The Prospective Association between Different Types of Exercise and Body Composition

CLEMENS DRENOWATZ[1], GREGORY A. HAND[2], MICHAEL SAGNER[3], ROBIN P. SHOOK[4], STEPHANIE BURGESS[5], and STEVEN N. BLAIR[1,6]

[1]Department of Exercise Science, University of South Carolina, Columbia, SC; [2]Department of Epidemiology, School of Public Health, West Virginia University, Morgantown, WV; [3]European Society of Lifestyle Medicine, Paris, FRANCE; [4]Department of Kinesiology, Iowa State University, Ames, IA; [5]College of Nursing, University of South Carolina, Columbia, SC; and [6]Department of Epidemiology and Biostatistics, University of South Carolina, Columbia, SC

ABSTRACT

DRENOWATZ, C., G. A. HAND, M. SAGNER, R. P. SHOOK, S. BURGESS, and S. N. BLAIR. The Prospective Association between Different Types of Exercise and Body Composition. *Med. Sci. Sports Exerc.*, Vol. 47, No. 12, pp. 2535–2541, 2015. **Purpose**: Despite the widely accepted benefits of exercise on chronic disease risk, controversy remains on the role of exercise in weight loss. This study examined the effect of different exercise types on measures of adiposity across different fat categories. **Methods**: A total of 348 young adults (49% male; 28 ± 4 yr), participating in an ongoing observational study provided valid data over a period of 12 months. Fat mass (FM) and lean mass (LM) were measured via dual x-ray absorptiometry every 3 months. Percent body fat was calculated and used to differentiate between normal-fat, "overfat," and obese participants. At each measurement time point, participants reported engagement ($\text{min}\cdot\text{wk}^{-1}$) in aerobic exercise, resistance exercise, and other forms of exercise. **Results**: Most participants (93%) reported some exercise participation during the observation period. Total exercise or specific exercise types did not significantly affect subsequent body mass index after adjusting for sex, ethnicity, age, and baseline values of adiposity and exercise. Resistance exercise affected LM ($P < 0.01$) and FM ($P < 0.01$), whereas aerobic exercise only affected FM ($P < 0.01$). Any exercise type positively affected LM in normal-fat participants ($P < 0.04$). In overfat and obese participants, FM was reduced with increasing resistance exercise ($P \leq 0.02$) but not with aerobic exercise ($P \geq 0.09$). Additionally adjusting for objectively assessed total physical activity level did not change these results. **Conclusions**: Despite the limited effects on body mass index, exercise was associated with beneficial changes in body composition. Exercise increased LM in normal-fat participants and reduced FM in overfat and obese adults. Adults with excess body fat may benefit particularly from resistance exercise. **Key Words:** RESISTANCE TRAINING, AEROBIC TRAINING, BODY FAT, LEAN MASS, FAT MASS

EPIDEMIOLOGY

An increasingly sedentary lifestyle has been suggested to be a key contributor to the high prevalence of overweight/obesity and associated comorbidities (43). With a decline in physical demands at work and for activities of daily living over the past several decades (2,7), exercise during leisure time has been emphasized as an integral part of a healthy lifestyle by various public health organizations (14,47). A recent meta-analysis further showed that leisure time exercise has a stronger association with mortality than occupational physical activity (PA) or transport-related PA (34). Despite the well-established benefits of exercise on health, controversy remains on the role of exercise in weight loss (39). The lack of conclusive evidence regarding the role of exercise in the regulation of body weight may partly be due to the selected outcome measure; body weight or body mass index (BMI) may not reflect changes in fat mass and lean mass, which are likely to occur in response to sustained exercise engagement. For example, there is an inverse dose–response relation between visceral fat and exercise (25,28). There is also a difference in the association between PA/exercise and adiposity by weight status (11), which may be due to the ability to engage in various types of exercise at different intensities. Excess body weight, for example, may hinder the ability to engage in a sufficient amount of aerobic exercise to induce changes in body composition in an overweight/obese population (46).

Nevertheless, exercise-based interventions for weight loss and weight management have predominantly focused on aerobic exercise. This may partly be due to higher energy expenditure during aerobic exercise compared with that during resistance exercise (38). Resistance exercise, however, has been associated with increase in functional capacity, which could affect total daily energy expenditure (TDEE) by an

Address for correspondence: Clemens Drenowatz, Ph.D., Department of Exercise Science, Public Health Research Center, University of South Carolina, 921 Assembly Street, Columbia, SC 29208; E-mail: drenowat@mailbox.sc.edu.
Submitted for publication February 2015.
Accepted for publication May 2015.

