Published in final edited form as:

Womens Health Issues. 2015 ; 25(6): 680–687. doi:10.1016/j.whi.2015.07.002.

Greater Leisure-Time Physical Activity is Associated with Lower Allostatic Load in White, Black, and Mexican-American Midlife Women: Findings from the National Health and Nutrition Examination Survey, 1999–2004

Dawn M. Upchurch, Ph.D., L.Ac.[1], **Bethany Wexler Rainisch, Ph.D., M.P.H.**[2], and **Laura Chyu, Ph.D.**[3]

Dawn M. Upchurch: upchurch@ucla.edu; Bethany Wexler Rainisch: bethany.rainisch@csun.edu; Laura Chyu: laurachyu@gmail.com

[1]Department of Community Health Sciences, UCLA Fielding School of Public Health, 650 Charles Young Drive South, Los Angeles, CA, USA 90095-1772. 01-310-794-9693

[2]Department of Health Sciences, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA, USA, 91330

[3]Public Health Science Program, Santa Clara University, 500 El Camino Real, Santa Clara, CA, USA, 95053

Introduction

Adverse environmental, social, and economic conditions are associated with numerous negative health outcomes and contribute to the generation and maintenance of health inequalities (Diez Roux, 2012; Link & Phelan, 1995; Phelan, Link, & Tehranifar, 2012; Taylor, Repetti, & Seeman, 1997). Allostatic load is a useful construct to understand how person-environment interactions accumulate over time to affect health and to identify possible physiological pathways through which these larger socioenvironmental conditions act (McEwen, 2004; Seeman et al., 2001; Seeman et al., 1997; Seeman et al., 2004). There is new interest in investigating and identifying health-enhancing lifestyle behaviors and their potential salutary effects on reducing allostatic load, and thus subsequent disease burden. The purpose of this study was to investigate the association between leisure-time physical activity and allostatic load level among a nationally representative sample of White, Black, and Mexican-American midlife women. Secondarily, we were also interested in characterizing demographic differences in allostatic load, with a focus on examining the extent to which racial and ethnic effects depend upon women's age.

Allostatic load is a measure of cumulative burden of dysregulation across multiple physiological systems (McEwen & Stellar, 1993; McEwen, 1998; McEwen, 2007; Sterling

Disclosure statement. No competing financial interests.

& Eyer, 1988). It occurs with long-term exposure to environmental and social stressors, leading to overaction and dysregulation, resulting in biological wear and tear (McEwen, 2004; Seeman et al., 1997; Seeman et al., 2001; Seeman et al., 2004). Allostatic load is a stronger predictor of subsequent morbidity and mortality than single, system-specific biological indices (Karlamangla et al., 2002; Karlamangla, Singer, & Seeman, 2006; Seeman et al., 2004). This greater predictability is because it provides an index of cumulative risk, summarizing what may be small changes in individual parameters but whose combined effects reflect greater overall evidence for dysregulation (McEwen, 1998; McEwen, 2007; McEwen & Stellar, 1993).

Midlife (roughly ages 40–59) is a pivotal period in women's lives marked by physiological changes and multiple social transitions (Kuh & Hardy, 2002; Willis & Reid, 1999). Much of women's lives are spent post-childbearing and postmenopausal and there is continuing interest in identifying successful strategies for healthy aging into the senior years (Bass & Caro, 2001; Kuh & Hardy, 2002). Allostatic load can be used as an "early warning" marker to track how lifestyle changes affect subsequent health risks and aging trajectories among midlife women.

The multiple and long-term benefits of regular physical activity are well established (e.g., Booth, Roberts, & Laye, 2012; Brown, Burton, & Rowan, 2007; Schoenborn & Stommel, 2011; USDHHS, 2008). Physical activity confers health benefits across multiple physiological systems (Silverman & Duster, 2014) and there is a dose-response gradient between level of activity and health benefits (USDHHS, 2008). Few studies have focused on the relationship between leisure-time physical activity and allostatic load explicitly, (see Gallo et al., 2011; Gay et al., 2013; Hampson, et al., 2009 as exceptions). However, several studies of allostatic load have controlled for health behaviors, including physical activity (e.g, Duru et al., 2012; Mattei et al., 2010; Peek et al., 2010; McEwen & Gianoros 2010). Moreover, there is support that physical activity is associated with individual biomarkers that comprise allostatic load. Several recent studies have reported that higher levels of leisure-time physical activity have beneficial effects on cardiovascular (Hamer, 2012; Luke, et al., 2011; Panagiotakos, et al., 2005), metabolic (Ford, et al., 2005; Golbidi, Mesdahninia, & Laher, 2012; Holmes, Ekkekakis, & Eisenmann, 2010), and inflammatory (Kasapapis & Thompson, 2005; Panagiotakos, et al., 2005) markers.

With respect to demographic factors, lower SES is associated with higher allostatic load in the adult U.S. population (e.g., Seeman et al., 2008) and among women of all ages (Chyu & Upchurch, 2011). Social and economic conditions have been proposed as fundamental causes of health inequalities (Diez Roux, 2012; Link & Phelan, 1995; Phelan, Link, & Tehranifar, 2010) and differences in allostatic load may be one pathway linking SES and health (Carlson & Chamberlain, 2005; Diez Roux, 2012; Phelan, Link, & Tehranifar, 2010). Specifically, the stresses of lower SES, including lack of resources (such as knowledge, money, power, prestige, and beneficial social conditions) contribute to health disadvantages (Link & Phelan, 1995; Phelan, Link, & Tehranifar, 2010; Rieker & Bird, 2005).

