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Adherence to Exercise Prescription and Improvements in the Clinical and Vascular Health of African Americans

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ABSTRACT

International Journal of Exercise Science 10(2): 246-257, 2017. Improvements in indices of vascular health and endothelial function have been inversely associated with hypertension, a risk factor for cardiovascular disease (e.g., myocardial infarction, stroke, and heart failure), renal failure, and mortality. Aerobic exercise training (AEXT) has been positively associated with improvements in clinical health values, as well as vascular health biomarkers, and endothelial function. The purpose of this study was to evaluate whether measures of exercise adherence were related to clinical outcome measures and indices of vascular health subsequent to a 6-month AEXT intervention in a middle-to-older aged African American cohort. Following dietary stabilization, sedentary, apparently healthy, African American adults (40 - 71 y/o) underwent baseline testing including blood pressure, flow-mediated dilation (FMD) studies, fasting blood sampling, and graded exercise testing. Upon completion of a supervised 6-month AEXT intervention, participants repeated all baseline tests. Exercise adherence was measured three ways: exercise percentage, exercise volume, and exercise score. There were no significant correlations between the changes in the vascular health biomarkers of the participants and any of the adherence measures. In addition, there were no significant correlations between any of the adherence measures and the clinical values of the participants that had been significantly changed pre-post-AEXT. Participants improved their clinical and vascular health and decreased risk factors

for hypertension and cardiovascular disease regardless of their level of adherence to AEXT. Future studies should continue to accurately quantify adherence in order to assess the exercise dose for improvements in vascular and clinical health.

INTRODUCTION

Physical inactivity is a modifiable risk factor for the development of numerous chronic diseases including obesity, Type 2 diabetes, hypertension, cardiovascular disease, and certain types of cancers (4, 36). Studies have demonstrated that chronic mild-to-moderate intensity aerobic exercise elicits improvements in multiple traditional cardiovascular risk factors (e.g., fasting glucose, blood lipids, blood pressure) (5, 19, 34), as well as vascular health biomarkers (20), and endothelial function (2, 17, 21). These documented improvements of indices pertaining to vascular health and endothelial function have included increased flow-mediated dilation (FMD), nitric oxide (NO), and interleukin-10 (IL-10), as well as decreased endothelial microparticles (EMP), C-reactive protein (CRP), and interleukin-6 (IL-6). These improvements are particularly significant because endothelial dysfunction has been considered to be an initial step in the pathogenic process underlying atherosclerosis development and has been associated with hypertension, a risk factor for cardiovascular disease (e.g., myocardial infarction, stroke, and heart failure), renal failure, and mortality (7, 28). Aerobic exercise training (AEXT) has been associated with favorable endothelial adaptations due to increased blood flow from shear stress (9, 22, 25, 31). In addition, the subsequent improvements in clinical health values and vascular health biomarkers may lead to the development of preventive measures to reduce hypertension and the risk of cardiovascular disease.

According to the U.S. Department of Health and Human Services (DHHS), African American adults are 40% more likely to have hypertension than their Caucasian counterparts (27). Given the disparate prevalence of the condition among African Americans, as well as the well-documented influence of aerobic exercise on vascular health, particular attention should be given to the implementation and evaluation of exercise programs as a clinical intervention for this population.

Exercise adherence, the degree to which an individual complies with his or her program, is central to evaluating the efficacy of exercise interventions and ultimately addressing health disparities (23). Adherence may be influenced by a range of factors, including those related to the individual (e.g., demographic and psychological characteristics), the environment (e.g., social support and accessibility), as well as the behavior itself (e.g., intensity, duration, and perceived effort) (33). Studies indicate that greater levels of adherence yield favorable outcomes (12, 13, 15); likewise, without adherence to exercise protocols, physiological improvements may be attenuated or may not occur (23, 26, 36). Adherence to exercise prescriptions is often mentioned, yet seldom reported in clinical interventions. Therefore, exercise prescriptions and

subsequent improvements cannot be sufficiently evaluated unless adherence is accurately measured.

In clinical interventions, exercise adherence is often measured as a dichotomous variable, where one either completes the treatment (i.e., adheres), or does not complete the treatment (i.e., does not adhere). Studies have investigated the effects of AEXT on improvements in clinical and vascular health outcomes (4, 16); however, few have examined the role that varied levels of adherence may play in this process, particularly among at-risk populations. The purpose of this study was to evaluate whether measures of exercise adherence were related to clinical outcome measures and indices of vascular health subsequent to a 6-month AEXT intervention in a middle-to-older aged African American cohort.

