



Effects of Behaviorally Supported Exercise and Exercise-Induced Mood Changes on Elevated Blood Pressure and Hypertension in African American Adults with Severe Obesity

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Abstract

African Americans with obesity have high rates of hypertension. Exercise has been shown to significantly reduce high blood pressure; however, effects through associated reductions in anxiety and depression are unclear. African American adults with either class 2 or 3 obesity ($n = 86$; $M_{\text{age}} = 43.4$ years) and either elevated blood pressure ($n = 16$) or stage 1 ($n = 33$) or stage 2 ($n = 37$) hypertension participated in a theoretically driven community-based weight-management program. There were significant increases in exercise outputs; while systolic and diastolic blood pressure, anxiety, and depression significantly decreased from baseline–month 6. Increased exercise significantly predicted reduced anxiety, depression, and diastolic blood pressure. Change in anxiety significantly mediated the relationship between exercise and both systolic and diastolic blood pressure changes. Increasing exercise from the equivalent of 1.5 to 4.5 moderate bouts/week reduced elevated blood pressure/hypertension in African American adults with severe obesity largely through their exercise-associated improvement in anxiety.

Keywords Exercise · Mood · Blood pressure · Hypertension · African American

Background

The prevalence of hypertension in African American adults is high, and significantly higher than their White counterparts (45% vs. 29%) [1]. African Americans are also less likely to have their blood pressure under control [2]. A lack of medical and/or behavioral management of elevated blood pressure is related to heart failure, coronary heart disease, stroke, diabetes, and death from the COVID-19 virus [3]. Behavioral recommendations for reducing high blood pressure include increasing exercise, losing weight through a healthier diet, limiting sodium intake, limiting alcohol consumption, and eliminating the use of tobacco [4]. However, possibly because adherence to those behavioral changes has been difficult to attain [5, 6], antihypertensive medications that often have unacceptable side effects such as increased

urination, weakness, and dizziness [7] have frequently been depended upon [4].

Anxiety and depression have also been associated with hypertension in previous research [8, 9]. However, most of the associated studies have been cross-sectional; failing to account for changes over time or directionality in relationships among variables. Exercise has been reliably associated with reductions in anxiety, depression, and sustained weight loss [10, 11]. Nevertheless, even with clear evidence of those effects, physicians do not regularly treat exercise as a central component of reducing high blood pressure. Although reasons why are unclear, this may be especially true when treating African American patients because adherence to such behavioral changes appears to be the lowest for that subgroup of adults and outside supports within the community that might increase adherence are rarely easily accessible [12].

Conceptual Framework

Individuals with obesity, a common co-morbidity of hypertension [13], tend to have high degrees of anxiety and depression [14]. Although exercise is advantageous for

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reducing high blood pressure and associated with improved anxiety and depression, and better mood is associated with lower blood pressure [8, 9], interrelations of their *changes* are unclear. If exercise-induced decreases in blood pressure are significantly mediated by associated reductions in anxiety and/or depression, this will inform both theory and treatment for African Americans who are especially vulnerable to hypertension, obesity, and physical inactivity [1, 2, 4, 5, 7]. It might also shape directions for community-based support.

Thus, this research assessed a group of African American adults with class 2–3 obesity [body mass index (BMI) ≥ 35.0 kg/m²] and elevated blood pressure/hypertension that were enrolled in a community-based weight-loss treatment on measures of exercise outputs, blood pressure, anxiety, and depression over 6 months. A treatment protocol based on self-regulation theory and social cognitive theory [10], that emphasized the development of self-regulatory skills to overcome lifestyle barriers, was selected for administration. Aims were to both assess treatment effects and evaluate the mediation of relations between changes in exercise outputs and blood pressure by depression and anxiety score changes. Hypotheses are as follows:

- (1) There will be significant increases over 6 months in exercise outputs, and significant reductions in depression and anxiety scores, and systolic and diastolic blood pressure.
- (2) Increased exercise will be significantly associated with reductions in measures of depression, anxiety, and blood pressure (using bivariate analyses).
- (3) Changes in scores on measures of depression and anxiety will significantly mediate associations between exercise and blood pressure changes (in separate mediation analyses).

