its institutional review board.

Sample 1

Sample 1 was comprised of 99 patients from the UCLA Jules Stein Eye Institute (JSEI) who had a diagnosis of ocular melanoma between January 1, 2002 and December 31, 2006 who were enrolled in a study of quality of life (see also Beran et al., 2009; Wiley et al., 2013).

Sample 2

Sample 2 included 299 patients referred to UCLA’s Ophthalmic Oncology Center at JSEI for diagnostic evaluation of ocular melanoma who were recruited prior to or on the day they came to the JSEI for diagnostic evaluation. Baseline questionnaires were collected immediately before their appointments.

Sample 3
Sample 3 was comprised of 88 women who had completed or were currently undergoing medical treatment for any stage breast cancer recruited from a community medical oncology practice. The data came from baseline questionnaires from a randomized controlled trial of an internet-based intervention designed to facilitate communication with participants’ social networks (Stanton et al., 2013).

Sample 4

Sample 4 included 129 students recruited from undergraduate psychology courses at UCLA for course credit. Participants were recruited into an experimental study regarding health and personality. Participants completed background questionnaires prior to the experimental manipulation, and the present study used those data.

Measures

Social resources.

*Medical Outcomes Study Social Support Survey (MOS SSS).* The MOS SSS (Sherbourne and Stewart, 1991) consists of four subscales (tangible, affectionate, positive interactions, and emotional or informational support) and was collected in Samples 1, 2, and 4 (all $\alpha$s $\geq .79$).

*Sources of Social Support Scale (SSSS).* Administered to Sample 3, SSSS (Carver, 2006) subscales were averaged across partners, family, and friends: *emotional support* ($\alpha = .73$), *instrumental support* ($\alpha = .60$), and * informational support* ($\alpha = .58$).

*Sarason Social Support Questionnaire (SSQ).* Administered to Sample 3, the SSQ (Sarason et al., 1987) has four subscales: *emotional number* ($\alpha = .91$) is the
number of people who provide support in several emotional domains; *instrumental number* ($\alpha = .83$) is the number of people who provide support in several instrumental (i.e., tangible or physical) domains; *emotional satisfaction* ($\alpha = .96$) is how satisfied the participant was with their emotional support; *instrumental satisfaction* ($\alpha = .93$) is satisfaction with instrumental support. The two number subscales and the two satisfaction subscales were averaged to create overall indices of structural support and social support satisfaction.

**Psychological resources.**

*Life Orientation Test-Revised (LOT-R).* The LOT-R (Scheier et al., 1994) was assessed in all four samples with positively and negatively valenced items used to form two subscales: *optimism* ($\alpha$s from .61-.74) and *low pessimism* ($\alpha$s from .54-.83). The LOT-R is often considered on these two dimensions (e.g., Segerstrom et al., 2011).

*Mastery.* The Pearlin and Schooler (1978) personal mastery scale is a one-dimensional scale that measures a sense of personal control or mastery over one’s life and was assessed in Samples 1 and 4 ($\alpha$s from .74-.77).

*Hope.* The Hope scale (Snyder et al., 1991) measures agency (a belief one has the ability to reach goals) and pathways (the ability to find ways to achieve goals) and was assessed in Sample 1 ($\alpha = 0.88$).

*Rosenberg Self-Esteem Scale (RSES).* The RSES (Rosenberg, 1965) measures self-esteem and was assessed in Sample 4 ($\alpha = .89$).

**Psychological health.**
**Center for Epidemiologic Studies Depression Scale (CES-D).** The CES-D (Radloff, 1977) measures depressive symptoms and was assessed in Samples 1, 2, and 3 (αs from .89-.91) with higher scores indicating more depressive symptoms.

**Negative Affect (NA).** NA was measured using the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) and was assessed in Sample 4. The NA subscale (α = .81) of the PANAS has 10 adjectives (e.g., “distressed”). Participants were prompted to respond how they felt “right now”.

**Positive Affect (PA).** PA was measured using the PANAS (Watson et al., 1988) and was assessed in Samples 1, 2, and 4. The PA subscale (αs from .88-.90) of the PANAS has 10 adjectives (e.g., “excited”). Samples 1 and 2 were prompted to respond how they felt “in the past week” whereas Sample 4 was “right now”.

**Satisfaction with Life Scale (SWLS).** The SWLS (Diener et al., 1985) measures overall life satisfaction and was assessed in Sample 3 (α = 0.89).

**Data Analysis**

To test the measurement model of PSRs, we compared two models. The first model included all resources as indicators for a single latent factor. The second model included two correlated factors, with social resource measures loading on one latent factor and psychological resource measures loading on the other. We expected a one- or two-factor structure to fit the data; however, model modifications were examined if a two-factor model did not provide adequate fit. For samples with only two indicators for psychological resources, their paths were constrained to be equal to identify the psychological resources factor. Because our samples were relatively small and to keep
the ratio of sample size to variables low, resource scales and subscales rather than items were used.

The best fitting measurement models were correlated with negative and positive indicators of psychological health. To synthesize results across samples, final models with psychological health variables were re-estimated using Bayesian SEM (Muthén and Asparouhov, 2012), and 500 samples were drawn using Markov chain Monte Carlo methods from the posterior distributions of the latent factors. The data from all four samples were meta-analyzed by combining factor scores and outcomes across samples using a multiple group model treating the repeated samples of the factor scores as multiply imputed data (Asparouhov and Muthén, 2010).

Full information maximum likelihood (FIML) estimation with robust standard errors was used for all estimates. FIML yields unbiased estimates when data are missing completely at random or missing at random, and is a more efficient estimator than listwise deletion (Enders and Bandalos, 2001). Analyses were conducted using R v. 3.0.1 (R Core Team, 2014) and Mplus v. 7.0 (Los Angeles, CA: Muthén & Muthén).

Good model fit was chosen as the combination of the Comparative Fit Index (CFI) > 0.95, standardized root mean squared residual (SRMR) < .08, root mean squared error of approximation (RMSEA) < .06, and a nonsignificant $\chi^2$ (Hu and Bentler, 1999).

Results

Descriptive Statistics

Descriptive statistics and correlations for all samples are reported in Supplementary Tables 1 – 4. Sample 1 contained 99 adults (48 females) with a mean
Sample 2 contained 299 adults (161 females) with a mean age of 58.9 years (%(SD = 13.6); 250 were white, 16 were Latino/a, and 33 were another or non-specified race/ethnicity. Mean years of education was 15.71 (SD = 3.15).

In Sample 3, 88 women completed baseline questionnaires an average of 63 months after diagnosis of breast cancer (%(SD = 50.4 months); 72 were white and 16 were another race/ethnicity. Mean years of education was 16.23 (SD = 2.77) (see Stanton et al. (2013) for details).

Sample 4 contained 129 undergraduates (94 females) with a mean age of 19.1 years (%(SD = 1.9); 61 were Asian, 30 were Latino/a, 30 were white, and 8 were Other/Unknown.

**Measurement Models**

A one-factor model of psychosocial resource indicators fit poorly across all four samples (Table 1), and factor loadings were highly variable. A two-factor model with a latent psychological and social resources factors fit the data well across all four samples (Table 1), and all factor loadings were consistently high and statistically significant. Across the samples, factor correlations ranged from .35 – .47. As the two-factor model fit well, no model modifications were explored.

**Final Models**
For all samples, the final model used the two-factor measurement model and correlated the psychological and social resources with a negative and positive indicator of psychological health.

Standardized estimates for factor loadings, model fit, and correlations for all samples are shown in Figure 1. For Sample 1, 2, and 3, psychological resources had moderate to large negative correlations with the CES-D. Psychological resources also had moderate to large positive correlations with PA in Samples 1, 2, and 4, and SWLS in Sample 3. Social resources demonstrated a similar pattern of correlations, although the magnitude of effects was lower than for psychological resources in Samples 1, 2, and 4. In Samples 1 and 4, social resources correlated significantly with CES-D, but were not statistically significantly correlated with PA. Sample 3 had different indicators for social resources than did the other samples, and in Sample 3, social resources correlated strongly and negatively with CES-D and positively with SWLS.

Meta-Analysis

Combining the data from all four samples, psychological and social resources correlated an average of $r = .40$ ($p < .001$). Psychological resources correlated an average of $r = -.50$ ($p < .001$) and $r = .51$ ($p < .001$) with the negative and positive indicators of psychological health, respectively. Social resources correlated an average of $r = -.32$ ($p < .001$) and $r = .28$ ($p < .001$) with the negative and positive indicators of psychological health, respectively. The negative and positive indicators of psychological health correlated an average of $r = -.39$ ($p < .001$).

Discussion
Common across several theoretical models of resources and health (e.g., Gallo and Matthews, 2003; Taylor and Stanton, 2007) is that multiple constructs are considered resources, which poses the methodological challenge of selecting which resource to test or whether to test multiple resources simultaneously. A general one-factor model of PSRs fit the data poorly. However, a two-factor psychological and social resources factor model demonstrated good fit to the PSRs assessed across all four samples, and the individual resources all loaded significantly on their respective factors. Other research also supports distinguishing psychological and social resources. For example, conceptually related work on eudaimonic well-being (Ryff, 1989) yielded a scale that measures six unique, albeit highly correlated, psychological (e.g., environmental mastery) and social (e.g., positive relations with others) dimensions.

Using individual resources separately requires multiple models to be examined or the “most important” psychosocial resource to be chosen. To the extent that resources function similarly, modeling resources individually adds unnecessary complexity. Our results suggest a resolution by using a factor for psychological (intrapersonal) and social (interpersonal) resources; these factors can encompass multiple measured resources.

Overall, the psychological and social resource factors demonstrated moderate to strong correlations with psychological health, consistent with previous research on individual resources, including optimism (Alarcon et al., 2013), personal control/self-efficacy (e.g., Brown et al., 2014), and social support (Helgeson and Cohen, 1996; Dour et al., 2014). Although not assessed in the present study, meta-analyses have also
demonstrated links between individual resources and objective outcomes including social support with treatment adherence (DiMatteo, 2004), optimism with physical health (Rasmussen et al., 2009), and mastery with cardiometabolic health and mortality (Roepke and Grant, 2011). Considering the strong relations between psychosocial resources and psychological health, one question is whether they are distinct constructs. In a factor analysis of items from psychological resources and a depressive symptoms scale, Saphire-Bernstein et al. (2011) found that the two constructs were distinct, but correlated at \( r = -.50 \).

The direction of associations between PSRs and psychological health were the same across samples, yet there were some differences. In that PSRs are trait-like, they may be more highly related to stable characteristics of psychological health than to state affect. Consistent with that notion, in Sample 3, social resources were strongly correlated with satisfaction with life, and in Sample 4, psychological and social resources demonstrated weaker relations to positive and negative affect reported “in the present moment”. Another explanation is that Sample 3 contains solely women for whom social resources may be particularly salient and Sample 4 consisted of healthy college-aged students with no known prior or current serious health-related threats providing limited room for protective effects of PSRs.

For a two-factor structure to be useful to health researchers practically, it needs to generalize across different populations and varying degrees of health or disease. In the present study, the two-factor structure demonstrated excellent fit across women and men, younger and older adults, and health statuses from healthy to recently diagnosed with eye cancer, active or completed breast cancer treatment, and eye cancer.
survivorship. Although most participants across samples were white, Sample 4 was diverse, with the largest proportion being Asian.

**Study Limitations**

A limitation of this study is that only a sample of the numerous psychosocial resources were assessed. Future studies should assess the structure of other PSRs. For the resources assessed (e.g., mastery/self-efficacy, social support), many published measures are available, and the social resources included in our studies primarily assessed *perceived* support, except in Sample 3. We did assess the most commonly studied domains of psychosocial resources, however.

Because this study involved secondary data analysis, identical measures were not collected in each sample, making it impossible to test whether the factor structure of psychological and social resources was invariant across populations. It is encouraging that in our study, a two-factor structure provided excellent fit across four samples with varying measures, and although not definitive, it sets a precedent for testing and using psychological and social resource factors in health research.

Because our samples were relatively small and SEM requires large samples, we used psychosocial resource subscales, not individual items, to keep the ratio of sample size to variables higher. Future studies with larger sample sizes would benefit from treating subscales as latent rather than observed variables. Despite these sample size concerns, the model did fit well in the largest sample ($N = 299$), and loadings and correlations between factors and psychological health were consistent across all samples. In the meta-analytic synthesis, the sample size reached 615.
Finally, participants were diverse with respect to sex, age, and health status. Generalizability is limited to primarily well-educated, urban-dwelling, white adults, although Sample 4 was racially diverse. Cultural or socioeconomic differences might exist in the structure or relative importance of PSRs.

**Summary and Directions for Research**

We showed the feasibility of using a two-factor model to measure a constellation of psychosocial resources across four samples, diverse with respect to health, age, and sex. Psychological and social resource factors demonstrated moderate to strong correlations with, yet are not redundant with, a variety of negative and positive indicators of psychological health. These results provide a methodological basis for researchers testing larger theories of psychological and physical adjustment to measure a constellation of resources and model resources using factors or composites to represent psychological and social resources, rather than selecting a single scale to represent each construct.

We suggest that researchers interested in PSRs at a minimum assess one measure of both psychological and social resources. Excellent model fit to the data in the present study suggests that the associations between the individual resources and psychological health indicators in the present samples were explained by psychological and social resource factors. Thus, the resource factors may be more important than the specific PSRs chosen as indicators. Prior work consistently demonstrates the relation between resources and physical health, but research is needed to determine whether the resource factors are sufficient to account for associations between resources and physical health or biomarkers. Distinct effects also may emerge when using resources
as moderators. Until these questions have been addressed, researchers interested in PSRs may wish to assess multiple resources in order to test whether any have distinct effects.

Given that psychological and social resources are distinct, albeit related, constructs, researchers may consider using the term “psychosocial” when resources from both domains are discussed and the more specific “psychological” or “social” when only one construct is examined. Although it is important not to promote a false dichotomy, it also is advisable to acknowledge conceptual and empirical distinctions among constructs when warranted.

Finally, multiple theories (e.g., Gallo and Matthews, 2003; Taylor and Broffman, 2011) posit PSRs as moderators and mediators of psychosocial constructs such as stress or socioeconomic status, and as playing key roles in the maintenance of good health and adjustment to stress. Future research should focus on moving beyond testing simple associations to evaluating more comprehensive models of health and adjustment including examining PSRs as predictors of psychological and physical health trajectories.

References


Carver CS. (2006) *Sources of social support scale*. Available at: [http://www.psy.miami.edu/faculty/ccarver/sclSSSS.html](http://www.psy.miami.edu/faculty/ccarver/sclSSSS.html).


He F, Zhou Q, Zhao Z, et al. (2014) Effect of perceived social support and dispositional optimism on the depression of burn patients. *Journal of Health Psychology*.


Table 1. Fit Statistics for One- and Two-Factor Psychological and Social Resources Measurement Models

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*Note. M1 = one-factor model, M2 = two-factor model, CFI = comparative fit index, SRMR = standardized root mean square residual, RMSEA = root mean standard error of approximation. Bold indicates the best-fitting model for each sample. All models were estimated using a robust estimator and chi-square.*
Figure 1. Final Structural Models of Psychological and Social Resources and Psychological Health

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. All models used a robust estimator and standardized estimates and fit well. Sample 1, $\chi^2(31) = 28.26$, $p = .61$, $CFI = 1.00$, $SRMR = .04$, $RMSEA = .00$, $N = 99$. Sample 2, $\chi^2(17) = 23.67$, $p = .13$, $CFI = .99$, $SRMR = .03$, $RMSEA = .04$, $N = 299$. Sample 3, $\chi^2(24) = 35.19$, $p = .07$, $CFI = .95$, $SRMR = .06$, $RMSEA = .07$, $N = 88$. Sample 4, $\chi^2(31) = 43.20$, $p = .07$, $CFI = .97$, $SRMR = .05$, $RMSEA = .06$, $N = 129$. 
Table 1. Descriptive Statistics and Correlations of Study Variables for Sample 1

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*Note.* SS = Social Support, CES-D = Center for Epidemiologic Studies Depression Scale. Descriptive statistics are maximum likelihood estimates using all available data.
Table 2. Descriptive Statistics and Correlations of Study Variables for Sample 2

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*Note. SS = Social Support, CES-D = Center for Epidemiologic Studies Depression Scale. Descriptive statistics are maximum likelihood estimates using all available data.*
Table 3. Descriptive Statistics and Correlations of Study Variables for Sample 3

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*Note. SS = Social Support, CES-D = Center for Epidemiologic Studies Depression Scale, SWLS = Satisfaction with Life Scale. Descriptive statistics are maximum likelihood estimates using all available data.*
Table 4. Descriptive Statistics and Correlations of Study Variables for Sample 4

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Note. SS = Social Support, RSES = Rosenberg Self-Esteem Scale. Descriptive statistics are maximum likelihood estimates using all available data.
PAPER 2: MODELING MULTISYSTEM PHYSIOLOGICAL DYSREGULATION

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Conflicts of Interest and Sources of Funding

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Abstract

Objective: The purpose of this study was to compare the relative fit of four alternative factor models of allostatic load (AL) and physiological systems, and to test factor invariance across age, medication use, race, and sex.

Methods: Data were from the Midlife in the United States (MIDUS) II study Biomarker Project, a large (N = 1,255) multisite study of adults aged 34–84. Specifically, 23 biomarkers were included, representing seven physiological systems: metabolic lipids, metabolic glucose, blood pressure, parasympathetic nervous system, sympathetic nervous system, hypothalamic-pituitary-adrenal axis, and inflammation. For factor invariance tests, age was categorized into three groups (≤ 45, 45 to 60, and >60 years), self-report medications were coded as zero or ≥ one medication(s), and race was categorized as White and Other Race/Ethnicity.

Results: A bi-factor model where biomarkers simultaneously load onto a common allostatic load factor and seven unique system-specific factors provided the best fit to the biomarker data (CFI = .967, RMSEA = .043, SRMR = .028). The bi-factor model was invariant across age groups, medication use, race, and sex.

Conclusions: These results support the theory that represents AL and operationalizes AL as multi-system physiological dysregulation and operationalizing AL as the shared variance across biomarkers. Results also demonstrate that in addition to the variance in biomarkers accounted for by AL, individual physiological systems account for unique variance in system-specific biomarkers.

Keywords: physiological dysregulation; allostatic load; biomarkers; MIDUS
Acronyms: AL = allostatic load; SNS = sympathetic nervous system; PSNS = parasympathetic nervous system; HPA = hypothalamic-pituitary-adrenal axis; WHR = waist-to-hip ratio; HDL = high density lipoprotein; LDL = low density lipoprotein; HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = glycosylated hemoglobin; SBP = systolic blood pressure; DBP = diastolic blood pressure; SDRR = standard deviation of beat to beat intervals; RMSSD = root mean square of successive differences (RMSSD) of beat to beat intervals; LFHRV = low frequency spectral power; HFHRV = high frequency spectral power; E = epinephrine; NE = norepinephrine; Cort = cortisol; DHEA-S = dihydroepiandrosterone sulfate; CRP = C-reactive protein; IL6 = interleukin-6; sE-Selectin = soluble E-selectin; sICAM-1 = soluble intracellular adhesion molecule 1; MIDUS = Midlife in the United States; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; TLI = Tucker Lewis Index.
Introduction

Psychosomatic research has characterized the relations of psychological variables and indicators of major physiological regulatory systems in humans such as the parasympathetic nervous system (PSNS) and the hypothalamic-pituitary-adrenal (HPA) axis (for examples of reviews, see 1, 2, 3). Measures of physiological systems are frequently operationalized via the use of biomarkers. As the field of psychosomatic medicine has advanced, it is increasingly common for multiple biomarkers to be assessed. Although many biomarkers exist for each physiological system, there is little consensus on how to integrate these biomarkers to assess the state and functioning of physiological systems and multi-system physiological dysregulation.

