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Racial differences in relative skeletal muscle mass loss during diet induced weight loss in women

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Abstract

Objective—It is unclear whether there are race-specific differences in the maintenance of skeletal muscle during energy restriction. We compared changes in relative skeletal muscle index [RSMI (limb lean tissue/height^2)] following: 1) diet alone (DIET); 2) diet + aerobic training (DAT) or; 3) diet + resistance training (DRT).

Methods—Overweight, sedentary African American (AA; $n = 72$) and European American (EA; $n = 68$) women were provided an 800 kcal/day diet to reduce BMI < 25 kg/m^2. Regional fat-free mass was measured with DXA. Steady-state VO_2 and heart rate responses during walking were measured.

Results—AA women had greater RSMI and preserved RSMI during DIET while RSMI was significantly reduced among EA (EA −3.6% *vs.* AA +1.1%; $p < 0.05$). DRT subjects retained RSMI (EA +0.2% *vs.* AA +1.4%; p=0.05), whereas DAE subjects decreased RSMI (EA −1.4% *vs.* AA −1.5%; p<0.05). Maintenance of RSMI was related to delta walking ease and economy.

Conclusions—Compared to AA, EA women are less muscular and lose more muscle during weight loss without resistance training. During diet-induced weight loss, resistance training preserves skeletal muscle especially among premenopausal EA women. Maintenance of muscle during weight loss associates with better ease and economy of walking.

Keywords

resistance training; aerobic training; limb lean tissue

Introduction

Weight loss is usually associated with the loss of fat-free mass (FFM). Although, organ mass and bone mass may be lost, the majority of fat-free mass loss is likely skeletal muscle (1).

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Decreased skeletal muscle can impair locomotion economy and ease (2) and contribute to reduced non-exercise activity thermogenesis (NEAT) (2;3). Exercise training, especially resistance training, has been shown to be successful in increasing skeletal muscle mass and NEAT (4–6). In addition, loss of FFM has been shown to be retained for individuals who resistance train during diet induced weight loss (7;8).

Sarcopenia refers to a progressive age-related loss in skeletal muscle mass. Decreased skeletal muscle mass accelerates with age (6), as 13–24% of individuals < 70 years are sarcopenic whereas over 50% of individuals >80 years are sarcopenic (9) ; (10). Low relative skeletal muscle mass can lead to loss of function, decreased physical activity, and potentially weight gain in older populations (9). Normally sarcopenia refers to older individuals, although it can occur in relatively young individuals. Since loss of muscle is an on-going process as we age, identification of individuals who are vulnerable for sarcopenia before it becomes problematic may be important. Because of the inherent risk of skeletal muscle loss during energy restriction this may be essential when individuals are undergoing weight loss. Identifying individuals who are sarcopenic or “pre-sarcopenic is not possible unless stature as well as skeletal muscle mass are considered. Baumgartner et al (9) suggests a simple measure that can used to objectively quantitate muscle relative to height, thus offering a measure that can be used to identify sarcopenia. This measure is obtained by dividing limb lean tissue by height squared (defined as relative skeletal muscle index, RSMI). Different researchers have proposed RSMI sarcopenic cut-points varying from 5.14 to 7.36 kg/m^2 (9;11;12).

Low relative skeletal muscle mass (RSMI) can lead to loss of function, decreased physical activity, and potentially weight gain in older populations (9). Decreased function is apparent in even relatively young individuals, especially women (13;14) when relative skeletal muscle mass is low but can be improved when individuals resistance train (2;5;15). Fat-free mass (8) and relative skeletal muscle mass has been reported to be greater in African Americans (AA) than European Americans (EA) (6). Although AA may lose less fat-free mass following weight loss (8) no one has compared the losses of RSMI between different weight loss interventions. In addition, it is not clear how loss of RSMI may affect ease and economy during locomotion.

