Original Report: Cardiovascular Disease and Risk Factors

Longitudinal Changes in Allostatic Load during a Randomized Church-based, Lifestyle Intervention in African American Women

Marissa Tan, DO, MPH[1]; Abdullah Mamun, MS[2,3]; Heather Kitzman, PhD[3]; Leilani Dodgen, MPH[2]

Introduction: African American (AA) women have disproportionately higher risk of cardiovascular disease than White women, which may be explained by the uniquely higher allostatic load (AL) found in AA women. No studies have tested the effect of lifestyle interventions on AL in AA women. Our objectives were to assess the change in allostatic load following a lifestyle intervention and explore the roles of lifestyle behaviors and socioeconomic factors on allostatic load change.

Methods: Participants were non-diabetic (mean age and SD: 48.8±11.2 y) AA women (n=221) enrolled in a church-based, cluster randomized trial testing a standard diabetes prevention program (DPP) and a faith-enhanced DPP with 4-months of follow-up. We assessed the relationships of changes in diet, physical activity, neighborhood disadvantage, individual socioeconomic factors, and other lifestyle variables to changes in AL at 4-months using a multilevel multinomial logistic regression model.

Results: Average AL decreased (-.13±.99, P=.02) from baseline to 4-months. After adjusting for other variables, a high school education or less (OR:.1, CI:.02–.49) and alcohol use (OR: .31, CI: .09-.99) contributed to increased AL. Living in a disadvantaged neighborhood was responsible for increased AL, though it was not statistically significant. There were no statistically significant associations between AL and other health behavior changes.

Conclusions: Lower education levels may dampen the benefits of lifestyle interventions in reducing AL. Although a significant reduction in AL was found after participation in a lifestyle intervention, more research is needed to determine how lifestyle behaviors and socioeconomic factors influence AL in AA women. *Ethn Dis*. 2019;29(2):297-308; doi:10.18865/ed.29.2.297

Keywords: Lifestyle Intervention; Allostatic Load; Health Behaviors; Church-based Program

[1] Bassett Medical Center, Cooperstown, New York
[2] University of North Texas Health Science Center, Fort Worth, Texas
[3] Baylor Scott & White Health, Dallas, Texas

Address correspondence to Marissa Tan, Bassett Medical Center; One Atwell Rd., Cooperstown, NY 13326; marissa.luan.tan@gmail.com

Introduction

African American women have higher rates of cardiovascular risk factors and >50% higher mortality from coronary artery disease, stroke, and congestive heart failure than White women.[1] Several models have been developed to explain this persisting health disparity in the context of the unique experiences of African American women. One model, the "Superwoman Role," describes the multiple, demanding roles that African American women are expected to fulfill in response to historical oppression, which bear the consequent risk of internalizing stress and developing coping behaviors that are harmful to health.[2, 3] Geronimus posited that the health of African American women may worsen earlier in life than White women due to enduring chronic socioeconomic stressors.[4] Both of these models share elements with the theory of allostatic load, which describes the physiologic toll of adapting to chronic and significant stressors, like individual socioeconomic and neighborhood disadvantage.[5-7] Allostatic load has been shown to be higher in African American women than in White women.[7] The high allostatic load found in African American women is theorized to predispose women to chronic illnesses, such as cardiovascular disease, at an earlier age.[8]

The role of lifestyle behaviors in chronic disease such as cardiovascular disease and type 2 diabetes is well-documented and has been the foundation of lifestyle interventions that emphasize weight loss, heart-healthy nutrition, and physical activity.[9] The diabetes prevention program (DPP) has been found to effectively reduce weight and cardiovascular disease risk factors in African Americans in faith-based locales like churches, which have served as culturally relevant agents of social change and community resources, especially among African American women.[10] However, few studies have described the impact of lifestyle behaviors on allostatic load in African American women. A healthy lifestyle score (composed of physical activity, diet, smoking, social support, and sleep) was associated with lower allostatic load in Puerto Ricans.[11] Mexican American women who met guidelines for moderate or vigorous physical activity and a multiethnic sample of midlife women who reported more leisure-time physical activity had lower allostatic load in cross-sectional studies.[12,13] Diets high in fat were associated with some metabolic biomarkers of allostatic load in midlife Korean women and Puerto Rican adults.[14,15] Health behaviors (diet, physical activity) have shown inconsistent roles as mediators between allostatic load or cumulative biological risk and neighborhood disadvantage in African Americans.[5,6]

> *The high allostatic load found in African American women is theorized to predispose women to chronic illnesses, such as cardiovascular disease, at an earlier age.[8]*

To our knowledge, existing research has not investigated the longitudinal change in allostatic load in African American women following a lifestyle intervention. Using the Better Me Within (BMW) program, our aims were to: 1) evaluate whether there is change in allostatic load following exposure to a church-based, diabetes prevention program; 2) explore the individual roles of health behavior changes to change in allostatic load; and 3) evaluate how socioeconomic (SES) variables including neighborhood SES influence these relationships. We further evaluated if providing a faith-enhancement to the diabetes prevention as part of the BMW program had any additional benefit on allostatic load.

Methods

Data for this study were obtained from baseline and 4-month data of the BMW program, a cluster, randomized controlled trial that evaluated a faith-enhanced DPP (FDPP) compared with a standard DPP (SDPP) in 11 churches on weight reduction in African American women with a BMI >25 in 11 churches. Data collection methods, study groups (FDPP and SDPP), and eligibility for BMW are described elsewhere.[16] Briefly, trained staff collected socioeconomic, health behavior, biomarker, and psychosocial data at baseline and 4-month intervals from February 2014-October 2016. The 221 eligible participants, of 333 women screened, resided in 148 census tracts in the Greater Dallas area. All participants provided informed consent. The Institutional Review Board at The University of North Texas Health Science Center approved this study.