Allostatic load also accrues more rapidly for certain groups of women, particularly women who are racial or ethnic minorities. Long-term exposure to social adversity is proposed to elicit chronic stress responses, increasing cumulative physiological burden, and contributing to earlier health deterioration among minorities, especially Blacks (Braveman, 2011; Geronimus et al., 2006; Geronimus et al., 2010; Peek et al., 2010). These forces are separate from those of SES in that they place additional constraints among individuals based on their race or ethnicity (Braveman, 2011). Fewer studies have analyzed Hispanics relative to other groups, however, there is evidence that they have higher allostatic load than Whites, but lower than Blacks (Crimmins, et al., 2007; Chyu & Upchurch, 2011; Peek et al., 2010).

The research presented here utilized a biopsychosocial approach that posits health status (here, allostatic load) is the product of social, psychological, behavioral, and biological processes. Thus, life conditions linked to characteristics of social placement result in variable exposure to social stressors with consequences to allostatic load. Similarly, lifestyle behaviors are shaped by social position and conditions. First, we hypothesized that higher levels of leisure-time physical activity will be associated with lower allostatic load in a dose-response fashion. Second, because allostatic load is cumulative in nature, we proposed older women will have higher load values than younger women. Additionally, we incorporated an intersectional approach because of differential aging/weathering according to race and ethnicity. Thus, we hypothesized that the effect of race and ethnicity will be contingent on age, with Black women especially at a disadvantage with respect to allostatic load level at a given age and Mexican-American women exhibiting somewhat higher allostatic load than Whites. Last, we hypothesized higher SES women will have lower allostatic load.

Materials and Methods

Survey Description

NHANES is an ongoing, cross-sectional study used to assess the health and nutritional status of the civilian, non-institutionalized U.S. population (Centers for Disease Control and Prevention and National Center for Health Statistics, 2007a). It utilizes a stratified, multistage probability sampling design of households, thus allowing for national, population-level estimates. NHANES is collected on a continuous basis and released every two years. Clinical and laboratory components of the survey occur in Mobile Examination Centers (MEC) and standardized protocols are used (Centers for Disease Control and Prevention and National Center for Health Statistics, 2007b). The response rate for the full sample was 77% for the interview section and 71% for the MEC examination. For women, among those who completed the interview section, the response rate for the MEC examination was 92%. Data from the 1999–2004 cycles of NHANES were used for the current study. The analytic sample was all women ages 40–59 who had valid data on all biomarkers, were not pregnant, and completed both the interview and MEC sections of the survey. Women who identified as “other” races were excluded because of the heterogeneity of that category. The final sample size was n = 1,680. The research was approved by the institution’s Investigational Review Board.

Description of Single Biomarkers and Composite Allostatic Load Score

Ten biomarkers were selected to reflect multiple physiological systems and disease risk, and included markers commonly used in previous research that were available in the data

(Beckie, 2012; Carlson & Chamberlain, 2005; Chyu & Upchurch, 2011; Geronimus et al., 2006; McEwen & Stellar, 1993; Seeman et al., 1997). Our operationalization of allostatic load was comparable to what others have done using NHANES to investigate cumulative physiological dysregulation (e.g., Chyu & Upchurch, 2011; Crimmins et al., 2007; Geronimus et al., 2006; Peek et al., 2010). *Cardiovascular* markers included systolic and diastolic blood pressure, homocysteine, and pulse rate. *Metabolic* markers included body mass index (BMI), glycosylated hemoglobin (HbA1c), high-density lipoprotein (HDL), and total cholesterol. *Inflammatory* markers included serum albumin and C-reactive protein (CRP).

Composite allostatic load scores were created using empirical cutoff points based on the weighted distribution of the analytic sample, employing a count-based summation method, which has been used extensively in the literature (Beckie, 2012; Chyu & Upchurch, 2011; Crimmins et al., 2003; Geronimus et al., 2006; Karlamangla et al, 2002; Peek et al., 2010; Seeman et al., 1997; Singer, Ryff, & Seeman, 2004, among others). The 75th percentile was used as the cutoff for high risk for all biomarkers except albumin and HDL, for which the 25th percentile was used as the cutoff. Allostatic load scores were calculated by summing the number of biomarkers that fell into the high-risk quartile.[1]

Leisure Time Physical Activity

The data were drawn from the NHANES physical activity questionnaire which measures participation in leisure-time physical activities. Specifically, self-reported information was collected on the frequency and duration of moderate and vigorous intensity physical activities engaged in leisure time recreation during the past 30 days. Following recommended procedures, we first calculated the moderate and vigorous activity minutes per month for all activities mentioned and linked each activity with its pre-assigned Metabolic Equivalent Task (MET) (http://www.cdc.gov/nchs/tutorials/PhysicalActivity/Preparing/PAX/index.htm). A MET is a measure of intensity of physical activity and is the ratio of the rate of energy expended during an activity to the rate of energy expended at rest (USDHHS, 2008). Monthly summaries were then converted to weekly summaries by dividing by 4.33. The final variable is measured as MET minutes per week. (Additional detail on recommended coding can be found at http://www.cdc.gov/nchs/tutorials/PhysicalActivity/Preparing/PAQ/Task4_Step2c.htm).

Following recent work on leisure-time physical activity and allostatic load (Gay et al., 2013), and because we are interested in assessing potential dose-response relationship, we created a four-category measure. Women with no activity (0 MET minutes per week) were coded as "Inactive;" those with <600 MET minutes per week were "Low Active;" those between ≥600 and 1500 MET minutes per week were "Moderate Active;" and those with > 1500 MET minutes per week coded as "High Active."

[1]In additional analyses, we also used the established clinical cutoff values for the construction of the allostatic load measure. Substantive results for this operationalization were no different than operationalization using the empirical cutoff values. (Results available from authors.)