Therefore, the purpose of the paper is to compare loss of RSMI following diet induced weight loss (DIET), diet induced weight loss with aerobic training (DAE), and diet induced weight loss with resistance training (DRT) in a cohort of AA and EA women. We hypothesize that AA women will have higher RSMI and will lose less RSMI than EA women during weight loss, but there will be no ethnic by group interaction difference (EA and AA women will respond similarly to the three interventions) in change of RSMI. Walking ease and economy have been associated with increased free living activity and reduced weight gain following weight loss (3;4;16;17), suggesting that factors that may impact walking ease and economy may be important for weight maintenance and metabolic health. Therefore a secondary aim was to observe the relationship between change in RSMI and change in walking economy after weight loss. We also hypothesize that decreased RSMI change will be positively associated with ease of walking on the flat and up a grade but negatively related to change in netVO_2 (increase in walking economy).

Methods

This study is a secondary analysis from a study designed to identify metabolic factors that predispose women to weight gain (Exercise training in post-obese Black and White women). Overweight (BMI > 27 and < 30 kg/m^2) women (72 AA and 68 EA) between the ages of 20–44 years who had not exercise trained during the prior year served as subjects. Race designation was self-selected. The women had a family history of obesity, experienced regular menstrual cycles, did not have a history of diabetes and had normal glucose tolerance, were sedentary, and did not take metabolism altering medication. All were tested at baseline after a 4 week weight stabilization period during which the subjects were weighed 3 times/week with food provided during the last 2 weeks. After evaluation they were randomly group assigned by race, age, and BMI to one of three groups: 1) Weight loss with aerobic exercise training 3 times/week (DAE); 2) Weight loss with resistance exercise training 3 times/week (DRT); and 3) weight loss without exercise training (DIET). During weight loss, the subjects were provided an 800 kcal diet until a BMI <25 kg/m^2 was reached. For four weeks after weight loss food was provided and subjects remained weight stable. The macronutrient content furnished by the General Clinical Research Center (GCRC) kitchen was 20–22% fat, 20–22% protein, and 56–58% carbohydrate both during weight loss and during weight stable time periods. Women were admitted to the GCRC 2 days prior to all testing to ensure that physical activity and diet was standardized. Testing was done in a fasted state in the morning after spending the night in the GCRC. The study was approved by the University of Alabama at Birmingham Institutional Review Board and informed consent was obtained from all subjects.

Exercise training

Exercise training occurred in a 1600 square foot exercise training facility devoted to research. All training was supervised by an exercise physiologist and was scheduled to occur 3 times each week. Both aerobic and resistance trainers warmed up with 5 minutes of walking and 3–5 minutes of stretching.

Aerobic Training

Continuous treadmill walking/jogging was used as the mode for aerobic training. Subjects did 20 min of continuous exercise at 67% maximum heart rate during the first week of training. Duration and intensity increased each week so that by the beginning of the eighth week, subjects exercised continuously at 80% of maximum heart rate for 40 minutes. Subjects were encouraged to increase intensity (either speed or grade) when average exercise heart rate was consistently below 80% of maximum heart rate. After the exercise session, subjects cooled down for 3–5 min with gradually decreasing exercise intensity.

Resistance training

The resistance training consisted of **s**quats, leg extension, leg curl, elbow flexion, triceps extension, lateral pull-down, bench press, military press, lower back extension, and bent leg sit-ups. After one week of familiarization (training with a light weight) one repetition maximum (1 RM) was measured. The first week following the 1 RM tests one set of 10 repetitions was performed at 65% 1 RM, with percent of 1 RM increasing on subsequent weeks until week four intensity was at 80% 1 RM. Starting at week five, two sets of 10 repetitions were attempted at 80% 1 RM for each exercise with 2 min rest between sets. Strength was evaluated every five weeks, and adjustments in training resistance were made based on the most current 1 RM.

Resting oxygen uptake/energy expenditure

Prior to weight loss and after weight loss three consecutive mornings in a fasted state and after an overnight stay in the General Clinical Research Center resting oxygen uptake and resting energy expenditure (REE) was determined between 6:00 and 6:50 a.m. Subjects remained awake in a quiet, softly lit, well-ventilated room in which temperature was maintained between 22 and 24 °C. Subjects laid supine on a comfortable bed and oxygen uptake was measured using a ventilated hood system. After resting for 15 minutes, oxygen uptake was measured for 30 minutes with a computerized, open-circuit indirect calorimetry system (Delta Trac II, Sensor Medics, Yorba, CA, USA). The last 20 minutes was used for analysis. Oxygen uptake values used in the determination of exercise net VO_2 (i.e. exercise VO_2 – resting VO_2) were means of the 3 morning values. The coefficient of variation for repeat VO_2 measures is < 4% in our lab.

