Lower depression scores associated with greater weight loss among rural black women in a behavioral weight loss program

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Abstract

Depression and stress have been associated with less weight loss among some participants in behavioral weight loss (BWL) programs. The purpose of this study was to (1) measure the levels of depression and stress among a sample of black women living in rural Alabama and Mississippi who were participating in a BWL program and (2) examine the association between these psychosocial variables and weight loss outcomes of participants at 6 months. Overweight and obese black women in a BWL program ($n = 409$) completed validated surveys to measure depression and stress at baseline and 6 months. Weight and height were also measured at baseline and 6 months. Statistical tests were conducted to examine associations between depression, stress, and weight loss. Mean BMI at baseline was 38.68 kg/m². Participants achieved a 1.17 kg/m² reduction in BMI at 6 months. When comparing by baseline depression or stress categories, no significant differences in weight loss outcomes were observed. Analysis of continuous data revealed a significant correlation between baseline depression score and change in BMI. In adjusted models, change in depression score over time was significantly associated with change in weight. No differences in weight loss outcomes at 6 months were observed when comparing participants with and without elevated depressive symptoms or elevated stress at baseline. This suggests that potential participants may not need to be excluded from BWL programs based on pre-specified cut points for these psychological conditions. Greater improvements in depression were associated with better weight loss outcomes suggesting that more emphasis on reducing depression may lead to greater weight losses for black women in BWL programs.

Keywords

Behavioral weight loss intervention, Stress, Depression, Black female, Rural, Deep South

INTRODUCTION

Obesity remains a public health crisis in the USA. Recent reports revealed that the prevalence of obesity has increased in adults over the past 15 years with 36% of US adults now considered clinically obese [1] (body

Implications

Practice: Health care professionals who provide behavioral interventions for obesity should be inclusive of individuals with elevated levels of depressive symptoms and/or perceived stress and should include concurrent treatment or strategies to relieve symptoms of depression to achieve greater weight loss among patients.

Policy: Lay community health advisors should be regularly included as a part of the health care system and utilized to effectively deliver health-related information to local communities.

Research: Ongoing research is required to understand health behaviors across diverse populations in order to optimize inclusion/exclusion criteria and intervention components for behavioral interventions.

Electronic supplementary material

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mass index (BMI) ≥ 30 kg/m²). Obesity is associated with multiple health risks [2–5] and also has a substantial economic impact [6]. Potential contributors to obesity are numerous [7] and approaches for treatment are varied [5].

Behavioral weight loss (BWL) interventions offer one approach that has demonstrated modest effectiveness in promoting weight loss among some obese participants. The Diabetes Prevention Program [8] (DPP) and the Weight Loss Maintenance Trial [9] (WLM) are regarded as the gold standard for BWL interventions and often include components like goal-setting and self-monitoring. While BWL interventions have resulted in clinically meaningful weight loss for some participants, on average, black women lose less weight than white women in BWL programs [10, 11]. For example, DPP, which produced some of the highest observed weight losses among black women

in a BWL program (4.7 kg at 6 months) still reported 2.8 kg more weight loss in white women [8]. The reasons for this difference in outcomes are not fully understood and highlight a need to further explore how to improve weight loss outcomes of black women, who have the highest prevalence of obesity (48%) of all racial/ethnic groups in the USA.

Besides race [12], other individual-level factors associated with weight loss in traditional BWL programs include behavioral factors related to treatment adherence (e.g., session attendance, self-monitoring) [9, 13, 14] and psychosocial factors including stress and depression [15–17]. While race and treatment adherence demonstrate a fairly consistent relationship with weight loss, the literature reporting the relationships between stress, depression, and weight loss is mixed. Several studies have reported inverse associations [12, 15, 17–19], i.e., higher levels of stress and/or depression were associated with less weight loss, while others have reported no association [20–22]. A more clear understanding of how these psychosocial factors may affect weight loss for BWL program participants is needed, particularly for black women who consistently report higher *stress* (e.g., chronic, acute, major life events) than non-Hispanic white women [23–25], who demonstrate a greater likelihood of reporting major *depression* in some studies [26, 27] and regularly lose less weight in BWL programs than non-Hispanic white women [10].