Demographics

Race and ethnicity were coded according to women's self-report, with priority given to any mention of being Hispanic: Non-Hispanic White, Non-Hispanic Black, and Mexican American. Age was coded into five-year categories (40–44, 45–49, 50–54, 55–59). Educational attainment was coded into three categories (less than high school, high school graduate (including GED), and more than high school). Annual family income in the past year was coded into four categories (<$20,000, $20,000–44,999, $45,000–74,999, and ≥ $75,000). Current marital status was coded into three categories (married/cohabiting, separated/widowed/divorced, and never-married). Nativity status was dichotomous (U.S. born, foreign born). We also created a racial/ethnic-by-age interaction variable. There were no missing data for race/ethnicity or age and a very small number for education, marital status, and nativity status. For these variables, missing cases were coded into modal categories. Missing values for family income were imputed using a multinomial regression that included race/ethnicity, age, education, marital status, and nativity status. Substantive results did not change whether or not missing cases were dropped or included.

Medication Use

Relevant self-reported medication use in the past 30 days was also considered to account for differences in biomarker values based on their use. We created three dummy variables to serve as controls (any hypertension medications, any diabetes medications, and any cholesterol medications). (In separate analysis not presented here, substantive results did not change when medication variables were added into the model.)

Analysis

All analyses were weighted using the NHANES individual-level sampling weights, which adjust for complex sample design, selection, and non-response. Mean differences for allostatic load for each covariate were assessed using bivariate regression and adjusted Wald F-test. Negative binomial regression models were used to investigate the combined effects of leisure-time physical activity and demographics on allostatic load. The functional form of negative binomial was used to account for over dispersion and to more accurately model the underlying count process (Winkelmann, 2008). In a separate analysis, adjusted mean allostatic load scores were predicted using estimates from the negative binomial model that included MET minutes per week, MET[2] minutes per week, racial/ethnic-by-age interactions, and controlling for the remaining variables (education, income, marital status, nativity status, medication use). We assessed predicted values of allostatic load at increments of 250 METs between 0 and 1500. The control variables were set to the weighted means. We then obtained adjusted predicted values (means) of allostatic load at each of the MET values for

[2]Because this is one of the first investigations to focus on leisure-time physical activity and allostatic load in a nationally representative sample, we investigated other possible specifications for our final model. We tested for moderation effects between leisure-time physical activity and race/ethnicity and with income; the omnibus tests for each were only marginally significant. We also performed structural equation modeling to examine direct and indirect effects of leisure-time physical activity on allostatic load. In this analysis, physical activity was assessed continuously as MET minutes per week. As expected, higher MET minutes per week was significantly associated with lower allostatic load. We also found that a portion of the effect of low income on higher allostatic load was explained by lower levels of physical activity among these women. No other indirect pathways were significant. (Data not shown. Available from the authors.)

each racial/ethnic-by-age group. These results are presented graphically for ease of interpretation. All analyses were performed using Stata 12.0 (StataCorp, 2011).[2]

Results

Table 1 shows the descriptive statistics of the individual biomarkers and summary allostatic load score. We also list established clinic cutoff values for comparison. Allostatic load score varied from 0–9 with M=2.30 (SD=1.29). Higher allostatic load indicates poorer health.

Population characteristics are represented in column one and mean allostatic scores by independent variables are shown in column two (Table 2). The majority (63%) of midlife women were either inactive or reported low level of physical activity in the past week. Only a minority (17%) reported a high level of physical activity. Almost two-thirds of women had more than a high school education, one-quarter were in the lowest category of family income, and one-third in highest family income. The majority of midlife women were currently married or cohabiting (71%) and more than one in ten were native born.

As expected, lower mean allostatic load significantly was significantly associated with higher levels of leisure time physical activity. A negative dose-response relationship between levels of leisure time physical activity and mean allostatic load scores was observed, with an overall 48% reduction in mean allostatic load from the lowest to highest level of physical activity. There was a significant bivariate association between allostatic load and all demographic variables except nativity status. Mean allostatic load increased with age for each racial/ethnic group. In each age category, White women had the lowest mean allostatic load, followed by Mexican-American women, and Black women the highest. Lower mean allostatic load decreased was associated with higher education and income. Married women had the lowest allostatic load compared to other marital groups.

The association between higher levels physical activity and lower allostatic load remained in the multivariate analysis (Table 3), although the dose-response pattern was significant only for moderate and high levels of physical activity. Compared to women with no activity, those with moderate or high levels had significantly lower allostatic load, with a greater benefit conferred for women engaging in high levels of physical activity. Compared to White women 40–44, all other racial/ethnic-by-age groups had significantly higher allostatic load, including Black and Mexican American women of the same age (40–44). Education was no longer significant and only women in the highest income category had lower allostatic load relative to the lowest income. Never married women had higher allostatic load than married women. (Medication use was also significantly associated with higher allostatic load. Not shown.)

Figure 1 shows the adjusted predicted means of allostatic load for each racial/ethnic group for each age category and according to level of physical activity. For all ages and all racial/ethnic groups, predicted values of allostatic load were lower with higher levels of leisure-time physical activity. Predicted means were similar for Whites and Mexican Americans for all age categories except ages 40–44. For the 45–49 and 55–59 age groups White women had slightly higher predicted means than Mexican American women. As expected, women at the highest level of leisure-time physical activity had the lowest predicted allostatic load, for all ages, and for all racial/ethnic groups. For example, in the 40–44 year age group, increasing MET minutes per week from 0 to the maximum 1500 MET minutes per week reduced allostatic load by almost one-quarter. Using the 2008 guidelines as a reference, for the same age group, increasing MET minutes per week from 0 to 500 or from 0 to 1000 reduced allostatic load by almost 10 percent and 17 percent, respectively. (The Appendix shows the predicted adjusted means for all racial and ethnic groups and ages at each MET level computed.)