One conceptual approach to integrating biomarkers of multiple systems is allostatic load (AL), which posits that the body’s adaptation to challenge and demands of the environment (allostasis; 4) over time takes a physiological toll and results in cumulative wear-and-tear or dysregulation across multiple physiological systems (5). Thus, the dysregulation is hypothesized to be a multi-systems phenomenon that occurs across multiple regulatory systems rather than in particular systems only. Figure 1 contains a diagram of three potential levels of analysis for biomarkers, from using specific biomarkers as outcomes (bottom), to combining multiple biomarkers to assess specific physiological systems (middle), and the highest aggregate combining multiple physiological systems (AL; top). The primary goal of this paper is to test several plausible measurement models of biomarkers hypothesized to represent both overall AL and individual physiological systems.
An individual with allostatic overload and system-wide dysregulation will demonstrate some degree of dysregulation in multiple physiological regulatory system involved in allostasis, and this physiological dysregulation may be assessed using a composite index from multiple systems. To date, such Indices of AL have typically been created by assuming equal influence of individual biomarkers, dichotomizing them into high and low health risk based on quartiles or clinical risk points, averaging within a particular physiological system (e.g., cardiovascular), and then summing (e.g., 6, 7). Similar indices have been created by first standardizing individual biomarkers and then summing (e.g., 8). Although less commonly applied to biological data, scale development and testing methods such as factor analysis have been used for years to develop and validate measures of latent constructs (e.g., depressive symptoms) from multiple observed indicators (e.g., feeling sad or blue, loss of interest). For an introduction to factor analysis in psychosomatic research, see (9).

The few studies that have examined the psychometric properties and tested the factor structure of biomarkers in relation to AL found that a second-order AL factor (i.e., biomarkers load onto individual system factors which in turn load onto AL) provided adequate fit to the data (10-12). Related work in metabolic syndrome has shown a similar hierarchical factor structure (e.g., 13, 14). In addition, a second-order AL factor model of biomarkers was found to be invariant across sex and ethnicity (11), and provided good fit when controlling for sex and age (10); it did, however, differ between participants on and off of medications in an elderly sample (12).

Limitations are apparent in the existing literature on AL. First, previous research has had relatively few biomarkers per system, leaving open the question whether the
same factor structure will emerge when systems are more comprehensively assessed. Second, although AL is hypothesized to be prominent in the aging process (15), to our knowledge, no previous study has tested whether the measurement of AL is invariant across adulthood or whether the relations among biomarkers differ as a function of age. Finally, although a second-order factor model provided adequate fit in previous studies, there was room for improvement of model fit. Given the complex relations among biomarkers, examining alternative models may be valuable.

In the present study, we used data from the Midlife in the United States (MIDUS) II Biomarker Project, to address the following aims.

**Aim 1**

To test and compare four theoretically-derived factor models that reflect one or both of two hypotheses: (1) biomarkers within a physiological system are associated, and (2) based on AL theory that there is system-wide dysregulation, biomarkers or systems should load onto a common factor. The specific models are discussed in the Data Analysis section, and illustrated in Figure 2. Model 1 reflects (2) only, Model 2 reflects (1) only, Models 3 and 4 are alternative models that reflect both (1) and (2). Specifically, we hypothesize that Model 1, which does not account for any system-specific effects, will demonstrate poor fit to the data. Models 2 and 3 will both demonstrate acceptable fit, with Model 3 representing a more parsimonious version of Model 2. To the extent that system-wide and system-specific effects overlap, Model 4 will demonstrate no better fit than Model 3, and be less parsimonious. To the extent that system-wide and system-specific have unique and non-overlapping elements, Model 4 should demonstrate better fit. Because we expect important, unique system-
wide and system-specific effects, we hypothesize that Model 4 will demonstrate the best fit.

**Aim 2**

To test whether the optimal factor structure underlying biomarkers of AL (Aim 1) are invariant across adulthood from 34 y to 84 y as well as across medication use, race/ethnicity, and sex.

**Methods**

**Sample**

The sample came from the larger MIDUS study. The first wave of data, MIDUS I, included phone interviews and mailed questionnaires for a national sample of adults, ages 25 to 74 designed to assess factors related to physical and psychological health and well-being in early adulthood, middle adulthood, and older age. Data for MIDUS I were collected in 1994-1995 in four parts: a large, national probability sample (the core sample; \( N = 3,487 \)), siblings of the core sample (\( N = 950 \)), twins (\( N = 957 \) pairs), and an over-sampling in metropolitan areas (\( N = 757 \)). Participants from MIDUS I, as well as an additional sample of urban African-Americans living in Milwaukee, WI (\( N = 592 \), to increase diversity) were assessed in 2005 for MIDUS II (16). MIDUS II included follow up questionnaires, and a subset of participants who were eligible and consented (\( N = 1,054 \) from the original sample and \( N = 201 \) from the Milwaukee sample) participated in the MIDUS II Biomarker Project where extensive biological data were collected (17).

**Procedure**
As part of the MIDUS II Biomarker project, participants went to one of three (University of California Los Angeles, University of Wisconsin, and Georgetown University) General Clinical Research Centers for a medical exam, comprehensive biomarker assessment (e.g., fasting blood draw, 12-hour urine, electrocardiography), and reported on medical history and major, chronic health conditions. Details on MIDUS are available online at http://www.midus.wisc.edu and for the biomarker project, see (17). The MIDUS II Biomarker Project was approved by the Institutional Review Boards of the University of Wisconsin, Madison, the University of California, Los Angeles, and Georgetown University.

Demographics and Health Outcomes

Demographic data including age, sex, and race/ethnicity were collected via self-report. For analysis, race/ethnicity was coded as White vs. Other Race/Ethnicity. Self-reported medication use, including antihypertensive medications, heart rate reducing (e.g., beta blockers), diabetes medications, cholesterol-lowering medications, and fibrates, was collected and used to code whether participants were taking one or more medication that would affect the biomarkers assessed or not.

Biological Measures

Seven physiological systems were measured using 23 biomarkers. Details on collection and assay of biomarkers are reported in Supplementary data file 1 in (18).

Lipids. The metabolic lipid system was measured using waist-to-hip ratio (WHR), triglycerides in mg/dL, high density lipoprotein (HDL) cholesterol in mg/dL, and low density lipoprotein (LDL) cholesterol in mg/dL.
Glucose. The metabolic glucose system was measured using the homeostatic model assessment of insulin resistance (HOMA-IR), fasting glucose in mg/dL, and glycosylated hemoglobin (HbA1c) in percent.

Cardiovascular. The cardiovascular system was measured with resting systolic blood pressure (SBP) in mmHg and diastolic blood pressure (DBP) in mm Hg. For the model, these were converted into pulse pressure (SBP – DBP) and SBP.

Parasympathetic Nervous System. The parasympathetic nervous system (PSNS) was measured using heart rate variability and resting pulse rate (in beats per minute). Heart rate variability was assessed via electrocardiography and was operationalized as the standard deviation of beat to beat intervals (R—R interval; SDRR), root mean square of successive differences (RMSSD), low frequency spectral power (LFHRV) and high frequency spectral power (HFHRV).

Sympathetic Nervous System. The sympathetic nervous system (SNS) was measured using 12-hour, overnight urinary epinephrine (E) in μg/g creatinine and norepinephrine (NE) in μg/g creatinine.

Hypothalamic Pituitary Adrenal Axis. The hypothalamic pituitary adrenal (HPA) axis was measured using 12-hour, overnight urinary cortisol mg/g creatinine and blood serum dihydroepiandrosterone sulfate (DHEA-S) in μg/dL.

Inflammation. Inflammation was measured using plasma levels of C-reactive protein (CRP) in mg/L, interleukin-6 (IL6), fibrinogen in mg/dL, sE-Selectin in ng/mL, and soluble intracellular adhesion molecule 1 (sICAM-1) in ng/mL.

Data Analysis
Structural equation modelling (SEM) was used to compare four, plausible alternative models of the relations among biomarkers, with age and sex included as covariates. The general structure of these models is diagrammed in Error! Reference source not found..

**Model 1.** All 23 biomarkers load onto a single factor. This model tests whether there is a single, common cause underlying individuals' levels on all biomarkers across all systems.

**Model 2.** Biomarkers load onto their respective physiological system, and the seven systems are allowed to freely covary. This model tests whether relations among biomarkers are explained by each physiological subsystem and the relation among physiological subsystems.

**Model 3.** Biomarkers load onto their respective physiological system, and the seven systems in turn load onto a second-order factor. This model tests whether relations among biomarkers are explained by each physiological subsystem, and the relations among the physiological subsystems are explained by a single, common factor.

**Model 4.** Biomarkers load onto their respective physiological system, and the seven systems are allowed to freely covary; in addition, each biomarker loads directly onto a common factor (AL). This bi-factor model tests whether the relations among biomarkers are explained by two processes: 1) a common factor, capturing the notion that there is an underlying process influencing multiple physiological systems and 2) system specific factors, capturing the notion that beyond the common portion shared
across biomarkers, there are unique effects of particular physiological systems that are independent of other systems.

Model fit indices were used to find the best fitting of the four hypothesized factor structures. Multiple group SEM was used to test whether the best-fitting model (1 – 4) was the same (invariant) or varied across different groups. Specifically, model invariance was tested for age group (≤ 45, 45 to 60, >60 years) to establish whether the structure is consistent or differs for younger and older participants, medication use because medications may artificially constrain certain biomarkers and because of the previous invariance reported (12), race/ethnicity (White vs. Other Race/Ethnicity), and sex (Female vs. Male).

**Statistical Methods**

Biomarkers were assessed for univariate normality and log transformations were applied to E, NE, SDRR, RMSSD, LFHRV, HFHRV, cortisol, DHEA-S, CRP, IL6, sE-Selectin, HbA1c, fasting glucose, HOMA-IR, and triglycerides. Outliers were addressed by windsorizing the lower and upper 0.5%. Because multivariate non-normality remained despite these transformations, a robust estimator and standard errors were used. To address the small amount (< 3%) of missing data, full information maximum likelihood (FIML) estimation was used (19). Standard errors and model tests were adjusted for clustering in siblings and twins.

Good model fit was chosen as the combination of the Comparative Fit Index (CFI) > 0.95, standardized root mean squared residual (SRMR) < .08, and root mean squared error of approximation (RMSEA) < .06 (20). Data management, descriptive statistics, and transformations were conducted using R v. 3.1.1 (21) and Mplus v. 7.3
Results

Participant age ranged from 34 to 84 with approximately equal numbers of females and males. Sample characteristics and descriptive statistics for the biomarkers (untransformed) are presented in Table 1. Based on preliminary analyses, three modifications were made to all hypothesized models. First, HOMA-IR was allowed to cross load on both the lipid metabolism and glucose metabolism factors. Second, heart rate was used as an indicator of the PSNS rather than the cardiovascular factor. Third, a residual correlation between HFHRV and RMSSD was allowed. No other modifications to the hypothesized models were done.

Aim 1: Model Comparisons

Model fit indices comparing the four alternative models (Figure 2) are shown in Table 2. As hypothesized, the one factor model (M1) demonstrated poor fit to the data (CFI = .533, RMSEA = .146, SRMR = .104). The correlated factors model (M2) demonstrated acceptable fit, with two of the three indices meeting the criteria for good fit, although the CFI did not (CFI = .932, RMSEA = .058, SRMR = .051). The second order model (M3) fit statistically significantly worse than the correlated factors ($\Delta \chi^2(df = 14) = 75.78, p < .001$); however, consistent with our hypotheses, the difference in fit indices was small ($\Delta$CFI = .004, $\Delta$RMSEA < .001, $\Delta$SRMR = .004), suggesting that the more parsimonious second order factor model (M3) provides similar fit to the correlated factors model. As expected, the bi-factor model demonstrated the best fit to the data,
and met all criteria for good model fit (CFI = .967, RMSEA = .043, SRMR = .028). The bi-factor model also fit significantly better than all alternative models (all ps < .001). These results suggest that a common factor does underlie the individual biomarkers, but that there are also unique system-specific effects.

**Aim 2: Model Invariance**

The fit of the bi-factor model was tested across age (≤ 45, 45 to 60, >60 years), medication (no medications, 1+ medications), race/ethnicity (White, Other Race/Ethnicity), and sex (female, male) groups using a multiple group model constraining both the factor loadings and the intercepts of the individual biomarkers to be equal across groups. Model fit indices are shown in Table 2. The invariant multiple group bi-factor model provided good fit to the data for all groups (all CFIs > .95, all RMSEAs < .05, all SRMRs < .06).

**Discussion**

Across 23 biomarkers in a large sample of adults, a bi-factor model of AL provided both good fit and was the best fitting of all alternative models tested. This result has two important implications. First, it confirms what previous studies have demonstrated that consistent with AL theory, a common factor underlies biomarkers of multi-system physiological functioning (10-12). Second, it is the first study, to our knowledge, that demonstrates that in addition to the common underlying AL factor, there are also significant system-specific factors.

In a recent editorial, Gallo, Fortmann, and Mattei (23) argued for a need to standardize the measurement of AL and for researchers to report on the specific
components of AL. We agree that the specific components of AL are important; indeed the bi-factor structure suggests that specific physiological systems account for additional variance in biomarkers over and above AL. Using a method that allows both AL and specific physiological systems to be used as independent predictors or outcomes facilitates examining both system-wide (AL) and system-specific effects. We believe that using a bi-factor model represents an important advance in psychosomatic research for untangling the relations between psychological factors and system-specific and system-wide physiological dysregulation.

We found that the bi-factor model was invariant across race/ethnicity and sex, which is consistent with prior research on AL (11), as well as across age groups. Contrary to findings from the Lothian birth cohort (12), in the MIDUS data, we found no difference in the relations among biomarkers for participants on or off medications (i.e., the bi-factor model was invariant by medication use). Perhaps the differences in results are due to differences in the age of the samples. In the Lothian cohort (12), the average age was 72.5 ($SD = .70$) whereas in the present sample, the average age was 54.5 ($SD = 11.71$), and the average age for participants taking at least one medication was only slightly older at 57.5, substantially lower than the age of participants in the sample used by (12).

Limitations of the current study should be noted. The sample was predominantly White, with fewer African-Americans and only small numbers of other races/ethnicities represented. Thus although we demonstrated that the bi-factor model was invariant across both Whites and Other Race/Ethnicity (primarily African-Americans), these results may not generalize to all races or ethnicities. In addition, only basal levels of
biomarkers were assessed; future research is needed to examine relations among functional measures of biomarkers (e.g., inflammatory response to antigens).

The study also has several important strengths. The current study comprehensively assessed seven physiological systems using 23 biomarkers. The use of many biomarkers ensures that each of the seven systems are measured by more than one biomarker, allowing us to differentiate effects shared across systems and effects unique to systems. Another strength is the large sample, with over 1,000 participants representing a broad age range from 34- to 84-years old. Finally, the current study used careful statistical analyses including: accounting for clustering in twins and siblings in the MIDUS data, non-normality of the biomarkers, missing data, investigating plausible alternative theoretical models, and testing for invariance across age, race/ethnicity, medication use, and sex.

In conclusion, across 23 biomarkers in MIDUS, we found evidence for a common AL factor, as well as for seven system-specific factors, and this model held across all subpopulations tested. Future research is needed to examine the predictive effects of AL and specific systems on health. Future research could also explore whether for specific outcomes, such as specific diseases, whether the common AL factor or a particular system-specific factor is most important. In order to standardize the measurement of AL as Gallo, Fortmann, and Mattei (23) suggest, further work is needed to reach consensus on how to define “optimal” measures of AL and specific physiological systems (e.g., predict disease incidence or mortality, predict functioning), and then to develop and validate sets of biomarkers for each system and for AL overall.

References


# Table 1. Descriptive statistics for sample demographics and raw biomarker values

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<tr>
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<th>Median (IQR) / N (%)</th>
</tr>
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<tr>
<td><strong>Demographics</strong></td>
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<tr>
<td>Age (years)</td>
<td>54 (45, 62)</td>
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<tr>
<td>Sex: Female</td>
<td>713 (56.8%)</td>
</tr>
<tr>
<td>Race/Ethnicity: White</td>
<td>967 (77.2%)</td>
</tr>
<tr>
<td>African American</td>
<td>222 (17.7%)</td>
</tr>
<tr>
<td>Other</td>
<td>64 (5.1%)</td>
</tr>
<tr>
<td>Medications: None</td>
<td>486 (38.7%)</td>
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<td><strong>Sympathetic nervous system</strong></td>
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<tr>
<td>Urine epinephrine (mg/g of creatinine)</td>
<td>1.67 (1.13, 2.46)</td>
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<tr>
<td>Urine norepinephrine (mg/g of creatinine)</td>
<td>24.80 (18.14, 32.94)</td>
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<td><strong>Parasympathetic nervous system</strong></td>
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<td>R-R interval standard deviation (ms)</td>
<td>32.53 (23.72, 44.62)</td>
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<td>Root mean square of successive differences (ms)</td>
<td>18.38 (12.13, 27.57)</td>
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<td>Low-frequency power (ms^2)</td>
<td>245.95 (114.95, 514.50)</td>
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<td>High-frequency power (ms^2)</td>
<td>140.45 (58.80, 304.75)</td>
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<td>Resting heart rate (beats per minute)</td>
<td>70.00 (64.00, 79.00)</td>
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<td><strong>Hypothalamic-pituitary-adrenal axis</strong></td>
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<td>Urine cortisol (mg/g of creatinine)</td>
<td>12.00 (6.75, 19.00)</td>
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<td><strong>Inflammation</strong></td>
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<td>Serum C-reactive protein (mg/L)</td>
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<td>Serum interleuken-6 (ng/L)</td>
<td>2.17 (1.37, 3.52)</td>
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<td>Fibrinogen (mg/dL)</td>
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<td>Soluble Intracellular adhesion molecule-1 (mg/L)</td>
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<td>Soluble E-selectin (ng/mL)</td>
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<td>Pulse Pressure (mm Hg)</td>
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<td>Systolic blood pressure (mm Hg)</td>
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<td>Blood glycosylated hemoglobin (%)</td>
<td>5.86 (5.60, 6.24)</td>
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<td>Fasting blood glucose (mg/dL)</td>
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<td>Homeostasis model assessed insulin resistance</td>
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<td>Low-density lipoprotein cholesterol (mg/dL)</td>
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<td>High-density lipoprotein cholesterol (mg/dL)</td>
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<td>Serum triglycerides (mg/dL)</td>
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<tr>
<td>Waist-to-hip circumference ratio</td>
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Table 2. Model Fit Statistics

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Note. CFI = Comparative Fit Index, TLI = Tucker Lewis Index, RMSEA = root mean square error of approximation, SRMR = standardized root mean square residual. Age group (≤ 45, 45 to 60, >60 years), medication (no medications or 1+ medications), race (White vs. Other Race/Ethnicity), and sex (female vs. male) invariance were tested for the best fitting, bi-factor model. Continuous age and sex were included as covariates in all models, except sex was omitted as a covariate in the sex invariance model. $N$ ranged from 1,252 – 1,254 due to missing data.
Figure 1. Continuum of specificity of biomarker outcomes, from the level of individual biomarkers, to individual physiological systems, to composites across multiple systems.
Figure 2. Sample diagrams of the four plausible factor models tested and compared.
PAPER 3: RELATIONS OF PSYCHOSOCIAL RESOURCES WITH ALLOSTATIC LOAD: A SYSTEMATIC REVIEW

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Abstract

Background: Allostatic load (AL) represents cumulative wear-and-tear on the body and is operationalized as a multi-system index of biomarkers. Research demonstrates the association of AL and important health outcomes such as morbidity and mortality, leading to a growing body of literature that uses AL as an outcome in itself. Psychosocial resources (PSRs) represent a broad class of constructs that are positively related to psychological and physical health. The current review seeks to characterize the relations between PSRs and AL.

