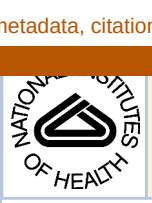

Published in final edited form as:

Hypertension. 2010 May ; 55(5): 1199–1205. doi:10.1161/HYPERTENSIONAHA.109.149153.

THE EFFECTS OF THE DASH DIET ALONE AND IN COMBINATION WITH EXERCISE AND CALORIC RESTRICTION ON INSULIN SENSITIVITY AND LIPIDS

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Abstract

This study examined the effects of the Dietary Approaches to Stop Hypertension (DASH) diet on insulin sensitivity and lipids. In a randomized control trial, 144 overweight (body mass index 25–40) men (N= 47) and women (N= 97) with high blood pressure (130–159/85–99 mm Hg) were randomly assigned to either: (1) DASH diet alone (DASH-A); (2) DASH diet with aerobic exercise and caloric restriction (DASH-WM); or usual diet controls (UC). Body composition, fitness, insulin sensitivity, and fasting lipids were measured before and following 4 months of treatment. Insulin sensitivity was estimated based on glucose and insulin levels in the fasting state and after an oral glucose load. Participants in the DASH-WM condition lost weight (−8.7 [95% CI = −2.0, −9.7] kg,), and exhibited a significant increase in aerobic capacity, while the DASH-A and UC participants maintained their weight (−0.3 [95% CI = −1.2, 0.5] kg and +0.9 [95% CI = 0.0, 1.7] kg, respectively) and had no improvement in exercise capacity. DASH-WM demonstrated lower glucose levels following the oral glucose load, improved insulin sensitivity, and lower total cholesterol and triglycerides compared to both DASH-A and UC, and lower fasting glucose and low-density lipoprotein cholesterol compared to UC; DASH-A participants generally did not differ from UC in these measures. Combining the DASH diet with exercise and weight loss resulted in significant improvements in insulin sensitivity and lipids. Despite clinically significant reductions in blood pressure, the DASH diet alone, without caloric restriction or exercise, resulted in minimal improvements in insulin sensitivity or lipids.

Keywords

Diet; Hypertension; Lipids; Insulin Resistance; Exercise

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Clinical Trial Registration: clinicaltrials.gov Identifier: NCT00571844

Disclosures

None reported.

Introduction

High blood pressure (HBP) affects more than 70 million Americans and is among the most common reasons for outpatient visits to physicians' offices[1]. Although HBP can be lowered pharmacologically[2, 3] anti-hypertensive medications may be costly, oftentimes must be used in combination to achieve adequate blood pressure (BP) control, and can be associated with side effects that impair quality of life and reduce adherence[2, 4]. Moreover, metabolic abnormalities associated with HBP, such as insulin resistance and hyperlipidemia, may persist or may be exacerbated by some medications[5]. Consequently, there is great deal of interest in the use of non-pharmacologic interventions in the prevention and management of HBP.

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7)[6] recommends that lifestyle modifications such as weight loss and regular aerobic exercise be the initial treatment strategy for lowering HBP, and specifically recommends the Dietary Approaches to Stop Hypertension (DASH) diet-- a diet rich in fiber, fruits, vegetables and low-fat dairy products, and low in fat. This diet was established as efficacious in reducing BP in a series of 4 to 8 week "feeding" trials, in which HBP patients were provided DASH meals in a controlled environment[7, 8]. A subsequent randomized trial to examine the efficacy of the DASH diet in an outpatient setting, the PREMIER study[9] demonstrated that the DASH diet could be successfully implemented in free-living persons. Both "established" JNC 6[10] recommendations and the JNC 6 recommendations plus the DASH diet (i.e., JNC 7 recommendations[6]) were associated with significant BP reductions compared to *advice only* controls. In an ancillary study, Ard et al.[11] reported results from a subsample of 52 PREMIER participants who received an oral glucose tolerance test (OGTT) at baseline and following 6-months of treatment. Those who received the "established" intervention with or without the DASH diet showed greater improvements in fasting insulin and glucose compared to controls, but only the "established plus DASH" intervention achieved greater improvements in insulin sensitivity. However, because participants in the "established plus DASH" treatment tended to lose more weight and reduce their waist circumference compared to participants in both the advice only control condition and the JNC 6 "established" intervention condition, the incremental benefit of the DASH diet to lifestyle modifications of weight loss, exercise, and sodium restriction could not be determined.