Discussion

This is one of the first studies to investigate the association between leisure-time physical activity and level of allostatic load in a nationally representative sample of White, Black, and Mexican-American midlife women. We find some support for a negative dose-response relationship between leisure-time physical activity and allostatic load, independent of demographic characteristics. In addition, our findings confirm racial and ethnic differences in allostatic load, that allostatic load increases with age, and that Black women experience earlier aging (or weathering) than White women. Also, as expected, higher SES midlife women have lower allostatic load than less affluent women. Last, our prediction model demonstrates that all racial and ethnic groups and all age categories of midlife women theoretically benefit from increases in leisure-time physical activity associated with respect to level of allostatic load.

Although there is a large literature addressing the relationship between leisure-time physical activity and single biomarkers (or markers from subsets of physiological systems) that comprise allostatic load (Ford, et al., 2005; Golbidi, Mesdahninia, & Laher, 2012; Hamer, 2012; Holmes, Ekkekakis, & Eisenmann, 2010; Kasapapis & Thompson, 2005; Luke, et al., 2011; Panagiotakos, et al., 2005; USDDH, 2008), only a few studies have focused on physical activity and allostatic load with mixed results (Gallo et al., 2011; Gay, et al., 2013; Hampson, et al., 2009). Two investigated the relationship in Mexican American samples, one from a Texas-Mexico border area (Gay, et al., 2013), another of midlife women from a California-Mexico border area (Gallo et al., 2011), and one in an ethnically diverse sample of midlife Hawaiians (Hampson, et al., 2009). One study found a significant association between high levels of leisure-time physical activity (> 1500 MET minutes per week) and lower allostatic load in Mexican Americans, but not in a dose-response fashion (Gay, et. al, 2013). However, the researchers dichotomized allostatic load into high and low versus evaluating it as a count, which may in part explain the difference in findings from our own. In the study of midlife Mexican American women, higher levels of physical activity was associated with lower allostatic load at the bivariate level, but the effects were not significant in multivariate analysis (Gallo, et al., 2011). However, the authors acknowledge their analysis was likely under-powered. Physical activity was not associated with allostatic load in women in the Hawaiian sample, even at the bivariate level (Hampson et al., 2009). The discrepancies in the findings may be due to the nature of the samples used and measurement differences, especially leisure-time physical activity. Additionally, many studies have used physical activity as one of several health behavior control variables. In general, they also find higher level of physical activity associated with lower allostatic load (e.g, see Beckie, 2012; Duru et al., 2012; Mattei et al., 2010; Peek et al., 2010; McEwen & Gianoros, 2010 for a review). While the recommendation about "how much" physical activity is necessary to reduce allostatic load to a level that is clinically meaningful is still an open question, a review concluded that even modest gains in women's physical activity may lower risk for some health problems (Brown, Burton, & Rower, 2007). Our findings from a nationally representative sample of midlife women are promising and suggest additional research on the contributions of leisure-time physical activity in potentially reducing allostatic load is warranted.

A new contribution with respect to demographic difference in allostatic load is our focus on midlife women. Much of the prior research has considered gender as a control variable. The observed racial and ethnic differences in levels of allostatic load are consistent with earlier studies investigating all adults and the elderly (Seeman et a., 2001; Seeman et al., 2004; Seeman et al., 2008) and one study examining women 18 and older (Chyu & Upchurch, 2011). We find for each age, Blacks have the highest allostatic load, followed by Mexican Americans, and last Whites. Thus our findings support the work of Geronimus and colleagues (2006; 2010) suggesting earlier aging, or weathering, especially among Black women. While Mexican American women have higher allostatic load than White women, there is also a protective effect of being foreign-born, and the majority of foreign-born in this sample is Mexican American. Work done by Crimmins and colleagues (2007) support the selective healthy immigrant hypotheses and more recent work by Peek and colleagues (2010) confirm selective immigrant effects. Our findings also point to the importance of considering intersectional approaches when investigating race and ethnicity (and undoubtedly other demographics).

Consistent with Link and Phelan's (1995; 2010) theory of social conditions as fundamental causes of health differences, we find lower education and income are associated with higher levels of allostatic load. The higher levels of chronic stresses associated with lower SES, including the lack of flexible resources potentially contribute to higher allostatic load, and ultimately poorer health (Karlamangla et al., 2002; 2006; Seeman, et al., 2004). The effects of education and income were somewhat reduced when leisure-time physical activity was added to our models, although the significant effects for the higher income level remain. As mentioned earlier, other ancillary analysis suggests part of the higher level of allostatic load among lower income women is explained by their lower levels of physical activity. However, more research is needed to test the ways in which lack of resources, and which resources, specially, affect allostatic load. Additionally, work that focuses on how lifestyle behaviors may mediate these effects is recommended.

We acknowledge limitations of the current research. Importantly, the cross-sectional design of NHANES prohibits the investigation of level and change in allostatic load over time. We do find strong support that allostatic load is higher for older ages in this sample, but these are not within-woman change estimates. We also cannot be certain about causal directionality with respect to physical activity and allostatic load. And although NHANES included a comprehensive set of biomarker measures and provides a good operationalization of allostatic load, there are key markers that would be useful to include (e.g., cortisol, epinephrine, norephephrine). However, there are well-known methodological challenges in accurately measuring these markers (Beckie, 2012). In addition, while the count-based score of allostatic load is common in the literature, there are other operational definitions that could be considered. We are also constrained in our ability to generalize beyond Mexican-American Hispanic women because of data limitations. Last, because we were interested in isolating possible leisure-time physical activity effects on allostatic load, we did not consider multiple lifestyle behaviors that may simultaneously contribute to level of allostatic load. These questions remain for future research.