VO_2max

A maximal modified Bruce protocol was used to determine VO_2max (18). Heart rate was measured using a POLAR Vantage XL heart rate monitor (Gays Mills, WI, USA). Oxygen uptake and carbon dioxide production were measured continuously using a MAX-II metabolic cart (Physiodyne Instrument Corporation, Quogue, NY). Gas analyzers were calibrated with certified gases of known concentrations. Standard criteria for heart rate (heart rate within 10 beats/min of estimated maximum), respiratory exchange ratio (RER above 1.2), and plateauing were used to ensure achievement of VO_2max. The coefficient of variation for repeat measures of VO2max are less than 3% in our lab.

Ease and Economy of Physical Activity

Heart rate (HR) and oxygen uptake (VO_2) were obtained during treadmill walk on the flat (4.8 km/hr), and a 2.5% grade treadmill walk (4.8 km/hr). The duration of each of the tasks was between 4 and 5 minutes and steady state was obtained. Oxygen uptake and carbon dioxide production were also measured using a MAX-II metabolic cart (Physiodyne Instrument Corporation, Quogue, NY). Net oxygen uptake (work steady state VO_2 minus resting VO_2) is reported in ml O_2/kg/min and is considered exercise economy for walking and stair climbing. HR increases as the intensity of exercise increases. Therefore, HR is considered an index of exercise difficulty.

DXA

Dual-energy X-ray absorptiometry (Lunar DPX-L densitometer; LUNAR Radiation, Madison WI) was used to determine total fat and FFM as well as arm and leg lean tissue according to the manufacturer’s instructions. Adult Software, version 1.33, was used to analyze the scans. RSMI was calculate by dividing limb lean (arm + leg) lean tissue by height squared.

SES

Socio-economic status (SES) was assessed using the Hollingshead 4-factor index of social class (19). This questionnaire derives SES from the occupational status and educational attainment of the participant and her spouse, if applicable, with higher scores reflecting greater SES.

Statistics

A three (group) by two (race) analysis of variance (ANOVA) was run for all the descriptive variables to identify any differences between groups and race. Two (time) by three (group) by two (race) analysis of variance (ANOVA) was run for RSMI with repeated measures on time. Multiple regression models for estimation of delta net oxygen uptake and heart rate during flat and grade walking test (Mean ± SE) with delta VO2max, delta RSMI, and race serving as independent variables.). Bonferroni corrected *post hoc t*-tests were run on contrasts of interest. SPSS was used for the analyses and α was set at 0.05.

Results

Baseline descriptive variables are contained in Table 1. No race or group differences were observed for any variable except VO_2max for which there was a race difference (EA women higher than AA women). During the weight loss intervention subjects decreased weight significantly 12.1±2.5 kg but there was no group or race differences in the weight loss. Table 2 shows the changes in RSMI with weight loss. There was a race and group effect, a time by race interaction, as well as a time by group by race interaction. Post hoc analysis revealed that AA women had larger RSMI (were more muscular) and lost less RSMI during the diet only intervention than EA women. In addition, resistance training resulted in a retention of RSMI in both AA and EA women but aerobic training resulted in decreased RSMI in both races. Figure one shows the percentage change for RSMI with post hoc analysis revealing significant difference between the AA (AA an increase of 1.1 %) and EA (EA women a 3.6 % decrease) for the diet only group.

In order to identify the independent contributions to changes in walking economy (delta steady state netVO_2) and ease (delta steady state heart rate) four multiple regression models were evaluated (Table 3). The models for both delta flat grade netVO_2 showed that both delta RSMI and delta VO_2max were independent correlates with the two walking tasks. The models for the submaximal flat and grade walks show that delta RSMI is an independent correlate of delta heart rate during the two submaximal walking tasks but delta VO_2max is not in either task. Race was not a significant correlate in any of the model. To insure that a race by RSMI interaction was not affecting the models we performed an additional multiple regression model that included an interaction term between race and RSMI. The interaction term was not a significant correlate in any of the models (data not shown).