Measures

Allostatic Load Score

Allostatic load was operationalized using the quartile method and 9 biomarkers: body mass index (BMI), waist circumference, high-density lipoprotein (HDL), total cholesterol/HDL ratio, triglycerides, glycosylated hemoglobin A1c (HbA1c), systolic blood pressure, diastolic blood pressure, and salivary cortisol with possible scores ranging from 0-9.[17] Saliva was collected approximately 1-4 hours after awakening and was transformed using 2 different wake-up times based on the collection time.[18] For participants who reported taking medication for hypercholesterolemia, hypertension, or prediabetes, their corresponding biomarkers were considered as high-risk, irrespective of numerical value.[19] The high-risk threshold at baseline for each biomarker was used to determine high-risk at the 4-month interval, reported previously.[7,20] A change in AL score from baseline to 4-months was categorized as "decreased," "unchanged," or "increased," and used as the outcome variable in analyses.

Health Behaviors

Diet was assessed using a food-frequency questionnaire developed for African Americans in the South and scored using the healthy eating index, HEI-2015.[21,22] HEI-2015 was developed to evaluate adherence to the 2015 US Dietary Guidelines for Americans and uses 13 nutrition components, summed for a total score of 0-100.[22] Alcohol consumption in the past 30 days (yes, no) and tobacco use (current, former, never) were self-reported by survey at baseline and 4-months follow-up. Participants' weekly physical activity were self-reported in minutes.[23,24]

Intervention

Participants in this study were categorized based on the type of intervention received: FDPP or SDPP, which were both delivered in church settings and have been described previously.[16] Briefly, the SDPP delivered the standard CDC-approved DPP, while the FDPP provided a faith-enhanced curriculum in addition to the standard DPP. Both programs were delivered by peer leaders.

Neighborhood Disadvantage

The methods on determining neighborhood disadvantage in the BMW study have been described elsewhere.[20] In short, we used exploratory principal component analysis of 10 neighborhood factors on the census-tract level from the 2015 American Community Survey (households living in poverty, households receiving public assistance, unoccupied housing units, renter-occupied housing, households living in the same house 5 years ago, occupied housing units with no vehicle, occupied housing units with more than 1 person per room, adults aged >25 years without a high school diploma or equivalent, unemployed individuals aged >16 years in the civilian work force, and female-headed households). We used the median value of the first principal component to dichotomize a participant's neighborhood as more or less disadvantaged.

Individual Socioeconomic Factors

Participants' household income (<\$25,000, \$25,000–\$49,999, \$50,000–\$74,999, and ≥\$75,000) and highest level of educational attainment (≤high school diploma or equivalent, some college or a technical degree, and college degree or more) were self-reported at baseline.

Perceived Stress

Perceived stress was measured with the 10-item Perceived Stress Scale, using 5-point Likert scales ranging from 0-4 for a total score of 0-40.[25]

Statistical Analysis

Changes in a subject's AL score was the outcome variable in our study, categorized as "decreased", "unchanged", or "increased" at 4-months compared with baseline. Health behavior and demographic characteristics were summarized using mean, standard deviation, and percentages. Statistical comparisons between continuous variables were carried out using t-test and paired t-test for normally distributed variables, Kruskal-Wallis test and Wilcoxon rank sum test for non-normal variables, and chi-square test and McNemar's test for categorical variables. Adjusted effects of the covariates on changes in AL score were estimated using multilevel multinomial logistic regression.

Complete case analyses were carried out for the descriptive statistics and univariate comparisons. Approximately 17% (n=37) of the participants were lost to follow-up at 4-months and few of the study variables were affected by missingness. Little's test confirmed that the data were missing completely at random (MCAR) (P=.124).[26] Also, there were no monotonic patterns in the missing values. Therefore, it was imperative to estimate the missing values to attain the required statistical power for a null hypothesis significance test and to reduce bias that might have incurred from list-wise deletion. A fully conditional specification (FCS) method was used to estimate a set of 20 multiply imputed datasets.

A two-level hierarchical multinomial logistic regression model was used for adjusted analysis to account for cluster randomization and the church-level correlation (ICC = .054). The level-1 model estimated the fixed effects of covariates on changes of AL score at the individual level. As shown in Figure 1, a random intercept was estimated for each church at the level-2 model. Findings from the univariate analysis and results from the previous study were used as a guiding tool for variable selection in the multivariable model.[20] Each of the conclusions about the statistical significance was drawn at a 5% level of significance. SAS version 9.4 (SAS institute Inc, 2013) was used for data analysis.

Results

Characteristics of the Participants

Eleven churches enrolled in the BMW trial, where 221 participants (mean age 48.85 years) received the 16-week intervention. Six churches in the FDPP had 119 total participants,

Level 1 model (between subject effect):

$$\eta_{1ij} = \log\left(\frac{Pr(R_{ij} = decrease)}{Pr(R_{ij} = increase)}\right) = \beta_{0j} + \sum_{k=1}^{p} \beta_{1k} X_{ikj}.$$

$$\eta_{2ij} = \log\left(\frac{Pr(R_{ij} = unchanged)}{Pr(R_{ij} = increase)}\right) = \beta_{0j} + \sum_{k=1}^{p} \beta_{2k} X_{ikj}.$$