Methods

Participants

Men and women responded to print and electronic media advertisements to volunteer for a 6-month program supporting exercise and healthy eating for weight loss. Their data were part of a larger research program on the behavioral treatment of obesity that had research goals different from the present study and is still in data collection. For the present investigation, inclusion criteria were: ≥ 21 years-of-age and self-reporting as African American, class 2–3 obesity, blood pressure of ≥ 120 mmHg diastolic and/or ≥ 80 mmHg systolic, current exercise of < 3 moderate sessions/week, and written clearance to participate from a physician. Also, if prescribed, no change in blood pressure and/or psychotropic

medication (including dosage) from 6 month prior to study start to study end was also a requirement for inclusion. The sample size of 86 (79 women) had a mean age of 43.4 years (SD = 9.3), a mean BMI of 42.1 kg/m² (SD = 6.4), and a median household income of ~ \$38,500/year (ie, generally lower to lower-middle income). Based on the recent guidelines from the American College of Cardiology and the American Heart Association [15], 16 participants (18%) had elevated blood pressure, 33 (38%) had stage 1 hypertension, and 37 (43%) had stage 2 hypertension. University institutional review board (IRB) approval was received for the study protocol, and signed IRB-approved written consent was obtained from each participant prior to the study's start.

Measures

Exercise output was measured by the Godin Leisure-Time Physical Activity Questionnaire [16, 17]. It required each participant to recall their number of mild intensity (eg, easy-paced walking), moderate intensity (eg, fast-paced walking, easy bicycling), and strenuous intensity (eg, running, vigorous swimming) activities of ≥ 15 min during the previous 7 days. These were multiplied by corresponding metabolic equivalents of 3, 5, and 9, respectively (1 MET approximates the use of 3.5 ml of O₂/kg/minute). That score was then summed. For example, 3 bouts of moderate exercise in the previous 7 days would yield a MET score of 15 (3 bouts \times 5 METs). Concurrent validity of the instrument was indicated through strong positive correlations with maximal oxygen uptake test and accelerometer values [18–21]. Its score changes also significantly predicted changes in both weight and waist circumference in a large sample of adults with obesity [22]. Test-retest reliability over 2 weeks was reported to be 0.74 [21]. The Godin Leisure-Time Physical Activity Questionnaire is sensitive to treatment-associated changes [22].

Depression and anxiety were measured using the Profile of Mood States Brief Form [23]. It required each participant to recall their mood over the previous week through responses of 0 (not at all) to 4 (extremely) to groups of 5 items, each, related to feelings of anxiety (eg, “uneasy,” “nervous”) and depression (eg, “gloomy,” “sad”). Those response scores were summed for a possible range of 0–20 for both the depression and anxiety scales. Internal consistency for the depression measure was reported to be Cronbach's $\alpha = 0.95$ (for both men and women), and for the anxiety measure it was reported at $\alpha = 0.90$ (women) and 0.92 (men). Test-retest reliabilities over 3 weeks were 0.70 and 0.74, respectively [23]. For the present overall sample, Cronbach's α was 0.87 (women) and 0.84 (men), respectively. In previous research, concurrent validity was indicated through strong positive correlations with well-accepted measures of depression and anxiety such as the Beck Depression

Inventory and State-Trait Anxiety Inventory [23, 24]. The Profile of Mood States Brief Form is sensitive to treatment-associated changes [10].

Systolic and diastolic blood pressure was measured in mmHg through use of a manual aneroid sphygmomanometer with stethoscope using current protocols [25]. No exercise was completed by the participant that day, and 5 min of quiet sitting was required prior to measurement. The blood pressure score was recorded when the Korotkoff sounds completely disappeared during cuff deflation (phase 5). The mean of two measurements spaced by 4–5 min was recorded.

Procedures and Data Collection

The study was conducted within community health and wellness centers in the eastern United States. Certified health education specialists administered both the exercise and nutrition treatment components to all participants. The exercise support component was based on a previously validated protocol [26] where the development of long- and short-term goal setting and self-regulatory skills (eg, relapse prevention, cognitive restructuring) to overcome barriers to exercise was supported by the health education specialists administering the treatment. That cognitive-behavioral protocol was grounded in tenets of self-regulation theory [27] and social cognitive theory [28]. Self-regulation theory focuses on individuals' use of strategies (eg, self-regulatory skills) to pursue goals and overcome constraints and barriers; while social cognitive theory focuses on interrelations between environmental factors (eg, supports/barriers), personal factors (eg, internal states/feelings), and behavioral factors (eg, goal-directed actions). Exercise plans were based on each participant's self-reported tolerance and preference. Although government exercise recommendations for health were disclosed [16], there was no mandate on where, when, or what amount to exercise. There were 6 one-on-one exercise-support meetings of 30–45 min, each occurring from baseline through month 6 (Table 1).