Discussion

Consistent with our hypothesis we found that AA women have higher RSMI and lose less RSMI than EA women during weight loss. Not consistent with our hypothesis we found that there were major racial differences in RSMI loss between groups with the AA and EA women responding similarly to the two weight loss regimens that included exercise training but major differences in RSMI loss for the women who underwent energy restriction without exercise training. The EA women who did not exercise train lost 3.6% of their RSMI while AA women who did not train gained 1.1% RSMI. Also consistent with our hypothesis, we found that decreased RSMI was negatively associated with decreased heart rate (increased ease of walking) and netVO_2 (increase in walking economy) while walking on the flat and up a grade. In other words maintenance of RSMI with weight loss was related with better walking economy and ease. Since resistance training was associated with maintenance of RSMI in both AA and EA women these results further support the inclusion of resistance training during energy restriction driven weight loss, especially for EA women.

Previous research has shown that AAs have more FFM and limb skeletal muscle than EAs even after adjusting for height and/or limb length (6;8). Our results support this finding. Little has been written concerning potential reasons for this difference, nor for explaining the ability of the AA women to maintain RSMI during weight loss even when not exercise training. The differences are not associated with diet macronutrient content since we fed all the subjects the same macronutrient diet (20–22% fat, 20–22% protein, and 56–58% carbohydrate). The differences are probably not mediated by a more active lifestyle for the AA women since we have previously shown that AA women have lower activity related energy expenditure than EA women (20) as well have shown that the difference persists following weight loss and exercise training (8). Hormone environment certainly may be playing a role. Recently, it has been reported that postmenopausal women taking hormone-replacement therapy had higher FFM than either premenopausal women or post-menopausal women not on hormone-replacement therapy (21). In addition, premenopausal AA women have higher blood estradiol than EA premenopausal women (22;23), at least suggesting that sex hormones may be playing a role in racial differences in FFM and possibly muscle. Of course genetic contributions may be playing a role in racial differences in RSMI. For example, we have previously reported that IGF-I polymorphism is associated with lean mass in women with the $IGF\text{-}I_{189}$ polymorphism associating with reduced lean tissue. Interestingly, over 47% of the AA women in this study were non-carriers but less than 7% of the EA women were non-carriers of the $IGF\text{-}I_{189}$ polymorphism.

Consistent with previous work (24) ease of locomotion (reduced heart rate while walking) was increased with weight loss. This is particularly important since ease of locomotion probably plays a role in participation in free living physical activity. We have shown previously that resistance training induced increases in strength and muscle are associated with increased ease of locomotion (4;15;17) while ease of locomotion is related to non-exercise training physical activity energy expenditure (NEAT) (3;5;20). These relationships further support the potential importance of maintaining RSMI during weight loss programs.

Further supporting the importance of maintaining RSMI, differences in RSMI were related to differences in walking economy and differences in walking ease while walking at a moderate speed (4.8 km/hr) on the flat and up a 2.5% grade at the same speed (Table 3) even after adjusting for aerobic capacity (VO_2max). Since as indicated above, ease and economy of locomotion probably contributes to the likelihood of being physically active and participation in physical activity is not only important for maintenance of weight but metabolic health (25) maintenance of locomotion ease is an important goal.

Since there is considerable range (varying from 5.45 to 7.36 kg/m^2) for identification of cut-points for individuals with sarcopenia (9;11;12), we selected a conservative cut-point of 6.29 kg/m^2 proposed by Bouchard et al (11). We identified 18 EA and 3 AA women below this cut-point prior to weight loss. Of the two AA and five EA who were sarcopenic prior to weight loss in the DRT group both AA and one EA woman increased muscle enough to no longer be sarcopenic after weight loss. The number of sarcopenic women remained constant in the no exercise group and the number of sarcopenic women in the aerobic group increased from 7 to 8.