In an effort to examine the independent and combined effects of the DASH diet and weight loss plus exercise on BP and biomarkers of risk, the ENCORE study examined 4 months of treatment with the DASH diet alone, without exercise or weight loss (DASH-A), or the DASH diet combined with a behavioral weight management program including caloric restriction and aerobic exercise (DASH-WM), in 144 men and women with HBP[12]. Results showed that both DASH-A and DASH-WM were associated with larger BP reductions compared to a usual diet control (UC) group, although the DASH-WM condition achieved larger BP reductions and greater improvements in such cardiovascular biomarkers as pulse wave velocity, baroreflex sensitivity, and left ventricular mass. The present study reports the findings from the ENCORE study on the secondary outcomes of insulin sensitivity and lipids.

Methods

Participants

As described in our primary paper[12], the ENCORE trial enrolled 144 healthy, but overweight adults with HBP (Figure 1). Persons were eligible if they were not taking anti-hypertensive medication and had a mean systolic blood pressure (SBP) 130–159 or diastolic blood pressure (DBP) 85–99 mm Hg averaged over four separate BP screening visits. Potential participants were asked to refrain from smoking or ingesting caffeine for at least 30-min prior to their

appointment time. BP measurements were standardized for cuff size, position, environment, and time of day. Other inclusion criteria included age 35 years or older, body mass index (BMI) of 25–40 kg/m^2, sedentary (i.e., not engaged in regular exercise), and no other medical comorbidities that would preclude safe participation in the trial, including diabetes requiring insulin or oral hypoglycemic agents. Clinic BPs were determined according to JNC 7 guidelines using a standard mercury sphygmomanometer and stethoscope.

Trial Overview

The ENCORE study was approved by the Institutional Review Board at Duke University Medical Center and written informed consent was obtained from all participants. Following completion of a series of baseline assessments (see below), participants were randomized to the DASH diet alone (DASH-A) or the DASH diet combined with a behavioral weight management program (DASH-WM), or to usual diet controls (UC). At the conclusion of the 4-month treatment period, assessments were repeated.

Assessments of Body Composition, Dietary Content, and Aerobic Fitness

Body weight was measured by a standard balance scale with participants dressed in light clothing without shoes. Body composition and fat distribution were assessed by dual energy absorptiometry (DEXA). This procedure provides measurements of fat mass, lean body mass, and percent body fat for both the whole body and designated anatomical subregions[13]. An independent assessment of dietary and nutritional content was obtained by two separate self-report measures of diet: a retrospective food frequency questionnaire (FFQ)[14], requiring participants to recall typical consumption over a 4-week period, and a 4-day food diary. The FFQ was analyzed by NutritionQuest (Berkeley, CA), while the diary data were analyzed using Food Processor SQL Edition software (version 10.3, ESHA Research, Salem, OR)[15]. Fitness was measured with a maximal graded exercise treadmill test in which workloads were increased at a rate of one metabolic equivalent per minute[16]. Expired air was collected by mouthpiece for quantification of minute ventilation, oxygen consumption, and carbon dioxide production with a Parvo Medics True One measurement system (Model 2400; Parvo Medics, Sandy, Utah).

Assessments of Insulin Sensitivity and Lipids

Measures of glucose tolerance and insulin sensitivity were based on results of an oral glucose tolerance test (OGTT) using an oral glucose load of 75g, with measurement of plasma glucose (by Beckman auto-analyzer) at 0, 30, 60, 90, and 120 minutes and insulin (by double-antibody radioimmunoassay) at 0 and 120 minutes. Insulin sensitivity was assessed using the quantitative insulin sensitivity check index (QUICKI), as described by Katz, et al.[17] and using a method based on dynamic glucose and insulin levels -- the Insulin Sensitivity Index ($ISI_{0,120}$), as described by Gutt, et al[18]. Both of these surrogate measures of insulin sensitivity provide estimates of insulin sensitivity that correlate closely with glucose clamp measurements and are predictive of the onset of type 2 diabetes[19, 20].