Method: A systematic review was conducted of studies examining the relation between at least one PSR and AL. From the 1,277 abstracts screened, 42 full-text articles were reviewed, and 25 studies met the criteria for inclusion.

Results: There was mixed evidence for a relationship between psychosocial resources and allostatic load. Compared to cross-sectional studies, longitudinal studies were more likely to report a significant relationship ($k = 10/12$ versus $k = 7/13$, respectively). Studies that reported a significant main or moderated relationship tended to have a larger sample size than those that reported no significant relationship (Median 782.0 vs. 224.5, respectively). Whether a study reported a significant main or moderated relationship did not differ by whether psychological ($k = 9/13$) or social ($k = 10/15$) resources were assessed.

Conclusions: Evidence for a relationship between PSRs and AL is equivocal, and obtained significant relationships are generally small in magnitude. Longitudinal studies and those with larger sample sizes appeared more likely to yield significant main or moderated relationships. Most ($k = 13/25$) studies used a cross-sectional design and
only one study investigated whether a PSR predicted change in AL. Future research is needed examining PSRs as predictors of change, not merely level, of AL.

**Keywords**: allostatic load; psychosocial resources; social relationships; review
Introduction

Allostatic load (AL) theory posits that repeated adaptation to challenge (allostasis or stability through change, 1) can lead to impaired ability to respond to stress (e.g., a failure to properly shut off stress response systems) and cumulative wear-and-tear on the body. AL has been operationalized by assessing indicators of multiple biological systems, such as the cardiovascular, metabolic, inflammatory, and neuroendocrine systems. Because the theory posits effects across the entire body, it suggests a common correlation among biological systems. Researchers have created multi-system indices of AL by measuring biomarkers from different systems, creating risk cutoffs (frequently based on the upper or lower 25th percentile), and summing the number of systems in which an individual is at risk. Research using multisystem indices of AL demonstrates robust relations between AL and health. For example, in older adults, AL is associated with declines in memory and cognition (3), higher incidence of cardiovascular disease (2), and mortality (4).

Since its introduction and the classic papers by Bruce McEwen and colleagues (5-7), scientific publication on AL and allostasis has grown steadily, with the number of published studies in PubMed going from 4 in 1998 to 126 in 2014. As the value of AL as a predictor of health outcomes and mortality has become apparent, research has shifted from utilizing AL as a predictor to using AL as an outcome. Although caution is warranted when examining biomarkers in place of clinical endpoints (c.f., 8) and researchers have noted the limitations of biomarkers as outcomes (e.g., 9), AL is an attractive outcome for pre-clinical studies and in populations where poor health may not have progressed to the point of indicating clinical risk. Furthermore, because AL can be
measured by continuous scores on biomarkers, it has the potential to be a sensitive marker of change. Sensitivity to small differences is particularly important in the biobehavioral sciences, where the effects of a focal variable on a given physiological system may be expected to be small. For example, a meta-analysis of 43 studies of optimism and objective physical health outcomes found a mean effect size of $d = 0.11$ (10). The primary goal of this review is to characterize the relations of psychological and social resources with allostatic load.

**Psychosocial Constructs and Allostatic Load**

Empirical work demonstrates a robust link between indicators of stress and adversity with AL. For example, lower socioeconomic status (SES) is associated with higher AL (e.g., 11, 12-15). Direct measures of chronic stress in the domains of work, finances, and caregiving also are associated with higher AL (16). However, studies examining other psychosocial predictors of AL are comparatively sparse.

**Defining psychosocial resources.**

Psychosocial resources (PSRs) represent a set of variables that may explain variation in AL and health outcomes. Broadly, anything that is intrinsically valuable or facilitates access to something intrinsically valuable may be considered a resource (17). Psychosocial resources then may be defined as “individual differences and social relationships that have beneficial effects on mental and physical health outcomes” (p. 1; 18). PSRs are distinguished from other resources such as socioeconomic status, biological resources, and cultural resources in their focus on either intraindividual psychological resources or interindividual social resources. Moreover, empirical
evidence supports the distinction between psychological and social resources (Wiley, Cleary, Beran, Karan, Jorge, McCannel, & Stanton, submitted); we adopt that distinction in this review.

It is important to distinguish between psychosocial resources and their hypothesized psychosocial and physical health consequences. Mental and physical health are intrinsically valued, but PSRs, such as a high perception of control, need not be valued in and of themselves. For a construct to be considered a PSR, it is sufficient that the construct help enhance or protect health, but by itself is not an indicator of health, such as psychological well-being or physical stamina.

Another important distinction is that between positive resources and their “negative” counterparts. For example, if high optimism is considered a psychological resource, should the low optimism and the absence of pessimism also be considered resources? Whether a construct is unidimensional or multidimensional matters. For example, if social integration is defined as frequent interactions with a large social network, and social isolation is defined as infrequent interactions with a social network, it is clear that the construct is unidimensional and whether it is framed positively (i.e., “social integration”) or negatively (i.e., “social isolation”), it is a social resource.

Unfortunately, such clarity as with social integration versus isolation rarely exists. How constructs are operationalized complicates determining whether a specific construct is a PSR. Because the literature on PSRs and AL is small, we included PSR constructs when their presence or absence could facilitate (but not be equivalent to) psychological or physical health outcomes.

**Psychosocial Resources, allostatic load, and health outcomes.**
Psychosocial resources are linked to diverse health outcomes. For example, social support predicts psychological adjustment to chronic disease (for a review, see 20) and physical health outcomes (21). Both functional (e.g., received and perceived social support) and structural (e.g., social integration) social support are protective factors for mortality on par in magnitude to commonly known risk factors such as smoking (for reviews, see 22, 23). Another PSR, optimism, is linked to both psychological and physical health outcomes (for a review, see 24). AL may be a conduit for the effects of PSRs on morbidity and mortality.

Psychosocial resources may influence physiology and AL via several pathways. First, PSRs may indirectly influence health via health behaviors. Thus, people who are high in PSRs may engage in fewer deleterious behaviors, such as cigarette smoking, or engage in more health-promoting behaviors, such as physical activity. Second, PSRs may have a direct influence on physiology. Third, PSRs may indirectly influence health by preventing or buffering (e.g., 25) the deleterious effects of stress and physiological stress reactivity on health. The mechanisms linking PSRs to physiology are important to consider when interpreting results, particularly when there are covariates in the model as these may actually represent the mechanisms through which PSRs influence physiology. For example, people who are high in PSRs may be more adherent to medical treatment and have a better diet and consequently have better health. Including adherence and diet as covariates, without examining how PSRs relate to each, would mask the salutary effects of PSRs on AL or health outcomes through health behaviors.
AL theory posits that repeated or extended exposure to stress, or failure to recover from the stressor, can provoke wear-and-tear on the body’s systems and subsequent adverse health outcomes (5). Despite the theoretical link between cumulative stress and AL, empirical evidence is equivocal. For example, Gersten (26) found no effect of cumulative life history stress on neuroendocrine AL. One explanation for the equivocal findings is that individuals' physiological responses to stressors may not be the same. For example, consistent with the buffering hypothesis of social support, individuals high in PSRs may not perceive events as stressful or may be able to recover well even after repeated stressful experiences. In this case, PSRs would buffer the effects of stress on health outcomes. Therefore, in addition to main effects of PSRs on AL, in the current review, potential moderating effects of psychosocial resources will be examined. The purpose of the current systematic review is to examine the empirical literature on both direct and moderating relations of PSRs, specifically indicators of social relationships and dispositional psychological resources, with AL.

**Methods**

This systematic review was conducted with a standard protocol in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.

**Search Strategy**

Systematic searches of literature were carried out across five databases: PubMed, CINAHL Plus, PsycInfo, Scopus, and Embase. The search duration was
between the inception of each database and December 2014. No language restriction was applied; records written in foreign languages were translated for review. Search strategy and terms were decided a priori. All records with either “allostatic load” or “allostasis” occurring anywhere in the title, abstract, or keywords of articles were included.

**Selection Criteria**

The following selection criteria were applied:

1) **Included empirical data and results.** Reviews, theoretical papers, and other papers not reporting data and analyses were excluded.

2) **Published in a scientific journal.** Dissertations and conference presentations were not included, unless they were published in a peer-reviewed, scientific journal, in order to partially control for quality of the study.

3) **Conducted on humans.** Only studies on humans were included. Nonhuman animal research was excluded.

4) **Included at least two biological systems and a composite index of AL.** For example, studies examining only PSRs and diurnal cortisol were not included. In order to focus on AL as the cumulative wear-and-tear across the system, studies that examined more than one system (e.g., salivary cortisol and salivary alpha-amylase), but that did not examine them as a composite, were excluded.

5) **Included at least one PSR.** Although being a “resource” suggests that higher levels should be beneficial, due to the limited research and the difficulty in distinguishing having high levels of something good versus low levels of something bad, psychosocial variables that were “good” at either high or low
levels were included. For example, social isolation was included. In the remainder of this paper, the terms “social resources” and “psychological resources” are used generally for these variables regardless of whether it is desirable to be high (e.g., social integration) or low (e.g., social isolation). Studies incorporating marital status into more complex measures of social integration were included; however, studies in which the only social relationship variable was marital status were excluded, because A) marital status alone is not a comprehensive measure of social network or integration, B) marital status alone does not capture quality of the relationship or available support, C) many studies do not focus on the relationship of marital status and AL, but rather include it among other covariates, and D) a large meta-analysis by Holt-Lunstad, Smith (23) of various measures of social network revealed that marital status alone had one of the weaker relations to mortality.

6) **Tested or reported the relation between PSRs and AL.** Included studies had to report on the relationship between PSRs and AL. Studies that assessed both but did not relate them were excluded.

**Screening**

Reference management software (PaperPile) was used to remove duplicates automatically and for an initial screen of criteria 1 and 2. Next, two authors (JFW and BB) independently screened the remaining records for eligibility of inclusion following criteria 1 – 5 listed above. Because not all studies including both PSRs and AL are focused on PSRs, we only required that PSRs be mentioned in the abstract, not explicitly related to AL, therefore, criterion 6 was not used at this stage of screening.
Disagreements were resolved via discussion. For the remaining abstracts, full text of the articles were retrieved and again screened independently by two authors (JFW and BB) for eligibility of inclusion following criteria 1 – 6.

**Data Extraction**

A data extraction sheet was developed based on the STROBE Statement, a guideline for reporting observational studies. There is not a gold standard quality assessment tool for systematic reviews of observational studies without direct group comparisons; however, in addition to extracting data regarding the sample and methods, we assessed three criteria related to quality of information on the association between PSRs and AL. Shown in Table 1, the three criteria were whether the study had a clearly described, directional a priori hypothesis, whether the sample size was justified, and whether the measures of psychosocial resources were validated and had adequate internal consistency reliability.

**Results**

**Study Design and Characteristics**

A study selection flow diagram is shown in Figure 1. From the 1,277 references screened, a total of 25 studies ultimately were eligible for review. Inter-rater reliability for inclusion or reason excluded was high for the 821 abstracts screened, $\kappa [95\% CI] = .81 [.78, .84]$ as well as the screening of the full text of 42 articles, $\kappa [95\% CI] = .96 [.87, 1.0]$. Quality assessments for each study are reported in Table 2. Most studies ($k = 13$) had an a priori directional hypothesis, did not discuss or justify the sample size at all ($k$
and used validated measures of PSRs and/or reported adequate internal consistency reliability (k = 15). None of the 25 studies justified the sample size a priori.

The 25 studies used 15 unique samples (details of the sample recruitment and setting are reported in Table 3). The majority (k = 19) of studies used data from large epidemiologic studies, often on subsamples of participants for whom biomarkers were available. Studies were geographically diverse conducted in Asia (k = 4), Europe (k = 4) and North America (k = 17). They also included a wide age range with the average age ranging from 9.2y to 74.5y. Samples contained an approximately equal number of females and males. All studies were observational and employed longitudinal (k = 12) or cross-sectional (k = 13) designs. Detailed study characteristics are reported in Table 4.

Measures of Allostatic Load

Table 5 presents the biomarkers included to assess AL in each study as well as the method used to create the AL index. The most common method of creating an AL index was by dichotomizing biomarkers into “at risk” or “not at risk” based on quartiles and then summing (k = 21), with the remaining studies standardizing (k = 3), and the last calculating risk as at below the 10th percentile or above the 90th percentile on each biomarker. These scores then were either directly summed, or first averaged within a biological system (e.g., cardiovascular, sympathetic) and then summed across systems, in order to give each system equal weight in the overall composite.

The number of biomarkers included in the AL indices ranged from 6 to 24 (Median = 10). The most common biomarkers were systolic blood pressure (k = 25), diastolic blood pressure (k = 23), epinephrine (k = 19), norepinephrine (k = 19), cortisol
(k = 18), high density lipoprotein cholesterol (k = 18), glycosylated hemoglobin (k = 17), and waist-to-hip ratio (k = 17), with the remaining biomarkers occurring less frequently (see Appendix 1 for the frequency of each biomarker).

**Psychological Resources and Allostatic Load**

Ten studies assessed only psychological resources, with three additional studies assessing both psychological and social resources in relation to AL. Control-oriented resources (e.g., self-control, self-regulation, perceived mastery, perceived control, perceived low constraints representing the opposite of perceived mastery/control) were the most frequently studied (k = 7), followed by optimism (k = 4), positive affect (k = 2), sense of coherence (k = 2), self-worth (k = 1), and shift and persist (k = 1). Detailed results are presented in Table 6.

**Control-related resources.**

In a longitudinal study of adolescent rural African American students (27), teacher-rated self-control/competence had no main effects but exacerbated the deleterious effect of SES-related risk on AL, suggesting that maintaining self-control/competence in the face of adversity may take a physiological toll. Similarly, in a cross-sectional study of adults caring for spouses with Alzheimer’s disease (28), mastery had no main effects, but exacerbated the effects of being a caregiver. However, in a longitudinal study of children (29), behaviorally assessed self-regulation did not interact with childhood poverty. Although the relation was not significant, self-regulation was associated with higher AL (29, 30). In contrast, in epidemiological samples of adults from longitudinal data from Taiwan (31) and cross-sectional data from
the US (32), higher mastery and perceived control and low perceived constraints were associated with significantly lower AL, and another cross-sectional study of adults reported no relation (33).

**Other psychological resources.**

One longitudinal (31) and two cross-sectional studies (34, 35) assessing optimism found no significant relation. In all three, higher optimism was associated with lower AL, but the effect sizes were near zero. In the fourth longitudinal study assessing optimism (36), in lifetime career patterns where the women tended to have high optimism the women also tended to have low AL. Although this effect appeared large ($r = -.61$), the data were not presented at the level of individual women, but only at the level of 10 distinct career patterns. Therefore, these results are based on essentially 10 data points. Two cross-sectional studies assessed positive affect (33, 37), and found no main effects, although one found that positive affect buffered the deleterious effect of parenting a child with a developmental disorder (37) on AL. Two studies assessed sense of coherence. One cross-sectional study reported higher sense of coherence was associated with lower AL, although the relationship was not significant (35). One longitudinal study found that higher AL predicted a decrease in sense of coherence 6 years later (38).

In a cross-sectional study, for adults with low SES, being high in indicators of both “shift” (positive reappraisal, control, and emotion regulation) and persistence was associated with lower AL (39), with a marginally significant main effect of high persistence associated with lower AL in the high-SES group. One longitudinal study (36) reported that across 10 distinct lifetime career patterns, psychological well-being
(self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life, and personal growth) had a strong negative association with AL. As described above, this study was limited due to the correlation being calculated at the group level rather than the individual level. Seven dispositional coping styles had no significant cross-sectional associations with AL (34), although most were in the direction that higher approach-oriented and lower avoidance-oriented coping were associated with lower AL. Finally, in a cross-sectional study of children, self-worth and persistence were non significantly associated with lower AL (30).

In summary, there is mixed evidence for a relationship between psychological resources and AL. Approximately equal number of studies reported a significant main effect only (k = 5/13), moderated effect (k = 4/13) and no significant effects (k = 4/13). Only one study that reported testing for moderation reported no significant moderated effects, whereas more (k = 4/13) reported at least one non-significant main effect, excluding studies that found significant moderated effects. Studies that assessed PRs tended to have a smaller sample size than studies that did not assess PRs (median $N = 339$ vs. 601). All studies assessing PRs reported some information on the quality of the PR measures, and most used validated measures or reported good internal consistency reliability (k = 9/13). There were no discernible differences in the quality of hypothesis or justification of sample size for studies with PRs versus those that did not assess PRs. Finally, most studies assessing PRs were cross-sectional (k = 8/13).

**Social Resources and Allostatic Load**

Twelve studies solely assessed social resources, with three additional studies assessing both social and psychological resources in relation to AL. Social support and
quality of relationships were the most frequently assessed social resources \((k = 14/15)\). Fewer studies assessed more structural variables such as indices of social connection, and quantity of social contacts or social activities \((k = 9/15)\), although many \((k = 8/15)\) studies assessed both social support/quality of relationships and structural measures. Detailed results are presented in Table 7 and in Table 6 for the studies assessing both psychological and social resources.

**Social support/quality of relationships.**

Three studies demonstrated that social support moderated the effects of adversity. Although emotional support had no main effect, in a longitudinal study, it buffered the effect of perceived discrimination on AL \((40)\). Similarly, in a three-way interaction, emotional support buffered the effect of a longitudinally assessed worsening pattern of neighborhood poverty, but had no impact for improving, stable low or stable high neighborhood poverty \((41)\). Finally, in a longitudinal study, having a pattern of positive relationships (above the median on caring from at least one parent and above median in one domain of bonding with current partner) versus negative relationships (below the median on caring from both parents or below median on both domains of bonding with current partner) was associated with lower AL in low but not high household income \((42)\).

In a longitudinal study, a composite of social support from friends, family, and spouse had no main effects, but was moderated by age, such that in younger adults higher social support was associated with lower AL, but in older adults higher social support was associated with higher AL \((43)\). Sex did not moderate any of these effects.

In contrast, in a cross-sectional study, AL was significantly lower for positive vs.
negative relationships for women, but not men (44). The same study found, however, that emotional support was associated with lower AL for men, but not women (44). The relations of low emotional support across multiple study assessments and low emotional support at any one study assessment also differed significantly by sex in adults aged 54y - 70y, with lower emotional support associated with higher AL for men but lower AL for women (45). The difference between women and men was significant, although neither simple effect was significant. However, no relationships between emotional support and AL were found in the elderly aged 71y and older (45), which is consistent with the results reported in (43).

Two studies reported main effects of social support. Social support was associated with lower AL in a cross-sectional study of middle-aged adults (46). In contrast, social support predicted higher AL four years later, controlling for concurrent social support, in a sample of older adults residing in England (47).

Despite these positive findings for social support, eight studies report null results. Four cross-sectional studies, found no relationship between AL and social support or loneliness (34), social support from either friends or family (33), instrumental support (44), or emotional or instrumental support in women (48). Two studies additional cross-sectional studies assessed job-related social support and found it had no main effect and did not interact with job demands (49) and had no main effect in women or men nor did it interact with age or occupational status (50). Two longitudinal studies reported no associations. High emotional support across multiple study assessments was not associated with AL, nor did it interact with age group or sex (45). Another longitudinal study found no main effects of emotional support and AL, although as one part of a
composite of 12 psychosocial indicators, the composite moderated the effect of stress so that the effects of stress were buffered by high resources (31). Individual psychosocial indicators were not tested as moderators making it impossible from that study to know whether social support would have specific buffering effects on stress.