METHODS

Participants
Participants included in the study were middle-to-older aged (40 - 71 y/o) African Americans at low-to-moderate risk for cardiovascular disease as previously described (2) and otherwise apparently healthy as defined by the American College of Sports Medicine (ACSM) (1).

Protocol
Baseline testing included office blood pressure measurements, FMD studies, fasting blood sampling, and graded exercise testing. Clinical laboratory values measured included body mass index (BMI), maximal oxygen uptake (VO_2max), systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides, and fasting blood glucose.

EMP, CRP, IL-10, IL-6, and NO were measured in the plasma samples, and FMD was measured in the brachial artery as previously described (2, 14, 35). Participants repeated all baseline tests at the conclusion of the intervention.

Participants engaged in a 6-month (24-week) aerobic exercise program under direct supervision of lab personnel, 3x/week, starting with 20 minutes of exercise per session at an intensity equivalent to 50% of VO_2max. Training duration was increased 5 minutes each week until 40 minutes of exercise at 50% of VO_2max was achieved. Upon achieving 40 minutes of exercise, training intensity was increased 5% each week until 65% of VO_2max was achieved. By week eight, participants reached the desired exercise duration of 40 minutes and an intensity at 65% of VO_2max, which they maintained as their exercise prescription for the remainder of the study. Exercise modes included treadmill walking/jogging, stair stepping, stationary cycling, elliptical cross-training, and rowing and arm ergometry. The participants used heart rate monitors during exercise in order to monitor exercise intensity, and study personnel recorded heart rates every 10 minutes to ensure adherence to the prescribed training program. Cardiovascular fitness was determined by a submaximal treadmill test and individualized exercise prescriptions were developed for the AEXT intervention as described previously (2).

Measures of adherence were calculated to account for physiological adaptations that may occur during exercise training as well as detraining effect. Three different adherence measures were calculated including exercise percentage, exercise volume, and exercise score. Exercise percentage was calculated by taking the 24-week program divided by the actual number of weeks that it took each participant to complete the program up to a maximum of 52 weeks (1 year). Participants were required to repeat a week's exercise prescription if they did not attend at least two sessions in a given week and maintain a 60% minimum exercise percentage. In order to demonstrate whether a higher volume of exercise elicited greater physiological adaptations, exercise volume was calculated by adding the total number of minutes that the subject completed during the training program. As already noted, relative intensity remained constant between the participants. Lastly, exercise score was calculated by taking the exercise volume divided by the number of weeks it took each participant to complete the program. This adherence measure considered current guidelines for exercise including frequency, intensity, and duration (1), and when compared to adherence volume, this measurement specifically considered whether frequency of exercise influenced physiological response.

Statistical Analysis
Among the 42 participants who completed the 6-month AEXT intervention, the data used in the statistical analysis for each clinical laboratory value were BMI (n=42), VO_2max (n=41), SBP (n=41), DBP (n=41), total cholesterol (n=36), LDL-C (n=36), HDL-C (n=36), triglycerides (n=36), and fasting blood glucose (n=34). The data used for each vascular health variable were FMD testing (n=26), NO (n=24), CD62E+ EMPs (n=28), CD31+ 42- EMPs (n=28), CRP (n=37), IL-6 (n=32), and IL-10 (n=26). The differences in sample sizes of each variable are related to issues such as inability to schedule subjects, failure to acquire blood samples, or faulty assay procedures.

Data are expressed as mean ± the standard error of the mean (SEM). The distribution of all variables was examined using the Shapiro-Wilk test of normality. Pre- and Post-AEXT were compared using the paired samples Wilcoxon signed-rank test. Spearman's Rho was used to calculate correlations between the adherence measures and the changes in clinical values as well as changes in vascular health biomarkers. Statistical significance was set at a p-value of <0.05. All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL).

RESULTS

The study group consisted of 42 African American men (n=6; 14.3%) and women (n=36; 85.7%). The mean age of the group was 52.7 ± 1.0 year. Ideal adherence would have been defined as a subject achieving an exercise percentage of 100%, resulting in an exercise volume of 2730.0 minutes and an exercise score of 113.8. The calculated adherence variables included the following: exercise percentage (81.6 ± 2.0%; range: 61.0 - 100.0%), exercise volume (2920.8 ± 86.8 min; range: 2330.0 - 4650.0 min), and exercise score (98.0 ± 2.8; range: 69.3 - 166.1).

The clinical laboratory values of the participants measured prior and subsequent to the AEXT intervention are presented in Table 1. The 6-month AEXT intervention significantly increased VO_2max and significantly decreased BMI, plasma triglycerides, and fasting blood glucose. Total cholesterol, LDL cholesterol, HDL cholesterol, and mean systolic and diastolic blood pressure were not significantly changed following the AEXT intervention.