We used DXA to measure limb lean tissue and calculate RSMI. Magnetic resonance imaging (MRI) and computed tomography (CT) may be more precise methods for measuring limb lean and thus RSMI than DXA. Both MRI and CT are very expensive and whole body CT adds significant radiation exposure to subjects. So neither technique is suitable for most studies. We feel that DXA is very reliable. The coefficient of variation for repeat scans in our lab is 1.1%. In addition, only one technician analyzed all scans and was blinded as to the race and group of the subjects, so we are confident that no group or racial biasing occurred with the analysis.

Conclusion

Premenopausal EA women are not only less muscular than AA women but lose significant amounts of muscle during weight loss that does not include resistance training, while AA women do not. Maintenance of muscle during diet induced weight loss programs is important for maintaining ease of locomotion which may have a positive effect on participation in physical activity. As shown in previous studies resistance training during diet induced weight loss helps to maintain muscle, especially in EA premenopausal women.

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What is already known about the subject?

1. What is already known about the subject?

   African Americans are more muscular than European Americans and resistance training improves maintenance of skeletal muscle mass during weight loss. Walking ease and economy are related to both relative skeletal muscle and free living activity related energy expenditure.

2. What does this study add? In the absence of training, African American women retain skeletal muscle mass during diet induced weight loss while European American women lose skeletal muscle mass. Resistance training is associated with skeletal muscle retention in both African American and European American women but aerobic training is associated with skeletal muscle loss in both African American and European American women. Lose of skeletal muscle during weight loss is associated with decreased ease and economy of walking.