Previously, we conducted one of the first studies demonstrating that an evidence-based BWL program could be delivered by lay health advisors to black women in rural areas of two Deep South states (Alabama and Mississippi) and produce moderate weight loss. Although average weight loss at 6 months was 2.3 kg among participants, which is consistent with what has been achieved in other translational studies among black populations [28], weight change in our study ranged from a loss of more than 9 kg to a gain of 2 kg. Very little is still known about how individual-level factors of interest from previous research studies are associated with weight loss outcomes of black women in the rural Deep South. While the aforementioned study was not specifically designed to address psychosocial components of weight loss, the data that were collected provided a unique and timely opportunity to examine the role of stress and depression on weight loss performance among black females in Alabama and Mississippi. The aims of this study were to (1) assess the levels of stress and depression in a large cohort of adult black females in the rural Deep South; (2) examine the baseline factors associated with both stress and depression; and (3) report the associations of stress and depression with weight loss performance over time.

METHODS

Study population

The data were obtained from the larger BWL intervention study. Briefly, a two-group cluster-randomized

trial design was utilized to test whether a 24-month evidence-based BWL program augmented with community strategies to support healthy lifestyles (weight loss plus) would produce greater weight loss than the evidence-based BWL program alone (weight loss only). Participants were overweight and obese black women residing in one of eight rural counties in Alabama ($n = 4$) and in Mississippi ($n = 4$). Women were recruited primarily through word-of-mouth, other personal contact, or ongoing local cancer awareness/outreach activities. Participants were eligible if they (1) were self-identified as black, (2) were age 30–70 years, (3) had BMI ≥ 25 kg/m², (4) lived in one of the study counties, and (5) expressed a willingness to participate in the study for the entire duration. Exclusion criteria included the following: (1) pregnancy or plans to become pregnant in the next year, (2) known major medical or psychological condition known to influence body weight loss (e.g., medicated or poorly controlled diabetes (glucose >126), uncontrolled hypertension (BP > 160 mmHg systolic or BP > 100 mmHg diastolic), cardiovascular event in the preceding 12 months, history of gastric bypass surgery, bariatric surgery, eating disorder), (3) history of psychiatric hospitalization in past 2 years, (4) history of substance abuse or eating disorder, or (5) any other condition by which a medical professional has suggested diet modification, physical activity, and/or weight reduction would be contraindicated. The study was approved by the University of Alabama at Birmingham's (UAB) Institutional Review Board and informed consent was obtained from all individual participants included in the study.

Intervention conditions—Eight counties were randomized to either a culturally tailored, evidence-based BWL program alone [29–32] or the same culturally tailored, evidence-based BWL program plus support for community strategies [33] to promote healthy eating and/or physical activity. Both trial arms included 20 weekly face-to-face (FTF) weight loss meetings, 3 months of bi-monthly FTF meetings, 3 months of monthly FTF meetings, and 12 monthly motivational telephone calls. FTF sessions were led by non-professional but trained local staff that included a full-time Regional Coordinator (who resided within the state-specific region) and a part-time County Coordinator (who resided within the specific county). Facilitators were aided by local lay volunteers called Community Health Advisors as Research Partners (CHARPs). Counties randomized to the weight loss plus arm also received financial and technical support for implementing strategies to promote healthy eating and/or physical activity in the local community. Investigators and research staff from UAB provided financial and technical support to aid local communities in implementing their chosen strategies (e.g., community garden, enhancement of a walking trail, local farmers' market incentives, and dance class).

Key measurements/clinical assessments—Clinical assessments were conducted in the local communities where the interventions took place. Data were collected by

UAB and local research staff and CHARPs. The outcome of interest for this study was weight loss performance, which included change from baseline to 6 months for both weight (in kg) and BMI. Participants were weighed (to the nearest 0.1 kg) at each assessment while wearing light clothing without shoes using a professional digital scale regularly calibrated to current standards. Height (to the nearest 0.1 cm) was measured at baseline without shoes using a portable and calibrated stadiometer. BMI was calculated using measured height and weight as weight (kg)/height (m²). The primary endpoint of this study was the absolute change in BMI; however, we also examined several calculated weight loss performance variables.