0195-9131/15/4712-2535/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000000701

increase in total PA (16,22), subsequently affecting body weight. The effect of exercise on habitual PA has been shown to be an important contributor regarding the effectiveness of exercise-based weight management programs (26). In response to superimposed exercise programs, there has been large variability in compensatory adaptations, which may contribute to inconsistent results of exercise-based interventions (19,26). Clinical exercise interventions have been associated with reduction in nonexercise activity thermogenesis or increase in energy intake, which minimizes the effect of exercise on body composition (8). Examining the effects of habitual exercise, rather than a superimposed exercise program, may help attenuate compensatory metabolic and behavioral changes and enhance the understanding of the effect of chronic exercise participation on body weight and body composition. Thus, the purpose of the present study was to examine the effects of various self-selected exercise types, rather than a specific exercise program, on measures of body composition. Furthermore, differences in the effect of various exercise types on adiposity measures among normal-fat, "overfat," and obese adults were examined.

METHODS

The present analyses include data from an ongoing observational study. Specifics of the Energy Balance Study, which examines primary and secondary determinants of weight change, have been described previously (13). Briefly, 430 young adults (49% male; 27.7 ± 3.8 yr) with a BMI between 20 and 35 kg·m^{-2} were recruited. Participants were free of major acute or chronic conditions and did not report any large changes in their health behaviors in the previous 3 months. Women who were pregnant in the previous 12 months, planning on getting pregnant, and planning to change their use of contraceptive medications during the study were excluded. The study protocol was approved by the University of South Carolina institutional review board and is in accordance with the Declaration of Helsinki. All participants signed an informed consent before data collection.

Measurements were repeated every 3 months over a period of 1 yr. To be included in the analyses, participants needed to provide data during at least three measurement times, including baseline and at 12-month follow-up.

Anthropometrics and body composition. Height (cm) and weight (kg) were measured with participants in surgical scrubs and bare feet. Height was measured to the nearest 0.1 cm via a wall-mounted stadiometer (model S100; Ayrton Corp., Prior Lake, MN), and weight was measured to the nearest 0.1 kg using an electronic scale (Healthometer® model 500KL; McCook, IL). BMI (kg·m^{-2}) was calculated using the average of three measurements. In addition, fat mass, fat-free mass, and lean tissue mass were measured via dual energy x-ray absorptiometry (DXA Lunar model 8743; GE Healthcare, Waukesha, WI). Percent body fat (%BF) was calculated (fat mass/body weight), and participants were classified as normal-fat, overfat, or obese on the basis of sex, age, and ethnicity-specific cut points (12). Specifically, %BF ranges were less than 20% and 33% for normal fat, 20%–25% and 33%–39% for overfat, and equal to greater than 33% and 39% for obese in men and women, respectively.

Exercise participation and PA level. Every 3 months, participants reported their habitual self-selected engagement in different exercise types. Specifically, frequency (d·wk^{-1}) and time (minutes per session) were reported for sports, cycling, running, swimming, aerobics/group exercise, upper body resistance exercise, lower body resistance exercise, and other forms of structured PA. Subsequently, time spent engaging in endurance exercise (sum of running, cycling, and swimming), resistance exercise (sum of upper body and lower body resistance exercise), other exercise (sum of sports, aerobics/group exercise, and other structured forms of PA), and total exercise was calculated (min·wk^{-1}).

In addition, TDEE was assessed with a multisensor device (SWA, SenseWear Mini Armband; Body Media, Pittsburgh, PA), which was worn over a period of 10 d every 3 months. Using triaxial accelerometry, galvanic skin response, heat flux, skin temperature, and near body temperature, the SWA has been shown to provide accurate estimations of TDEE in free-living conditions (18,37). Resting metabolic rate (RMR) was measured after an overnight fast and a minimum of 24-h abstention from exercise. PA level (PAL = TDEE/RMR) was calculated and used as an indicator of overall PA, including planned exercise.

Energy intake was calculated on the basis of changes in body composition and objectively determined energy expenditure because of limitations in the accuracy of self-reported dietary intake and the effect of body composition on dietary misreporting (24,30). Specifically, the change in fat mass and fat-free mass was used to calculate the energy gap for each 3-month interval (i.e., difference in EI and TDEE) (40,41), which was subsequently added to average TDEE of the respective measurement period:

$$\text{energy intake} = 1020\frac{\Delta \text{FFM}}{\Delta t} + 9500\frac{\Delta \text{FM}}{\Delta t} + \text{TDEE}$$

where ΔFFM refers to change in fat free mass (kg) over time, ΔFM refers to change in fat mass (kg) over time, and Δt refers to the number of days between respective measurement times.