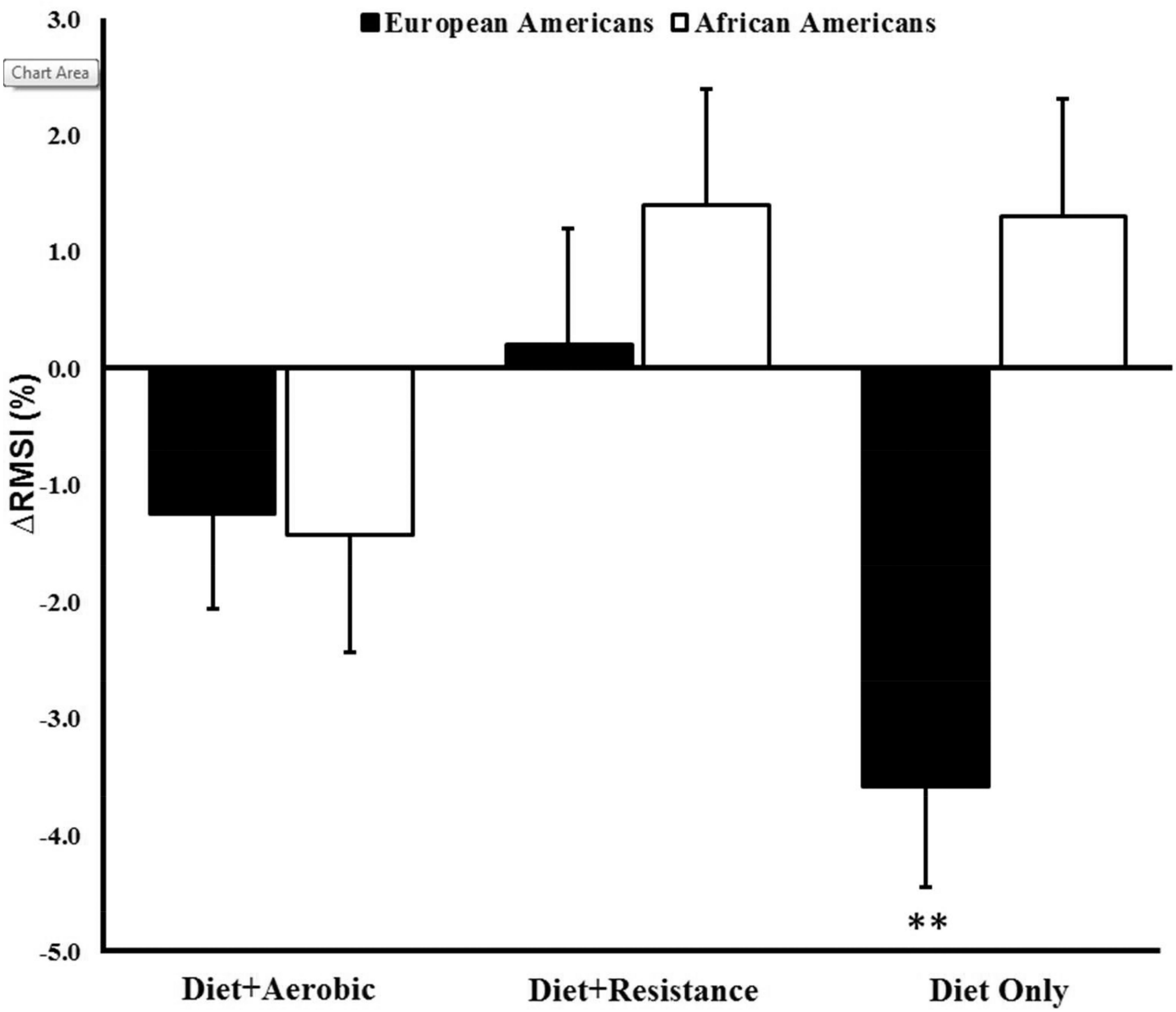

Figure 1.

Percent RSMI of change of AA and EA women for Diet + Exercise, Diet + Resistance and Diet Only groups. ** Denotes significant decrease in RSMI.

Table 1

Descriptive variables for subjects (mean±SD).

	Diet Only		Diet + Aerobic Training		Diet + Resistance Training	
	EA *n* = 17	**AA *n* = 17**	**EA *n* = 22**	**AA *n* = 23**	**EA *n* = 29**	**AA *n* = 32**
Age (years)	36.6 ± 4.8	34.6 ± 6.0	35.0 ± 7.4	33.8 ± 6.7	35.6 ± 6.7	34.0 ± 5.6
Socioeconomic Status^	44.6 ± 13	47.0 ± 9.2	48.8 ± 11.7	49.8 ± 5.8	47.0 ± 10.8	46.4 ± 11.2
Height (cm)	165.9 ± 7.0	165.8 ± 5.1	164.0 ± 5.8	164.8 ± 7.2	168.0 ± 7.8	164.4 ± 5.6
Body Weight (kg)	78.5 ± 8.5	77.7 ± 5.6	76.3 ± 6.8	77.3 ± 6.8	79.8 ± 9.3	75.8 ± 5.4
BMI (kg/m^2)	28.3 ± 1.4	28.2 ± 1.4	28.3 ± 1.6	28.5 ± 1.3	28.1 ± 1.3	28.0 ± 1.0
VO_2max (ml/kg/min)	27.7 ± 3.8	27.7 ± 3.9	30.1 ± 4.1	26.1 ± 3.0	29.3 ± 3.9	28.7 ± 3.3
$FW_{N\dot{V}O2}$ (ml/kg/min)	8.9 ± 1.5	9.6 ± 1.5	9.8 ± 1.2	9.0 ± 0.8	9.4 ± 1.1	9.3 ± 1.2
FW_{HR} (beats/min)	119.6 ± 16.2	116.6 ± 14.4	116.6 ± 10.8	126.0 ± 15.4	120.2 ± 12.7	120.4 ± 12.8
$GW_{N\dot{V}O2}$ (ml/kg/min)	11.6 ± 1.6	12.3 ± 1.4	12.4 ± 1.6	12.1 ± 1.2	12.3 ± 1.2	12.1 ± 1.5
GW_{HR} (beats/min)	134.1 ± 18.6	134.5 ± 16.6	130.3 ± 9.8	143.2 ± 16.4	133.3 ± 13.6	135.8 ± 15.1

No significant differences were detected between groups or race (all comparisons, $p > 0.20$), with the exception of race for VO_2max; Socioeconomic Status calculated from the Hollingshead 4- factor index of social class, wherein higher scores reflect greater socioeconomic status;

EA = European Americans; AA = African Americans; VO_2max = maximum oxygen uptake; $FW_{N\dot{V}O2}$ = net oxygen uptake while walking at 3 mph on the flat; FW_{HR} = heart rate while walking at 3 mph on the flat; $GW_{N\dot{V}O2}$ = net oxygen uptake while walking at 3 mph up a 2.5% incline; FW_{HR} = heart rate while walking at 3 mph up a 2.5% incline.