The two primary explanatory variables of interest for this study were changes in stress and depression. Stress was assessed using the Perceived Stress Scale (PSS), a widely used 10-item psychological instrument for measuring the degree to which aspects of an individual's life are stressful. Depression was assessed using the Center for Epidemiologic Studies Short Depressions scale (CES-D 10) [34, 35], a 10-item instrument which assesses emotions and response behaviors to situations during the past week (i.e., I had trouble keeping my mind on what I was doing) where valid responses include "less than 1 day," "1–2 days," "3–4 days," or "5–7 days." Higher values of both variables are indicative of higher stress and depression, respectively. Both stress and depression were assessed at baseline and 6 months, where the difference over time was calculated as the absolute change from baseline to 6 months. Negative values suggest a worsening of symptoms and positive values suggest an improvement over time. Both the CES-D and PSS have been found to have good internal consistency [34–37]. The CES-D is appropriate for identifying individuals at risk for clinical depression [38] and the PSS-10 is positively correlated with a variety of self-report and behavioral indices of stress in adult populations [37]. We also classified participants as having elevated depressive symptoms (EDS) based on having a CES-D value of 10 or greater as suggested by previous research [39, 40]. Similarly, we dichotomized the PSS scores using a threshold of 13, based on a US probability sampled norm [41], to assess high and low stress at baseline and 6-month follow-up.

Covariates

Covariates of interest for this analysis included age, education, employment, income, marital status, number of comorbid conditions, and the number of intervention sessions attended. These variables were chosen a priori based on their relationship to the outcome variable as well as the explanatory variables. Age was defined as the self-reported age at survey; education was categorized as "High school graduate or less," "Some Post-HS education," and "College graduate;" employment was categorized as "Employed or self-employed," "Unemployed," and "Other;" income was categorized as "≤\$10 k," "\$10 k–\$19 k," "\$20 k–\$29 k," "\$30 k–\$39 k," and "\$40 k+;" marital status was categorized as "Married," "Never married,"

"Divorced," and "Other." The number of comorbid conditions was based on self-reports of different cancers (breast, colon, cervical, other) and other health conditions (high blood pressure, high cholesterol, heart disease/angina, stroke, diabetes, and menopause).

Data analysis

Continuous variables are presented as means and standard deviations. Categorical variables are presented as frequencies and percentages. Baseline characteristics of the study population overall and stratified by baseline measures of PSS and CES-D were calculated, where thresholds of 13 and 10, respectively, were used to separate strata for (1) high versus low stress and (2) EDS or no-EDS. Between group differences were assessed using chi-square tests for categorical variables and independent sample *t* tests for continuous variables.

Percent weight loss was calculated as the difference from baseline to 6 months divided by baseline weight and presented as a percentage. Similarly, we calculated the absolute change in BMI as well as the percent change in BMI. Negative values indicate an increase in weight over time and positive values indicate a decrease in weight over time. We also created a categorical variable to examine the proportion of participants who achieved greater than or equal to 3% weight loss as 6 months.

We examined baseline to 6-month changes in CES-D and PSS classifications using McNemar's test for paired dichotomous data to assess progression and remission from high stress and depressive states separately. For our primary analysis, we examined the relationship between BMI and changes in CES-D and PSS scores by calculating Pearson correlation coefficients between the primary outcome, the explanatory variables of interest, and the covariates. We then examined the relationship between change in BMI and explanatory variables adjusting for the presence of covariates using hierarchical linear regression modeling with time-varying predictors. As previously mentioned, covariate selection was based on a priori hypothesized relationships with the explanatory variables and the outcome. In the full model, we used a variance inflation factor threshold of 5 and did not observe any multicollinearity between predictors. The repeated measure data were examined using hierarchical linear models to account for the within-subject time-varying coefficients. We first examined the unadjusted bivariate associations between BMI and predictors. Then, we examined the associations between BMI and psychosocial factors adjusting for the presence of the covariates. We investigated interaction terms between psychosocial factors with each other and changes over time. Based on the lack of significance of interaction terms as well as assessing the model fit with the Akaike Information Criterion