The nutrition component followed the same theoretical framework as the exercise-support component. However, it was administered in six small group sessions of 8–15 participants of 60 min each over 3 months. These started 6 weeks after initiating exercise support. The same self-regulatory skills used for the exercise support component were adapted to facilitate healthier eating (eg, increased fruit/vegetable intake; reduced unhealthy fats). No specific nutritional process to counter elevated blood pressure (eg, reduced sodium) was suggested. Rather, foci remained with the overall goal of weight reduction (Table 1). Separate manuals supported the administration of both treatment components.

Random fidelity checks of approximately 15% of sessions were conducted through direct observation by a study staff member using a standardized form, and indicated adequate

protocol compliance. The few deviations, typically around maintaining the required administration treatment time frame of sessions, were easily corrected.

Analyses

The 14% of missing cases, all at month 6, met the criteria for being missing at random [29]. Therefore, the expectation maximization algorithm [30] was used for imputation, enabling the desired intention-to-treat research format [31]. For the primary regression analysis, a minimum of 76 total participants was required to detect the moderate effect size of $f^2 = 0.15$ at the statistical power of 0.80 ($\alpha < 0.05$) [32].

Dependent *t* tests were first calculated to assess participants' changes in exercise outputs, anxiety, depression, and systolic and diastolic blood pressure from baseline to month 6. As suggested [33], there was no correction of α for multiple tests. Corresponding effect sizes were assessed as Cohen's *d* $[(M_{\text{month 6}} - M_{\text{baseline}})/SD_{\text{baseline}}]$, where 0.20, 0.50, and 0.80 were considered small, moderate, and large effects, respectively. Intercorrelations were next computed. Consistent with previous theory and research [34–36], a series of mediation analyses were then fit where the prediction of change in blood pressure by exercise output was tested for significant mediation by changes in anxiety and depression in separate models (see Figs. 1 and 2). Based on current principles using bootstrapped resampling of the data [37–39], a significant relationship between the independent and dependent variables was not required to proceed with testing for mediation.

Statistical significance was set at $\alpha \leq 0.05$, 2-tailed for *t* tests, and because directionality was indicated in previous research [4, 11, 14], 1-tailed for the regression analyses. Also reported were 95% confidence intervals (95% CI), which assessed significance of mediation. R^2 was used to evaluate the strength of the overall prediction models, and path *a* (independent variable \rightarrow mediator), path *b*, (mediator \rightarrow dependent variable), and path *c'* (independent variable \rightarrow dependent variable, controlling for the mediator) were reported as unadjusted Beta values (*B*) and their corresponding standard errors (SE_B). SPSS Statistics version 26, integrating the Process macro-instructional software model 4 with 50,000 bias-corrected bootstrapped resamples [38], was used for the statistical analyses.

Results

Preliminary Analyses

Preliminary analyses were conducted to assess if the small number of male participants could confound results and, thus, should be excluded. Because one-way ANOVAs

Table 1 Timeline of treatment components

Week	Exercise support component (one-on-one meetings)	Nutrition component (small group meetings)
1	Long-term goals assessed; exercise options overviewed; self-regulatory skill = dissociation from discomfort	
2	Short-term goals negotiated; exercise tracking method set; behavioral contract set; self-regulatory skill = relapse prevention part 1	
6	Review goal progress; revise exercise plan and behavioral contract; self-regulatory skills = relapse prevention part 2 and recruiting social supports	Review of previous attempts at weight loss; self-regulatory skills = long- and short-term goal setting and use of food tracking (diaries)
8		Maximizing fruits, vegetables, and water; self-regulatory skills = relapse prevention and recruiting social supports
10	Review goal progress; revise exercise plan and behavioral contract; self-regulatory skill = cognitive restructuring	Lowering unhealthy fats and sugars; self-regulatory skill = review of food tracking related to long- and short-term goal setting
12		Redesigning recipes; self-regulatory skills = stimulus control, dissociation from non-hunger eating cues, and cognitive restructuring
14		Hunger patterns; food selections; self-regulatory skill = review of food diaries related to long- and short-term goal setting
16	Review goal progress; revise exercise plan and behavioral contract; self-regulatory skills = stimulus control and contingency-based self-reward	Portion sizes; self-regulatory skill = controlling prompts to eating; review of all covered self-regulatory skills; continuity planning
24	Review long- and short-term goal setting; review of all covered self-regulatory skills; plan for continuity of exercise	

(dfs = 1, 84) indicated no significant difference in change terms between the men and women participants on exercise outputs ($F=0.17$, $p=0.680$), depression ($F=1.01$, $p=0.319$), anxiety ($F=1.60$, $p=0.209$), systolic blood pressure ($F=2.64$, $p=0.108$), or diastolic blood pressure ($F=0.03$, $p=0.855$), the men participants' data were retained to maximize experimental power. However, no separate analyses or contrasts by sex were deemed appropriate.