Lipid profiles, including total cholesterol, high-density lipoprotein (HDL)- and low-density lipoprotein (LDL)-cholesterol, very-low-density lipoprotein (VLDL)-cholesterol, and triglycerides were obtained from fasting blood samples drawn between 0800 and 0900 hrs; assays were measured enzymatically (Labcorp Inc, Burlington, NC).

Randomization

Upon completion of the baseline assessments, patients were randomized in blocks of 2–5 participants. Participants were provided their group assignments in sealed envelopes; staff performing assessments was unaware of participants' treatment group assignments. Assignments were stratified by baseline clinic BP, BMI, and age.

Interventions

Immediately following randomization, participants received 2-week controlled feeding on the Duke Clinical Research Unit, in which they ate the assigned dietary patterns (controlled usual diet, DASH diet or a reduced calorie DASH diet). Participants ate their evening meal on the unit, and took home their breakfast, lunch and snack for the following day. The controlled feeding period was modeled after the original DASH feeding studies[7, 8]. Participants in the DASH-A and UC conditions consumed study meals isocalorically for weight maintenance, whereas the caloric level in the DASH-WM arm was set at a 500 calories per day deficit to allow weight loss of about 0.5–1.0 pound a week.

After the first 2 weeks of controlled feeding, participants were instructed to maintain the DASH diet either with (DASH-WM) or without weight loss (DASH-A). Participants in the DASH-A condition met weekly with a nutritionist and modified the content of their diet to meet DASH guidelines but did not exercise or attempt to lose weight.

Participants in the DASH-WM condition received the same instruction in the DASH diet from the same nutritionist as in the DASH-A group, but also met with a clinical health psychologist who provided a structured, cognitive behavioral weight loss intervention that employed cognitive behavioral strategies[21] and appetite awareness training[22]; the DASH recommendations provided participants with guidance regarding *what* to eat, while weight management (WM) was designed to help individuals learn *when*, *how*, and *how much* to eat. Participants also engaged in supervised exercise 3-times per week for 30 minutes at a level of 70–85% of their initial heart rate reserve determined during their baseline treadmill test.

Participants in the UC condition were asked to maintain their usual dietary and exercise habits for 4 months until they were re-evaluated. Weight and BP were monitored biweekly.

Statistical Analysis

Treatment effects were evaluated using the general linear model in the SAS 9.1 software (SAS Institute, Cary, NC), with separate models for each outcome. Each model included treatment condition as a three-level factor, and the corresponding pre-treatment value of the outcome, age, gender, and ethnicity (Caucasian vs. non Caucasian) as adjustment covariables. We compared post-treatment group means using pairwise treatment group comparisons that were adjusted using Tukey's Honestly Significant Difference procedure. Data for all outcomes were analyzed following the intent-to-treat principle, with missing data managed using the multiple imputation method available in SAS PROC MI. For a given outcome, we estimated that we would have about 80% power to detect a 0.5 standard deviation difference between the active treatments and UC, and a 0.6 standard deviation difference between DASH-A and DASH-WM.

Results

Participant flow

As described previously[12], 3129 participants initially inquired about the study, 447 met our initial inclusion criteria, and 144 participants were randomized to the DASH-WM (N=49); DASH-A (N=46); or UC (N=49). Post-treatment glucose and lipid data were available for 46 participants in DASH-WM, 44 in DASH-A, and 48 in UC. For body composition variables, post-treatment data were available for 46 participants in DASH-WM, 46 in DASH-A, and 47 in UC.

Participant characteristics

Table 1 displays the demographic and medical characteristics of the sample across the three treatment groups at baseline. On average, participants were 52 years old; 39% were African

American and 67% were women. The mean clinic BP was 138/86 mm Hg. The majority of participants were college-educated and relatively affluent. The groups were generally comparable across the background variables.

Adherence to protocol

Attendance to the exercise and diet classes was excellent. DASH-WM participants attended 90% (median = 38) of scheduled exercise sessions and spent most time (median = 94%) at or above their target heart rate training range. DASH dietary class attendance also was excellent, with the median number of sessions attended 12 (92%) in both intervention groups. As reported previously[12], compared to DASH-A and UC, participants in DASH-WM on average consumed significantly fewer total calories (1648 [95% CI = 1521–1774] kcal, 1962 [95% CI = 1833–2090] kcal, 2095 [95% CI = 1961–2228] kcal for DASH-WM, DASH-A, and UC respectively), and both DASH conditions consumed more calories from protein (19.5%, 19.4%, 16.7% for DASH-WM, DASH-A, and UC respectively), less saturated fat (26.3%, 27.8%, 36.8% for DASH-WM, DASH-A, and UC respectively), and more fiber (25g, 26g, 16 g for DASH-WM, DASH-A, and UC respectively) compared to those in UC (P's < .001).