Table 1 | Overall and stratum-specific characteristics of the enrolled population

	Overall		CES-D < 10		CES-D ≥ 10		PSS < 13		PSS ≥ 13		p value	
	n = 409	%	n = 326	%	n = 83	%	n = 133	%	n = 273	%		
Intervention arm	Control	154	37.7	121	37.1	33	39.8	50	37.6	101	37.0	0.9069
	Treatment	255	62.4	205	62.9	50	60.2	83	62.4	172	63.0	
Sessions attended	(mean, SD)	10.55	6.6	10.83	6.6	9.42	6.6	10.58	6.8	10.51	6.5	0.9122
Age	(mean, SD)	46.51	9.9	46.71	10.1	45.72	9.4	47.82	10.4	45.81	9.6	0.0562
Education	Less than HS	23	5.7	11	3.5	12	14.6	4	3.1	19	7.0	0.4222
	HS graduate	141	35.2	115	36.1	26	31.7	47	36.7	92	34.1	
	Some post HS	74	18.5	66	20.7	8	9.8	26	20.3	48	17.8	
	College grad	163	40.7	127	39.8	36	43.9	51	39.8	111	41.1	
Marital	Married	162	40.0	132	40.7	30	37.0	58	44.3	104	38.4	0.4283
	Not married	19	4.7	12	3.7	7	8.6	4	3.1	15	5.5	
	Separated	21	5.2	16	4.9	5	6.2	6	4.6	15	5.5	
	Divorced	54	13.3	44	13.6	10	12.4	21	16.0	32	11.8	
Income	Widowed	16	4.0	12	3.7	4	4.9	3	2.3	2	4.4	
	Never married	133	32.8	108	33.3	25	30.9	39	29.8	93	34.3	
	LE \$10K	81	20.1	61	18.9	20	25.0	25	19.1	56	20.8	0.0587
	\$10–19K	91	22.6	71	22.0	20	25.0	33	25.2	57	21.2	
Employment	\$20–29K	84	20.8	72	22.3	12	15.0	25	19.1	58	21.6	
	\$30–39K	61	15.1	53	16.4	8	10.0	19	14.5	41	15.2	
	\$40–49K	34	8.4	19	5.9	15	18.8	8	6.1	26	9.7	
	\$50K+	39	9.7	37	11.5	2	2.5	20	15.3	19	7.1	
Overall health	Employed	279	70.3	226	71.5	53	65.4	87	68.0	189	71.1	0.6228
	Self-employed	10	2.5	8	2.5	2	2.5	4	3.1	6	2.3	
	Retired	24	6.1	23	7.3	1	1.2	12	9.4	12	4.5	
	Disabled	30	7.6	15	4.8	15	18.5	8	6.3	22	8.3	
Overall health	Homemaker	11	2.8	9	2.9	2	2.5	4	3.1	7	2.6	
	Student	6	1.5	5	1.6	1	1.2	2	1.6	4	1.5	
	Unemployed	37	9.3	30	9.5	7	8.6	11	8.6	26	9.8	
	Poor	16	4.0	11	3.5	5	6.0	4	3.1	12	4.4	0.0126
Overall health	Fair	101	25.1	77	24.1	24	28.9	21	16.3	78	28.9	
	Good	220	54.7	177	55.5	43	51.8	74	57.4	145	53.7	
	Very good	53	13.2	43	13.5	10	12.1	25	19.4	28	10.4	
	Excellent	10	2.5	9	2.8	1	1.2	5	3.9	5	1.9	
0	159	38.9	126	38.7	33	39.8	46	34.6	113	41.4	0.4966	