Implications for Practice and/or Policy

Midlife is a critical period in women's life course and helping women integrate strategies for healthy aging into their lives has high public health relevance as baby boomers age into midlife and the senior years. Allostatic load can serve as an early warning indicator and marker of women's risk at midlife. The multiple health benefits of physical activity are well established and the results from this study demonstrate that leisure-time physical activity also has salutary benefits with regard to allostatic load. Thus our findings point to the importance of preventive health programs and interventions targeted at women during midlife that emphasize health-enhancing lifestyle behaviors like physical activity. Public policy efforts directed at developing exercise-friendly built environments will provide greater opportunities for a diversity of women to engage in these practices.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The corresponding author, Dr. Dawn Upchurch, had full access to all data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis.

References

Bass, C.; Caro, G. Productive aging: a conceptual framework. In: Morrow-Howell, N.; Hinterberg, J.; Sherraden, M., editors. Productive Aging: concepts and challenges. Baltimore: Johns Hopkins University Press; 2001. p. 37-78.

Beckie TM. A systematic review of allostatic load, health, and health disparities. Biological Research in Nursing. 2012; 14:311–346.

Braveman PS, Egerter S, Williams DR. The social determinants of health: coming of age. Annual Review of Public Health. 2011; 32:381–398.

Brown WJ, Burton NW, Rowan PJ. Updating the evidence on physical activity and health in women. American Journal of Preventive Medicine. 2007; 33:404–411. [PubMed: 17950406]

Carlson ED, Chamberlain RM. Allostatic load and health disparities: a theoretical approach. Research in Nursing and Health. 2005; 28:306–315. [PubMed: 16028266]

Carlson SA, Fulton JE, Schoenborn CA, Loustatlot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. American Journal of Preventive Medicine. 2010; 39:305–313. [PubMed: 20837280]

Centers for Disease Control and Prevention and National Center for Health Statistics. National Health and Nutrition Examination Survey content, 1999–2004. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2007a.

Centers for Disease Control and Prevention and National Center for Health Statistics. NHANES response rates and CPS totals, 1999–2004. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2007b.

Chyu L, Upchurch DM. Racial and ethnic patterns of allostatic load among adult women in the United States: findings from the National Health and Nutrition Examination Survey 1999–2004. Journal of Women's Health. 2011; 20:575–583.

Crimmins EM, Kim JK, Alley DE, Karlamangla A, Seeman T. Hispanic paradox in biological risk profiles. American Journal of Public Health. 2007; 97:1305–1310. [PubMed: 17538054]

Diez Roux AV. Conceptual approaches to the study of health disparities. Annual Review of Public Health. 2012; 33:41–58.

Duru OK, Harawa NT, Kermah D, Norris KC. Allostatic load burden and racial disparities in mortality. Journal of the National Medical Association. 2012; 104:89–95. [PubMed: 22708252]

Ford ES, Kohl HW, Mokdad AH, Anjani UM. Sedentary behavior, physical activity, and the metabolic syndrome among U.S. adults. Obesity Research. 2005; 13:608–614. [PubMed: 15833947]

Gallo LC, Jimenez MA, Shivpuri S, Espinos de los Monteros K, Mills PJ. Domains of chronic stress, lifestyle factors, and allostatic load in middle-aged Mexican-American women. Annals of Behavioral Medicine. 2011; 41:21–31. [PubMed: 20878511]

Gay JL, Salinas JJ, Buchner DM, Mirza S, Kohl HW, Fisher-Hoch SP, McCormick JB. Meeting physical activity guidelines is associated with lower allostatic load and inflammation in Mexican Americans. Journal of Immigrant and Minority Health. 2013 epub ahead of print. doi:10-1007/s10903-013-9950-1.

Geronimus AT, Hicken MT, Keene D, Bound J. "Weathering" and age patterns in allostatic load scores among blacks and whites in the United States. American Journal of Public Health. 2006; 96:826–833. [PubMed: 16380565]

Geronimus AT, Hicken MT, Pearson JA, Seashols SJ, Brown KL, Cruz TD. Do U.S. black women experience stress-related biological aging? Human Nature An Interdisciplinary Biosocial Perspective. 2010; 21:19–38.

Golbidi S, Mesdahinia A, Laher I. Review article: exercise in the metabolic syndrome. Oxidative Medicine and Cellular Longevity. 2012; 2012:349710. doi:10.1155120121349710. [PubMed: 22829955]

Hamer M. Psychosocial stress and cardiovascular disease risk: the role of physical activity. Psychosomatic Medicine. 2012; 74:896–903. [PubMed: 23107839]

Hampson SE, Goldberg LR, Vogt LR, Hiller TA, Dubanoski JP. Using physiological dysregulation to assess global health status: associations with self-rated health and health behaviors. Journal of Health Psychology. 2009; 14:232–241. [PubMed: 19237490]

Holmes ME, Ekkekakis P, Eisenmann JC. The physical activity, stress, and metabolic syndrome triangle: a guide to unfamiliar territory for the obesity researcher. Obesity Research. 2010; 11:497–507.

House JS, Lantz PM, Herd P. Continuity and change in the social stratification of aging and health over the life course: evidence from a nationally representative longitudinal study from 1986 to 2001/2002 (Americans' Changing Lives Study). Journals of Gerontology Series B-Psychological Sciences and Social Sciences. 2005; 60:15–26.

Karlamangla AS, Singer BH, McEwen BS, Rowe JW, Seeman TE. Allostatic load as a predictor of functional decline: MacArthur Studies of Successful Aging. Journal of Clinical Epidemiology. 2002; 55:696–710. [PubMed: 12160918]

Karlamangla AS, Singer BH, Seeman TE. Reduction in allostatic load in older adults is associated with lower all-cause mortality risk: MacArthur Studies of Successful Aging. Psychosomatic Medicine. 2006; 68:500–507. [PubMed: 16738085]

Kasapapis C, Thompson PD. The effects of physical activity on serum C-reactive protein and inflammatory markers: a systematic review. Journal of the American College of Cardiology. 2005; 45:1563–1569. [PubMed: 15893167]

Kuh, D.; Hardy, R. A lifecourse approach to women's health. New York: Oxford University Press; 2002.