**Structural social resources.**

Several studies have observed gender-related differences in the effects of structural social resources. In a longitudinal study, for adults aged 54y - 70y the effect of being married at all study waves differed significantly between women and men. Although simple effects were not significant, being married was associated with higher AL for women but lower AL for men (45). The association between AL and having above median number of ties with immediate family across study waves also differed between women and men. High number of ties with immediately family was associated with higher AL for men but lower AL for women (45). Conversely, overall social integration (sum of ties with children, close relatives and friends) was associated with lower AL for men, but not women in a cross-sectional study (44). Similarly, social integration (ties with children, close relatives, and close friends) was not associated with AL in women in another cross-sectional study (48).

Other studies report no differences as a function of participant sex. Higher contact with friends and family was associated with higher AL across men and women in a longitudinal study (43). In another longitudinal study, having more social ties (number of close friends and relatives) was associated with lower AL (46), and this effect was not moderated by sex or age. In a longitudinal study of adults aged 71y or more, high ties with non-relatives were associated with significantly lower AL across
women and men (45). Similar to the finding of high ties with non-relatives rather than relatives being related to AL, frequency of friend contact, but not family contact, was associated with lower AL in a cross-sectional study (33).

There is also some suggestion that structural social resources may moderate the effects of stress. In one study, social connections were assessed at multiple waves and results from each indicator summed. There were no main effects for living with children, frequency of contact with children, regular contact with relatives, regular contact with non-relatives, or social activities (31). However, a composite of 12 psychosocial indicators (including each of the structural measures) moderated the effect of stress, such that the effects of stress were buffered by low vulnerabilities (high resources).

Two studies reported null results. Neither number of social roles nor a weighted composite of social ties were significantly associated with AL in a cross-sectional study of adults (34). Likewise in a longitudinal study, there was no association between AL and count of study waves below median on social activities, below median on number of friends or neighbors seen or talked to at least weekly, at least weekly non-resident child contact, or co-residing with a child (51).

In summary, the evidence for the relationship between social resources and AL is mixed, with some consistency in the evidence that social support buffers the effects of low SES or stress on AL. Two studies have found sex differences in the effects of both social support and structural social resources; however, four studies also reported no sex differences for at least one social resource. Studies that included a social resource tended to have a larger sample size (for studies with a social resource, the median was 782 versus 290 for studies without any social resource assessed). Nine of the studies
that assessed social resources reported testing for moderation of which 6 (66.7%) reported at least one significant moderated effect. Eight of the 15 studies assessing social resources reported at least one significant main effect. More studies assessing social resources than that assessed psychological resources had lower quality measures, with four (26.7%) studies using unvalidated measures and reporting no internal consistency metrics, four (26.7%) reporting inadequate internal consistency reliability, and seven (46.7%) using validated measures or reporting adequate internal consistency reliability.

Discussion

Summary of Findings

The goal of this systematic review was to characterize empirical findings on the relations between psychological resources, social resources, and AL. Across populations diverse with respect to age, race, and sex, mixed evidence exists for a relationship between these resources and AL. In general, when PSRs were significantly associated with AL, they had either direct protective effects (k = 9) or buffered the effects of stress and adverse conditions (k = 4). However, in four studies with statistically significant effects, higher PSRs were associated with worse AL, or PSRs exacerbated the effects of stress and adverse conditions. The four studies with significant effects were split between control and mastery (k = 2) and social support and contact (k = 2). One study found that, controlling for AL in 2004/5 and social support in 2008/9, higher social support in 2004/5 predicted higher AL in 2008/9 (47). This study is noteworthy because it is the only study predicting longitudinal change in AL from a
PSR and was based on a sample of over 6,000 adults in England. Although it was not statistically significant, higher concurrent social support was associated with lower AL. Taken together, these results suggest that participants who were high in social support at study entry and then low four to five years later, may have an increase in AL, whereas those who were low at study entry and then high at follow-up may have a decrease in AL.

An important finding from this review is that many studies (k = 14/25) tested for moderation, and nonsignificant main effects often (k = 6/14) were qualified by significant interactions. Significant moderators include perceived discrimination, neighborhood poverty, SES-related risk, household income, parental education (construed as childhood SES), age, number of stressors, caregiver status (presumably a chronic stressor), and sex. Thus, effects of psychological and social resources varied as a function of other environmental and individual contexts.

There were no apparent differences in whether significant main or moderated results were found by whether psychological (k = 9/13, 69.2%) or social resources (k = 10/15, 66.7%) were assessed. Studies that reported statistically significant main effects tended to have a larger sample size (Median = 871) than those that reported a non significant main effect (Median = 282.5), and studies that tested and found a significant moderated effect had a larger sample size (Median = 454.5) than studies that tested but did not find a significant moderated effect (Median = 282.5). Studies with a longitudinal design were more likely to report a significant main or moderated effect (k = 10/12, 83.3%) versus studies with a cross-sectional design (k = 7/13, 53.8%). Studies with an a priori and directional hypothesis were more likely to test for moderation (k = 11/13,
84.6%) than were studies with non directional or no hypotheses about PSRs and AL (k = 3/12, 25.0%); however, this was not associated with finding significant moderated effects among those studies that did test for moderation (k = 8/11, 72.7% for a priori directional hypotheses and k = 2/3, 66.7% for non directional hypotheses). There were no apparent differences by the quality of PSR measure(s) included and results found.

**Effect Sizes**

Even for statistically significant results, effect sizes were typically small. For example, for psychological resources, the interaction of self-control/competence with SES-related risk uniquely accounted for 4.3% of the variance in AL (27), and when AL predicted change in sense of coherence, it accounted for 3% of the variance (38). For social resources, one study reported the difference between participants with the highest versus lowest social ties was Cohen's d = .22 and for the highest versus lowest social support was Cohen's d = .26 corresponding to small effects (32). Including non significant results, correlations or adjusted standardized regression coefficients tended to be in the range of 0 to .10. An implication of these relatively small effects is studies on PSRs and AL will need relatively large samples to be adequately powered. For example, to have power of .80 to detect a Cohen’s d of .22 requires a sample size of 651, and to detect a correlation of .10 requires a sample size of 782.

**Limitations**

Results from this review should be interpreted in light of several limitations. At the level of the review, because there is ambiguity in the definition of PSRs, it is possible that some studies that should have been included were missed. In addition,
the first steps of the search were conducted by searching through titles, abstracts, and keywords. It is possible that some studies included a PSR as a covariate only and did not mention it in any of the fields examined. It is encouraging, however, that several of the included studies only assessed PSRs as covariates or potential confounds, suggesting that our search process was successful in identifying even studies that did not focus on PSRs. The current results may also be influenced by publication bias for significant findings. However, many studies reporting multiple PSRs included null as well as significant results, and there were studies published with solely null results. Another limitation is that in the studies reported, there is substantial heterogeneity in measures of PSRs, design and duration of studies, sample sizes, and whether moderation (and if so which moderators) was examined. In light of such heterogeneity and the relatively small literature, it was difficult to explain contradictory findings.

The studies included in this review also have limitations. Although potentially indicating a lack of publication bias, the fact that several studies did not focus on PSRs or included them solely as covariates calls into question the quality of evidence regarding the relations between PSRs and AL (see Table 2 for quality assessments). It is noteworthy that of the 13 studies with an a priori, directional hypothesis about the relations between PSRs and AL, 69% (k = 9/13) used validated PSR measures or reported good psychometric properties, whereas for studies with no hypothesis, only 40% (k = 2/5) did so. Examining the nine studies with both a priori directional hypotheses and adequate PSR measures, all tested for moderation. Seven (77.8%) reported significant moderated effects and 8 (88.9%) reported non significant main effects.
Another limitation is that most of the study designs were cross-sectional (k = 13/25). Most of the remaining studies that employed a longitudinal design used earlier PSRs to predict later AL, with only a single study (47) predicting longitudinal change in AL. Thus, it is difficult to draw any conclusions about the direction of effects or causality.

**Strengths**

This review has a number of strengths. We mitigated the risk of missing relevant studies by using a broad search strategy to retrieve all studies including "allostatic load" or "allostasis." Two independent raters screened each study. Because many of the studies used epidemiologic datasets, most results are based on large samples of more than 300 participants (k = 16/25), and only three studies had fewer than 100 participants. Indices of AL were also well constructed, with k = 13/25 studies using at least 10 biomarkers. Finally, samples were diverse with respect to age, sex, race/ethnicity, and geographic location.

**Directions for Future Research**

This review identifies several gaps in the literature. First, many studies on psychological resources tended to examine only one resource, such as mastery, and the measures of social integration were often comparatively crude (e.g., sum of self-reported frequency of contact with family and friends). In order to evaluate carefully the potential links between PSRs and AL, diverse and thorough measures of social networks or integration as well as rich measures of psychological resources are needed. This may be particularly important for social integration, in light of a meta-
analysis by Holt-Lunstad, Smith (23) showing stronger effects for complex (versus simple) measures of social integration on mortality.

Second, findings suggest that many relationships of PSRs with AL are qualified by significant interactions. Future research on PSRs and AL should carefully consider potential interactions (e.g., with SES, stressors such as perceived discrimination and caring for an ill loved one, sex/gender), in order to avoid calling a missed moderated relationship a null relationship.

Third, only one study predicted longitudinal change in AL from PSRs. Most studies examined cross-sectional relationships, and those that were longitudinal typically used PSRs to predict AL, but not change in AL. In order to establish 1) whether there is a consistent association between PSRs and AL, and 2) if there is a relationship, to establish the nature and direction of that relationship, future studies need to move beyond cross-sectional associations and main-effects predictions, to studies assessing change in AL and PSRs over time.

We believe there is a need for work to develop theories and models that explain which PSRs, for whom, and under what conditions are related to AL. Identification of mechanisms for their relations also is needed. For example, in the current review social resources were related to lower AL among women or among men in different studies. Perhaps social resources are important to both sexes, but the specific resources vary as a function of gender-related factors. It may also be that sex moderates effects because of other concomitant differences (e.g., different resources are better matched to the kinds of stressors most often faced by women and men in these samples). Certain resources (e.g., perceived mastery and control) exacerbated the effects of
stressors (SES-related risk and caring for a spouse with Alzheimer's disease) whereas others (positive affect) buffered the effect of caring for a child with a developmental disorder. In order to move forward, theories that explain and integrate both main and moderated effects of potentially different resources are needed.

Finally, the literatures on AL as a predictor and AL as an outcome are distinct. Few studies have merged these two approaches, and none of the studies included in this systematic review of PSRs and AL included a fully specified model, as suggested by Friedman and Kern (9). For example, no study examined a model that included PSRs, AL, and health outcomes, with PSRs predicting change in AL, and change in AL predicting health outcomes. If AL is to be used as a surrogate endpoint in place of health outcomes such as disease incidence or mortality, it is important to demonstrate not only that AL is related to the health outcomes, but also that AL accounts for the relationship between PSRs and health outcomes. If PSRs and AL are two separate and unique predictors of health outcomes, it is not reasonable to substitute AL for health outcomes when studying the relationship between PSRs and health. Only once the causal ordering of PSRs, AL, and health outcomes has been established can we draw strong inference about health outcomes or risk for health outcomes from studies of PSRs and AL alone.

**Conclusion**

Some evidence exists for both a direct relationship between PSRs and AL and a role of PSRs moderating the relations of stressors such as discrimination, low SES, and caregiving status with AL. Nevertheless, these findings are tempered by numerous null and primarily cross-sectional results. Future research developing theoretical models to
explain the relations among PSRs, moderators, and AL and studies utilizing rigorous, longitudinal designs to predict change in AL from comprehensive assessments of PSRs will help to clarify the direction of the relationship between PSRs and AL as well as their strength and magnitude.

References


### Table 1. Quality Assessment Scoring

<table>
<thead>
<tr>
<th></th>
<th>-</th>
<th>O</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A priori hypothesis</strong></td>
<td>No hypothesis reported</td>
<td>hypothesis reported, but non direction</td>
<td>Directional hypothesis reported</td>
</tr>
<tr>
<td><strong>Sample Size Determination</strong></td>
<td>No information on sample size determination reported</td>
<td>Sample size unjustified or discussed post hoc</td>
<td>Sample size justified to be adequate</td>
</tr>
<tr>
<td><strong>Quality of PSR Measure</strong></td>
<td>Unvalidated and no psychometric properties reported</td>
<td>Psychometrics reported but inadequate (Cronbach’s α &lt; .70)</td>
<td>Validated scale, objective outcome, or good psychometric properties reported</td>
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</table>
Table 2. Quality of Study Assessment

<table>
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<th>Sample size</th>
<th>Quality of PSR Measure(s)</th>
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<td>-</td>
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</tr>
<tr>
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<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Brody 2013 (27)</td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Brooks 2014 (43)</td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Chen 2012 (39)</td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Evans 2003 (30)</td>
<td>-</td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>Evans 2013 (29)</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Glei 2007 (31)</td>
<td>o</td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>Gruenewald 2011 (33)</td>
<td>-</td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>Hawkley 2011 (34)</td>
<td>o</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Johansson 2007 (36)</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Juster 2013 (50)</td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Lindfors 2006 (38)</td>
<td>o</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Maselko 2007 (48)</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Read 2014 (47)</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Roepke 2010 (28)</td>
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<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Schnorpfeil 2003 (49)</td>
<td>+</td>
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<td>Seeman, M. 2014 (32)</td>
<td>+</td>
<td>o</td>
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</tr>
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<td>Seeman, T. 2004 (45)</td>
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<td>Seeman, T. 2014 (46)</td>
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<td>-</td>
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<tr>
<td>Seeman, T. 2002 (44)</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Singer 2000 (42)</td>
<td>o</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Song 2014 (37)</td>
<td>+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Tanaka 2011 (35)</td>
<td>o</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Weinstein 2003 (51)</td>
<td>+</td>
<td>o</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. Description of categories can be found in Table 1.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Recruitment Info</th>
<th>Setting</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSAFHAP</td>
<td>Initially recruited from lists of 5th grade students. AL assessed on a random sample of families that participated.</td>
<td>9 rural communities in Georgia, US</td>
<td>Brody 2014a (40); Brody 2014b (40); Brody 2013 (27)</td>
</tr>
<tr>
<td>MIDUS</td>
<td>Random digit dialing to form initial sample of middle-aged adults. A subset of these were invited (and agreed) to have biomarkers assessed.</td>
<td>3 US GCRC</td>
<td>Brooks 2014 (43); Chen 2012 (39); Gruenewald 2011 (33); Seeman, M. 2014 (32); Song 2014 (37)</td>
</tr>
<tr>
<td>I</td>
<td>Children were recruited from public schools and state and federal programs targeting low-income families.</td>
<td>5 rural counties in northeast US</td>
<td>Evans 2003 (30); Evans 2013 (29)</td>
</tr>
<tr>
<td>SEBAS</td>
<td>A random subsample of participants from the Survey of Health and Living Status of the Near-Elderly and Elderly in Taiwan, a national sample of adults aged 60+ in 1989 and expanded in 1996 to include adults 50-66 years old were recruited in 2000 for another study including biomarkers, with residents of urban areas oversampled.</td>
<td>3 centers in Taiwan</td>
<td>Glei 2007 (31); Seeman, T. 2004 (45)</td>
</tr>
<tr>
<td>CHASRS</td>
<td>Selected from older adults born between 1935 and 1952 living in Illinois US using a multistage probability sampling design designed to obtain approximately equal numbers of females and males who were White, Black, and Hispanic.</td>
<td>Population sample from Illinois, US</td>
<td>Hawkley 2011 (34)</td>
</tr>
<tr>
<td>IDA</td>
<td>Data collection began on all children age 10 in 1960 in Orebro, Sweden. This cohort was repeatedly followed and in 1998 completed interviews and questionnaires with biological data assessed on a subset of participants.</td>
<td>Sweden</td>
<td>Johansson 2007 (36); Lindfors 2006 (38)</td>
</tr>
<tr>
<td>II</td>
<td>Healthy female and male workers recruited through newspapers and community centers in Montreal Canada from 2005 to 2007.</td>
<td>Healthy community sample from Montreal Canada</td>
<td>Juster 2013 (50)</td>
</tr>
<tr>
<td>MAC</td>
<td>Adults aged 70-80 were subsampled from the Established Population for Epidemiologic Studies of the Elderly cohort comprised of three communities in the US.</td>
<td>3 communities in the northeast US</td>
<td>Maselko 2007 (48); Seeman, T. 2002 (44)</td>
</tr>
<tr>
<td>ELSA</td>
<td>Nationally representative longitudinal study of adults aged 50+ in England.</td>
<td>England</td>
<td>Read 2014 (47)</td>
</tr>
<tr>
<td>III</td>
<td>Spousal caregivers of patients with Alzheimer’s disease and married non-caregiving controls recruited from the community.</td>
<td>1 community in southwest US.</td>
<td>Roepke 2010 (28)</td>
</tr>
<tr>
<td>IV</td>
<td>Random sample of employees from an airplane manufacturing plant in urban Germany.</td>
<td>Manufacturing plant in urban Germany</td>
<td>Schnorpfeil 2003 (49)</td>
</tr>
<tr>
<td>CARDIA</td>
<td>Data collection began in 1985-1986 on roughly equal numbers of black and white females and males aged 18 to 30. Current study used year 15 exam data. A subsample was invited to have biomarkers assessed.</td>
<td>2 centers in US</td>
<td>Seeman, T. 2014 (46)</td>
</tr>
<tr>
<td>Sample</td>
<td>Recruitment Info</td>
<td>Setting</td>
<td>References</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>WLS</td>
<td>A random sample (N = 10,317) of women and men who graduated high schools in 1957 in Wisconsin and were interviewed again in 1975 and 1992-1993. A small subsample of these completed additional questionnaires and had biological data collected in 1997.</td>
<td>GCRC in Wisconsin US</td>
<td>Seeman, T. 2002 (44);</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Singer 2000 (42);</td>
</tr>
<tr>
<td>V</td>
<td>Undergraduates from a Japanese university, details of recruitment NR.</td>
<td>Japanese University</td>
<td>Tanaka 2011 (35)</td>
</tr>
<tr>
<td>VI</td>
<td>In 1997 - 1998 elderly Taiwanese who had participated in the Study of Health and Living Status of the Elderly in Taiwan, a national sample of adults (elderly) aged 60+ in 1989, were recruited from Taichung, Taiwan.</td>
<td>Urban and rural parts of one city in Taiwan</td>
<td>Weinstein 2003 (51)</td>
</tr>
</tbody>
</table>