Number of conditions ^a	1	135	33.0	110	33.7	25	30.1	49	36.8	85	31.1
	2	80	19.6	65	19.9	15	18.1	28	21.1	50	18.3
	3	28	6.9	19	5.8	9	10.8	7	5.3	21	7.7
	4	7	1.7	6	1.8	1	1.2	3	2.3	4	1.5
Outcomes	BMI at baseline	38.68	8.1	38.43	8.0	39.65	8.5	0.2214	38.37	8.4	38.73
	BMI at 6 months	37.46	7.8	37.20	7.7	38.53	8.1	0.2095	36.82	7.4	37.62
	absolute change in BMI	-1.16	2.2	-1.25	2.3	-0.77	1.8	0.0653	-1.30	2.5	-1.11
	Percent BMI change	2.93	4.9	3.15	5.0	1.98	4.2	0.0793	3.22	5.3	2.84
	Weight at baseline	227.97	50.0	226.40	50.0	234.00	50.0	0.2166	228.87	53.4	227.01
	Weight at 6 months	220.62	49.0	219.30	49.0	226.30	49.1	0.2964	219.66	49.4	220.35
	Percent weight loss	2.78	4.3	2.96	4.3	2.01	4.2	0.1046	2.96	4.5	2.74
	Weight loss GE 3%	152	37.2	127	39.0	25	30.1	0.1369	52	39.1	100
Stress	Baseline PSS	15.55	5.4	14.31	5.0	20.39	4.2	<0.0001	9.43	3.0	18.54
	PSS < 13	133	32.8	59	18.3	1	1.2	<0.0001			
	PSS ≥ 13	273	67.2	264	81.7	82	98.9				
	Month 6 PSS	15.59	6.1	14.70	5.9	19.33	5.6	<0.0001	12.10	6.1	17.30
	PSS < 13	111	31.8	58	20.6	4	6.0	0.0050	58	51.3	52
	PSS ≥ 13	238	68.2	224	79.4	63	94.0		55	48.7	181
Depression	Baseline CES-D	6.72	4.6	4.90	2.5	13.75	3.8	<0.0001	3.88	2.6	8.13
	CES-D < 10	326	79.7						132	99.3	191
	CES-D ≥ 10	83	20.3						1	0.8	82
	Month 6 CES-D	5.98	5.0	5.15	4.5	9.46	5.2	<0.0001	4.18	4.1	6.82
	CES-D < 10	346	84.6	291	89.3	55	66.3	<0.0001	123	92.5	221
	CES-D ≥ 10	63	15.4	35	10.7	28	33.7		10	7.5	52

^a This includes breast, colon, cervical, and other cancers, in addition to high blood pressure, cholesterol, heart disease, stroke, diabetes, and menopause

Table 2 | Correlations between BMI and psychosocial factors assessed over time

	Baseline BMI		Month 6 BMI		Change in BMI	
	Rho	<i>p</i> value	Rho	<i>p</i> value	Rho	<i>p</i> value
Baseline CES-D	0.04	0.4647	0.06	0.2588	0.14	0.009
Month 6 CES-D	0.06	0.2601	0.14	0.0094	0.24	<0.0001
CESD Δ^a	−0.05	0.3664	−0.09	0.088	−0.12	0.0259
Baseline PSS	0.03	0.5659	0.08	0.1557	0.07	0.186
Month 6 PSS	0.12	0.0308	0.17	0.0016	0.14	0.0076
PSS Δ^b	−0.09	0.0917	−0.12	0.0281	−0.09	0.0917

^a CES-D Δ is calculated as the 6 month's CES-D score subtracted from the baseline^b PSS Δ is calculated as the 6 month's PSS score subtracted from the baseline

(AIC), our final model examined changes in BMI as a function of time, CESD, CESD-by-time interaction, PSS, the number of sessions attended, age, comorbidities, education, employment, income, and marital status. We estimated the beta coefficients, their standard errors, and each variable's type 3 *p* values. All analyses were performed using SAS v 9.4, where *p* values <0.05 were considered statistically significant.