Level 2 model (church effect):

$$\beta_{0j} = \gamma_{00} + u_{0j}; j = 1, 2, \dots, 11\ churches.$$

$$\beta_{1k} = \gamma_{1k0}; \text{ for } k = 1, 2, \dots, p\ covariates.$$

$$\beta_{2k} = \gamma_{2k0}; \text{ for } k = 1, 2, \dots, p\ covariates.$$

$$u_{0j} \sim N(0, v_j); for\ jth\ church.$$

Here, R_{ij} represents the category of the outcome variable (decreased/unchanged/increased allostatic load score) of subject i at the church j. The two equations in the level-1 model correspond to the log odds (η_{1ij}) of a decrease in comparison to an increase in allostatic load score at 4-months and the log odds (η_{2ij}) of an unchanged vs. an increase in allostatic load score at 4-months for subject i at the church j after adjusting for the effect of k covariates. Also, β_{1k} is the average effect on log odds (η_{1ij}) for the kth covariate (X_{ikj}) for the ith subject at jth church. The level-2 model, β_{0j} is the adjusted effect of j^{th} church. We assume that $u_{0j}(\sim N(0, v_j))$ is the level-2 error term representing a unique effect associated with church j.

Figure 1. Two-level hierarchical multinomial logistic regression model showing cluster randomization and church-level correlation

and the remaining five churches in the SDPP had 102 participants. Table 1 presents baseline demographic, socioeconomic, and health behavior characteristics. Average age, baseline weight, and baseline BMI of the participants were similar in the two intervention groups (SDPP vs FDPP). However, average baseline AL score was significantly higher for the participants randomized to the SDPP than those in the FDPP (P<.01). Education level and annual household income of the FDPP participants were significantly higher than those in the SDPP group (P<.01 and P<.01, respectively). Participants in the SDPP group were almost two times more likely to be smokers than those in the FDPP group (25% vs 12%) (P<.05).

AL Score and Behavioral Factors

Table 2 shows participants' health behavior changes from baseline to 4-months. Table 3 shows AL biomarker changes from baseline to 4-months

Table 1. Baseline demographic, socioeconomic, and health behavior characteristics by intervention conditions of the participants, n = 221[a] (15, 19)

	All	Faith-enhanced DPP	Standard DPP	P
N	221	119	102	
Age, mean (SD)	48.84 (11.24)	48.03 (10.27)	49.80 (12.28)	.2533[b]
Allostatic load score, mean (SD)	2.31 (1.69)	2.00 (1.56)	2.67 (1.77)	.0032[c]
Weight (lb), mean (SD)	215.07 (50.45)	212.3 (47.75)	218.3 (53.47)	.3804[b]
BMI (Kg/m^2), mean (SD)	36.7 (8.43)	36.01 (7.70)	37.43 (9.17)	.2123[b]
Level of education				<.0001[d]
High school or less, n (%)	32 (15.38)	7 (6.19)	25 (26.32)	
Technical degree or some college, n (%)	76 (36.54)	35 (30.97)	41 (43.16)	
College degree or more, n (%)	100 (48.08)	71 (62.83)	29 (30.53)	
Household annual income				.0002[d]
<$25,000	40 (19.23)	12 (10.71)	28 (29.17)	
$25,000 - $49,999	68 (32.69)	37 (33.04)	31 (32.29)	
$50,000 - $74,999	47 (22.60)	23 (20.54)	24 (25.00)	
≥$75,000	53 (25.48)	40 (35.71)	13 (13.54)	
Smoking status				.0167[d]
Never, n (%)	170 (81.73)	99 (87.61)	71 (74.74)	
Current or former, n (%)	38 (18.27)	14 (12.39)	24 (25.26)	
Alcohol consumption in last 30 days				.856[d]
Yes, n (%)	112 (54.63)	60 (54.05)	52 (55.32)	
No, n (%)	93 (45.37)	51 (41.95)	42 (44.68)	
Living in a more disadvantaged neighborhood				<.0001[d]
Yes, n (%)	107 (50)	41 (35.65)	66 (66.67)	
No, n (%)	107 (50)	74 (64.35)	33 (33.33)	
Stress, mean (SD)	15.46 (6.90)	15.95 (7.27)	15.88 (6.42)	.2746[b]

a. Complete case analysis. Some variables had missing values (0% to 7%).
b. P was calculated from t-test.
c. P was calculated from Kruskal-Wallis test.
d. P was calculated from Chi-square test.

and thresholds to determine high-risk values for each biomarker. The average AL score (mean±SD) decreased by .13±.99 units from baseline to 4-months (P=.02). Two-thirds of the participants observed a reduction in AL score at 4-months from baseline, whereas one-fifth observed an increase. Participants showed significant improvements in health behaviors related to cardiovascular health at 4-months. Participants' individual average energy, fat, and sodium intake decreased by 707.73±1447.05 calories (P<.01), 31.03±69.76 grams (P<.01), and 1035.53±2172.59 milligrams (P<.01, results not shown), respectively. Compared with baseline, on average, participants had increased their individual weekly physical activity by 118.12 ± 316.97 minutes at 4-months (P<.01; results not shown). There were no changes in alcohol use, smoking, or average perceived stress score from baseline to 4-months.

Univariate Analyses to Detect the Association of Covariates with AL Score

Table 4 presents the association of demographic, socioeconomic, and behavioral factors with changes in AL score at 4-months compared with baseline. Participants with at least a college degree were more likely (36%) to have lower AL score compared with participants with a high school degree or less (30%). More participants in the SDPP intervention had reduced AL score than the FDPP arm (43% vs 27% and average reduction .23±.94 vs .03±1.04, respectively). However, participants in SDPP started with a higher level of AL score at baseline than those in FDPP and remained at a higher level at 4-months (SDPP: 2.7±1.77 and 2.43±1.64 and FDPP: 2.0±1.56 and 1.97±1.55 at baseline and 4-months, respectively). For each of the AL change categories, FDPP participants had a lower mean AL score than those in SDPP.