Note. I – VI = unique samples with allostatic load measures. SAAFHAP = Strong African American Families Health Adolescent Project, MIDUS = Midlife in the United States Study; SEBAS = Social Environment and Biomarkers of Aging Study; CHASRS = Chicago Health, Aging, and Social Relations Study; IDA = Individual Development and Adaptation cohort; MAC = MacArthur Study of Successful Aging; ELSA = English Longitudinal Study of Aging; CARDIA = Coronary Artery Risk Development in Young Adults Study; WLS = Wisconsin Longitudinal Study.
<table>
<thead>
<tr>
<th>Ref</th>
<th>N</th>
<th>Age M</th>
<th>n (% Female)</th>
<th>n (% White)</th>
<th>In/Exclusion</th>
<th>Design</th>
<th>Length of Longitudinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brody 2014a (40)</td>
<td>331</td>
<td>20.2</td>
<td>190 (57%)</td>
<td>Rural African Americans</td>
<td>NR</td>
<td>L1</td>
<td>2 years (AL at age 20; emotional support at age 18; perceived discrimination at ages 16, 17, 18)</td>
</tr>
<tr>
<td>Brody 2014b (41)</td>
<td>420</td>
<td>19.2</td>
<td>227 (54%)</td>
<td>Rural African Americans</td>
<td>NR</td>
<td>L1</td>
<td>1 years (AL at age 19; Emotional support at age 18; neighborhood poverty at age 11 and age 19)</td>
</tr>
<tr>
<td>Brody 2013 (27)</td>
<td>489</td>
<td>19.2</td>
<td>265 (54%)</td>
<td>Rural African Americans</td>
<td>NR</td>
<td>L1</td>
<td>8 years (AL at age 19; Self Control at ages 11, 12, 13; Perceived Competence at ages 11, 12, 13; SES at ages 11, 12, 13)</td>
</tr>
<tr>
<td>Brooks 2014 (43)</td>
<td>649</td>
<td>55.1</td>
<td>512 (54%)</td>
<td>891 (94%)</td>
<td>For a subset of analyses, included only participants with spouses (n = 660)</td>
<td>L1/C</td>
<td>Approximately 9 years but also cross-sectional (AL in mid 2000s, social support and relationships in mid 1990s and mid 2000s)</td>
</tr>
<tr>
<td>Chen 2012 (39)</td>
<td>1207</td>
<td>54.5</td>
<td>680 (56%)</td>
<td>970 (80%)</td>
<td>NR</td>
<td>C</td>
<td>N/A</td>
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<tr>
<td>Evans 2003 (30)</td>
<td>339</td>
<td>9.2</td>
<td>166 (49%)</td>
<td>319 (94%)</td>
<td>NR</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>Evans 2013 (29)</td>
<td>241</td>
<td>9 &amp; 13 (17.3 at study)</td>
<td>121 (50%)</td>
<td>NR</td>
<td>NR</td>
<td>L1/C</td>
<td>4 years (AL at age 9 and 13 were averaged; self-regulation at age 9)</td>
</tr>
<tr>
<td>Glei 2007 (31)</td>
<td>851</td>
<td>66.1</td>
<td>356 (42%)</td>
<td>Taiwanese</td>
<td>NR except for age</td>
<td>L1</td>
<td>4 years (AL in 2000, PSRs in 1996 and 1999).</td>
</tr>
<tr>
<td>Gruenewald 2011 (33)</td>
<td>1008</td>
<td>58.1</td>
<td>552 (55%)</td>
<td>929 (92%)</td>
<td>NR</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>Hawkley 2011 (34)</td>
<td>208</td>
<td>58.4</td>
<td>110 (53%)</td>
<td>78 (37.5%)</td>
<td>NR</td>
<td>C</td>
<td>N/A</td>
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<tr>
<td>Johansson 2007 (36)</td>
<td>529</td>
<td>43</td>
<td>529 (100%)</td>
<td>Swedes Females only.</td>
<td>L2</td>
<td>6 years (AL assessed in 1998; PSRs assessed in 2004)</td>
<td></td>
</tr>
<tr>
<td>Ref</td>
<td>N</td>
<td>Age M</td>
<td>n (%) Female</td>
<td>n (%) White</td>
<td>In/Exclusion</td>
<td>Design</td>
<td>Length of Longitudinal</td>
</tr>
<tr>
<td>----------------</td>
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<td>--------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
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<td>------------------------</td>
</tr>
<tr>
<td>Juster 2013</td>
<td>199</td>
<td>41.4</td>
<td>118 (59%)</td>
<td>173 (87%)</td>
<td>No utilization of mental health services in past year; no medications/health problems affecting AL biomarkers</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>(50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lindfors 2006</td>
<td>200</td>
<td>43</td>
<td>200 (100%)</td>
<td></td>
<td>No chronic diseases; no medications affecting AL biomarkers</td>
<td>L2</td>
<td>6 years (AL assessed in 1998; PSRs assessed in 1998 and 2004)</td>
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<tr>
<td>Maselko 2007</td>
<td>853</td>
<td>74.2</td>
<td>460 (54%)</td>
<td>700 (82%)</td>
<td>Included 70y-80y; high physical and cognitive functioning</td>
<td>C</td>
<td>N/A</td>
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<tr>
<td>(48)</td>
<td></td>
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<tr>
<td>Read 2014</td>
<td>6132</td>
<td>71.5</td>
<td>3403 (55.5%)</td>
<td></td>
<td>Excluded participants younger than 60</td>
<td>L1</td>
<td>4 years (AL in 2004-2005 and 2008-2009; social support in 2004-2005)</td>
</tr>
<tr>
<td>(47)</td>
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<td></td>
<td></td>
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<tr>
<td>Roepke 2010</td>
<td>130</td>
<td>74.5</td>
<td>88 (68%)</td>
<td>121 (95%)</td>
<td>Included 55+; living with spouse; free of serious illness; not on anticoagulant medications</td>
<td>C</td>
<td>N/A</td>
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<tr>
<td>(28)</td>
<td></td>
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<tr>
<td>Schnorpfell 2003</td>
<td>324</td>
<td>40.6</td>
<td>52 (16.1%)</td>
<td></td>
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<td>NR</td>
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<tr>
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<tr>
<td>Seeman, M. 2014</td>
<td>1239</td>
<td>54.5</td>
<td>701 (56.6%)</td>
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<td>NR</td>
<td>C</td>
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<tr>
<td>(32)</td>
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<tr>
<td>Seeman, T. 2004</td>
<td>531</td>
<td>68.4</td>
<td>395 (41.6%)</td>
<td></td>
<td></td>
<td>NR</td>
<td>L1</td>
</tr>
<tr>
<td>Near Elderly, 419 Elderly</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Seeman, T. 2014</td>
<td>782</td>
<td>40</td>
<td>453 (57.9%)</td>
<td>354 (45.3%)</td>
<td></td>
<td>NR</td>
<td>C</td>
</tr>
<tr>
<td>(46)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Seeman, T. 2002</td>
<td>WLS: 106, MAC: 765</td>
<td>58.5, 74.2</td>
<td>WLS: 49 (46.2%), MAC: 389 (50.8%)</td>
<td>WLS: NR, MAC: Included 70y-80y; high physical and cognitive functioning</td>
<td>C</td>
<td>N/A</td>
<td></td>
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<td>(44)</td>
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<tr>
<td>Ref</td>
<td>N</td>
<td>Age M</td>
<td>n (%) Female</td>
<td>n (%) White</td>
<td>In/Exclusion</td>
<td>Design</td>
<td>Length of Longitudinal</td>
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<tr>
<td>Song 2014</td>
<td>76</td>
<td>55.1</td>
<td>46 (60.5%)</td>
<td>NR</td>
<td>Participants who self-reported caregiving for a child with child onset ADD/ADHD, learning disabilities, autism, cerebral palsy, epilepsy, Down syndrome, intellectual disabilities, or brain injury. Matched controls were selected from MIDUS participants with children without developmental disorders.</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>Tanaka 2011</td>
<td>37</td>
<td>24.8</td>
<td>0 (0%)</td>
<td>Japanese</td>
<td>Healthy, males over age 22 who showed no clinical signs of cardiovascular disease</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>Weinstein 2003</td>
<td>101</td>
<td>72.6</td>
<td>47 (46.5%)</td>
<td>Taiwanese</td>
<td>Elderly otherwise NR.</td>
<td>L1</td>
<td>unclear exactly what waves PSRs were assessed.</td>
</tr>
</tbody>
</table>

*Note.* When possible, age is reported as age when allostatic load data were collected. NR = not reported; N/A = not applicable; L1 = earlier PSRs predicting later AL; L2 = earlier AL predicting later PSRs; C = cross-sectional. MAC = MacArthur Study of Successful Aging; WLS = Wisconsin Longitudinal Study. When reported, data were taken directly from studies. When not directly reported, if possible estimates were calculated from the data provided.
Table 5. Measures of Allostatic Load

<table>
<thead>
<tr>
<th>Biomarkers</th>
<th>Risk quartile and sum</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP, DBP, BMI, E, NE, CORT</td>
<td>Brody 2014b (41); Brody 2013 (27); Evans 2003 (30); Evans 2013 (29)</td>
<td></td>
</tr>
<tr>
<td>SBP, pulse pressure, BMI, WHR, HDL, LDL, triglycerides, HbA1c, glucose, HOMA-IR, LFHRV, HFHRV, pulse, SDRR, RMSSD, E, NE, CORT, DHEA-S, CRP, Fibrinogen, IL-6, E-selectin, s-ICAM</td>
<td>Brooks 2014 (43); Seeman, M. 2014 (32)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, BMI, WHR, HDL, LDL, triglycerides, HbA1c, glucose, HOMA-IR, LFHRV, HFHRV, pulse, SDRR, RMSSD, E, NE, CORT, DHEA-S, CRP, Fibrinogen, IL-6, E-selectin, s-ICAM</td>
<td>Chen 2012 (39); Gruenewald 2011 (33)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL, TC, HbA1c, PEF</td>
<td>Johansson 2007 (36); Lindfors 2006 (38)</td>
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<tr>
<td>SBP, DBP, BMI, WHR, HDL, LDL, triglycerides, SDRR, insulin, glucose, HOMA-IR, CRP, TNF-a, IL-6, AUC ground of stress reactivity salivary cortisol</td>
<td>Juster 2013 (50)</td>
<td></td>
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<tr>
<td>SBP, DBP, HDL, TC, HbA1c, E, NE, CORT, DHEA-S</td>
<td>Maselko 2007 (48)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL/TC, triglycerides, HbA1c, PEF, Fibrinogen, CRP</td>
<td>Read 2014 (47)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, BMI, HDL, TC/HDL, plasma norepinephrine, plasma epinephrine</td>
<td>Roepke 2010 (28)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, BMI, WHR, HDL, TC, HbA1c, E, NE, CORT, DHEA-S, albumin, TNF-a, CRP</td>
<td>Schnorpfeil 2003 (49)</td>
<td></td>
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<tr>
<td>SBP, DBP, WHR, HDL, TC, HbA1c, E, NE, CORT, DHEA-S</td>
<td>Seeman, T. 2004 (45)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL, LDL, triglycerides, glucose, insulin, LFHRV, HFHRV, pulse, E, NE, CORT RISE, CORT SLOPE, CRP, IL-6</td>
<td>Seeman, T. 2014 (46)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL, TC, HbA1c, E, NE, CORT, DHEA-S</td>
<td>Seeman, T. 2014 (46)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL, TC/HDl, HbA1c, E, NE, CORT, DHEA-S, CRP</td>
<td>Song 2014 (37)</td>
<td></td>
</tr>
<tr>
<td>SBP, DBP, WHR, HDL, HDL/TC, HbA1c, E, NE, CORT, DHEA-S</td>
<td>Weinstein 2003 (51)</td>
<td></td>
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</tbody>
</table>

**Standardized and summed**

| SBP, DBP, BMI, E, NE, CORT, CRP | Brody 2014a (40) |
| SBP, DBP, waist circumference, HDL, TC, HbA1c, E, NE, CORT | Hawkley 2011 (34) |
| SBP, DBP, WHR, HDL, HDL/TC, triglycerides, HbA1c, HOMA-IR, CRP | Tanaka 2011 (35) |

**< 10% or > 90% and sum**

| SBP, DBP, BMI, WHR, TC, TC/HDl, triglycerides, HbA1c, glucose, E, NE, dopamine, CORT, DHEA-S, IL-6, IGF-1 | Glei 2007 (31) |

*Note. SBP = systolic blood pressure; DBP = diastolic blood pressure; E = overnight urinary epinephrine; NE = overnight urinary norepinephrine; CORT = overnight urinary cortisol; AUC = area under the curve; TC = total cholesterol; HDL = high-density lipoprotein cholesterol; LDL = low-density lipoprotein cholesterol; CRP = C-reactive protein; HbA1c = glycated hemoglobin; HOMA-IR = homeostatic model assessment insulin resistance; WHR = waist-to-hip ratio; BMI = body mass index; DHEA-S = serum dihydroepiandrosterone sulfate; LFHRV = low frequency heart rate variability; HFHRV = high frequency heart rate variability; SDRR = standard deviation of R-R interval; RMSSD = root mean square successive difference; PEF = peak expiratory flow; IL-6 = interleukin; TNF-a = tumor necrosis factor alpha; s-ICAM = soluble intracellular adhesion molecule; IGF-1 = insulin-like growth factor 1.*
<table>
<thead>
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<th>Ref</th>
<th>Measure of PSRs</th>
<th>Results</th>
<th>Covariates</th>
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<tr>
<td>Brody 2013 (27)</td>
<td><strong>Self control/competence</strong>: composite of teacher rated self-control (12-item Self-Control Inventory) and competence (scholastic and social; 14-item Perceived Competence Scale) averaged across repeated assessments at ages 11, 12, and 13.</td>
<td><strong>Self control/competence</strong> no main effect ($r = - .044$). <strong>Self control/competence</strong> moderated effect of SES-related risk (standardized $\beta = .122$, $p &lt; .01$, $R^2 = .043$), such that adolescents with high self-control/competence and high SES-related risk in childhood had significantly higher AL in later adolescence.</td>
<td>sex, health problems, SES-related risk</td>
</tr>
<tr>
<td>Chen 2012 (39)</td>
<td><strong>Shift (1)</strong>: a composite of positive reappraisal (4-item positive reappraisal of the Primary and Secondary Control questionnaire) and emotion regulation (3-item stress reactivity subscale of the Multidimensional Personality Questionnaire). <strong>Persist (2)</strong>: four items from the &quot;Live for Today&quot; subscale of the Planning and Making Sense of the Past questionnaire.</td>
<td>Significant three-way interaction between (1) x (2) x childhood SES (parental education), $\beta = - .07$, $p = .02$. Results reported separately by SES. For low SES ($n = 300$), (1) and (2) interacted ($\beta = -.15$, $p = .04$) so that participants who were high on both had lower AL. For high SES ($n = 907$), (1) and (2) did not interact ($\beta = .01$, $p = .36$) and no main effects (1) $\beta = .02$, $p = .40$ nor (2) $\beta = -.07$, $p = .06$.</td>
<td>age, sex, race, diabetes, CVD, smoking status, current education</td>
</tr>
<tr>
<td>Evans 2003 (30)</td>
<td><strong>Self worth (1)</strong>: global self-worth subscale from the Harter Perceived Competency Scale. <strong>Self regulation (2)</strong>: delay gratification assessed behaviorally as seconds delayed to receive a larger plate of candy rather than immediately receiving a smaller plate of candy. <strong>Persistence (3)</strong>: assessed behaviorally as seconds persisting on an unsolvable task.</td>
<td>No associations with AL (1) $r = -.04$, (2) $r = -.09$, (3) $r = -.07$.</td>
<td>none</td>
</tr>
<tr>
<td>Evans 2013 (29)</td>
<td><strong>Self regulation</strong>: delay gratification assessed behaviorally as seconds delayed to receive a larger plate of candy rather than immediately receiving a smaller plate of candy.</td>
<td><strong>Self regulation</strong> no main effects (standardized $\beta = .062$, $p = .363$). <strong>Self regulation</strong> not moderated by poverty (standardized $\beta = -.002$, $p = .979$).</td>
<td>single parent status</td>
</tr>
<tr>
<td>Ref</td>
<td>Measure of PSRs</td>
<td>Results</td>
<td>Covariates</td>
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<tr>
<td>Grei 2007* (31)</td>
<td><strong>Live with children</strong> (1): 0-2 variable whether living with children in 1996 and/or 1999. <strong>Contact with children</strong> (2): 0-2 variable of weekly contact with nonresident child(ren) in 1996 and/or 1999. <strong>Social ties relatives</strong> (3): sum of relatives with regular contact in 1996 and 1999. <strong>Social ties non relatives</strong> (4): sum of non relatives with regular contact in 1996 and 1999. <strong>Social activities</strong> (5): sum of up to 11 social activities engaged in in 1996 and/or 1999. <strong>Emotional support</strong> (6): 4-items assessing emotional support in 1996 and 1999. <strong>Mastery</strong> (7): 5-items from the Pearlin scale. <strong>Optimism</strong> (8): 0-2 variable of response to “do you expect that in the future happy things will occur?” in 1996 and 1999. <strong>Overall Vulnerability</strong> (9): a composite of the previous 8 measures (reversed so higher is worse) along with four other non PSR variables.</td>
<td>PSRs (1 - 8) entered simultaneously as main effects, and their composite (9) entered as an interaction with number of stressors. Thus results for (1 - 8) are ‘simple main effects’ and (9) is a moderated effect. No association with AL for (1) b [95% CI] = -.005 [-.180 , .170], (2) b [95% CI] = .003 [-.201 , .206], (3) b [95% CI] = .002 [-.010 , .014], (4) b [95% CI] = .000 [-.010 , .010], (5) b [95% CI] = -.005 [-.055 , .044], (6) b [95% CI] = .191 [-.078 , .460], or (8) b [95% CI] = -.061 [-.218 , .006]. (7) associated with lower AL, b [95% CI] = -294 [-3.537 , -0.050], p &lt; .01. (9) significantly moderated number of stressors, so that the effect of stress was stronger for lower resources (i.e., higher vulnerability), b [95% CI] = .012 [.001 , .024], p &lt; .01.</td>
<td>sex, age, urban residence, number of stressors, education, socioeconomic index, engagement, index of advantages of growing old, perceived stress</td>
</tr>
<tr>
<td>Gruenewald 2011* (33)</td>
<td><strong>Positive affect</strong> (1): 14 item positive affect subscale of the Mood and Symptom Questionnaire. <strong>Perceived Mastery</strong> (2): 4 items assessing personal mastery/control. <strong>Perceived Constraints</strong> (3): 8 items measuring perceived lack of control (low mastery/constraints). <strong>Friend contact</strong> (4): eight level item assessing frequency of contact with friends. <strong>Family contact</strong> (5): eight level item assessing frequency of contact with family. <strong>Friend Social support</strong> (6): 4 items assessed perceived social support from friends. <strong>Family Social support</strong> (7): 4 items assessed perceived social support from family.</td>
<td>Primarily examined relations between SES and AL. PSRs (1 - 7) were assessed as covariates. Results are not reported, except that (4) was associated with significantly lower AL.</td>
<td>age, number of health conditions, current smoker status, anxiety, frequency of fast food consumption, light alcohol consumption, gender, race/ethnicity, and SES</td>
</tr>
<tr>
<td>Ref</td>
<td>Measure of PSRs</td>
<td>Results</td>
<td>Covariates</td>
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<tr>
<td>Hawkley 2011* (34)</td>
<td><strong>Loneliness (1):</strong> 20-item revised UCLA loneliness scale. <strong>Social support (2):</strong> 12-item Interpersonal Support Evaluation List. <strong>Optimism (3):</strong> 6-item Life Orientation Test Revised. <strong>Network roles (4):</strong> the number of roles reported that involved at least bi-monthly social interactions. <strong>Social network index (5):</strong> weighted composite of social ties. <strong>Avoidance Coping (6):</strong> 4-items from Coping Inventory for Stressful Situations (CISS). <strong>Task-oriented coping (7):</strong> 3-items from CISS. <strong>Emotion-focused coping (8):</strong> 3-items from CISS. <strong>Active coping (9):</strong> 2 items from the COPE. <strong>Behavioral withdrawal (10):</strong> 2 items from the COPE. <strong>Seeking social support (11):</strong> 2 items from the COPE. <strong>Seeking emotional support (12):</strong> 2 items from the COPE.</td>
<td>Primarily examined relations between stress and AL; however, partial correlations for PSRs were presented (non significant). (1) r = .09. (2) r = -.08. (3) r = -.08. (4) r = -.07. (5) r = -.02. (6) r = .13. (7) r = .07. (8) r = -.08. (9) r = -.03. (10) r = .07. (11) r = -.03. (12) r &lt; .01.</td>
<td>sex, and white race/ethnicity</td>
</tr>
<tr>
<td>Johansson 2007 (36)</td>
<td><strong>Optimism (1):</strong> 6-item Life Orientation Test Revised. <strong>Psychological well-being (2):</strong> 18-item Ryff's Psychological well-being Scales including self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life, and personal growth.</td>
<td>Focused on the relationship of different career patterns to AL and PSRs. Relations between PSRs and AL not reported; however, based on reported means of AL and psychosocial variables across the 10 job types, correlations were calculated (data are shown in Appendix 2). (1) r = -.61. (2) r = -.65.</td>
<td>none</td>
</tr>
<tr>
<td>Lindfors 2006 (38)</td>
<td><strong>Sense of coherence (SOC):</strong> assessed using a short 3-item version (validated using factor analysis) in 1998 and 2004. Scores were reversed so that high scores indicate weak SOC.</td>
<td>Controlling for weak SOC in 1998, AL in 1998 predicted weak SOC in 2004 six years later (β = .17, p &lt; .01, R² = 3%).</td>
<td>marital status, education, number of children, SOC in 1998, nicotine consumption age, sex, years smoked, antihypertensive medication, cholesterol-lowering medication</td>
</tr>
<tr>
<td>Roepke 2010 (28)</td>
<td><strong>Mastery: 7-item Pearlin Master Scale</strong></td>
<td><strong>Mastery</strong> no main effect (statistics not reported). <strong>Mastery</strong> interacted with caregiver status such that caregiving status only had an effect on AL when Mastery was high (t(121) = 2.19, p = .030). High mastery exacerbated the deleterious effects of being a caregiver.</td>
<td>age, sex, years smoked, antihypertensive medication, cholesterol-lowering medication</td>
</tr>
<tr>
<td>Seeman, M. 2014 (32)</td>
<td><strong>Perceived Mastery (1):</strong> 4 items assessing personal mastery/control. <strong>Perceived Constraints (2):</strong> 8 items measuring perceived lack of control (low mastery/constraints). Single items on a 10 point scale assessing perceived Work Control (3). Finance Control (4). Contributions to Others Control (5). Relationship with Children Control (6). Marital Relationship Control (7). Domain Control (8): composite of 3 - 7.</td>
<td>No association with AL (1) β = -.024, p &gt; .05. (6) β = -.021, p &gt; .05. (7) β = -.020, p &gt; .05. (2) associated with higher AL (beta = .089, p &lt; .01). Associated with lower AL: (3) β = -.036, p &lt; .01. (4) β = -.037, p &lt; .01. (5) β = -.041, p &lt; .01, (8) β = -.067, p &lt; .001.</td>
<td>age, race, sex, income, education, marital status, imputation flag</td>
</tr>
<tr>
<td>Ref</td>
<td>Measure of PSRs</td>
<td>Results</td>
<td>Covariates</td>
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<tr>
<td>Song 2014 (37)</td>
<td>Positive affect: 14 item positive affect subscale of the Mood and Symptom Questionnaire.</td>
<td>No main effect of <strong>positive affect</strong> on AL ($b = -0.033, se = 0.032$). <strong>Positive affect</strong> interacted with caregiver status ($b = -0.104, se = 0.048, p &lt; 0.05$).</td>
<td>age, sex, medications (antihypertensive, antidepressant), smoking, negative affect</td>
</tr>
<tr>
<td>Tanaka 2011 (35)</td>
<td>Sense of coherence (1): Japanese version of the SOC 13. Optimism (2): Japanese version of the Life Orientation Test Revised.</td>
<td>No association with AL (1) $r = -0.08$, (2) $r = -0.01$</td>
<td>age</td>
</tr>
</tbody>
</table>