Changes in Study Variables

A significant improvement was found in each study variable (Table 2). Effects sizes were very large for increases in exercise outputs, and small-moderate for reductions in the measures of anxiety, depression, and blood pressure. Of the 86 participants, 28 (32.6%) moved to a lower blood pressure category at month 6.

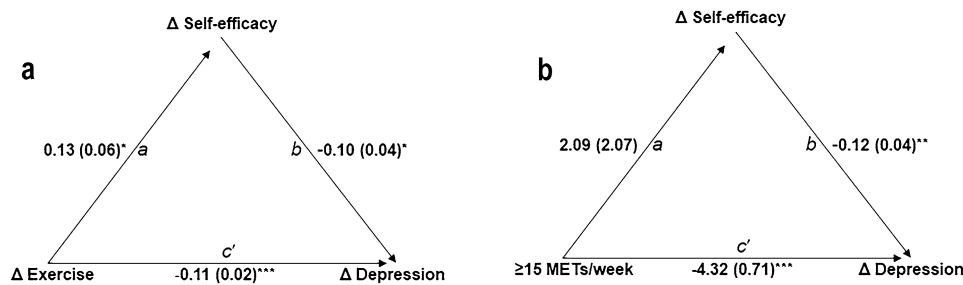


Fig. 1 Mediation of the relationship between changes in exercise output and systolic and diastolic blood pressure by anxiety change. Path a—dependent variable → mediator. Path b—mediator → dependent variable. Path c'—independent variable → dependent variable, controlling for the mediator (path a × path b). * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$

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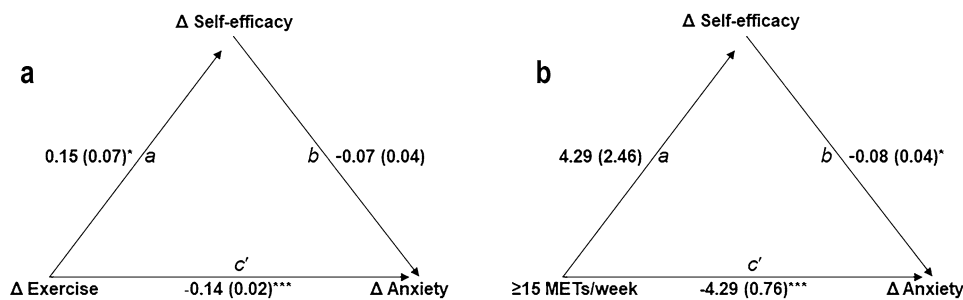


Fig. 2 Mediation of the relationship between changes in exercise output and systolic and diastolic blood pressure by depression change. Path a—dependent variable → mediator. Path b—mediator → dependent variable. Path c'—independent variable → dependent variable, controlling for the mediator (path a × path b). * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$

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Table 2 Changes in study variables over 6 months

	Baseline		Month 6		Score change		t (85)	p	95% CI	d
	M	SD	M	SD	M	SD				
Exercise output (METs/week)	7.48	8.10	23.09	18.13	15.60	17.27	8.38	<0.001	11.90, 19.31	1.93
Depression	3.38	3.70	2.51	3.06	-0.87	2.40	3.37	0.001	-1.39, -0.36	0.24
Anxiety	3.19	3.33	2.52	3.09	-0.66	3.01	2.04	0.044	-1.31, -0.02	0.20
Systolic blood pressure (mmHg)	134.00	12.90	131.44	15.58	-2.56	11.03	2.15	0.034	-4.92, -0.19	0.20
Diastolic blood pressure (mmHg)	84.71	8.12	81.85	9.38	-2.86	8.61	3.08	0.003	-4.71, -1.01	0.35

N = 86. Score change, change from baseline to month 6. Analyses are 2-tailed

d = Cohen's measure of effect size ($M_{\text{month 6}} - M_{\text{baseline}} / SD_{\text{baseline}}$)

95% CI—95% confidence interval

Relationships Among Variables

In bivariate correlations (Table 3), increased exercise was significantly associated with decreased anxiety, depression, and diastolic blood pressure. The inverse correlation between exercise and systolic blood pressure was not significant ($p=0.202$). There were significant positive associations between decreased anxiety and reductions in systolic and diastolic blood pressure. However, positive relationships between systolic and diastolic blood pressure and depression scores did not reach statistical significance.