Lantz PM, House JS, Lepowski JM, Williams DR, Merro RP, Chen J. Socioeconomic factors, health behaviors, and mortality: results from a nationally representative prospective study of U.S. adults. Journal of the American Medical Association. 1998; 279:1703–1708. [PubMed: 9624022]

Lantz PM, House JS, Mero RP, Williams DR. Stress, life events, and socioeconomic disparities in health: results from the Americans' Changing Lives Study. Journal of Health and Social Behavior. 2005; 46:274–288. [PubMed: 16259149]

Link BG, Phelan J. Social conditions as fundamental causes of disease. Journal of Health and Social Behavior. 1995; 35:80–94. [PubMed: 7560851]

Luke A, Dugas LR, Durazo-Arvizu RA, Cao G, Cooper RS. Assessing physical activity and its relationship to cardiovascular risk factors: NHANES 2003–2006. BMC Public Health. 2011; 11:387–398. [PubMed: 21612597]

Mattei J, Demissie S, Falcon LM, Ordovas JM, Tucker K. Allostatic load is associated with chronic conditions in the Boston Puerto Rican Health Study. Social Science and Medicine. 2010; 70:1988–1996. [PubMed: 20381934]

McEwen BS, Seeman T. Protective and damaging effects of the mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. Annals of the New York Academy of Sciences. 1999; 896:30–47. [PubMed: 10681886]

McEwen BS, Stellar E. Stress and the individual: mechanisms leading to disease. Archives of Internal Medicine. 1993; 153:2093–2101. [PubMed: 8379800]

McEwen BS. Stress, adaptation, and disease: allostasis and allostatic load. Annals of the New York Academy of Sciences. 1998; 840:33–44. [PubMed: 9629234]

McEwen BS. Protection and damage from acute and chronic stress: allostasis and allostatic overload and relevance to the pathophysiology of psychiatric disorders. Annals of the New York Academy of Sciences. 2004; 1032:1–7. [PubMed: 15677391]

McEwen BS. Physiology and neurobiology of stress and adaptation: central role of the brain. Physiological Reviews. 2007; 87:873–904. [PubMed: 17615391]

McEwen BS, Gianaros PJ. Central role of the brain in stress and adaptation: links to socioeconomic status, health, and disease. Annals of the New York Academy of Sciences. 2010; 1186:190–222. [PubMed: 20201874]

Panagiotakos DB, Pitsavos C, Chrysohoou C, Kavouras S, Stefanadis C. The associations between leisure-time physical activity and inflammatory and coagulation markers related to cardiovascular disease: the ATTICA study. Preventive Medicine. 2005; 40:432–437. [PubMed: 15530595]

Peek MK, Cutchin MP, Salinas JJ, Sheffield KM, Eschbach K, Stowe RP, Goodwin JS. Allostatic load among non-Hispanic whites, non-Hispanic blacks, and people of Mexican origin: effects of ethnicity, nativity, and acculturation. American Journal of Public Health. 2010; 100:940–946. [PubMed: 19834005]

Phelan JC, Link BG, Tehranifar P. Social conditions as fundamental causes of health inequalities. Journal of Health and Social Behavior. 2010; 51:S28–S40. [PubMed: 20943581]

Rieker PP, Bird CE. Rethinking gender differences in health: why we need to integrate social and biological perspectives. Journal of Gerontology, Series B. 2005; 60B:40–47.

Seeman TE, McEwen BS, Rowe JW, Singer BH. Allostatic load as a marker of cumulative biological risk: MacArthur Studies of Successful Aging. Proceedings of the National Academy of Sciences in the Unites States of America. 2001; 98:4770–4775.

Seeman TE, Singer BH, Rowe JW, Horwitz RI, McEwen BS. Price of adaptation – allostatic load and its health consequences: MacArthur Studies of Successful Aging. Archives of Internal Medicine. 1997; 157:2259–2268. [PubMed: 9343003]

Seeman TE, Crimmins E, Huang M, Singer BH, Bacur A, Gruenewald T, Berkman LF, Reuben DB. Cumulative biological risk and socioeconomic differences in mortality: MacArthur Studies of Successful Aging. Social Science and Medicine. 2004; 58:1985–1997. [PubMed: 15020014]

Silverman MN, Deuster PA. Biological mechanisms underlying the role of physical fitness in health and resilience. Interface Focus. 2014; 4(5):20140040. doi:101098/rsfs.2014.0040. [PubMed: 25285199]

Singer, BH.; Ryff, C.; Seeman, TE. Operationalizing allostatic load. In: Schulkin, J., editor. Allostasis, homeostasis, and the cost of physiological adaptation. Cambridge: Cambridge University Press; 2004. p. 113-149.

StataCorp. Stata statistical software: release 12.0. College Station: Stata; 2011.

Sterling, P.; Eyer, J. Allostasis: a new paradigm to explain arousal pathology. In: Fisher, S.; Reason, J., editors. Handbook of life stress, cognition, and health. New York: John Wiley; 1988. p. 629-649.

Taylor SE, Repetti RL, Seeman TE. Health psychology: what is an unhealthy environment and how does it get under the skin? Annual Review of Psychology. 1997; 48:411–447.

Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S. adults: compliance with the physical activity guidelines for Americans. American Journal of Preventive Medicine. 2011; 40:454–461. [PubMed: 21406280]

U.S. Department of Health and Human Services, Physical Activity Guidelines Advisory Committee. Physical activity guidelines advisory committee report, 2008. Washington: U.S. Department of Health and Human Services; 2008.