*Note.* * Indicates studies that assessed both psychological and social resources. AL = allostatic load; SES = socioeconomic status; NR = not reported.
<table>
<thead>
<tr>
<th>Ref</th>
<th>Measure of PSRs</th>
<th>Results</th>
<th>Covariates</th>
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</thead>
<tbody>
<tr>
<td>Brody 2014a (40)</td>
<td>Emotional support: composite of primary caregiver support (11-item Family Support Inventory) and peer support (4-item subscale from Carver Support Scale)</td>
<td>Emotional support no main effect ($r = -.036$). Emotional support moderated the effect of perceived discrimination trajectory class (low and increasing vs. high and stable) ($b = -1.446, p &lt; .001$), such that for low emotional support, there was a significant difference between discrimination trajectories ($b = 2.517, p = .001$), but no difference for those high emotional support ($b = -.259, p = .643$).</td>
<td>cumulative socioeconomic risk, perceived stress, depressive symptoms, unhealthy behavior at age 20</td>
</tr>
<tr>
<td>Brody 2014b (41)</td>
<td>Emotional support: composite of primary caregiver support (11-item Family Support Inventory) and peer support (4-item subscale from Carver Support Scale)</td>
<td>Emotional support no main effect ($r = -.44$) Three-way interaction emotional support x neighborhood poverty in 2010 x neighborhood poverty in 2000 ($b = .19, p = .01, n = 284$), such that emotional support buffered the effects of neighborhood poverty on AL. Emotional support buffered the effects of a worsening pattern (i.e., low neighborhood poverty in 2000, high neighborhood poverty in 2010). No differences for improving (high to low) or stable (high high or low low). Similar results adjusting for residential stability using a larger sample ($b = .10, p = .04, n = 420$).</td>
<td>family poverty at age 11, family poverty at age 19 and their interaction; sex, residential stability, and all at age 19: diet, smoking, binge drinking, perceived stress, unemployment, and financial stress</td>
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<tr>
<td>Ref</td>
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<tr>
<td>Brooks</td>
<td><strong>Friend support</strong> (1): social support from friends (4-items). <strong>Family support</strong> (2): social support from family (4-items). <strong>Spouse support</strong> (3): social support from spouses (6-items). <strong>Network support</strong> (4): composite of 1, 2, &amp; 3. <strong>Friend contact</strong> (5): single item about amount of contact. <strong>Family contact</strong> (6): single item about amount of contact. <strong>Network contact</strong> (7): average of 5 &amp; 6. For all measures, responses at both MIDUS I and MIDUS II were averaged.</td>
<td>(1) Main effect not reported; however moderated by age ($b = .01, p &lt; .05$) so that in older adults (1) was associated with higher AL but in younger adults there was no effect. No significant association: (2) $b = .02, p &gt; .05$, (6) $b = .03, p &gt; .05$. Age did not moderate (2) $b = .01, p &gt; .05$. (6) statistics not reported. (3) associated with lower AL ($b = -.19, p &lt; .05$), age did not moderate (statistics not reported). (4) main effect not reported: however moderated by age ($b = .02, p &lt; .01$) such that in younger adults higher (4) was associated with lower AL, but in older adults higher (4) was associated with higher AL. (5) associated with higher AL ($b = .05, p &lt; .05$), age did not moderate (statistics not reported). (7) associated with higher AL ($b = .04, p &lt; .05$), age did not moderate (statistics not reported). Sex did not moderate (1 - 7) (statistics not reported).</td>
<td>age, sex, race, education, major chronic conditions, functional status, smoking, physical activity, and anxiety and depressive symptoms</td>
</tr>
<tr>
<td>Juster</td>
<td><strong>Social support</strong>: 11-items assessing job place social support provided by coworkers and supervisors</td>
<td><strong>Social support</strong> no association in men ($\beta = .048, \rho = .333$) or women ($\beta = .021, p = .613$). Two-way interactions of <strong>Social support</strong> with age and occupational status were tested but not significant (no statistics were reported).</td>
<td></td>
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<tr>
<td>Maselko</td>
<td><strong>Social integration</strong> (1): sum of the number of reported ties with children, close relatives, and close friends. <strong>Emotional support</strong> (2): 6-items assessing emotional support from partners, children, and friends/relatives. <strong>Instrumental support</strong> (3): 6-items assessing instrumental support from partners, children, and friends/relatives.</td>
<td>In women, (1), (2), and (3) were not associated with AL. Results only reported for women to test if they accounted for relationship between religious service attendance and AL, which was significant for women but not men.</td>
<td>age, income, education, white race, married, physical functioning, diagnoses of CHD, diabetes, or cancer</td>
</tr>
<tr>
<td>Ref</td>
<td>Measure of PSRs</td>
<td>Results</td>
<td>Covariates</td>
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<tr>
<td>Schnorpel 2003 (49)</td>
<td><strong>Social support</strong>: 4 items assessing social support from coworkers and 4 items assessing supportive behavior from supervisors with a composite based on a factor analysis created.</td>
<td><strong>Social support</strong> not associated with AL. <strong>Social support</strong> did not significantly interact with job demands (b = .003, p = .220).</td>
<td>sex, smoking status, job demands, decision latitude, age, individual models: age, sex; multivariate models: age, sex, ethnicity, male respondent or husband's education, number of waves difficulty meeting expenses, number of waves in poor/not good health, number of waves with any functional difficulties, spouse poor health in any wave</td>
</tr>
<tr>
<td>Seeman, T. 2004 (45)</td>
<td>For the elderly measures were assessed in 1989, 1996, and 1999. For the near elderly, measures were assessed in 1996 and 1999. At each wave, measures were categorized, and then constructs created by summing across waves to generate cumulative measures. <strong>Married at all waves</strong> (1). <strong>Married at baseline but divorced, separated, or widowed later</strong> (2). <strong>Low ties with immediate family</strong> (3). <strong>High ties with immediate family</strong> (4). <strong>Low ties with other relatives</strong> (5). <strong>High ties with other relatives</strong> (6). <strong>Low ties with non relatives</strong> (7). <strong>High ties with non relatives</strong> (8). <strong>Living with children</strong> (9). <strong>Weekly contact with non resident children</strong> (10). <strong>No social activities</strong> (11). <strong>Low emotional support</strong> (12). <strong>High emotional support in any wave</strong> (13). <strong>Low emotional support in any wave</strong> (14). <strong>High emotional support in any wave</strong> (15).</td>
<td>Models examined separately for elderly and near elderly. Given the number of social indicators, only significant results are discussed. A first set of models tested indicators individually adjusting for age and sex. Near elderly: no significant main effects. <strong>Near elderly</strong> sex significantly moderated (1), b = -.42, p = .13 for men, b = .32, p = .18 for women. (4), b = .29, p = .05 for men, b = -.17, p = .24 for women. (12), b = -.26, p = .27 for men, b = -.39, p = .15 for women; (14), b = .42, p = .16 for men, b = -.63, p = .06 for women. Elderly: significant effect for (8), b = -.29, p = .005. Elderly, no significant interactions with sex. Results were similar in multivariate models including variables that had significant main/interactive effects in the individual analyses.</td>
<td>age, sex, race, education, income, smoking, physical activity</td>
</tr>
<tr>
<td>Seeman, T. 2014 (46)</td>
<td><strong>Social ties</strong> (1): 2 items assess number of close friends and relatives where possible responses to each item were 0, 1-2, 3-5, 6-9, 10+. Items were averaged and categorized into: 0-2, 2.5, 3-5, and 6+. <strong>Social support</strong> (2): 4 items assessing social support from family and friends, which were categorized as 1-1.5 (&quot;a little or no support&quot;), 1.75-2.25 (&quot;a little&quot;), 2.75-3 (&quot;some&quot;), 3.25+ (&quot;some&quot; to &quot;a lot&quot;).</td>
<td>(1) associated with lower AL (p = .018, d = .22 for comparison of highest versus lowest level). (2) associated with lower AL (p = .011, d = .26 for comparison of highest versus lowest level). No significant interactions (statistics not reported) of sex or race for either (1) or (2).</td>
<td>age, sex, race, education, income, smoking, physical activity</td>
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<tr>
<td>Ref</td>
<td>Measure of PSRs</td>
<td>Results</td>
<td>Covariates</td>
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<tr>
<td>Seeman, T. 2002 (44)</td>
<td>WLS. Mother caring (1) and Father caring (2): 12 caring items from the Parental Bonding Scale. Emotional/sexual adult pair bonding (3): composite of emotional and sexual subscales of the Personal Assessment of Intimacy Relationships (PAIR) Inventory. Intellectual/recreational adult pair bonding (4): composite of intellectual and recreational subscales from PAIR. <strong>Relationship pathways (5):</strong> summary created coded as “negative” if below median on both 1 &amp; 2 and/or both 3 &amp; 4; “positive” if above the median on at least one of 1 or 2 and at least one of 3 or 4. <strong>MAC. Social integration (6):</strong> sum of the number of reported ties with children, close relatives, and close friends. <strong>Emotional support (7):</strong> 6-items assessing emotional support from partners, children, and friends/relatives. <strong>Instrumental support (8):</strong> 6-items assessing instrumental support from partners, children, and friends/relatives.</td>
<td>Classified (1 - 4) as above or below the median and comparing mean AL scores separately in women and men. Mean differences (high - low): for men were -.71 (1), +.05 (2), -.30 (3), +.05 (4), all non significant; for women were +.21 (1), +.25 (2), -.32 (3), -.83, p &lt; .05 (4), with only (4) significant. (5) mean difference (positive - negative): for men -.69, p &lt; .10, for women -.66, p &lt; .05. (6) associated with lower AL for men (β = -.03, p &lt; .05) but not women (β = -.01, p = .22). (7) associated with lower AL for men (β = -.33, p &lt; .05), but not women (β = -.09, p = .52). (8) not significant for men or women (statistics not reported).</td>
<td>NR</td>
</tr>
<tr>
<td>Singer 2000 (42)</td>
<td><strong>Mother caring (1) and Father caring (2): 12 caring items from the Parental Bonding Scale. Emotional/sexual adult pair bonding (3):</strong> composite of emotional and sexual subscales of the Personal Assessment of Intimacy Relationships (PAIR) Inventory. <strong>Intellectual/recreational adult pair bonding (4):</strong> composite of intellectual and recreational subscales from PAIR. <strong>Relationship pathways (5):</strong> summary created coded as “negative” if below median on both 1 &amp; 2 and/or both 3 &amp; 4; “positive” if above the median on at least one of 1 or 2 and at least one of 3 or 4.</td>
<td>Results only presented for (5). Fewer participants in the positive pathway had AL 3+ (28%) than in the negative pathway (56%). For participants with low household income in 1957, there was a significant difference between the negative and positive pathway (64% vs. 21% AL 3+), p &lt; .05, but this was not the case for those with high household income in 1957 (47% vs. 33% AL 3+).</td>
<td>NR</td>
</tr>
<tr>
<td>Weinstein 2003 (51)</td>
<td><strong>Social activities (1): count of assessments below median participation in social activities. Social contact (2): count of assessments below median number of friends or neighbors seen or talked to at least weekly. Child contact (3): count of assessments visiting at least weekly with at least one non-resident child. Child Residence (4): count of assessments co-residing with a child.</strong></td>
<td>(1) r = .15, p = .14. (2) r = .09, p = .36. (3) r = -.04, p = .66. (4) r = .15, p = .14.</td>
<td>none</td>
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</table>

**Note.** AL = allostatic load; SES = socioeconomic status; NR = not reported.
Figure 1. Flow chart of study retrieval, review, and inclusion in systematic review.
Appendix 1. Frequency of use of each biomarker across the 25 studies
Appendix 2. Plot of the means of allostatic load against the means of various psychosocial variables for each of the 10 occupational groups.

Note. Data were reported in Table 3 of (36). Point size indicates the number of people in a given group. Analyses of the reported means showed allostatic load was negatively correlated with optimism ($r = -0.62$), and psychological well-being ($r = -0.65$).
PAPER 4: TESTING A MODIFIED RESERVE CAPACITY MODEL WITH SES, PSYCHOSOCIAL RESOURCES, AND ALLOSTATIC LOAD IN THE MIDLIFE IN THE UNITED STATES STUDY

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Abstract

**Background:** Rich conceptual models of how socioeconomic status and psychosocial factors “get under the skin” have guided research on these questions. Few studies, however, have attempted to test comprehensive conceptual models in a single study. The present study tests a modified form of the Reserve Capacity Model (Gallo & Matthews, 2003) for understanding psychosocial, behavioral, and biological factors linking socioeconomic status and health outcomes.

**Methods:** The sample of 1,050 participants came from the large Midlife in the United States (MIDUS) study. Psychosocial factors including socioeconomic status (SES), stressful life events (SLEs), psychological (PRs) and social (SRs) resources, and positive (PM) and negative (NM) mood were assessed via self-report, as were health behaviors including smoking status and physical activity (PA). Seven biological systems, including 23 biomarkers, indicated allostatic load (AL). The number of major health conditions, the health outcome, was coded from medical history collected via interview. Path analysis was conducted to test the complete conceptual model.

**Results:** SES predicted PA, AL and NM both directly and indirectly via higher PR and fewer SLEs. SES also predicted the number of major health conditions indirectly via PA, AL and NM, which all were directly associated with health conditions. SRs and PM were not associated significantly with the number of health conditions.

**Conclusions:** Findings support most but not all the predictions from the modified Reserve Capacity Model. Testing comprehensive models is feasible and provides a way to integrate more micro-level research. Our results reveal both proximal (i.e., NM,
PA, AL) and more distal (i.e., SLEs, PRs) factors that may be helpful intervention targets to reduce existing disparities in health outcomes as a function of SES.

**Keywords**: reserve capacity model; psychosocial resources; socioeconomic status; allostatic load; health behaviors
Introduction

Researchers have proposed integrative frameworks linking environmental factors, stress, psychological responses, health behaviors, and health outcomes (e.g., Adler & Snibbe, 2003; Gallo & Matthews, 2003; Taylor, Repetti, & Seeman, 1997). Hypotheses generated from these conceptual models have catalyzed numerous studies characterizing the associations of physical health endpoints with socioeconomic status (SES; Chen, Miller, Lachman, Gruenewald, & Seeman, 2012; Gruenewald et al., 2012), affect/mood (Pressman & Cohen, 2005), personality (Rasmussen, Scheier, & Greenhouse, 2009), and social support (Uchino, 2009). Focused studies have deepened our understanding of the mechanisms explaining how psychosocial factors “get under the skin” including via behavioral processes such as physical activity (PA) (Steptoe, Wright, Kunz-Ebrecht, & Iliffe, 2006) and biological processes such as hypothalamic-pituitary-adrenal axis function (Agbedia et al., 2011; Dickerson & Kemeny, 2004), immune function (Bower, Kemeny, Taylor, & Fahey, 1998; Pressman et al., 2005), neural mechanisms (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007), cellular aging (Epel et al., 2004), and gene expression (Cole et al., 2007).

Links between particular psychosocial factors and health outcomes are well established (Carver, Scheier, & Segerstrom, 2010; Uchino, 2006). However, a dearth of research comprehensively tests the rich conceptual models connecting psychosocial processes, health behaviors, biological markers, and physical health outcomes (for an example, see Matthews, Räikkönen, Gallo, & Kuller, 2008). Reviewing the literature linking SES and health, Matthews and Gallo (2011) called for research to test integrated models. Another recent review called for comprehensive models of causes,
mechanisms, and correlates of personality and health outcomes (Friedman & Kern, 2014).

The present study aims to test a comprehensive conceptual model of socioeconomic status, psychosocial resources, and health outcomes, which is an extension of the Reserve Capacity Model (RCM; Gallo & Matthews, 2003; Matthews & Gallo, 2011). As shown in Figure 1, this model differs from the RCM in hypothesizing: (a) direct paths from SES to mood, (b) direct paths from psychosocial resources (PSRs) to mood and the health outcome, which in this study is the number of major medical conditions (e.g., diabetes, stroke) experienced by the participant; and (c) PSRs as moderators of the direct effects of SES on mood, biobehavioral pathways, and health outcomes. In the following sections, we briefly discuss each facet of the model. These modifications have their basis in the empirical literature briefly characterized here.