Changes in body weight and body composition

Adjusting for baseline weight, age, gender, and ethnicity, the mean post-treatment weight for the DASH-WM group was significantly lower (84.5 kg) compared to DASH-A (92.9 kg; $p < .001$) and to UC (94.1 kg; $p < .001$). The weight change was −8.7 kg in DASH-WM, −0.3 kg in DASH-A, and +0.9 kg in UC.

Following treatment, the DASH-WM group showed lower percent body fat and trunk fat compared to DASH-A and UC (Table 2). DASH-WM also had lower lean body mass compared to the other groups. DASH-A did not differ significantly from UC on any body composition measure.

Changes in aerobic fitness

Adjusting for pretreatment levels, age, gender, and ethnicity, the mean post-treatment peak maximal oxygen consumption (VO_2) was higher in DASH-WM (29 ml/kg/min) compared to DASH-A (23 ml/kg/min, $p < .001$) and UC (22 ml/kg/min) ($p < .001$). Participants in the DASH-WM group showed a 19% increase in peak VO_2, compared to small, and non-significant, decreases in the DASH-A (−1.2%) and UC (−3.2%).

Glucose Tolerance and Insulin Sensitivity

Results of the OGTT revealed that participants in the DASH-WM condition achieved greater improvements in glucose response compared to DASH-A and UC (Figure 2). Compared to UC, participants in the DASH-WM group showed lower fasting glucose levels (Table 3). DASH-WM also exhibited lower glucose AUC and greater insulin sensitivity, as measured by both QUICKI and $ISI_{0,\ 120}$ compared to DASH-A or UC. DASH-A did not differ from UC on any measure of glucose metabolism or insulin sensitivity.

We also noted that 24% (N = 34) of participants were considered overweight (BMI = 25–29.9), while 76% (N = 110) were considered obese (BMI >30) at baseline. The treatment group by BMI interaction was not significant, however, for glucose AUC ($p = .385$), QUICKI ($p = .528$), or $ISI_{0,\ 120}$ ($p = .142$), suggesting that pre-treatment body weight did not moderate the effects of treatment on glucose metabolism or insulin sensitivity.

In a *post hoc* analysis, participants were classified as diabetic (>199 mg/dl), pre-diabetic (141–199 mg/dl), or normal (<140 mg/dl) based upon their glucose levels at 2 hrs during the OGTT. Overall, 72% (N=13) of the 18 participants in DASH-WM who were either prediabetic or

diabetic at study entry improved by at least one category over the course of the trial, compared to 54% (7/13) in DASH-A and 42% (8/19) in UC. Among participants who were either not diabetic or pre-diabetic upon study entry, diabetic classification worsened in only 2% (1/44) of participants in DASH-WM, compared to 16% (7/43) in DASH-A and 11% (5/46) in UC.

Serum Lipids

Participants in the DASH-WM group obtained significantly lower total cholesterol and triglyceride levels compared to DASH-A and UC participants and lower LDL-cholesterol levels compared to UC, but not DASH-A (Table 4). Participants in DASH-A had marginally lower HDL-cholesterol levels than UC, but otherwise participants in DASH-A were not different from UC participants on any other lipid measure.

Discussion

Our findings demonstrate that adherence to the DASH diet alone, although sufficient to modify BP values[12], resulted in significant improvements in metabolic indices of cardiovascular risk only when accompanied by aerobic exercise and weight loss. In the DASH-WM group, participants lost an average of 19 pounds over 4 months and increased their aerobic capacity by 19%. While both the DASH-A and DASH-WM groups achieved clinically meaningful reductions in BP and improvements in other cardiovascular biomarkers of risk, as described in our earlier publication[12], only DASH-WM participants demonstrated significant improvements in glucose tolerance and insulin sensitivity.