Change in anxiety significantly mediated the relationship between changes in exercise and systolic blood pressure ($B = -0.04$, $SE_B = 0.03$, 95% CI -0.115 ,

-0.002 ; Fig. 1a), and changes in exercise and diastolic blood pressure ($B = -0.03$, $SE_B = 0.02$, 95% CI -0.077 , -0.004 ; Fig. 1b). The overall prediction models were significant ($R^2 = 0.08$, $p = 0.039$, and $R^2 = 0.10$, $p = 0.010$, respectively).

Change in depression did not significantly mediate the relationship between changes in exercise and systolic blood pressure ($B = 0.00$, $SE_B = 0.04$, 95% CI -0.060 , 0.067 ; Fig. 2a), or changes in exercise and diastolic blood pressure ($B = 0.01$, $SE_B = 0.03$, 95% CI -0.051 , 0.057 ; Fig. 2b). The overall prediction models were also not significant ($R^2 = 0.01$, $p = 0.705$, and $R^2 = 0.05$, $p = 0.119$, respectively).

Supplementary Analyses

To assess possible alternate accounts of the significant mediation models, changes in weight ($M = -3.05$ kg, $SD = 6.13$; measured by study staff) and fruit/vegetable intake ($M = 0.21$ portions/day, $SD = 0.85$; measured by validated self-report [22] as a proxy for the health of the diet as a whole [40]) were entered into step 2 of stepwise multiple regression equations where changes in exercise and anxiety were initially fit as the predictors of blood pressure change in step 1. For the prediction of changes in systolic and diastolic blood pressure, neither changes in weight nor fruit/vegetable intake significantly added to the variances explained by changes in exercise output and anxiety (Table 4).

Table 3 Intercorrelations across study variables (N=86)

	1	2	3	4	5
1. Δ Exercise output	–	–0.42***	–0.21*	–0.09	–0.22*
2. Δ Depression		–	0.45***	0.03	0.07
3. Δ Anxiety			–	0.27**	0.28**
4. Δ Systolic blood pressure				–	0.49***
5. Δ Diastolic blood pressure					–

Δ —change from baseline to month 6

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (1-tailed tests)

Table 4 Stepwise multiple regression analyses predicting blood pressure changes (N=86)

	B	SE_B	β	R^2	F	p	ΔR^2	F_Δ	p
Predicting change in systolic blood pressure									
Step 1				0.08	3.39	0.038			
Change in exercise output	–0.02	0.07	–0.04			0.736			
Change in anxiety	0.97	0.40	0.27			0.016			
Step 2				0.09	1.87	0.124	0.01	0.40	0.674
Change in exercise output	0.00	0.08	0.01			0.966			
Change in anxiety	0.94	0.40	0.26			0.021			
Change in weight	0.16	0.22	0.09			0.481			
Change in fruit/vegetable intake	–0.28	0.90	–0.03			0.760			
Predicting change in diastolic blood pressure									
Step 1				0.10	4.85	0.010			
Change in exercise output	–0.09	0.05	–0.17			0.107			
Change in anxiety	0.69	0.30	0.24			0.027			
Step 2				0.11	2.49	0.049	0.01	0.23	0.794
Change in exercise output	–0.09	0.06	–0.19			0.119			
Change in anxiety	0.69	0.31	0.24			0.029			
Change in weight	–0.01	0.17	–0.01			0.958			
Change in fruit/vegetable intake	0.44	0.69	0.07			0.529			

For Step 1, $dfs = 2, 83$

For Step 2, $dfs = 4, 81$

dfs for change (Δ) in $R^2 = 2, 81$

Discussion

Interpretation of Findings

The cognitive-behavioral treatment supporting adherence to a program of exercise and a healthier diet was associated with significant increases in exercise outputs, and reductions in measures of negative mood and blood pressure. Although the observed mean decrease of ~3 mmHg was below the 10 mmHg systolic blood pressure drop considered clinically significant for reductions of risk for diabetes and major health issues of the heart and kidneys in some research [41], the present degree of reduction was considered beneficial in other research [42]. This was found to be especially true for lowering risks for heart failure, coronary heart disease, and stroke in African American adults [42]. As expected, and consistent with previous research on obese, African American, and overall populations [11], increasing low amounts of exercise to moderate volumes was associated with decreased anxiety and depression scores. However, it should be noted that the present effect sizes on mood improvement were smaller than in research with individuals of a lower weight [11].