**Socioeconomic Status**

SES plays a role in numerous psychological, social, and physical processes, including: (a) PSRs such as mastery, self-esteem and social relationships (House et al., 1994); (b) subjective well-being (Pinquart & Sörensen, 2000); (c) biological outcomes such as blunted diurnal cortisol (Agbedia et al., 2011), body mass (Chapman, Fiscella, Duberstein, Coletta, & Kawachi, 2009), inflammation (Gruenewald, Cohen, Matthews, Tracy, & Seeman, 2009), and allostatic load (AL; Gruenewald et al., 2012); and (d) health outcomes such as functional status (House et al., 1994) and mortality. As a striking example, in two prospective cohorts with a total of more than 20,000 participants, SES predicted mortality more than 15 years later, after accounting for the substantial effects of health behaviors such as alcohol consumption, smoking, and PA
SES may have such broad influences in part due to its effects on human development beginning in utero and continuing through childhood and adolescence (Bradley & Corwyn, 2002). Studies comparing the effects of childhood SES and adulthood SES on health have documented effects for both. For example in a large sample of community-dwelling adults, both childhood SES and adulthood SES were associated with inflammation (Pollitt et al., 2007), although the effect of adulthood SES was stronger, a finding echoed in another study examining childhood and adulthood SES as predictors of coronary heart disease morbidity (Marmot, Shipley, Brunner, & Hemingway, 2001). In summary, the effects of concurrent SES may be stronger than childhood SES, although there is evidence that both may be important.

**Psychosocial Resources**

Psychosocial resources (PSRs) represent a broad class of both intraindividual (e.g., personality, self-, and ego-related psychological factors such as optimism, mastery, self-esteem) and interindivial (e.g., emotional support, instrumental support, social integration, social relationships) resources that are hypothesized to have salutary effects on psychological and physical health (Taylor & Broffman, 2011). Psychosocial resources have robust relationships with psychological health and adjustment (Brenner, Melamed, & Panush, 1994; Brissette, Scheier, & Carver, 2002; Helgeson & Cohen, 1996; Henselmans et al., 2010; Hobfoll, Johnson, Ennis, & Jackson, 2003; Horton & Wallander, 2001; Taylor & Armor, 1996; Wethington & Kessler, 1986). A large body of research also demonstrates relations between PSRs and biomarkers including cortisol, blood pressure, and inflammatory markers (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995; Loucks, Berkman, Gruenewald, & Seeman, 2006; Loucks, Sullivan, et al., 2006;
Pressman et al., 2005; Segerstrom, 2001; Segerstrom, Taylor, Kemeny, & Fahey, 1998; Younger, Finan, Zautra, Davis, & Reich, 2008). Further, PSRs are related to health outcomes such as cardiovascular endpoints and mortality (Berkman & Syme, 1979; Carver et al., 2010; Holt-Lunstad & Smith, 2012; Mausbach et al., 2007; Rasmussen et al., 2009; Seeman, 1991; Uchino, 2006, 2009). Finally, there is some evidence that PSRs are related to AL. For example, in one study, high positive reappraisal and emotion regulation ability combined with a future orientation in childhood predicted lower AL in middle age, but only for participants low in SES (Chen et al., 2012). In another study, positive relationship histories were associated with lower AL (Seeman, Singer, Ryff, Love, & Levy-Storms, 2002). However, null results also exist. For example, one study found no direct effect of social support, optimism, or social network on AL (Hawkley, Lavelle, Berntson, & Cacioppo, 2011) and another demonstrated no effect of social support (Juster, Moskowitz, Lavoie, & D'Antono, 2013). Finally, studies have found that PSRs moderate the effects of SES on AL (Brody, Lei, Chen, & Miller, 2014) and between SES and health (Schöllgen, Huxhold, Schüz, & Tesch-Römer, 2011).

**Mood**

The original RCM posited that cognitive and emotional constructs, including mood, partially explain the health disadvantage of having low SES (Gallo & Matthews, 2003). We included measurements of positive and negative mood (PM, NM), which are considered to be distinct (Watson & Clark, 1997). PM represents an experience of pleasurable engagement, and low PM indicates sadness and lack of energy (Watson, Clark, & Tellegen, 1988). Higher PM is related to lower rates of hospitalization for
cardiovascular disease (Middleton & Byrd, 1996) and better disease and health outcomes (Pressman & Cohen, 2005). A meta-analysis of 35 studies of healthy individuals and 35 studies of individuals with disease demonstrated that PM predicted longevity (Chida & Steptoe, 2008). Little research exists on the relationship of PM with AL. One study found that PM buffered the deleterious effects of being a caregiver on AL (Song et al., 2014); however, some evidence suggests that PM is associated with health behaviors, such as physical exercise and sleep, as well as to autonomic nervous system and hypothalamic-pituitary-adrenal axis responses (Pressman & Cohen, 2005).

NM represents the experience of distress, hostility, and generally unpleasant engagement (Watson et al., 1988). Many studies link higher NM and related constructs such as depressed mood to poorer health outcomes. For example, meta-analyses reveal depression to be a significant risk factor for coronary heart disease (Rugulies, 2002) and mortality (Cuijpers & Smit, 2002), a relationship accounted for in part by health behaviors including PA (Whooley et al., 2008). The relationship between depressive and anxiety symptoms with AL is mixed (Juster et al., 2011; Juster et al., 2013).

Allostatic Load

Many studies link AL with diverse health and disease outcomes (for a recent review, see Beckie, 2012). For example, higher AL predicts functional decline (Karlamangla, Singer, McEwen, Rowe, & Seeman, 2002), lower cognitive and physical functioning, higher incidence of cardiovascular disease (Seeman, Singer, Rowe, Horwitz, & McEwen, 1997), and higher mortality (Karlamangla, Singer, & Seeman, 2006).
A systematic review (Wiley, Bei, Bower, & Stanton, in preparation) demonstrated that when PSRs are related to AL, the effects often vary by sex of the participant. Further, Matthews and Gallo (2011) suggest that the relationship between SES and health may differ as a function of gender-related factors. Therefore, participant sex may represent an important moderator in the proposed model. In the present study, we use study entry and follow-up data from the Midlife in the United States (MIDUS) study. Our primary aim is to test an integrative model of SES, PSRs, AL, health behaviors, and health outcomes, and to explore the potential moderating role of participant sex.

**Hypothesis 1 (SES)**

Higher childhood SES and an increase in SES from childhood to adulthood will predict: (1) *higher* psychological and social resources (PR, SR), PM, and PA, (2) *lower* NM, smoking, and AL, and (3) *fewer* stressful life events (SLEs) and major health conditions.

**Hypothesis 2 (Stress)**

Because SLEs occur across the lifespan, whereas PSRs and mood are assessed in adulthood only in this study, a greater number of SLEs will predict (1) *lower* PR, SR, and PM and (2) *higher* NM.

**Hypothesis 3 (Psychosocial Resources)**

PR and SR will be associated with (1) higher PM and PA, (2) lower NM, smoking, and AL, (3) fewer major health conditions, and (4) will buffer the deleterious effects of low SES and high stress on mood, health behaviors, and AL.

**Hypothesis 4 (Mood)**
Higher PM and lower NM will be associated with (1) higher PA and (2) lower AL and smoking.

**Hypothesis 5 (Biobehavioral)**

Higher allostatic load and smoking and lower physical activity will be associated with more major health conditions.

**Exploratory Hypothesis**

PR and SR will demonstrate differential associations as a function of participant sex (i.e., moderation).

**Methods**

**Sample**

The sample came from the Midlife in the United States (MIDUS) study. MIDUS I is a longitudinal study with baseline psychosocial and sociodemographic data collected in 1994-1995 on a large, national probability sample (the core sample; \( N = 3,487 \)), siblings of the core sample (\( N = 950 \)), twins (\( N = 957 \) pairs), and an over-sampling in metropolitan areas (\( N = 757 \)). An additional Milwaukee sample that was a city-specific oversample of African Americans was recruited in 2005. Approximately ten years later in 2004-2006, MIDUS II was conducted with the goal of following all possible participants from MIDUS I (Radler & Ryff, 2010). In addition to completing surveys, a subset of participants from MIDUS II were invited to participate in the MIDUS II Biomarker Project and those who agreed (39.3% response rate, \( N = 1,054 \) from the original sample and \( N = 201 \) from the Milwaukee sample) had biomarker data collected (Love, Seeman, Weinstein, & Ryff, 2010).
**Procedures**

As part of the MIDUS II Biomarker Project, participants went to one of three (University of California Los Angeles, University of Wisconsin, and Georgetown University) General Clinical Research Centers for a medical exam and comprehensive biomarker assessment (e.g., fasting blood draw, 12-hour urine, electrocardiography). They also reported on medical history and major, chronic health conditions. For more details on the biomarker project, see Love et al. (2010). The MIDUS II Biomarker Project was approved by the Institutional Review Boards of the University of Wisconsin, Madison, the University of California, Los Angeles, and Georgetown University.

**Measures**

**Socioeconomic status.** A childhood SES advantage index (based on retrospective reports from MIDUS I) was calculated by summing three measures: (1) whether on welfare as a child (0 = yes, 2 = no), (2) financial status when growing up (0 = worse off than others, 1 = same as others, 2 = better off than others), and (3) highest parental education (0 = < high school, 1 = high school/GED, 2 = ≥ some college), with the total score ranging from 0 to 6.

An adulthood SES advantage index (based on responses at MIDUS II) was calculated by summing five measures: (1) participant education (0 = high school/GED, 1 = some college/AA, 2 = college degree or greater), (2) family-adjusted poverty to income ratio (0 = < 300%, 1 = 300 – 599%, 2 = ≥ 600%), (3) current financial situation (0 = worst, 1 = average, 2 = best), (4) money sufficient to meet needs (0 = not enough, 1 = just enough, 2 = more than enough), and (5) difficulty paying bills (0 = very or somewhat difficult, 1 = not very difficult, 2 = not difficult at all), with the total score
ranging from 0 to 10. Both the childhood and adulthood SES measures were standardized to have a mean of zero and standard deviation of one, and a difference score was calculated as \( \Delta \text{SES} = \text{adulthood} - \text{childhood} \). Childhood SES and \( \Delta \text{SES} \) were used in analysis.

**Stressful life events.** A checklist of 27 SLEs was administered in MIDUS II. For example, participants were asked if they had ever experienced events such as “Flunked out of school”, “Physically assaulted or attacked”, or “Suffered a financial or property loss unrelated to work.”

**Psychological resources.** Perceived personal mastery (4 items; e.g., “I can do just about anything I really set my mind to”) and constraint (8 items; e.g., “Other people determine most of what I can and cannot do”) were measured using items selected from the Pearlin and Schooler (1978) Mastery Scale and items created by Lachman and Weaver (1998), all rated on a seven-point Likert scale from 1 (strongly agree) to 7 (strongly disagree). Self-esteem was measured using 7 items (e.g., “I take a positive attitude toward myself”) rated on a seven-point Likert scale from 1 (strongly agree) to 7 (strongly disagree), all from the Rosenberg Self-Esteem Scale (Rosenberg, 1965). Dispositional optimism and low pessimism were measured using 6 items (e.g., “In uncertain times, I usually expect the best”) rated on a five-point scale (1 = agree a lot agree, 5 = disagree a lot), all from the Life Orientation Test Revised (Scheier, Carver, & Bridges, 1994). All scales were administered in MIDUS II.

**Social resources.** A composite SR factor was created from items assessing social support from spouse/partner (six items), family (four items), and friends (four items), all rated on a four-point scale (1 = a lot, 4 = not at all). Example items include,
“How much do your friends [family] really care about you?”, “How much can you rely on them for help if you have a serious problem?”). Spouse/partner support was measured using the four items from friends and family and two additional items (“How much does he or she appreciate you?” and “How much can you relax and be yourself around him or her?”) rated on the same four-point scale. Social support items in MIDUS were revised from those in Schuster, Kessler, and Aseltine Jr. (1990) and administered in MIDUS II.

**Mood.** NM was measured using 11 items, prompted by “During the past 30 days, how much of the time did you feel . . .” and example items include, “so sad nothing could cheer you up”, “nervous”, “hopeless”, and “irritable”. Items were rated on a five-point scale (1 = all of the time, 5 = none of the time). PM was measured similarly with ten positive items including, “cheerful”, “extremely happy”, “calm and peaceful”, and “proud”. Items were drawn from Mroczek and Kolarz (1998). All scales were administered in the MIDUS II main survey.

**Health behaviors.** Health behaviors were assessed as part of the medical history exam from the MIDUS II Biomarker Project. Two items asking “Have you ever smoked cigarettes regularly – that is, at least a few cigarettes every day?” and “Do you currently smoke cigarettes regularly?” were recoded to create smoking status (0 = non-smoker, 1 = ex-smoker, 2 = current smoker).

For PA, participants were first given definitions of vigorous (“causes your heart to beat so rapidly you can feel it in your chest and you perform it long enough to work up a good sweat and breath heavily”), moderate (“causes your heart rate to increase slightly and you typically work up a sweat”), and light (“requires little physical effort”) levels of activity and then asked whether they engaged in regular exercise or activity of any type.
for 20 minutes or more at least three times per week ("no" response was coded as 0). If participants responded "yes" they were asked to list the type of activity (up to seven), the number of times they did the activity per week on average, the average number of minutes per session, and the intensity (3 = vigorous, 2 = moderate, 1 = light). A total PA index was created as sessions per week x average minutes per session x intensity, and this was split into tertiles (1 = lowest tertile, 2 = middle tertile, 3 = upper tertile).

**Allostatic load.** AL was measured using 23 biomarkers from seven physiological systems assessed in the MIDUS II Biomarker Project. Biomarkers included: (a) lipid indicators, including triglycerides, high and low density lipoprotein cholesterol, waist-to-hip ratio, (b) glucose indicators, including homeostatic model assessment of insulin resistance, fasting glucose, and glycosylated hemoglobin, (c) cardiovascular indicators including resting systolic blood pressure and diastolic blood pressure, converted into pulse pressure (systolic – diastolic) and systolic blood pressure, (d) parasympathetic nervous system indicators including resting pulse rate, standard deviation of beat to beat intervals, root mean square of successive differences, low frequency spectral power, and high frequency spectral power, (e) sympathetic nervous system indicators including 12-hour, overnight urinary epinephrine and norepinephrine, (f) hypothalamic pituitary adrenal axis indicators including 12-hour, overnight urinary cortisol and blood serum dihydroepiandrosterone sulfate, and (g) inflammatory indicators including plasma C-reactive protein, interleukin-6, fibrinogen, soluble E-Selectin, and soluble intracellular adhesion molecule 1.

**Health conditions.** A detailed medical history was conducted as part of MIDUS II Biomarker Project. As part of the interview, a number of health conditions were
assessed by asking participants, “Have you ever had any of the following conditions/illnesses?” and if they responded “yes” then “was it diagnosed by a physician?” In this study, we focused on major conditions. Eight major domains were identified and specific conditions were first aggregated into them: lung problems, high blood pressure, diabetes, stroke, cancer, heart disease, circulation problems, and blood clots. Thus, participants could get a score of 0 or 1 if they had one or more condition in a particular domain. As in previous studies (Gruenewald et al., 2012), scores on all domains were summed to create a total count of major conditions at the time of biomarker assessment, with a possible range from 0 to 8.

**Covariates.** Participant age (at MIDUS II) and sex were collected via self-report.

**Analytic Plan**

**Preliminary analyses.** Three separate confirmatory factor analyses were conducted to validate study constructs: (1) PR and SR factors, (2) PM and NM factors, and (3) an AL factor. Due to the complexity of the theoretical model being tested and the number of items for all constructs, rather than including latent factors for each construct, factor scores were extracted. Briefly, after confirming good fit, factor models were re-estimated using Bayesian SEM (Muthén & Asparouhov, 2012), and 50 samples drawn using Markov chain Monte Carlo methods from the posterior distributions of the latent factors. These multiply imputed factor scores were then merged to create 50 datasets with the repeated samples of the factor scores treated as multiply imputed data (Asparouhov & Muthén, 2010a, 2010b). All factors were standardized to have a mean of zero and standard deviation of one.
**Primary analyses.** The theoretical model and hypotheses were tested using path analysis. Participant sex and age were included as covariates for all dependent variables in the model. Moderated effects were tested by including interactions (e.g., psychological resources x sex, psychological resources x ΔSES). If interactions were not statistically significant, they were reported and dropped from the final model.

**Statistical Methods**

For the preliminary confirmatory factor analyses, good model fit was chosen as the combination of the Comparative Fit Index (CFI) > 0.95, standardized root mean squared residual (SRMR) < .08, root mean squared error of approximation (RMSEA) < .06, and a nonsignificant $\chi^2$ (Hu & Bentler, 1999). SRMR and CFI are sensitive to different types of model misspecification. For the first factor model (i.e., psychological and social resources) and the second factor model (i.e., positive and negative affect), items were treated as ordered categorical data and estimated using all available data using the weighted least squares with means and variance adjusted (WLSMV) estimator in Mplus. For categorical data, SRMR is not available. The final factor model for allostatic load was based on factor scores from a previously validated bi-factor model (Wiley, Gruenewald, Karlamangla, & Seeman, submitted).

For the primary analyses, to address potential non-normality of the data, maximum likelihood estimation with robust standard errors was used for all estimates, pooled across the 50 multiply imputed datasets. In the path analyses, smoking status and PA were modeled as ordered categorical variables using ordinal logistic regression. SLEs (count of stressful events) and count of major health conditions were modeled using Poisson regression appropriate for count data. All other variables were treated as
continuous and normally distributed. Because of the categorical and count variables, overall model fit indices were not available. To obtain approximate estimates of overall model fit, a separate analysis was conducted in which the final model was repeated assuming all variables were normally distributed.

All models were adjusted for non-independence due to twins and siblings using cluster robust standard errors. Data management, descriptive statistics, and transformations were conducted using R v. 3.1.2 (R Core Team, 2014). Mplus v. 7.3 (Los Angeles, CA: Muthén & Muthén) via MplusAutomation v. 0.6-3 (Hallquist & Wiley, 2014) was used for the confirmatory factor analyses and path analyses.

Results

Preliminary Analyses

Based on parallel models previously developed and validated in four separate samples (Wiley, Cleary, Beran, Karan, Jorge, McCannel, & Stanton, in preparation), for PR and SR, we tested a model with first-order latent factors of perceived personal mastery, low constraints, self-esteem, optimism, and low pessimism, all loading onto a second-order PR factor, and first-order latent factors of spouse/partner support, friend support, and family support all loading onto a second-order SR factor. No modifications were made to the model. All participants with any data from the MIDUS II main survey were included in this analysis ($N = 4,041$). The model provided adequate fit to the data, $\chi^2 = 7366.94$, $df = 693$, $p < .001$, $CFI = .953$, $RMSEA = .049$, 90% CI = [.048, .050]. All but three items had absolute standardized factor loadings > .60. Although the chi-
square test was significant, the fit indices indicated adequate fit to the data. Next, 50 sets of plausible factor scores were extracted.

For PM and NM, all items loaded directly onto two correlated first-order latent factors. Again all participants with any data on the mood items from MIDUS II were included ($N = 4,025$). No model modifications were performed. The model provided acceptable fit to the data, $\chi^2 = 6507.54$, $df = 188$, $p < .001$, $CFI = .951$, $RMSEA = .091$, $90\% CI = [.089, .093]$. All items had absolute standardized factor loadings > .70. Although the RMSEA was slightly higher than recommended, we opted to continue with our a priori specified model rather than perform post hoc model modifications, and 50 sets of plausible factor scores were extracted.

For AL, we used 50 sets of plausible factor scores based on the general factor from a bi-factor model (i.e., each biomarker loading onto its respective system as well as a general AL factor). This model ($N = 1,254$) has been previously shown to provide good fit to the data, $\chi^2 = 623.6$, $df = 189$, $p < .001$, $CFI = .967$, $RMSEA = .043$, $SRMR = .028$ (Wiley, Gruenewald, Karlamangla, & Seeman, submitted). Importantly, this model adjusted for participant age and sex; therefore, the AL scores are already adjusted for those effects.