Participants' diet improved from

Table 2. Changes in physiological and health behavioral variables at 4-months in comparison with baseline, N=221[a]

	Baseline	4-months	P
N	214	169	
Allostatic load, mean (SD)	2.31 (1.69)	2.18 (1.61)	.0216[b]
Diet, mean (SD)			
Energy, Kcal	2507.47 (1657.45)	1709.26 (1097.71)	<.0001[c]
Fat, g	109.92 (71.28)	75.76 (57.02)	<.0001[c]
Sodium, mg	3939.88 (2568.96)	2789.35 (1750.20)	<.0001[c]
Healthy Eating Index (HEI), mean (SD)	54.20 (11.70)	61.52 (9.94)	<.0001[c]
Physical activity, # active min/wk, mean (SD)	115.47 (155.05)	233.59 (308.00)	<.0001[c]
Alcohol consumption; at least one drink in last 30 days, n (%)			.5900[d]
Yes	80 (51.28)	83 (53.21)	
No	76 (48.72)	73 (46.79)	
Smoking, n (%)			.4795[d]
Never	135 (83.85)	133 (82.61)	
Former/current	26 (16.15)	28 (17.39)	
Stress, mean (SD)	15.46 (6.90)	14.78 (6.51)	.2116[c]

a. Complete case analysis. Some variables had missing value (0% to 27%).
b. P was estimated for the difference of baseline and 4-month allostatic load score using Wilcoxon sign rank test (nonparametric) due to violation of normality assumption.
c. P was estimated for the difference of baseline and 4-month measures using paired t-tests.
d. P was estimated for the difference of baseline and 4-month measures for paired data using McNemar's test.

baseline to 4-months, as reflected in the greater HEI-2015 score (Table 2) but was not significantly associated with changes in AL score. Despite improved physical activity at 4-months compared with baseline (increased by 118.12 minutes on average), change in physical activity was not associated with reduced AL score.

Participants who lived in a more disadvantaged neighborhood had a higher AL score at baseline than their counterparts, 2.63±1.75 vs 1.95±1.60 (P<.01). Consequently, the likelihood of observing a reduction in AL score was slightly higher for participants living in more disadvantaged neighborhoods than those who were living in less disadvantaged neighborhoods (37% vs 32%). Though the unadjusted analysis did not find a statistically significant association between alcohol consumption and change in AL score, participants who did not consume alcohol in the past 30 days were more likely to have decreased AL score than those who drank alcohol at least once in the past 30 days at baseline or at 4-months (37% vs 33%).

Table 3. Descriptive characteristics of allostatic load biomarkers at baseline and 4-months

Allostatic load biomarkers	High-risk quartile threshold[a]	Baseline	4-months
		Median (Q1[b], Q3[c])	Median (Q1, Q3)
Systolic blood pressure	≥ 138.50	125.50 (114.50, 138.50)	122.25 (112.25, 132.25)
Diastolic blood pressure	≥89.00	81.50 (75.00, 89.00)	79.50 (72.75, 85.50)
Salivary cortisol	≥5.51	4.04 (2.86, 5.51)	4.14 (2.91, 5.82)
Body mass index	≥40.80	34.54 (31.07, 40.59)	34.02 (30.02, 40.14)
Waist circumference	≥45.25	40.63 (36.70, 45.13)	39.00 (35.50, 42.87)
High-density lipoprotein (HDL)	≤46.00	54.00 (46.00, 66.00)	51.00 (44.00, 61.00)
Total cholesterol/HDL	≥3.77	3.15 (2.73, 3.77)	3.14 (2.70, 3.76)
Triglycerides	≥140.00	95.00 (71.00, 140.00)	85.50 (66.00, 116.00)
Glycosylated hemoglobin A1c	≥6.40	5.90 (5.60, 6.40)	5.80 (5.40, 6.20)

a. The high-risk quartile is the highest quartile within the study sample for each biomarker with exception to HDL, for which the high-risk quartile is the lowest quartile within the study sample.
b. Q1, First quartile.
c. Q3, Third quartile.

Table 4. Univariate analysis of demographics and behavioral change variables by the change of allostatic load score, N=221[a]

	Change of allostatic load score, baseline to 4-months			P[b]
	Decrease	No change	Increase	
	Mean (SD)/ n (%)	Mean (SD)/ n (%)	Mean (SD)/ n (%)	
Allostatic load score	58 (34.32)	80 (47.34)	31 (18.34)	.0361
Intervention				
Faith-enhanced DPP	24 (26.67)	47 (52.22)	19 (21.11)	.1437
Standard DPP	34 (43.04)	33 (41.77)	12 (15.19)	
Age (year)	48.92 (11.77)	49.31 (11.73)	50.21 (10.53)	.9344
Weight loss (lb)	6.53 (9.13)	3.78 (6.80)	5.37 (6.79)	.1919
Level of education				
≤High school	8 (29.63)	10 (37.04)	9 (33.33)	
Technical degree or some college	21 (33.87)	28 (45.16)	13 (20.97)	.1854
≥College degree	26 (36.11)	37 (51.39)	9 (12.50)	
Household income				
<$25,000	14 (40.00)	16 (45.71)	5 (14.29)	
$25,000 - $49,999	21 (38.89)	22 (40.74)	11 (20.36)	.6394
$50,000 - $74,999	12 (34.29)	14 (40.00)	9 (25.71)	
≥$75,000	9 (24.32)	22 (59.46)	6 (16.22)	
Change in diet (4-months – baseline)				
Energy (Kcal)	658.42 (1250.25)	803.71 (1766.66)	573.92 (848.43)	.8185
Fat (g)	33.60 (54.52)	36.51 (74.47)	15.98 (78.14)	.5644
Sodium (mg)	1069.99 (1920.86)	1089.54 (2640.51)	869.60 (1254.97)	.8762
Change in healthy eating index	7.38 (11.73)	5.81 (11.71)	4.98 (11.34)	.9319
Increase in physical activity (min/wk)[c]	116.04 (237.05)	84.25 (187.78)	75.60 (247.09)	.4660
Alcohol consumption[d]				
Yes (at baseline or 4-months)	32 (32.65)	42 (42.86)	24 (24.49)	.1361
No (not at baseline, 4-months)	18 (37.50)	25 (52.08)	5 (10.42)	
Smoking				
Never (not at baseline, 4-months)	31 (31.00)	47 (47.00)	22 (22.00)	.4425
Former/current (either at baseline or 4-months)	14 (45.16)	12 (38.71)	5 (16.13)	
Living in a more disadvantaged neighborhood				
Yes	30 (37.04)	33 (40.47)	18 (22.22)	.3961
No	26 (32.10)	42 (51.85)	13 (16.05)	
Change in stress (4-months – baseline)	-1.14 (6.79)	-.09 (5.23)	-1.10 (7.72)	.8450