Although the DASH diet has been shown to reduce BP in controlled “feeding” studies[7, 8] and in studies of free living individuals[9, 12] the present study found that ENCORE participants who adhered to the DASH diet but did not exercise or lose weight achieved minimal improvements in glucose metabolism or insulin sensitivity, and also in lipids, relative to controls. Our findings contrast with results from the PREMIER substudy[11], in which addition of the DASH diet to an established intervention of weight loss, reduced sodium intake, increased physical activity, and moderation of alcohol intake resulted in a significant improvement in insulin sensitivity relative to controls. However, because there was no difference in insulin sensitivity between groups randomized to the established intervention with or without the DASH diet, and there was a trend toward greater weight loss in the DASH group, the added value of the DASH diet is uncertain. The present ENCORE study findings indicate that despite DASH-related reductions in BP[12], the DASH diet by itself produced minimal improvements in insulin sensitivity.

Our study was designed to evaluate only the DASH diet, and it is possible, even likely, that other diets, either alone or combined with exercise, could be beneficial. Many studies have examined the impact of various diets on weight loss[23–26]. Sacks et al.[23], for example, randomized overweight adults to one of four diets in which the targeted percentages of energy derived from fat, protein and carbohydrates varied. After 2 years, groups achieved similar benefits in weight loss and lipid-related risk factors and fasting insulin levels. It was concluded that reduced calorie diets result in significant weight loss regardless of the macronutrient content. Foster and colleagues[25] reported that a low carbohydrate, high protein and high fat (Atkins) diet was associated with greater weight loss after 6 months compared to a conventional low fat, low calorie, high carbohydrate diet, but that the differences were not significant after 12 months. With respect to body composition, the present findings confirm the results of previous findings suggesting that a low fat, weight loss diet (50% carbohydrate, 30% fat, 20% protein) results in reduced lean body mass. However, very low carbohydrate diets have been found to result in even greater reductions in weight and lean body mass compared to low fat diets[27–29]. Lipid changes were generally similar over time, and both diets were associated with lower DBP and insulin response to an oral glucose load.

While weight loss is associated with improved lipids, particularly LDL-cholesterol[30], and increased insulin sensitivity[31–33], diet composition also may affect lipids and glucose metabolism independent of weight loss. For example, with a 4-week, isocaloric weight maintenance diet, both the Ornish diet and South Beach diet have been shown to favorably reduce lipids, while high fat diets may be associated with increased LDL and total cholesterol levels[34]. However, the number of calories consumed appears to be more important relative to the content of the calories with regard to the development of diabetes[35].

Exercise also was a key component of the DASH-WM intervention, but its effects on insulin sensitivity could not be determined independent from weight loss. Although exercise is widely considered to be important for successful weight loss, studies of the effects of exercise in the absence of weight loss on glucose, insulin sensitivity and lipids have produced mixed results. Exercise has been shown to improve insulin sensitivity, either due to chronic effects of exercise training or to the residual effects of acute exercise. Studies of both healthy adults and patients with type 2 diabetes have demonstrated that improved insulin sensitivity is maintained up to 16 hr after a single bout of exercise[36, 37] but may be diminished 60 hours after the final exercise training session[38, 39]. Some studies have demonstrated that exercise training is associated with reduced glucose levels and improved glycemic control[40–44], while others have not[45–50]. Because studies that have shown improvements in glucose control after exercise training have not established that these effects are due to exercise independent of weight loss[51], the extent to which the exercise component of the DASH-WM condition contributed to the metabolic improvements observed in the ENCORE study is not known. The effects of exercise training on lipids also have provided mixed results[52] although recent evidence suggests that high levels of exercise without weight loss may be required to achieve improvements in lipid and lipoprotein variables[53].

Finally, it should be noted that some studies also have suggested that obesity may moderate the effects of exercise training on insulin sensitivity. Poirier et al.[48], for example, reported no improvement in insulin sensitivity in obese type 2 diabetic patients after 12 weeks of aerobic training, although insulin sensitivity was improved in nonobese type 2 diabetic subgroups. Our data, in overweight but non-diabetic patients revealed no evidence that obesity moderated the effects of treatment. Therefore, our findings suggest that the improvements in insulin sensitivity observed in the DASH-WM intervention are generalizable to both obese and non-obese populations.