RESULTS

Participant characteristics by depression and stress status

Descriptive characteristics of the overall sample and stratum-specific estimates for both depression and stress can be found in Table 1. Those with EDS were more likely to be disabled (*p* < 0.01), have lower annual household incomes (*p* < 0.001), and have no high school diploma (*p* < 0.001) compared to those

Table 3 | Unadjusted and adjusted model estimates for associations between BMI, psychosocial factors, and covariates

Effect		Unadjusted estimates			Adjusted model estimates		
		β estimate	SE	<i>p</i> value	β estimate	SE	<i>p</i> value
Time	6 months vs baseline	−1.17	0.13	<0.0001	−1.89	0.24	<0.0001
CES-D		0.10	0.03	0.0005	−0.03	0.03	0.2207
CES-D × time interaction		−	−	−	0.12	0.03	0.0003
PSS		0.06	0.02	0.0234	0.02	0.02	0.4542
# of sessions attended		−0.17	0.06	0.0063	−0.11	0.07	0.0931
Age		−0.14	0.04	0.0003	−0.14	0.05	0.0058
Comorbid conditions ^a	1 vs 0	1.49	0.99	0.2068	2.08	1.01	0.0900
	≥2 vs 0	−0.18	1.03		1.94	1.17	
Education	vs HS grad or less	0.87	1.18	0.6567	0.12	1.22	0.9689
	vs HS grad or less	0.74	0.93		0.26	1.03	
Employment	Employed vs unemployed	−0.05	1.50	0.9981	0.46	1.63	0.7654
	Other vs unemployed	−0.10	1.73		1.19	1.81	
Income	LE \$10k vs \$40k+	0.01	1.35	0.1493	−0.80	1.64	0.3459
	\$10k–\$19k vs \$40k+	1.55	1.29		1.07	1.40	
	\$20k–\$29k vs \$40k+	−1.31	1.31		−1.28	1.34	
	\$30k–\$39k vs \$40k+	−1.26	1.42		−0.99	1.45	
Marital	Married vs never married	−1.36	0.98	0.2696	−0.90	1.07	0.7446
	Divorced vs never married	−2.51	1.36		−1.44	1.42	
	Other vs never married	−0.86	1.35		−0.77	1.37	

^a This includes breast, colon, cervical, and other cancers, in addition to high blood pressure, cholesterol, heart disease, stroke, diabetes, and menopause

without EDS. No differences in age, marital status, or mean baseline weight by depression status were observed. When comparing by stress level, no significant differences in demographic characteristics were observed. At baseline, participants with EDS were more likely to be categorized as high stress compared to those without EDS (98.9 vs 81.7%, $p < 0.01$). The mean PSS score for those with EDS was also significantly higher (20.4 vs 14.3; $p < 0.01$). No differences were observed in the number of intervention sessions attended according to depression (low = 10.8 vs EDS = 9.4; $p = 0.08$) or stress (low = 10.6 vs high = 10.3; $p = 0.91$) category.

Baseline depression score and weight measures

When comparing weight measures by baseline depression status, no statistically significant differences in any of the weight change measures at baseline or 6 months were observed (Table 1). Baseline CES-D score was not correlated with baseline BMI ($\rho = 0.04$, $p = 0.47$) nor was it associated with BMI at 6 months ($\rho = 0.06$, $p = 0.26$); however, baseline CES-D score was associated with the change in BMI from baseline to 6 months ($\rho = 0.14$, $p < 0.01$) (Table 2).

Baseline perceived stress score and weight loss performance

No differences in weight change measures by baseline stress category were observed (Table 1). Baseline PSS score was not associated with baseline BMI ($r = 0.03$; $p = 0.57$), BMI at 6 months ($\rho = 0.08$; $p = 0.16$), or change in BMI from baseline to 6 months ($\rho = 0.07$; $p = 0.19$) (Table 2).

Changes in CES-D and PSS scores

The average individual change in CES-D score from baseline to 6 months was statistically significant (mean difference = 0.64; $p = 0.01$) where baseline scores were higher than follow-up suggesting an overall decrease of depressive symptoms (Supplemental Table 1). Of those without baseline EDS, 10.7% progressed to EDS at follow-up. Of those with baseline EDS, 66.3% did not report EDS at 6 months. Using an exact McNemar's test, a statistically significant difference in the proportion of EDS subjects at baseline and 6 months follow-up ($p = 0.04$) was observed (data not shown).