a. Complete case analysis. Some variables had missing value that ranges from 0% to 27%.
b. P values were estimated from multilevel multinomial logistic after adjusting for the random effect of churches.
c. Increase in physical activity from baseline to 4-months (# of active minutes per week).
d. At least one drink in last 30 days.

Multivariable Effect of Socioeconomic Characteristics and Health Behaviors on Changes in AL Score at 4-Months in Comparison with Baseline

Table 5 presents the adjusted effect of socioeconomic status, demographic characteristics, and health behavior change on changes in AL score. Adjustment for baseline AL score did not significantly change the analysis results and was excluded in the final analysis (results not shown). Participants in the FDPP arm had significantly lower adjusted odds ratios for the effects of a decrease in AL score than an increase in comparison with the participants in SDPP (OR=.26; 95% CI = (.08, .87)). Odds of maintaining the same AL score vs an increase were lower for FDPP participants than SDPP; however, the association was not significant in the adjusted model. Education level was significantly associated with changes in AL score. After adjusting for other variables, participants with a high school degree or less had significantly lower odds of decreased or unchanged AL score than increased score, compared with participants with a col-

Table 5. Adjusted effect of socioeconomic status, demographic characteristics, and health behavior on changes in allostatic load score (AL) from baseline to 4-months, N=221

	Decreased vs increased AL[a]			Unchanged vs increased AL [b]		
	Estimate (SE)	P	Odds ratio (95% CI)	Estimate (SE)	P	Odds ratio (95% CI)
Intercept	3.20 (1.65)	.054		3.27 (1.54)	.035	
Intervention						
Faith-enhanced DPP	-1.35 (.62)	.031	.26 (.08,.87)	-.78 (.58)	.181	.46 (.15, 1.43)
Standard DPP	Reference					
Age	-.01 (.02)	.819	.99 (.95, 1.03)	.01 (.02)	.915	1.01 (.97, 1.05)
Increased physical activity[c]	.01 (.08)	.982	1.01 (.86, 1.18)	-.02 (.07)	.809	.98 (.85, 1.12)
Level of education						
≤High school	-2.35 (.84)	.005	.1 (.02, .49)	-2.02 (.78)	.010	.13 (.03, .61)
Technical degree or some college	-1.01(.62)	.101	.36 (.11, 1.23	-.81 (.59)	.171	.45 (.14, 1.41)
≥College degree	reference					
Household income						
<$25,000	.99 (.85)	.246	2.68 (.51, 14.24)	.53 (.80)	.510	1.7 (.35, 8.15)
$25,000 - $49,999	.39 (.69)	.571	1.48 (.38, 5.71)	-.16 (.61)	.793	.85 (.26, 2.82)
$50,000 - $74,999	-.12 (.68)	.860	.89 (.23, 3.36)	-.55 (.64)	.387	.58 (.16, 2.02)
≥$75,000	reference					
Increased Healthy Eating Index	.02 (.02)	.404	1.02 (.98, 1.06)	.01 (.02)	.587	1.01 (.97, 1.05)
Alcohol consumption[d]						
Yes[e]	-1.18 (.60)	.048	.31 (.09, .99)	-1.16 (.54)	.033	.31 (.11, .90)
No[f]	reference					
More disadvantaged neighborhood						
Yes	-.50 (.54)	.352	.61 (.21, 1.75)	-.65 (.51)	.202	.52 (.19, 1.42)
No	reference					

a. Column presents the odds of decreased allostatic load score versus the odds of increased allostatic load score.
b. Column displays the odds of unchanged allostatic load score versus the odds of increased allostatic load score.
c. Increased physical activity from baseline to 4-months in active hours per week
d. Alcohol consumption: at least one drink in last 30 days.
e. Reported either at baseline or 4-months
f. Reported neither at baseline nor at 4-months.

lege degree or more. Similar, though non-significant, associations were observed for participants with a technical degree compared with the participants with a college degree. Participants who reported alcohol use had significantly lower odds of observing decreased or unchanged AL score than increased score in comparison with those who reported no alcohol use, adjusting for other variables. Living in more disadvantaged neighborhoods was inversely associated with the odds of reduced or unchanged AL score than an increase after adjusting for other variables. However, the associations were not significant.