Perspectives

In summary, the results of the ENCORE study indicate that while the DASH diet alone can reduce BP in overweight, sedentary adults with HBP, there was little evidence that the DASH diet improved insulin sensitivity or lipids without the addition of exercise and weight reduction. It would appear that caloric consumption rather than nutrient composition is most salient for improved metabolic function.

Acknowledgments

Sources of Funding

Supported by grants from the National Heart, Lung, and Blood Institute (HL074103) and the General Clinical Research Center, National Institutes of Health (M01-RR-30). This publication was made possible by Grant Number 5UL1RR024128-03 from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH), and NIH Roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NCRR or NIH. There are no conflicts of interest to report. The principal investigator (JAB) had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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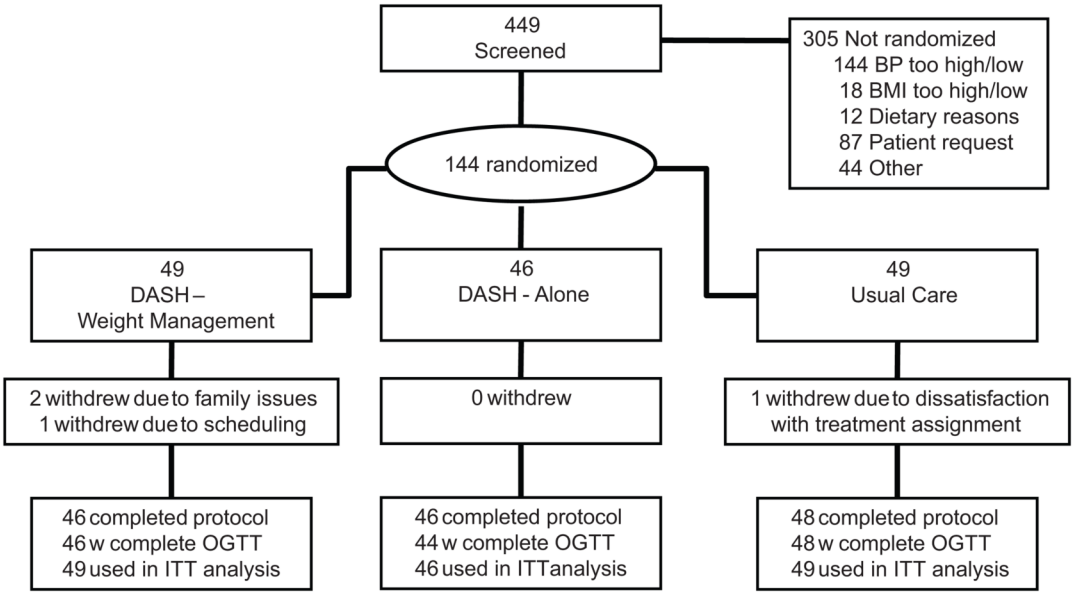

Figure 1.
Participant flow in the ENCORE clinical trial. OGTT indicates oral glucose tolerance test; ITT refers to intent-to-treat.