Average individual changes in PSS score from baseline to 6 months were not significant (mean difference = -0.02 ; $p = 0.93$), where average scores were similar at both time points. Of those with low stress at baseline, 48.7% progressed to high stress at follow-up. Of those categorized as high stress at baseline, 22.3% were considered low stress at 6 months. Using an exact McNemar's test, no difference in the proportions of high stress subjects at baseline and 6-month follow-up was observed ($p = 0.85$, data not shown).

Results of the unadjusted and adjusted hierarchical linear regression analyses can be found in Table 3. In the unadjusted analysis, time, CES-D, and PSS, the number of sessions attended and participant age were

significantly associated with changes in BMI. The mean reduction in BMI at 6-month follow-up was 1.17 kg/m^2 ($p < 0.0001$); every one unit increase in CES-D score was associated with a 0.1 kg/m^2 increase in BMI ($p < 0.001$); every one unit increase in PSS score was associated with a 0.06 kg/m^2 increase in BMI ($p = 0.02$); each additional session attended was associated with a decrease of -0.17 kg/m^2 in BMI ($p < 0.001$); and older age was associated with lower BMI (-0.14 kg/m^2 ; $p < 0.001$).

Several multivariable models were examined which included both psychosocial variables (i.e., PSS, CES-D) and each variable with their corresponding interactions with time, as well as interactions with each other. The non-significant interaction term between PSS and time was not considered for inclusion in the final model. Moreover, we did not observe a significant interaction between CES-D and PSS; this along with the AIC values led us to omit this interaction term from our final model. In our multivariable-adjusted model, we observed that time, CES-D-by-time interaction, and age were significantly associated with weight loss performance. After adjusting for the presence of covariates, the average effect of time on change in BMI was -1.89 kg/m^2 ($p < 0.001$), the interaction between depressive symptoms and time suggested that increasing depressive symptoms over time is associated with increased BMI ($\beta = 0.12 \text{ kg/m}^2$; $p < 0.001$). Additionally, we observed that increased age was associated with decreased BMI (-0.14 kg/m^2 ; $p < 0.01$). Increased comorbidities were marginally associated with higher BMI ($p = 0.05$).

DISCUSSION

Previous studies have reported conflicting results on the association between psychosocial factors and the effectiveness of BWL programs. In this study of black women in the rural Deep South—a group at the highest risk of obesity—baseline depression score and change in depressive symptoms were associated with changes in BMI. Specifically, improvements in depressive symptoms were associated with greater BMI decreases over time. There was no association between baseline stress score and weight loss performance; however, there was a trend towards greater reductions in stress being associated with greater reductions in BMI. No relationships were observed between baseline stress or depression and typical indicators of treatment adherence including session attendance and food journaling/self-monitoring. Overall, our data suggests that changes in depressive symptoms were associated with weight loss outcomes among our sample of rural black women in a BWL program. Our findings suggest that additional focus on treating depression may lead to improved weight loss outcomes for some rural black female participants in BWL programs.

These findings are consistent with much of the research in this area conducted among other groups. For example, Trief et al. reported that elevated depressive symptoms predict less weight loss among participants

at each time point over a 2-year intervention [17, 19]. Other studies have also suggested a relationship between depression and weight loss as correlations in changes of the two variables over time [42] as seen in the current study. In contrast, baseline depression did not predict weight loss among a subsample of participants in the lifestyle arm of the DPP study [43] nor in the Weight Loss Maintenance Trial [22]. While many of the individual studies examining the relationship between depression and weight loss yield mixed results, in a review, Stubbs and colleagues (2011) concluded that insufficient evidence exists to support that pre-existing depression would prevent weight loss [21].