Willis, SL.; Reid, JD. Life in the middle: psychological and social development in middle age. San Diego: Academic Press; 1999.

Winkelmann, R. Econometric analysis of count data. 5. New York: Spinger-Verlag; 2008.

Biographies

Dawn M. Upchurch, Ph.D., L.Ac. is Professor of Public Health at the UCLA Fielding School of Public Health. She studies women’s health and well-being over the life course, with an emphasis on psychosocial stressors and lifestyle behaviors on health, and alternative and integrative medicine strategies to improve women’s health.

Bethany Wexler Rainisch, Ph.D., M.P.H. is Assistant Professor in the Public Health Program in the Health Sciences Department at California State University, Northridge. Her focus is on adolescent health and biological markers of stress.

Laura Chyu, Ph.D., is a Lecturer in the Public Health Program at Santa Clara University. Her areas of interest lie in women’s health, social disparities in health, and embodiment of social contexts.

Appendix. Adjusted Predicted Mean Allostatic Load Values for Distinct MET Minutes per Week, by Race/Ethnicity and Age Groups, NHANES, 1999–2004 (n=1,680)

40–44							
	0 MET	**250 MET**	**500 MET**	**750 MET**	**1000 MET**	**1250 MET**	**1500 MET**
White	1.91	1.83	1.75	1.68	1.62	1.56	1.50
Black	2.73	2.62	2.51	2.41	2.31	2.23	2.15
Mex. Am.	2.34	2.24	2.15	2.07	1.99	1.91	1.84
45–49							
White	2.45	2.35	2.25	2.16	2.08	2.00	1.92
Black	2.96	2.84	2.72	2.61	2.51	2.42	2.34

40–44							
	0 MET	**250 MET**	**500 MET**	**750 MET**	**1000 MET**	**1250 MET**	**1500 MET**
Mex. Am.	2.25	2.15	2.07	1.98	1.91	1.83	1.78
50–54							
White	2.58	2.42	2.33	2.23	2.14	2.06	1.99
Black	2.71	2.60	2.49	2.39	2.30	2.21	2.13
Mex. Am.	2.57	2.46	2.36	2.26	2.18	2.09	2.02
55–59							
White	2.76	2.64	2.53	2.43	2.34	2.50	2.17
Black	3.12	2.99	2.87	2.75	2.65	2.55	2.45
Mex. Am.	2.55	2.45	2.35	2.25	2.17	2.08	2.01

Note: See text for further description.

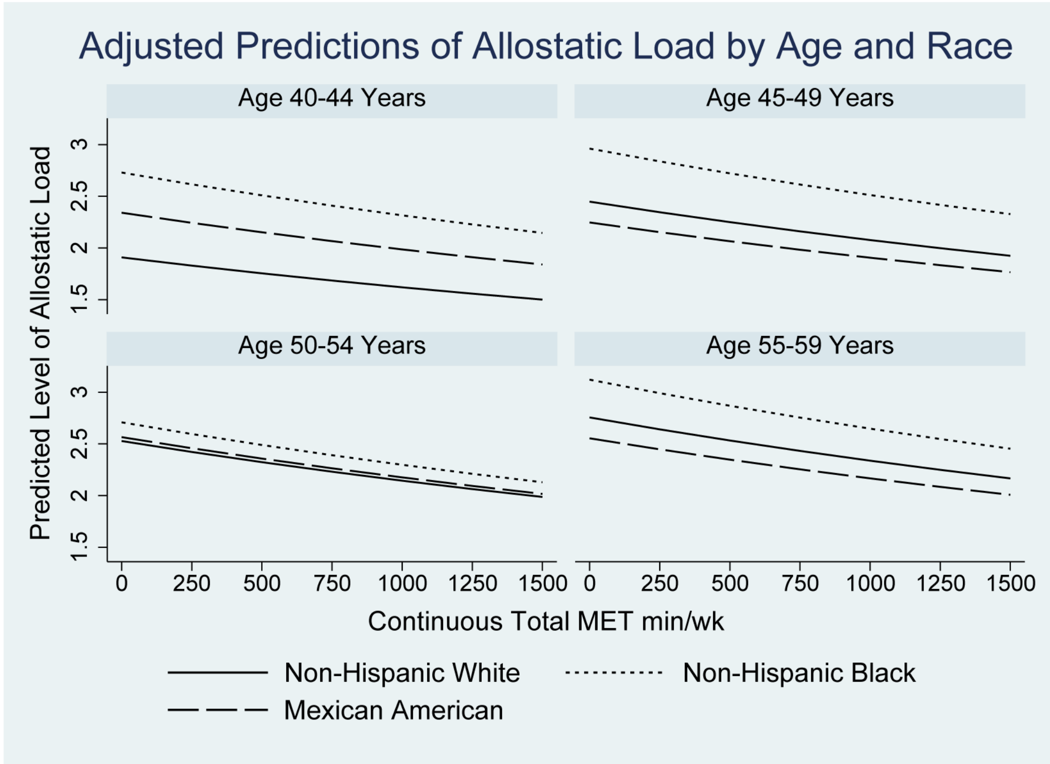
Adjusted Predictions of Allostatic Load by Age and Race
Age 40-44 Years
Age 45-49 Years
Age 50-54 Years
Age 55-59 Years
Predicted Level of Allostatic Load
1.5
2
2.5
3
0
250
500
750
1000
1250
1500
Continuous Total MET min/wk
Non-Hispanic White
Non-Hispanic Black
Mexican American

Figure 1.