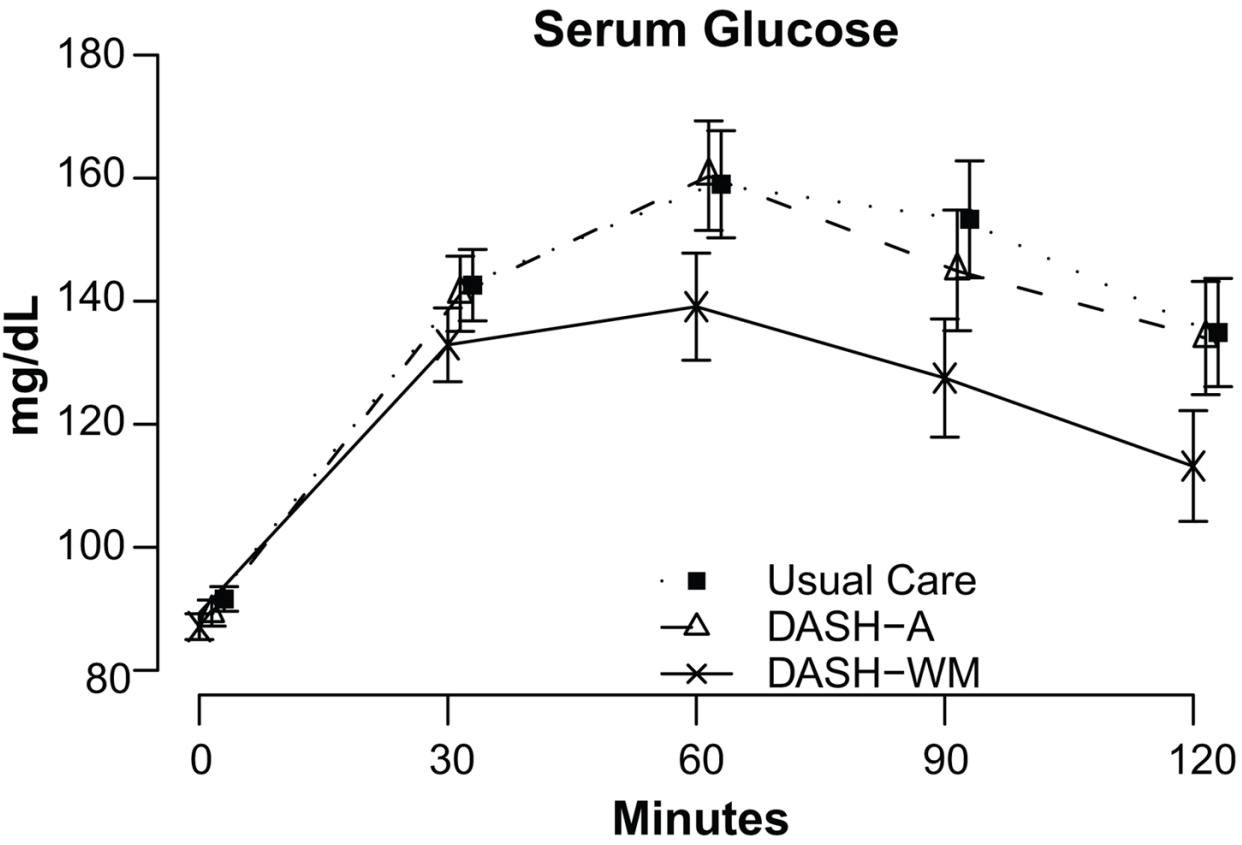

Figure 2.
Post-treatment glucose response during oral glucose tolerance test. Values are adjusted for pretreatment glucose levels, gender, age, and ethnicity. Error bars represent 95% confidence limits.

Table 1

Background characteristics of the sample

Demographics	DASH-WM N=49	DASH-A N = 46	UC N = 49	All N = 144
Age (years)	52.3 (10)	51.8 (10)	51.8 (9)	52.0 (10)
Gender: Female	69% (34)	63% (29)	69% (34)	67% (97)
Ethnicity				
Caucasian	69% (34)	50% (23)	59% (29)	60% (86)
African American	31% (15)	48% (22)	39% (19)	39% (56)
Asian	0% (0)	2% (1)	2% (1)	1% (2)
Level of Education				
High School	31% (15)	30% (14)	42% (20)	34% (49)
Some College	8% (4)	9% (4)	14% (7)	11% (15)
Completed College	29% (14)	30% (14)	18% (9)	22% (32)
Post-Graduate School	20% (10)	28% (13)	20% (10)	24% (34)
Other	12% (6)	13% (6)	2% (1)	9% (13)
Weight (kg)	93.9 (14)	93.0 (14)	92.6 (15)	93.1 (14.1)
BMI (kg/m^2)	33.5 (4.4)	32.8 (3.4)	33.0 (3.9)	33.1 (3.9)

Values are mean (standard deviation) for continuous variables and group percent (n) for categories.

Table 2

Body Composition (DEXA) measures before and after treatment

		Treatment Group			P-value from pairwise comparison after treatment		
Variable		**DASH-WM**	**DASH-A**	**UC**	**DASH-WM vs. DASH-A**	**DASH-WM vs. UC**	**DASH-A vs UC**
Total % Body Fat	Before	37.6 (35.5, 39.7)	35.4 (33.2, 37.5)	36.4 (34.3, 38.5)			
	After	33.1 (32.4, 33.8)	36.2 (35.5, 36.8)	36.9 (36.2, 37.6)	< .001	< .001	.293
Total Lean Body Mass (Kg)	Before	56.0 (53.0, 59.1)	57.5 (54.2, 60.7)	56.7 (53.7, 59.8)			
	After	54.3 (53.8, 54.9)	56.8 (56.2, 57.4)	56.5 (55.9, 57.0)	< .001	< .001	.694
Total Trunk Fat (Kg)	Before	17.7 (16.4, 19.0)	16.2 (14.9, 17.5)	16.9 (15.6, 18.2)			
	After	13.6 (13.1, 14.1)	16.6 (16.1, 17.1)	17.1 (16.7, 17.6)	< .001	< .001	.217