**Descriptive Statistics**

For the primary analyses, data came from participants in MIDUS I (when childhood SES was assessed), MIDUS II main survey (when adult SES and psychosocial variables were assessed), and MIDUS II Biomarker Project (when AL, health behaviors, and number of major health conditions were assessed), leaving a final sample size of 1,050 with approximately equal numbers of women ($n = 575$) and men ($n =$...
= 475). On average, participants were 55 years old, married or living with a partner (n = 786) with most having a college degree or greater (n = 489), with fewer having only some college or an associate degree (n = 300), or high school diploma/GED (n = 248). Most participants had never smoked (n = 581) with fewer past (n = 349) and current (n = 120) smokers. For PA, approximately equal number of participants never engaged in regular physical activity (n = 226) as fell into each of the remaining tertiles for those participants who reported at least some PA (lowest n = 272, middle n = 292, highest n = 260). Means, standard deviations, and correlations among variables for the primary analyses are reported in Table 1.

Primary Analyses

We tested whether Childhood SES, ΔSES, or Sex moderated any of the direct paths from PR or SR to PM or NM, AL, PA or smoking status, or number of major health conditions. A more focal set of interactions of PR and SR x SLEs were tested for PM and NM based on exploratory questions from our theoretical model. Only one statistically significant interaction emerged. PR and ΔSES interacted to explain NM, such that higher PR buffered the effects of a decline in SES from childhood to adulthood on NM. The final model after dropping all non-significant interactions is presented in Figure 2. The model provided good fit to the data $\chi^2 = 10.967, \text{df} = 9, p = .28, \text{CFI} = .99, \text{RMSEA} = .013, \text{SRMR} = .012$. Estimates and standard errors are reported for both significant and non-significant paths in Table 2.

Socioeconomic status. As hypothesized, childhood SES and ΔSES independently predicted fewer SLEs, with incident rate ratios of .73 and .81, respectively, indicating that a 1 SD difference in childhood SES predicted .73 times as a
many SLEs, whereas a 1 SD positive change from childhood to adulthood SES was associated with .81 times as many SLEs ($p < .001$). Both childhood SES and ΔSES also predicted higher PR and SR ($p < .001$), lower odds of smoking ($OR = .80, p = .016$ and $OR = .85, p = .026$, respectively), and lower AL ($b = -.09, p = .004$ and $b = -.14, p = .021$). Contrary to expectation, no main effects of SES were found for mood ($p > .10$), PA ($p > .05$), or the number of major health conditions ($p > .05$).

**Stressful life events.** As hypothesized, a greater number of SLEs predicted lower PR and SR, as well as lower PM and higher NM (all $p < .05$). Although not explicitly hypothesized, more SLEs also predicted higher odds of smoking ($OR = 1.21, p < .001$) and higher AL ($b = .03, p = .028$).

**Psychosocial resources.** As hypothesized, both PR and SR were associated with higher PM ($p < .001$ and $p = .026$, respectively), and PR were associated with lower NM ($p < .001$) and higher PA, with a 1 SD difference in PR associated with 1.24 times higher odds of more PA ($p = .024$). Contrary to expectation, neither PR nor SR were associated with smoking, AL, or number of major health conditions$^1$, and SR were not associated with NM or PA.

With regard to moderation hypotheses, there was a significant interaction between change in SES and PR on NM ($b = .04, p = .05$) such that higher PR buffered the effects of change in SES on NM. At 1 SD below the mean on PR, a 1 SD increase in SES was associated with .08 SD lower NM (simple slope $p = .019$), but at 1 SD above the mean on PR, a 1 SD increase in SES was associated with only .01 SD lower NM.

$^1$ Because PR and SR were highly correlated at $r = .64$, a separate model was tested including only PR. Results were similar with the only substantive difference being the emergence of an association between PR and smoking ($OR = 1.20, p = .03$). The model was repeated including only SR, and for this model the only difference was an association between SR and lower NM ($b = -.32, p < .001$).
(simple slope $p = .79$). None of the other tested interactions of psychological and social
resources with SES, SLEs, or participant sex were significant ($ps > .05$).

**Mood.** None of the hypothesized associations for PM and NM were statistically
significant (all $ps > .10$). Although not hypothesized, the only significant effect of mood
that emerged was an association with more major health conditions, such that a 1 SD
difference in NM was associated with 1.11 times as many major health conditions ($p =
.044$).

**Biobehavioral variables.** As hypothesized, a 1 SD difference in PA was
associated with .92 times as many major health conditions ($p = .003$). There was no
relationship between smoking status and health conditions ($p = .86$). A 1 SD difference
in AL was associated with 1.28 times as many major health conditions ($p < .001$).

**Discussion**

Using a large sample of women and men extensively profiled psychologically,
socially, and physiologically, we tested a comprehensive model of the relations of SES,
psychosocial, and biobehavioral variables with physical health endpoints. Building on
research that has characterized the relationships between specific constructs in depth,
such as SES and AL (Gruenewald et al., 2012) and social relationships and AL (Brooks
et al., 2014), this study focuses on the bigger picture of how these factors may function
together.

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2 Because PM and NM were highly correlated at $r = -.72$, an identical model was tested including
only PM or NM. Including NM only, the only result that changed was the emergence of a relationship
between higher NM and 1.26 times higher odds ($p = .007$) of smoking. Including PM only, the only
change was the emergence of a relationship between higher PM and .92 times lower odds ($p = .004$) of
smoking and a marginally significant association between higher PM and lower AL ($b = -.087, p = .054$).
Taken as a whole, three pathways emerged connecting SES to the number of major health conditions. The first is a behavioral pathway via PA. SES predicts higher PR both directly and indirectly via fewer SLEs, and PR in turn is associated with more PA, which is associated with fewer major health conditions. Second, there is a physiological pathway via AL. Higher SES predicts lower AL both directly and indirectly via fewer SLEs, and lower AL is associated with fewer major health conditions. Third, there is a mood pathway. Higher SES indirectly predicts lower NM via fewer SLEs and higher PR, and lower NM is associated with fewer major health conditions.

Considering the relations between SES and the psychosocial variables (i.e., PSRs, SLEs, mood), the results supported all except one predicted pathway, namely that PSRs would moderate the effects of stress on mood. Strong support also emerged for associations between biobehavioral factors (i.e., PA, smoking, AL) and the health outcome, the number of major conditions. However, fewer hypotheses regarding how these two “sides” of the model fit together were supported. For example, in the fully specified model SES did not directly predict the number of major health conditions; instead the effects of SES were all indirect via health behaviors, AL, and mood. Also unexpected was the absence of significant associations between SR and mood with health behaviors or AL (although sensitivity analyses indicated that when PM was not controlled, there was a significant association between NM and smoking). The lack of significant results for SR and mood may also be due to their overlap; as mood over the past 30 days was measured, both PM and NM were strongly associated with PR and

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^3 Analyses (not shown) only examining the association between childhood SES, change in SES, and number of major health conditions demonstrated strong effects, with a 1 SD difference in childhood SES predicting .85 times as many major health conditions, and a 1 SD change from childhood to adulthood predicting .91 times as many major health conditions (p < .001 and p = .003, respectively).
had somewhat weaker unique associations with SR. As unique effects over and above the other variables in the model, these results suggest that PR and NM have the strongest associations. In regard to the exploratory hypothesis that sex would moderate the association the associations with PSRs, none of the interactions with stress were significant, which although inconsistent with some studies (Seeman et al., 2004) is consistent with others (Seeman, Gruenewald, Cohen, Williams, & Matthews, 2014).

Unexpected significant associations also emerged. SLEs were directly associated with both smoking and AL. Although more SLEs were associated with lower PM and higher NM, mood did not account for the association between SLEs and AL or health behaviors, indicating a need to identify alternate pathways. Likewise, a direct association was evident between NM and the number of major health conditions. Perhaps this association represents the burden of disease on mood, in that the relationship was cross-sectional and reciprocal or reverse causality is possible. If NM is indeed a risk factor for major health conditions, further work is needed to identify potential mechanisms beyond those examined in the present study, including additional health behaviors such as adherence to treatment, diet/nutritional factors, sleep, or potentially more specific physiological mechanisms than AL.

Limitations and Strengths

Results should be interpreted in light of several limitations. First, although childhood SES was assessed 10 years prior to the other variables, the remaining data are cross-sectional. Therefore, these data should not be interpreted as providing evidence for causal associations. Nevertheless, significant relationships are largely consistent with what would be expected based on the theoretically and empirically
grounded conceptual model. In addition, because the sample was predominantly White (92% for the primary analyses), generalizability is limited. It is challenging to capture overall physical health outcomes. One of the single most important health outcomes, mortality, was not available in the current study; however, the health conditions assessed, including cancer and cardiovascular disease, are major causes of morbidity and mortality.

There are also limitations inherent in testing large and comprehensive models. It is possible that there are alternative models that provide equal or better explanations of the observed data. However, with 12 variables, even if each variable only predicts one other variable, more than 479 million possible combinations exist, making it untenable to examine all possible combinations. Theoretical work is needed to guide the empirical models tested. These models can then be refined both by micro-level research testing specific pathways and more macro-level investigations testing multiple relationships or comprehensive theoretical models.

This study also has a number of notable strengths. It includes a large sample of participants, who were initially recruited into MIDUS I using random digit dialing. MIDUS is also one of the only studies to include high quality and comprehensive measures of psychosocial factors, health behaviors, biomarkers, and health outcomes. For example, psychological resources were characterized by self-esteem, mastery, and optimism, and 23 biomarkers from seven systems were assessed for AL. The combination of a large sample size and comprehensive and broad measures make MIDUS ideal for testing models integrating psychosocial, behavioral, physiological, and health factors. Another strength is the careful analyses including (a) construction of PR
and SR, PM and NM, and AL indicators using confirmatory factor analysis, and multiply imputed factor scores to mitigate the effects of measurement error, (b) clustered standard errors to account for siblings and twins in the MIDUS data, and (c) sophisticated path analysis accounting for the non-normal distributions of stressful life events and number of major conditions.

**Conclusions and Future Directions**

Findings from this study were largely consistent with the tenets of the RCM. Specifically, the data were consistent with the notion that SES in childhood and adulthood influences PSRs, life stress, health behaviors, and physiology, and through these mechanisms are linked to health outcomes. Although the data did not support the hypothesis that PSRs would be associated with physiological processes directly, they did support an association between PSRs and health behaviors, which in turn were associated with both AL and health outcomes. Interestingly, we found limited evidence of relationships of mood with biobehavioral factors or health outcomes, although SLEs and PSRs did demonstrate the expected associations with PM and NM. To investigate whether this result was a function of the measures employed, we conducted separate analyses (data not shown) using depressive symptoms and anxiety symptoms in place of NM; results were substantially similar.

Future research is needed to examine whether the current model generalizes to populations other than non-Hispanic whites in the United States. Future research would also benefit from taking a lifespan developmental perspective, including longitudinal assessment of these constructs and consideration of whether timing matters. For example, different effects may emerge if PSRs and emotions/mood were assessed
before or concurrent with SLEs occurrence. Likewise, for health behaviors such as PA, lifetime history of PA may be more important than assessing levels of PA only in adulthood. Further theoretical work is needed that synthesizes both micro- and macro-level research to explain inconsistent results, such as that PA, but not smoking, was associated with both AL and number of major health conditions.

Although these data do not support causal inference, results have practical implications. The protective effects of high childhood SES and an increase from childhood to adulthood in SES appear to be conveyed through psychosocial and behavioral pathways. Specifically, adults with low childhood SES or a decrease in SES after childhood are more likely to experience stressful life events, smoke, have higher AL, and have compromised PSRs, which in turn are associated with lower PA. From the perspective of primary prevention, although intervening on SES and major SLEs may be challenging, interventions designed to bolster PSRs and improve health behaviors, particularly PA, may help to counter the deleterious effects of low SES on negative mood, physiological function and health. Although SR did not have unique effects in this study, other research has found that in African-American adolescents, high emotional support from parents and peers buffered the deleterious effects of racial discrimination from ages 16 to 18 on AL at age 20 (Brody, Lei, Chae, et al., 2014) as well as buffering the effects of increasing neighborhood poverty on AL (Brody, Lei, Chen, et al., 2014), suggesting that it may be useful to target both PRs and SRs. From the perspective of secondary prevention, individuals with low SES who are already compromised psychosocially and behaviorally may benefit from increased screening for
physiological dysregulation and, where applicable, treatment aimed to prevent or slow further physiological dysregulation.

The modified version of the Reserve Capacity Model tested in this study provides insight into how plausible mechanisms for the relationship between SES and health outcomes link together. Testing complete conceptual models can help to determine whether the evidence supports the conceptual model or which specific components warrant revision or future research to clarify further. In summary, although there were no significant associations of mood with health behaviors and AL, the remaining results largely supported the Reserve Capacity Model, suggesting that it is a useful conceptual framework to guide research.

References


Development in Young Adults (CARDIA) study. *Psychoneuroendocrinology, 43*, 126-138. doi: 10.1016/j.psyneuen.2014.02.008


Table 1. Means and Correlations among Study Variables

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Note. N = 1,050. PR = psychological resources, SR = social resources, SLE = stressful life events, NM = negative mood, PM = positive mood, AL = allostatic load, PA = physical activity, SES = socioeconomic status. Standard deviations are shown on the diagonal. All estimates are pooled across multiple imputations.
Table 2. Path estimates (standard error) from final model

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<th>Life Stress</th>
<th>PR</th>
<th>SR</th>
<th>PM</th>
<th>NM</th>
<th>PA</th>
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<td>.07 (.05)</td>
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Note. N = 1,050. PR = psychological resources, SR = social resources, PM = positive mood, NM = negative mood, AL = allostatic load, SES = socioeconomic status, PA = physical activity. Unstandardized estimates are reported, although Childhood SES, PR, SR, PM and NM are all on standardized scales so that one unit change is one standard deviation.

* p ≤ .05, ** p ≤ .01, *** p ≤ .001
Figure 1. Hypothesized model to be tested, based on suggested pathways in Matthews and Gallo (2011), which was modified from the original Reserve Capacity Model (RCM; Gallo & Matthews, 2003). Dashed lines indicate paths that were not suggested in Matthews and Gallo (2011). SES = socioeconomic status, SR = social resources, PR = psychological resources, PM = positive mood, NM = negative mood, AL = allostatic load. Shaded regions represent when in MIDUS a particular set of variables were assessed.
Figure 2. Final study model. Only statistically significant paths are shown. Sex and age were included as covariates for all dependent variables (paths not shown). In addition, two covariances between psychological and social resources and between positive and negative mood were freely estimated (not shown). Childhood SES, psychological resources, social resources, positive mood, negative mood, and allostatic load variables are on standardized scale (mean zero, standard deviation one). For paths from Childhood SES and ∆SES, solid lines indicate paths from Childhood SES and dashed lines indicate paths from ∆SES. *p ≤ .05; **p ≤ .01; ***p ≤ .001
GENERAL DISCUSSION

The overarching aim of the present studies was to take a macro-level perspective to examine the role of psychosocial resources (PSRs) in an integrative model of health. Conceptually, numerous constructs fall under the umbrella of PSRs, and although empirical work confirms that many individual PSRs are associated with health (e.g., Carver, Scheier, & Segerstrom, 2010; Uchino, 2006), guidelines on which PSRs are most important to assess and whether individual PSRs have unique effects over and above other PSRs is less available. In light of substantial inter correlations among PSRs and their common health-promoting role, we hypothesized that PSRs may represent a single common factor or separate psychological (PR) and social (SR) resource factors. In the first manuscript, results revealed that across four independent samples, a two-factor structure emerged for the PSRs of optimism, self-esteem, mastery, hope, and several types of social support. These results also suggest that, at least when the focus of research is on the overall construct of PSRs, rather than needing to examine the relations between many individual PSRs and health, examining the relations of PR and SR with health is sufficient.

Allostatic load (AL) theory posits that repeated adaptation to stress results in system wide, cumulative physiological dysregulation (McEwen & Stellar, 1993). This would suggest that measures of many individual physiological systems will have at least partial shared variance. Results from the second manuscript supported AL theory, revealing that a general system-wide factor, in addition to individual system factors, provided the best fit among 23 biomarkers from seven physiological systems. No
evidence emerged that this overall structure differed as a function of sex, age, race/ethnicity, or medication use.

If PSRs are associated with health outcomes, it is plausible that they would also be associated with AL. Whether research supports this hypothesis was examined by conducting a systematic review of the literature on PSRs and AL. The results from this third manuscript suggest that the relationship between PSRs and AL is complex and mixed, with some studies finding that higher PSRs were associated with significantly lower AL, others finding null effects, and still others finding that higher PSRs were associated with significantly higher AL. Such heterogeneity in results may point to the importance of assessing potential moderators, and indeed there was some evidence that PSRs interact with SES, stress, and sex, although none of these findings consistently emerged across studies. These results also suggest that AL may not represent a strong candidate mechanism to explain the association between PSRs and health outcomes and point to the need to consider alternative mechanisms as well, such as health behaviors.

The final manuscript integrated PSRs AL, SES, stress, mood, health behaviors, and major health conditions to test a broader conceptual model based on a modified form of the Reserve Capacity Model (Gallo & Matthews, 2003) of how SES is associated with health outcomes. The results revealed that childhood SES and change in SES from childhood to adulthood predicted adult PSRs and number of stressful life events, which in turn were associated with physical activity, AL, and negative mood—the final factors associated with number of major health conditions. Although PSRs buffered the effects of SES on negative mood, no other interactions between SES or
stress and PSRs or between PSRs and sex emerged. Major stressful life events experienced across the lifespan (though collected retrospectively) also predicted lower adulthood PSRs.

**General Limitations**

All of the empirical studies utilized cross-sectional data that cannot support causal inference. Lacking longitudinal data also limits the ability to examine how these processes unfold over time and potentially miss important change. For example, affective or physiological responses shortly after major life stress may be different than several years after the stressful experience. Although the goal was to characterize the overall construct of PSRs, only a subset was assessed (i.e., optimism, self-esteem, mastery/control, hope, several types of social support). These are the PSRs most commonly assessed in the literature, however. Finally, the health outcomes were limited to self-reported major health conditions; future studies can examine multiple aspects of health or mortality.

**Conclusion**

Overall, the results suggest a role for PSRs in health, although the relationship is not always a simple one. Although PSRs are hypothesized to be fairly stable trait-like factors, higher childhood SES and change from childhood to adulthood SES predict higher adulthood PSRs. Furthermore, the occurrence of major stressful life events across the lifespan appears to erode adulthood PSRs. PSRs, especially PR, are strongly associated with both positive and negative mood, and buffer the effects of SES.
on negative, but not positive, mood. No evidence emerged for a direct association between PSRs and AL; however, PRs were associated with higher physical activity, which was associated with both AL and the number of health conditions. A tentative conclusion may be that PSRs are more strongly associated with health behaviors than directly to physiology, and future research could explore additional health behaviors that act as mechanisms including diet/nutrition, regular health checkups, medical regimen adherence, and sleep. Interestingly, after accounting for all hypothesized mechanisms, there was no direct association between SES and major health conditions, suggesting that the model fully accounts for the effects of SES on health outcomes, via physical activity, AL, and negative mood (remaining mechanisms were not significantly associated with health outcomes).

To our knowledge, this is one of the few studies to test a complete conceptual model of SES, PSRs, and health. By taking this macro-level approach, we are able to provide empirical support for the major tenets of the modified Reserve Capacity Model, as well as to identify areas that need further work. For example, identification of mechanisms that explain the remaining direct association between SES and AL, as well as the association between negative mood and health outcomes, represents a necessary direction for research.

References