Table 1

Descriptive Statistics of Individual Biomarkers and Summary Allostatic Load Score among Women 40–59, NHANES 1999–2004 (n = 1,680)

Biomarker	Range	Mean	25%	50%	75%	Clinical Cutoff[a]
Cardiovascular markers						
Systolic blood pressure (mm Hg)	76–202	121.7	110	121	133	≥140
Diastolic blood pressure (mm Hg)	22–110	74.6	68	74	81	≥90
Homocysteine (μmol/L)	1.65–60.74	7.97	6.23	7.32	8.87	---
Pulse rate (bt/min)	38–134	73.5	66	72	80	≥85
Metabolic markers						
Body mass index (kg/m^2)	14.70–66.44	28.78	23.36	27.45	32.99	≥25
Glycosylated hemoglobin (%)	4.0–14.6	5.45	5.10	5.30	5.60	≥7.0
HDL (mg/dL)	8–124	58.67	47	56	68	<50
Total cholesterol (mg/dL)	85–410	208.62	183	206	256	≥240
Inflammatory markers						
Albumin (g/dL)	2.9–5.3	4.24	4.00	4.20	4.40	≤3.5
CRP (mg/dL)	0.1–10.7	0.52	0.10	0.27	0.64	≥0.3
Allostatic Load Score	0–9	2.30	1	2	3	---

For empirically-based AL score, 75% are the cutoff values and 25% for albumin and HDL.

Abbreviations: SD=standard deviation; mm=millimeter; Hg=mercurcy; μmol= micromole; L=liters; bt=beats; min=minutes; kg=kilogram; m^2=meters squared; mg=millilgrams; dL=deciliter; g=grams.

[a]Clinical cutoffs based on medical recommendations and guidelines for clinical high risk. There are no clinical high-risk standard for homocysteine.

Table 2

Weighted Percentage Distributions of Leisure Time Physical Activity and Demographics and Mean Allostatic Load Scores among Women 40–59, NHANES 1999–2004 (n=1,680)

	Percent %	Mean AL score
Leisure Time Physical Activity		
Inactive	34.4	2.85***
Low	28.9	2.32
Moderate	20.1	1.99
High	16.6	1.49
Demographics		
Race/ethnicity-by-age		
White 40–44	22.4	1.70***
White 45–49	23.3	2.14
White 50–54	21.6	2.37
White 55–59	14.7	2.63
Black 40–44	3.8	2.78
Black 45–49	3.9	3.31
Black 50–54	2.3	3.26
Black 55–59	1.9	3.49
Mexican American 40–44	2.2	2.26
Mexican American 45–49	1.7	2.32
Mexican American 50–54	1.3	2.61
Mexican American 55–59	0.7	2.80
Education		
Less than high school	15.3	2.85***
High school/GED	23.7	2.60
More than high school	61.0	2.05
Family income		
<$20,000	24.4	2.90***
$20,000–44,999	17.3	2.74
$45,000–74,999	24.3	2.27
≥$75,000	34.0	1.67
Marital status		
Married/cohabiting	70.8	2.13***
Separated/divorced/widowed	22.8	2.58
Never married	6.4	3.13
Nativity status		
US-born	92.4	2.31
Foreign-born	7.6	2.12
Cholesterol lowering medication		
No	92.6	2.25**

	Percent %	Mean AL score
Yes	7.4	2.93
Hypertension medication		
No	85.1	2.10***
Yes	14.9	3.43
Diabetes medication		
No	96.2	2.21***
Yes	3.8	4.37

** p≤.01;

*** p≤.001, adjusted Wald F-test.

Table 3

Weighted Negative Binomial Regression for Allostatic Load Score by Leisure Time Physical Activity and Demographics, Women 40–59, NHANES 1999–2004 (n = 1,680)

Characteristics	Coefficients	Estimated Count Ratios	95% Confidence Interval
Leisure Time Physical Activity			
Inactive	--	1.00	--
Low	−0.08	0.92	(0.81 – 1.05)
Moderate	−0.18**	0.83	(0.74 – 0.94)
High	−0.47***	0.62	(0.54 – 0.73)
Demographics			
Race-by-Age			
White 40–44	--	1.00	--
White 45–49	0.24**	1.27	(1.09 – 1.49)
White 50–54	0.27***	1.31	(1.14 – 1.51)
White 55–59	0.35***	1.43	(1.22 – 1.66)
Black 40–44	0.35***	1.42	(1.16 – 1.74)
Black 45–49	0.43***	1.54	(1.31 – 1.81)
Black 50–54	0.34***	1.41	(1.16 – 1.71)
Black 55–59	0.48***	1.62	(1.32 – 2.00)
Mexican American 40–44	0.19+	1.21	(0.99 – 1.48)
Mexican American 45–49	0.16+	1.17	(0.97 – 1.42)
Mexican American 50–54	0.30*	1.35	(1.01 – 1.82)
Mexican American 55–59	0.21+	1.31	(0.97 – 1.78)
Education			
< High school	--	1.00	--
High school graduate	0.02	1.03	(0.92 – 1.14)
> High school	−0.08	0.92	(0.83 – 1.02)
Family income			
<$20,000	--	1.00	--
$20,000–44,999	0.02	1.02	(0.91 – 1.16)
$45,000–74,999	−0.10+	0.91	(0.80 – 1.03)
≥$75,000	−0.31***	0.73	(0.62 – 0.86)
Marital status			
Married/cohabit	--	1.00	--
Separated, widowed, divorced	0.00	1.00	(0.88 – 1.45)
Never married	0.21*	1.23	(1.03 – 1.47)
Nativity status			
US born	--	1.00	--
Foreign born	−0.12+	0.89	(0.77 – 1.03)

[+] $p \leq .1$;

[*] $p \leq .05$;

[**] $p \leq .01$;

[***] $p \leq .001$ t-test for adjusted coefficient in multivariate model.

Note: Also included in the model presented here were controls for current medication use (hypertension medications, diabetes medications, and cholesterol lowering medications). See text for additional detail.