Table 1: Clinical laboratory values of subjects Pre- and Post-AEXT.

Variable	Subject Number	Pre-AEXT	Post-AEXT	Percent Change
BMI (kg/m²)	n=42	31.4 ± 0.9	30.6 ± 0.8*	-2.5%
VO₂max (mL/kg/min)	n=41	25.9 ± 0.9	28.2 ± 1.1**	8.9%
SBP (mm Hg)	n=41	124.2 ± 1.9	123.6 ± 2.2	-0.5%
DBP (mm Hg)	n=41	78.7 ± 1.1	78.9 ± 1.2	0.3%
TCH (mg/dL)	n=36	192.1 ± 4.3	191.4 ± 5.1	-0.4%
LDL-C (mg/dL)	n=36	108.7 ± 3.6	111.9 ± 4.3	2.9%
HDL-C (mg/dL)	n=36	66.8 ± 3.3	65.6 ± 3.4	-1.8%
Triglycerides (mg/dL)	n=36	83.0 ± 5.7	70.1 ± 3.3**	-15.5%
FBG (mg/dL)	n=34	95.1 ± 1.7	88.5 ± 1.8**	-6.9%

Subject number represents usable sample for variables.
Values are expressed as mean ± SEM. BMI, body mass index; VO₂max, maximal oxygen uptake; SBP, systolic blood pressure; DBP, diastolic blood pressure; TCH, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose.
*Denotes significant differences; $p < 0.05$
**Denotes significant differences; $p < 0.01$

The vascular health biomarkers: FMD, NO, CD62E+ EMP, CD31+42- EMP, CRP, IL-6, and IL-10, considered indices of vascular health, were measured prior and subsequent to the AEXT intervention and are presented in Table 2. The 6-month AEXT intervention significantly increased FMD and NO and significantly decreased CD62E+ EMPs, CD31+CD42- EMPs, CRP, and IL-6. There was an increase in IL-10 following the AEXT intervention; however, the increase was not significant.

Table 2: Vascular health biomarkers of subjects Pre- and Post-AEXT.

Variable	Subject Number	Pre-AEXT	Post-AEXT	Percent Change
FMD (%)	n=26	6.0 ± 0.6	9.6 ± 0.4**	60%
NO (μmol/L)	n=24	23.7 ± 1.8	37.1 ± 3.2**	56.5%
CD62E+EMP (events/μL)	n=28	42.5 ± 5.3	22.4 ± 3.8**	-47.3%
CD31+42-EMP (events/μL)	n=28	3.6 ± 0.4	2.2 ± 0.3**	-38.9%
CRP (mg/L)	n=37	3.3 ± 0.5	2.8 ± 0.5*	-15.2%
IL-6 (pg/mL)	n=32	5.0 ± 0.2	4.4 ± 0.4*	-12%
IL-10 (pg/mL)	n=26	0.81 ± 0.06	0.85 ± 0.06	4.9%

Subject number represents usable sample for variables.
Values are expressed as mean ± SEM.
FMD, flow mediated dilation; NO, nitric oxide, EMP, endothelial microparticle; CRP, C-reactive protein; IL-6, interleukin-6; IL-10, interleukin-10.
*Denotes significant differences; $p < 0.05$
**Denotes significant differences; $p < 0.01$

Correlations between adherence measures and delta variables are presented in Table 3. There was a significant positive correlation between exercise volume and the change in systolic blood pressure, and a significant positive correlation between exercise score and the change in HDL cholesterol subsequent to the AEXT intervention. There were no other significant correlations between any of the adherence measures and the changes in clinical values of the participants. Changes in vascular health biomarkers were not significantly correlated with any of the adherence measures.

Table 3: Correlations between adherence measures and changes in variables Pre-Post AEXT.