The strength of association for age, increased physical activity, annual household income, and increased HEI-2015 in AL score were weak and statistically insignificant. To test whether the sample size was adequate to detect a statistically significant association between neighborhood disadvantage and AL score, a post hoc power analysis was performed and suggested that a sample size of 221 had the statistical power of .40 in the presence of other variables in the model. To attain the statistical power of .80, a sample size of 576 would have been required. A statistically significant difference was observed between SDPP and FDPP in terms of educational status, annual household income, smoking status, and proportion of participants living in the disadvantaged neighborhood due to cluster randomization (Table 1). However, none of the interaction effects of each of these covariates with intervention conditions were found significant in the adjusted model [results not shown].

Discussion

In this study, we found that AL score decreased from baseline to

4-months among African American women who participated in the diabetes prevention program held in a church-based setting. Though we demonstrated that allostatic load is modifiable, lifestyle behavior changes (diet and physical activity) were not strong predictors of the change in allostatic load. However, participants with a high school education or less and those who reported alcohol use had a higher likelihood of greater allostatic load at 4-months follow-up. Women who lived in more disadvantaged neighborhoods had a statistically non-significant trend of increased or unchanged allostatic load. Participants in the SDPP intervention had greater likelihood of decreased allostatic load at 4-months than those in the FDPP intervention, though SDPP participants had higher allostatic load at baseline. Overall, this study provides longitudinal data on lifestyle behaviors and demographic variables in an intervention on allostatic load in African American women.

Consistent with our study's results, Upchurch, Stein et al observed a higher slope of increased allostatic load over eight years among middle-aged women with lower education, higher perceived stress, lower income, African American race, and experienced discrimination. Our results were also consistent with Bo et al, in which metabolic syndrome biomarkers were significantly reduced over the course of a lifestyle intervention in Italian adults, but were significantly affected by low education level.[27]

Though neighborhood disadvantage was not statistically significant in our study, its direction is similar to previous literature of other minority groups, which found that the DPP for American Indians and Alaska Natives had suboptimal outcomes in disadvantaged neighborhoods.[28] Other longitudinal studies also observed greater increases in allostatic load among African American youth who lived in neighborhoods with higher concentrations of neighborhood poverty if youth did not receive high levels of emotional support.[29] Another study found that adults who experienced low SES in childhood and had lower allostatic load in adulthood were more likely to maintain "shift and persist" resiliency, characterized by adaptation to stressors and focus on the future.[30] Correspondingly, Woods-Giscombe and Black offer promising support for incorporating mindfulness and resilience training into health interventions to more specifically address allostatic load in African American women.[2] While our study did not examine coping behaviors relative to identity, future research may benefit from studying how the Superwoman Role identity and its associated stressors may contribute to allostatic load. Further, the DPP includes stress reduction and social support components that may be associated with reduced allostatic load in our study. In our sample of African American women, low educational attainment may blunt the health-promoting effects associated with the DPP or may require the addition of resiliency-promoting tools to reduce this chronic socioeconomic disparity.

The findings that improved diet and greater physical activity were not correlated with lower allostatic load are in contrast with other studies' conclusions. However, most of the studies that found an association between allostatic load and physical activity or nutrition were cross-sectional, included other ethnicities, and measured behaviors with more rigorous methods, such as metabolic equivalents or surveys validated with accelerometers for physical activity.[5, 11-15] In contrast, the MESA study, using a large and longitudinal, multiethnic sample of middle-age and older adults, tested clusters of allostatic load domains and found that physical activity and low to moderate drinking behaviors were individually associated with allostatic load clusters with higher metabolic and blood pressure biomarkers.[31] Our study was consistent with one cross-sectional study on depression that did not find an association between physical activity and allostatic load.[32] Schulz et al[6] similarly did not find relationships between allostatic load and physical activity (measured in METs) and Healthy Eating Index in a multiethnic, cross-sectional

In this study, we found that AL score decreased from baseline to 4-months among African American women who participated in the diabetes prevention program held in a church-based setting.

sample in Detroit in the context of neighborhood poverty. Barber et al[5] explained that lifestyle behaviors may represent one pathway mediating the relationship between neighborhood disadvantage and allostatic load, which may not be the predominant pathway in our sample of overweight and obese African American women.

The trend of a higher likelihood to have the same or increased allostatic load among women who reported alcohol use differs from previous literature of neighborhood disadvantage. One multiethnic, cross-sectional study found that alcohol use was associated with lower allostatic load,[6] while another longitudinal study in African American youth found that binge-drinking was not associated with allostatic load.[29] We did not characterize how much alcohol was consumed, and this trend may reflect greater initial stress prompting alcohol use as a coping mechanism during the follow-up period. Our study suggests that alcohol use may diminish the benefits of a lifestyle intervention on allostatic load.

The trend of greater likelihood to have increased allostatic load among those in the FDPP intervention arm is likely a result of cluster randomization. Those in the SDPP arm had disproportionately higher baseline allostatic load, were more likely to live in disadvantaged neighborhoods, have lower incomes, be current/former smokers, and have less education than those in the FDPP arm.

Our study has several strengths. To our knowledge, this study is the first to assess allostatic load changes during a lifestyle intervention in African American women. We tested multiple domains of possible predictors for change in allostatic load, including health behaviors and both individual and neighborhood socioeconomic factors. We also evaluated the potential of two diabetes prevention programs, a standard DPP and a faith-enhanced DPP, to improve allostatic load in community-based settings. By studying allostatic load changes in women who lived in disadvantaged neighborhoods, we tested whether health behaviors could attenuate the weathering of socioeconomic disadvantage.