Values are mean and 95% confidence interval. Values after treatment are adjusted for pretreatment levels of outcome variable, age, gender, and ethnicity. P-values are adjusted using Tukey's Honestly Significant Difference procedure.

Table 3

Glucose and insulin values before and after treatment

Variable		Treatment Group			P-value from pairwise comparison after treatment		
		DASH-WM	DASH-A	UC	DASH-WM vs. DASH-A	DASH-WM vs. UC	DASH-A vs UC
Fasting glucose (mg/dl)	Before	89.4 (86.4, 92.3)	90.4 (87.3, 93.5)	91.3 (88.4, 94.3)			
	After	87.2 (85.1, 89.3)	89.4 (87.3, 91.5)	91.9 (89.9, 93.9)	.324	.006	.214
Fasting insulin (μU/ml)	Before	18.1 (15.7, 20.4)	16.6 (14.2, 19.0)	18.0 (15.7, 20.3)			
	After	12.5 (10.8, 14.3)	17.6 (15.9, 19.4)	18.6 (16.9, 20.2)	< .001	< .001	.711
Glucose AUC (mg/dl· minutes)	Before	6057 (5221, 6893)	6087 (5224, 6951)	6345 (5508, 7181)			
	After	4947 (4340, 5554)	6238 (5637, 6838)	6334 (5756, 6912)	.011	.005	.958
$ISI_{0,120}$ ($mg \cdot L^2/mmol \cdot \mu U \cdot min$)	Before	74.4 (67.1, 81.8)	70.9 (63.5, 78.3)	66.0 (58.8, 73.2)			
	After	75.3 (71.8, 78.8)	68.7 (65.1, 72.3)	68.8 (65.4, 72.2)	.031	.026	.981
QUICKI	Before	0.319 (0.313, 0.325)	0.319 (0.313, 0.325)	0.315 (0.309, 0.321)			
	After	0.334 (0.329, 0.339)	0.318 (0.313, 0.323)	0.316 (0.312, 0.321)	< .001	< .001	.850

Values are mean and 95% confidence interval. Values after treatment are adjusted for pretreatment levels of outcome variable, age, gender, and ethnicity. P-values are adjusted using Tukey's Honestly Significant Difference procedure.

Hypertension. Author manuscript; available in PMC 2011 May 1.

Table 4

Serum lipids before and after treatment

		Treatment Group			P-value from pairwise comparison after treatment		
Variable		**DASH-WM**	**DASH-A**	**UC**	**DASH-WM vs. DASH-A**	**DASH-WM vs. UC**	**DASH-A vs UC**
Total Cholesterol (mg/dl)	Before	209 (198, 220)	199 (188, 211)	206 (195, 217)			
	After	184 (177, 199)	199 (192, 205)	205 (199, 211)	.008	< .001	.364
Low Density Lipoprotein-Cholesterol (mg/dl)	Before	128 (118, 138)	122 (112, 132)	126 (116, 136)			
	After	112 (106, 117)	122 (116, 127)	125 (119, 130)	.054	.005	.715
High Density Lipoprotein-Cholesterol (mg/dl)	Before	55 (50, 59)	53 (49, 57)	55 (51, 59)			
	After	54 (52, 55)	51 (50, 53)	54 (53, 56)	.115	.911	.047
Triglycerides (mg/dl)	Before	133 (116, 149)	122 (106, 139)	122 (106, 139)			
	After	93 (81, 106)	129 (117, 142)	130 (118, 142)	< .001	< .001	.900

Values are mean and 95% confidence interval. Values after treatment are adjusted for pretreatment levels of outcome variable, age, gender, and ethnicity. P-values are adjusted using Tukey's Honestly Significant Difference procedure.