Delta Variable	Exercise Percentage	Exercise Volume	Exercise Score
BMI (kg/m²)	-0.143	0.147	-0.089
VO_2max (ml/kg/min)	0.226	-0.111	-0.037
SBP (mm Hg)	-0.136	0.331*	0.106
DBP (mm Hg)	0.010	0.107	0.013
TCH (mg/dL)	0.016	0.258	0.118
LDL-C (mg/dL)	-0.046	0.160	-0.058
HDL-C (mg/dL)	0.166	0.281	0.400*
Triglycerides (mg/dL)	-0.105	0.002	-0.149
FBG (mg/dL)	0.016	-0.180	-0.275
FMD (%)	-0.267	0.325	0.017
NO (μmol/L)	-0.118	0.345	0.080
CD62E+EMP (events/μL)	0.005	0.317	0.334
CD31+42-EMP (events/μL)	0.277	-0.111	0.054
CRP (mg/L)	0.213	-0.152	-0.065
IL-6 (pg/mL)	0.116	-0.091	0.017
IL-10 (pg/mL)	-0.029	0.214	0.336

BMI, body mass index; VO_2max, maximal oxygen uptake; SBP, systolic blood pressure; DBP, diastolic blood pressure; TCH, total cholesterol; LDL-C, low- density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose; FMD, flow mediated dilation; NO, nitric oxide; EMP, endothelial microparticle; CRP, C-reactive protein; IL-6, interleukin-6; IL-10, interleukin-10.
*Denotes significant differences; $p < 0.05$

DISCUSSION

Research data have demonstrated that significant physiological adaptations may occur subsequent to AEXT interventions (3, 5, 9, 22, 25, 29, 30). The results from the present study expand upon our previous findings that AEXT is a nonpharmacologic treatment modality that may improve health and reduce cardiovascular risk in middle-to-older aged African American adults free from overt cardiovascular disease. Specifically, we have reported that AEXT demonstrated improvements in both clinical outcome measures as well as vascular health markers (2, 14, 35). As a complement to this previous work, the present study was designed to elucidate whether levels of exercise adherence played a significant role in the favorable physiological adaptations in this African American cohort. The primary findings of this study revealed that the significant improvements in clinical and vascular health measures pre-post AEXT in this cohort were not associated with any of the measured levels of exercise adherence.

The minimal significant associations between the adherence measures and clinical health measures did not include any of the clinical health measures that were significantly changed pre-post AEXT. To our knowledge, this study is novel because it is the first study that has evaluated relationships between measured indices of exercise adherence and improvements in physiological markers subsequent to AEXT in a middle-to-older aged African American cohort.

Exercise adherence is not uniformly quantified in clinical research; therefore, this should be taken into account when interpreting and comparing study findings. Currently, there is no gold standard in adherence measurement (6, 32); however, Miller and colleagues suggest that quantifying adherence as cumulative exercise exposure, rather than simply sessions attended, may yield more accurate outcome data (24). Adherence in clinical trials has been measured a number of ways, including pedometry (13), accelerometry (11), self-monitoring through exercise diaries (23), dividing kilocalories expended by kilocalories prescribed (8, 11), and calculating minutes completed within prescribed target heart rate range divided by total minutes prescribed (18). The results of the aforementioned studies collectively have demonstrated favorable outcomes in body composition, clinical markers, and aerobic fitness levels.

Lack of adherence to clinical exercise interventions is another factor contributing to the difficulty in assessing adherence. A number of demographic, physiological, and psychological factors are associated with one's adherence to an exercise program, including cardiovascular disease risk, body mass index, exercise enjoyment, past exercise behavior, social support, and self-efficacy for exercise (10, 33, 36). Several strategies for enhancing adherence have been identified, including cognitive behavioral, social support, and programming approaches. One of the strategies utilized in this intervention was to gradually increase the duration and intensity of exercise throughout the program in order to minimize pain and fatigue, and to maximize feelings of exercise self-efficacy. Additionally, tokens for public transit, as well as complimentary parking, were provided in order to enhance convenience.

In the present study, the amount of exercise each subject completed was objectively quantified by recording frequency and duration, and heart rate monitoring was used to assess intensity. Furthermore, exercise adherence was calculated three ways in order to comprehensively measure and assess the relationship between exercise adherence and physiological adaptations to exercise. The first method of measuring adherence, exercise percentage, was calculated by dividing 24 (the number of weeks comprising the exercise prescription) by the number of weeks it took each subject to complete the 24-week program. If participants did not attend at least two sessions in a given week, they would be required to repeat that week's exercise prescription. A minimum level of 60% adherence percentage was required to continue in the program. This method took into account the adaptations that occur from regular exercise training, as well as the detraining effects that may occur from interrupted participation.

The second method of measuring adherence, exercise volume, was measured by calculating the total minutes of exercise each participant completed while enrolled in the study. Participants who took longer to complete the program typically obtained higher exercise volume scores due to repeating the exercise prescription for specific weeks where they may not have met the

requirements for 2-3 sessions in a given week. According to the ACSM, it is recommended that most adults engage in moderate-intensity cardiorespiratory exercise training for a total of ≥150 minutes per week; however, the exercise program should be modified according to an individual's health status, physical function, habitual physical activity, exercise responses, and stated goals (15). In addition, adults who are unwilling or unable to meet the exercise targets outlined in ACSM's Position Stand may still benefit from engaging in amounts of exercise less than recommended (15). Therefore, this measure of adherence considered whether the total number of minutes achieved by this African American cohort was adequate to elicit favorable physiological adaptations.