Notably, any bivariate association between improvement in exercise and blood pressure was rendered non-significant when change in anxiety was entered into the corresponding regression model as a mediator. It could thus be concluded that in the present sample of African American adults with class 2–3 obesity and either elevated blood pressure, stage 1 hypertension, or stage 2 hypertension, the impact of increased exercise on reduced blood pressure was *completely mediated by* (“completely through”) its association with decreases in anxiety. Supplementary analyses ruled out the chance that those effects were based on covariances with changes in weight and/or eating behavior. However, the R^2 values also suggested that other predictive variables not addressed here, likely both psychosocial and physiological in nature, are also correlates of change and should be addressed in extensions of this research.

Principally because the treatment was focused on weight loss rather than on blood pressure reduction, other key variables known to affect blood pressure such as sodium intake and alcohol use were unaddressed in the curriculum, and thus not measured. They should be assessed in replications of this research. Although the overall significant reduction in depression scores, and the association between increased exercise and reduced depression, were important for quality-of-life enhancements, they did not significantly affect blood pressure.

Limitations

Although the community-based setting was an advantage, several limitations should be acknowledged and addressed in extensions of this research. For example, the lack of a control group, dependence on a volunteer sample of a very high weight, and reliance on self-report (although strongly validated) measures limit both the confidence in, and generalizability of, findings. However, assessments completed within a weight-loss treatment setting reduced expectation and social support effects that are common confounds in studies dealing with interactions between psychological and physiological changes, even when control conditions are present [43]. Future related research should consider quantifying exercise outputs through accelerometry, and using more comprehensive dietary measures to better-assess nutritional changes thought to be relevant to blood pressure. However, those methods must be weighed against the increased burden to participants, challenging their compliance and response accuracies [44]. Although change in blood pressure medication was accounted for, more detail on implications of medication types will also enhance future findings, as will the determination of effects based on degree of participation in the intervention. Although a dearth of male volunteers is common in weight-loss research [45], specific effort should be made to secure enough men to examine effects by sex in forthcoming investigations. Also, longer study time frames will enable better evaluation of longitudinal changes and associated long-term impacts on health risks. Finally, adaptations of treatment processes to a virtual medium might enhance its cost-efficiency and increase dissemination, especially within a home environment.

Conclusion

Based on the present findings with African American adults with severe obesity and elevated blood pressure or hypertension, medical professionals should advocate for increases in exercise for improvements in mood that serve as facilitators of blood pressure reductions. However, because adherence to exercise is problematic [26], especially for the present subgroup that might possess high degrees of environmental challenges to overcome [46, 47], theoretically driven support will be advantageous relative to simply advising individuals of that need. An emphasis on self-regulation through lifestyle change barriers may be critical for success in reliably changing health behaviors [12]. Based on the present study, community-based organizations might serve as partners in providing such support on an economical, ethnically/racially sensitive, and large-scale basis. As future research is conducted to better understand the interaction of exercise, nutrition change, weight loss, and the use of medication

for blood pressure reductions, the health professions will attain improved tools to more reliably address the problem of hypertension that continues to be disturbing in African American and other typically underserved communities.

New Contribution to the Literature

Although exercise was already known as advantageous for addressing high blood pressure, its effects through psychological channels were previously unclear. Through the present research, community-based treatments incorporating cognitive-behavioral methods for addressing severe obesity were shown to be effective for increasing exercise which, in turn, served to improve mood. This, then, was associated with significantly reduced blood pressure in a sample of African American adults with class 2–3 obesity and elevated blood pressure. The mediation-based findings were robust, even after addressing additional effects from changes in the diet and weight. This study provides a starting point and rationale for incorporating large-scale behavioral and psychological change methods in advance of more invasive pharmacological/surgical interventions for hypertension which carry considerable risks and side effects.

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Declarations

Conflict of interest The author(s) has no conflicts of interest.

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