Table 2

Descriptive analysis of relative skeletal muscle index (RSMI, mean ± SD). Post-hoc analysis revealed that the AA women compared to EA women had higher RSMI and lost less RSMI during the diet only condition. Post hoc analysis also revealed that both AA and EA women maintained RSMI when resistance training was combined with diet but both AA and EA women lost RSMI when aerobic training was combined with diet (mean±SD).

		Diet only				Diet + Aerobic Training				Diet + Resistance Training				*Significant effect*
	Time	***n***	**EA**	***n***	**AA**	***n***	**EA**	***n***	**AA**	***n***	**EA**	***n***	**AA**	
RSMI (kg/m^2)	T0	17	6.66 ± 0.56	17	7.07 ± 0.63	22	6.56 ± 0.69	23	7.12 ± 0.43	29	6.63 ± 0.40	32	7.28 ± 0.53	R, G
	T1	17	6.42 ± 0.53	17	7.15 ± 0.68	22	6.47 ± 0.63	23	7.01 ± 0.48	29	6.64 ± 0.38	32	7.38 ± 0.60	T × R
	Δ	-	−0.24	-	0.08	-	−0.09	-	−0.11	-	0.01	-	0.10	T × G × R

Δ (change), weight loss – baseline;

AA = African-American; EA = European-American; R = race effect; G = group effect; T = time effect; RSMI = relative skeletal muscle index; T0 = baseline; T1 = weight-loss; significant effect ($p \leq 0.05$).

Table 3

Multiple linear regression models for estimation change (Δ, delta) in net oxygen uptake and heart rate during flat and grade walking test after weight loss (mean ± SE).

	Model	Model R^2	Intercept	Slope	Partial *r*	*P*-value
$\Delta FW_{N\dot{V}O2}$		0.17	−1.1 ± 0.2			< 0.001
	ΔRSMI			−1.34 ± 4.5	−0.27 *	0.002
	$\Delta\dot{V}O_{2max}$			0.16 ± 0.1	0.34 *	< 0.001
	Race			−0.03 ± 0.3	−0.01	0.913
ΔFW_{HR}		0.06	−8.1± 1.9			0.035
	ΔRSMI			−8.94 ± 3.7	−0.21 *	0.016
	$\Delta\dot{V}O_{2max}$			−0.59 ± 0.3	−0.15	0.088
	Race			0.42 ± 2.1	0.02	0.850
$\Delta GW_{N\dot{V}O2}$		0.23	−1.3 ± 0.2			< 0.001
	ΔRSMI			−1.69 ± 0.5	−0.31 *	0.001
	$\Delta\dot{V}O_{2max}$			0.2 ± 0.1	0.40 *	< 0.001
	Race			0.1 ± 0.3	0.03	0.722
ΔGW_{HR}		0.09	−9.9 ± 2.2			0.007
	ΔRSMI			−11.1 ± 3.5	−0.26 *	0.001
	$\Delta\dot{V}O_{2max}$			−0.5 ± 0.3	−0.12	0.175
	Race			−0.3 ± 2.1	−0.01	0.902

ΔFW_{HR} = delta heart rate during flat walking; $\Delta FW_{N\dot{V}O2}$ = delta net oxygen uptake during flat walking (walking steady-state $\dot{V}O_2$ – resting $\dot{V}O_2$); ΔGW_{HR} = delta heart rate during grade walking; $\Delta GW_{N\dot{V}O2}$ = delta net oxygen uptake during grade walking (walking steady-state $\dot{V}O_2$ – resting $\dot{V}O_2$); ΔRSMI = delta relative skeletal muscle index; $\Delta\dot{V}O_{2max}$ = delta maximal oxygen uptake. Race coded 0 European Americans and 1 African Americans.

* $p < 0.05$.