Inconsistencies in the literature also exist when considering the relationship between stress and weight loss success for participants in a BWL program. Our findings are consistent with other studies that found no relationship between baseline stress and weight loss [22]. However, other researchers have reported relationships between stress and weight loss [15, 17, 42]. For example, Elder et al. reported that as baseline stress levels increased, weight loss was less [42].

The limited relationship observed between stress and weight change among this population of rural black women is not surprising. We observed no relationship between stress or depression and program adherence markers like attendance which have been linked to weight loss outcomes in several populations including the group analyzed for this report [44]. Although this finding generally contradicts other research, it may offer an explanation for the lack of association between stress or depression and weight change. If the relationship between stress or depression and weight loss is typically mediated through program adherence, then the absence of an initial correlation between the psychosocial variables and adherence would diminish any relationship between the psychosocial variables and weight change. Furthermore, previous research conducted among a similar population demonstrated no association between perceived stress and dietary pattern [45], which would suggest that stress may not influence weight change among this group through traditional behavioral pathways.

A study limitation is the inability to reliably quantify the use of anti-depressant medication due to how medication data were collected. A qualitative review of the medication data suggest that the number of participants taking anti-depressants was negligible. While we acknowledge that anti-depressant use could potentially confound study findings based on evidence that some medications may lead to weight gain while improving depressive symptoms, we are confident that the reported anti-depressant use among this sample was minimal and would not significantly impact study findings. Our study findings also support this assumption due to the fact that participants with *greater* improvements in depression lose *more* weight, which would be counterintuitive if anti-depressant use was

pervasive among this group. Another study limitation is the lack of other measures of stress and coping that may be unique to this population including assessments of racism, discrimination, and the Superwoman Schema [46] which have been linked to poorer health outcomes among black women and may play a role in weight loss efforts. For example, previous research has suggested that discrimination is positively associated with visceral adiposity [47]. Although the measures of stress and depression utilized in this study have been deemed valid for diverse populations, more in-depth examinations of stressors that may be unique to this population, e.g., discrimination, are warranted. The strengths of this study outweigh its limitations. First, the study population of rural black women is one that is understudied and not well characterized, yet bears a disproportionate burden of obesity and obesity-related diseases. The evidence-based BWL intervention and validated psychometric measures lend support for the internal validity of this research.

The findings of this study are important to inform further refinement and efficiency of BWL programs. Potential participants in BWL programs are often excluded due to less than ideal psychological profiles, especially depression. However, this research suggests that individuals with EDS and/or high levels of perceived stress at baseline can achieve weight losses similar to that of participants without elevated levels of depression or stress. In addition, our study findings indicated that greater improvements in depression scores were associated with more weight loss. This would suggest that this subset of individuals may not need to be excluded from BWL research studies and could participate in traditional behavioral weight loss programs with some success. Additionally, even greater weight loss success may be achieved with tailoring or attention to depression treatment as augmentation to standard evidence-based BWL programs. While we did not observe a change in stress levels over time, future studies may benefit from examining the mechanisms through which stress can be mediated in order to affect positive change in BWL studies.

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Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Adherence to ethical standards disclosure: 1. The corresponding author, Tiffany Carson, has the approval of all other listed authors for the submission and publication of all versions of the manuscript.

2. All who have made an independent material contribution to the manuscript have been included on the author list.

3. The work submitted in the manuscript is original and has not been published elsewhere and is not presently under consideration of publication by any other journal.

4. The material in the manuscript has been acquired according to modern ethical standards and has been approved by the legally appropriate ethical committee.

5. If any of the statements above ceases to be true, the authors will notify the journal as soon as possible so that the manuscript can be withdrawn.
6. The authors have full control of all primary data and agree to allow the journal to review the data if requested.
7. All procedures and research activities were approved by the Institutional Review Board (IRB) at the University of Alabama at Birmingham. The guiding ethical principles of the IRB—respect for persons, beneficence and justice—are embodied in the “Belmont Report”: Ethical Principles and Guidelines for the Protection of Human Subjects of Research (The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, April 18, 1979). All human subjects participated in the informed consent process and indicated their informed consent by signing a written document.
10. No animals were involved in the reported research.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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