Our study also has several limitations. First, our sample size was relatively small (N=221) and lacked the statistical power to adequately test the association of neighborhood disadvantage with allostatic load change. Also, a substantial amount of data were missing (17%), requiring imputation. Second, we cannot attribute allostatic load change directly to the lifestyle intervention, since we did not have a control group for comparison. Third, the temporal interval we measured may have been too short to demonstrate the full impact of lifestyle behavior changes and other socioeconomic factors on allostatic load.

Conclusion

Our research has implications for future allostatic load research. Our study found significant reductions of allostatic load among African American women during a lifestyle intervention. Future studies may need to incorporate a longer follow-up duration, process measures to capture detailed information on changes in lifestyle behaviors during the intervention, analysis of allostatic load clusters, and more robust measures of physical activity, such as an accelerometer, and diet, such as multiple pass 24-hour dietary recalls. Larger studies that evaluate additional constructs such as resiliency may identify the mechanisms by which allostatic load is reduced. This study also demonstrates that socioeconomic variables, especially educational attainment, persisted through the lifestyle intervention and differentially affected allostatic load outcomes. Consequently, in pursuit of health equity, we should pursue both structural and community-based interventions that specifically address these socioeconomic barriers to health in African American women.

Acknowledgements

We thank all the women, churches, staff, and volunteers involved in Better Me Within for their hard work and support in this study. Research was supported by a National Institutes of Health (NIH) grant R25HL125447 (to Dr. J.K.Vishwanatha) and NIH grant P20MD006882-2. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Tan, Mamun, Kitzman; Acquisition of data: Tan, Mamun, Kitzman, Dodgen; Data analysis and interpretation: Tan, Mamun, Kitzman; Manuscript draft: Tan, Mamun, Kitzman, Dodgen; Statistical expertise: Mamun; Acquisition of funding: Kitzman; Administrative: Tan, Dodgen; Supervision: Kitzman, Dodgen

References

1. Williams RA. Cardiovascular disease in African American women: a health care disparities issue. *J Natl Med Assoc*. 2009;101(6):536-540. https://doi.org/10.1016/S0027-9684(15)30938-X PMID:19585921