In order to account for the variable amount of time it took the participants to complete the 24-week equivalent exercise training program, a third method of measuring adherence was created and each participant's exercise score was determined. This measure was calculated by dividing each participant's total exercise minutes (exercise volume) by the actual number of weeks it took the participant to complete the program. This final method of calculating adherence took into account the frequency of exercise participation, given that participants worked at uniform intensities (beginning at 50% VO_2max and working up to 65% VO_2max). Exercise intensity was closely regulated with study personnel recording participants' exercise heart rates every 10 minutes to ensure they were working at their prescribed intensities. This measurement permitted exercise dose (i.e., intensity, duration, and frequency) to be closely monitored, which is necessary in order to amply interpret outcome variables (26). As previously noted, the exercise scores of participants who were required to repeat weeks of exercise may have been impacted by their higher exercise volumes.

While statistically significant improvements following AEXT in both clinical and vascular health measures were observed in this African American cohort, these improvements were not related to the participants' levels of adherence to the exercise prescription. Only two clinical variables were significantly correlated with exercise adherence in the present study: systolic blood pressure and HDL cholesterol. Systolic blood pressure was positively correlated with exercise volume (total minutes); however, there was no relationship between systolic blood pressure and exercise percentage or exercise score. HDL cholesterol was positively correlated with exercise score, but not exercise percentage or exercise volume. The findings demonstrated that there were no statistically significant differences in systolic blood pressure and HDL cholesterol pre-post AEXT. Further analysis revealed Cohen's effect size value for the change in systolic blood pressure (d=0.06) and the change in HDL cholesterol (d=0.14), and also suggests low practical significance. In addition, none of the vascular health markers were significantly correlated with any exercise adherence measure. Exercise adherence in this population at levels lower than recommended in ACSM's Position Stand may prove to have clinical and vascular health benefits.

Results from the present study indicate that participants benefited from AEXT regardless of their individual level of exercise adherence as defined in this study. Exercise adherence is often difficult to quantify; thus adherence was conceptualized three separate ways in order to

comprehensively measure the construct. These adherence measures were created to complement the experimental design of the present study. Participants in this study improved their vascular health and decreased their risk factors for cardiovascular disease, and these favorable alterations were not associated with the measured indices of adherence to the exercise prescription. This suggests that the axiom, some exercise is better than none, may be particularly true when working with members of this at-risk population. Future studies should continue to accurately quantify adherence in order to assess the exercise dose for improvement in vascular and clinical health.

As previously mentioned, findings from this study demonstrate little significance between levels of exercise adherence and changes in physiological outcomes; however, the current study had a number of limitations that should be addressed. First, the study sample size was relatively small, but this was due to the exclusions to create a more homogenous group in order to eliminate confounding variables that may influence clinical or vascular health markers. Despite the small sample size, significant changes were observed in four clinical outcomes and all but one vascular health marker. Second, it is important to consider that while levels of adherence varied among participants in the current study, participants who were unable to make satisfactory progress toward completion of the program (i.e., not attending at least 60% of sessions) were asked to discontinue participation in the study. Based on the literature, it is reasonable to deduce that excluded participants that fell below this study's minimum adherence requirements would not have experienced similar improvements in clinical and vascular health measures (23, 26, 36). Finally, the sample population was predominantly female African Americans; therefore, our findings may not be generalizable to African American males or other ethnic populations.

Accurately measuring adherence is essential because one must engage in ample AEXT (e.g., frequency, intensity, duration) in order for physiological adaptations to occur, and ultimately, to receive health benefits. In the present study, improvements in clinical and vascular health as a result of AEXT were observed regardless of the variation in the exercise adherence indices measured; however, all of the participants in this cohort met the minimum requirements for adherence as outlined in the study. Given the lack of correlations between levels of exercise adherence and significant improvements in clinical and vascular health measures, achieving high levels of adherence may have less merit; however, this warrants further investigation. Future studies should further examine the role of adherence in the dose-response relationship between AEXT and clinical and vascular health outcomes. Based on these findings, participating in a regular AEXT program below published guidelines for healthy populations in order to achieve minimum physiological benefits may result in unforeseen clinical and/or physiological beneficial effects in certain populations.

ACKNOWLEDGEMENTS

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