2. Woods-Giscombé CL. Superwoman schema: African American women's views on stress, strength, and health. *Qualitative Health Research*. 2010; 20(5):668-83. https://doi.org/10.1177/1049732310361892. PMID: 20154298
3. Woods-Giscombé CL, Black AR. Mind-body interventions to reduce risk for health disparities related to stress and strength among African American women: the potential of mindfulness-based stress reduction, loving-kindness, and the NTU therapeutic framework. *Complement Health Pract Rev*. 2010;15(3):115-131. https://doi.org/10.1177/1533210110386776 PMID:21479157
4. Geronimus AT. The weathering hypothesis and the health of African-American women and infants: evidence and speculations. *Ethn Dis*. 1992;2(3):207-221. PMID:1467758
5. Barber S, Hickson DA, Kawachi I, Subramanian SV, Earls F. Neighborhood disadvantage and cumulative biological risk among a socioeconomically diverse sample of African American adults: an examination in the Jackson Heart Study. *J Racial Ethn Health Disparities*. 2016;3(3):444-456. https://doi.org/10.1007/s40615-015-0157-0 PMID:27294737
6. Schulz AJ, Mentz G, Lachance L, Johnson J, Gaines C, Israel BA. Associations between socioeconomic status and allostatic load: effects of neighborhood poverty and tests of mediating pathways. *Am J Public Health*. 2012;102(9):1706-1714. https://doi.org/10.2105/AJPH.2011.300412. PMID:22873478
7. Upchurch DM, Stein J, Greendale GA, Chyu L, Tseng CH, Huang MH, et al. A longitudinal investigation of race, socioeconomic status, and psychosocial mediators of allostatic load in midlife women: findings from the study of Women's Health Across the Nation. *Psychosomatic Medicine*. 2015; 77(4):402-412. https://doi.org/10.1097/PSY.0000000000000175. PMID: 25886828
8. Geronimus AT, Hicken M, Keene D, Bound J. "Weathering" and age patterns of allostatic load scores among Blacks and Whites in the United States. *Am J Public Health.* 2006; 96(5):826-833 https://doi.org/10.2105/AJPH.2004.060749
9. Artinian NT, Fletcher GF, Mozaffarian D, et al; American Heart Association Prevention Committee of the Council on Cardiovascular Nursing. Interventions to promote physical activity and dietary lifestyle changes for cardiovascular risk factor reduction in adults: a scientific statement from the American Heart Association. *Circulation*. 2010;122(4):406-441. https://doi.org/10.1161/CIR.0b013e3181e8edf1 PMID:20625115
10. Maynard MJ. Faith-based institutions as venues for obesity prevention. *Curr Obes Rep*. 2017;6(2):148-154. https://doi.org/10.1007/s13679-017-0257-8 PMID:28401491
11. Sotos-Prieto M, Bhupathiraju SN, Falcon LM, Gao X, Tucker KL, Mattei J. A healthy lifestyle score is associated with cardiometabolic and neuroendocrine risk factors among Puerto Rican adults. *J Nutr.* 2015; 145(7):1531-1440. https://doi.org/10.3945/jn.114.206391. PMID: 25948783.
12. Gay JL, Salinas JJ, Buchner DM, Mirza S, Kohl HW, 3rd, Fisher-Hoch SP, et al. Meeting physical activity guidelines is associated with lower allostatic load and inflammation in Mexican Americans. *J Immigr Minor Health.* 2015;17(2):574-81. https://doi.org/10.1007/s10903-013-9950-1.
13. Upchurch DM, Rainisch BW, Chyu L. 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 through 2004. *Womens Health Issues*. 2015;25(6):680-687. https://doi.org/10.1016/j.whi.2015.07.002 PMID:26344446
14. Lee KH, Park SW, Ye SM, Kim SY, Kim SY, Han JS, et al. Relationships between dietary habits and allostatic load index in metabolic syndrome patients. *Korean Journal of Family Medicine.* 2013; 34(5):334-346. https://doi.org/10.4082/kjfm.2013.34.5.334. PMID: 24106586.
15. Mattei J. Higher Adherence to a diet score based on American Heart Association recommendations is associated with lower odds of allostatic load and metabolic syndrome in Puerto Rican adults. *J of Nutr*. 2011; 143(11):1753; -9; 9. https://doi.org/10.3945/jn.113.180141.
16. Kitzman H, Dodgen L, Mamun A, et al. Community-based participatory research to design a faith-enhanced diabetes prevention program: the Better Me Within randomized trial. *Contemp Clin Trials*. 2017;62(suppl C):77-90. https://doi.org/10.1016/j.cct.2017.08.003 PMID:28807739
17. Juster R-P, McEwen BS, Lupien SJ. Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neurosci Biobehav Rev*. 2010;35(1):2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002 PMID:19822172
18. Miller R, Stalder T, Jarczok M, Almeida DM, Badrick E, Bartels M, et al. The CIRCORT database: reference ranges and seasonal changes in diurnal salivary cortisol derived from a meta-dataset comprised of 15 field studies. *Psychoneuroendocrinology*. 2017;76:226-227. https://doi.org/10.1016/j.psyneuen.2016.07.201. PMID: PMC5108362.
19. Mattei J, Demissie S, Falcon LM, Ordovas JM, Tucker K. Allostatic load is associated with chronic conditions in the Boston Puerto Rican Health Study. *Soc Sci Med.* 2010; 70(12):1988-96. https://doi.org/10.1016/j.socscimed.2010.02.024. PMID: 20381934.
20. Tan M, Mamun A, Kitzman H, Mandapati SR, Dodgen L. Neighborhood disadvantage and allostatic load in African American women at risk for obesity-related diseases. *Preventing Chronic Disease.* 2017; 14:1701-1743. https://doi.org/10.5888/pcd14.170143. PMID: PMC5703650.
21. Carithers TC, Talegawkar SA, Rowser ML, Henry OR, Dubbert PM, Bogle ML, et al. Validity and calibration of food frequency questionnaires used with African American adults in the Jackson Heart Study. *J Am Diet Assoc.* 2009https://doi.org/10.1016/j.jada.2009.04.005. PubMed PMID: 19559135.
22. National Cancer Institute, Division of Cancer Control and Population Sciences. *Comparing the HEI-2015, HEI–2010 & HEI–2005.* 2018. Last accessed April 1, 2019 from: https://epi.grants.cancer.gov/hei/comparing.html.
23. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA*. 2018;320(19):2020-2028. https://doi.org/10.1001/jama.2018.14854 PMID:30418471
24. Pettee Gabriel K, McClain JJ, Lee CD, et al. Evaluation of physical activity measures used in middle-aged women. *Med Sci Sports Exerc*. 2009;41(7):1403-1412. https://doi.org/10.1249/MSS.0b013e31819b2482 PMID:19516161
25. Cohen S, Williamson G. Perceived stress in a probability sample of the United States. In: Spacapan S, Oskamp S, eds. *The Social Psychology of Health: Claremont Symposium on Applied Social Psychology*. Newbury Park, CA: Sage; 1988. p. 33-65.
26. Enders CK. *Little's MCAR test using Chi-square. SAS 8.2 or Higher Ed*. New York: Guilford Press; 2015.
27. Bo S, Ciccone G, Baldi C, Benini L, Dusio F, Forastiere G, et al. Effectiveness of a lifestyle intervention on metabolic syndrome. A randomized controlled trial. *J Gen Intern Med.* 2007; 22(12):1695-703. https://doi.org/10.1007/s11606-007-0399-6. PMID: PMC2219825.
28. Jiang L, Chang J, Beals J, Bullock A, Manson SM; Special Diabetes Program for Indians Diabetes Prevention Demonstration Project. Neighborhood characteristics and lifestyle intervention outcomes: Results from the Special Diabetes Program for Indians. *Prev Med*. 2018;111:216-224. https://doi.org/10.1016/j.ypmed.2018.03.009 PMID:29534990
29. Brody GH, Lei M-K, Chen E, Miller GE. Neighborhood poverty and allostatic load in African American youth. *Pediatrics*. 2014;134(5):e1362-e1368. https://doi.org/10.1542/peds.2014-1395 PMID:25311604

30. Chen E, Miller GE, Lachman ME, Gruenewald TL, Seeman TE. Protective factors for adults from low childhood socioeconomic circumstances: the benefits of shift-and-persist for allostatic load. *Psychosomatic Medicine*. 2012 74(2):178-186. https://doi.org/10.1097/PSY.0b013e31824206fd. PMID: PMC3273596.
31. Forrester SN, Leoutsakos JM, Gallo JJ, Thorpe RJ Jr, Seeman TE. Association between allostatic load and health behaviours: a latent class approach. *J Epidemiol Community Health*. 2019;73(4):340-345. https://doi.org/10.1136/jech-2018-211289 PMID:30700494
32. Rodriquez EJ, Livaudais-Toman J, Gregorich SE, Jackson JS, Nápoles AM, Pérez-Stable EJ. Relationships between allostatic load, unhealthy behaviors, and depressive disorder in U.S. adults, 2005-2012 NHANES. *Prev Med*. 2018;110:9-15. https://doi.org/10.1016/j.ypmed.2018.02.002 PMID:29421445