Statistical analysis. Descriptive statistics were calculated for the total sample and separately for normal-fat, overfat, and obese participants. Individual change in exercise engagement, energy intake, and PAL was determined via linear mixed modeling (LMM). Subsequently, linear regression analysis, adjusting for sex, ethnicity, age, baseline exercise time, and baseline adiposity measures, was used to examine the effect of change in total exercise time (model 1) and change in specific exercise types (model 2) on measures of adiposity at follow-up. In a second analysis, changes in energy intake and PAL were included as additional covariates to adjust for potential changes in diet and PA outside the reported exercise. All analyses were performed for the total sample and separately for normal-fat, overfat, and obese participants using IBM SPSS Statistics for Windows (version 21.0; IBM Corp., Armonk, NY).

RESULTS

A total of 348 participants (49% male) provided valid data for at least three measurement time points including baseline and 12-month follow-up. There was no difference in baseline characteristics between those included in the analysis and those excluded because of incomplete data. The baseline characteristics of the participants included in the analysis are shown in Table 1. Two-thirds of the participants were White, with the majority (86%) having a college degree. The prevalence of White participants decreased across fat categories (P for trend = 0.02), but there was no difference in education between normal-fat, overfat, and obese participants. Sex distribution differed significantly across fat categories, with an increase in male participants from normal-fat to obese (P for trend < 0.01). Age also increased with increasing fatness (P for trend = 0.01). As expected, BMI and fat mass increased across fat categories (P for trend < 0.01), but there was no difference in lean mass after adjusting for sex, ethnicity, and age. There was no significant difference in TDEE, RMR, and calculated energy intake across fat categories.

Over 12 months, average BMI increased by 0.5 $kg \cdot m^{-2}$ ($P < 0.01$), with individual changes ranging between −1.4 and 1.7 $kg \cdot m^{-2}$. The average weight gain was associated with increase in fat mass ($P < 0.01$), whereas there was no change in average lean mass ($P = 0.38$), resulting in an increase in %BF ($P < 0.01$). Individual change in lean mass ranged from a loss of 1.2 kg to a gain of 2.3 kg. Change in fat mass and %BF ranged from −3.9 to 2.6 kg and −3.2% to 2.3%, respectively. Change in adiposity measures did not differ across fat categories after adjusting for ethnicity, sex, age, and baseline values.

Most of the participants (93%) reported some exercise during the observation period, and 60% of the participants met current PA guidelines (14), with a decline in the prevalence of participants meeting guidelines with increasing BF. Exercise participation did not differ between men and women, and there was no difference in age between exercisers and nonexercisers. Nonexercisers had significantly higher %BF ($P < 0.01$) because of lower lean mass ($P < 0.01$), but there was no difference in BMI at baseline. Energy intake, TDEE, and PAL were higher in exercisers compared with those in nonexercisers ($P = 0.01$). The prevalence of nonexercisers increased with increasing fatness (P for trend < 0.01). Total exercise time and the number of total exercise sessions decreased across fat categories (P for trend < 0.01). Time spent in specific exercise categories also decreased across fat categories (P for trend ≤ 0.03), but the number of exercise sessions differed only for other exercise (P for trend < 0.01). The difference in aerobic and resistance exercise across fat categories was due to a difference in exercise time during single sessions. Interestingly, there was no difference in objectively determined PAL (Table 2).

Exercise time decreased during the observation period ($P < 0.01$), but there was no significant change in TDEE and energy intake. On an individual level, change in energy intake over a period of 12 months, however, ranged from a reduction of 580 $kcal \cdot d^{-1}$ to an increase of 599 $kcal \cdot d^{-1}$. The range for change in total exercise time was from a reduction of 79 $min \cdot wk^{-1}$ to an increase of 67 $min \cdot wk^{-1}$. Change in specific exercise types ranged from −41 to 28 $min \cdot wk^{-1}$, −47 to 48 $min \cdot wk^{-1}$, and −69 to 30 $min \cdot wk^{-1}$ for aerobic exercise, resistance exercise, and other exercise types, respectively. Change in exercise time, TDEE, and energy intake did not differ across fat categories after adjusting for ethnicity, sex, age, and the respective baseline measures.

Regression analysis for the total sample showed a significant inverse effect of change in total exercise time on subsequent fat mass and a significant direct effect on subsequent lean mass ($P < 0.01$), resulting in an inverse effect of total exercise time on %BF ($P < 0.01$) (Table 3). There was no effect of change in total exercise on BMI. These results remained essentially unchanged after including change in PAL and energy intake into the respective models. There was a direct effect of change in energy intake on BMI ($\beta = 0.05$, $P < 0.01$), whereas no significant effect of change in energy intake was observed for fat mass and %BF. An increase in energy intake, however, was directly associated with lean mass at 12 months ($\beta = 0.05$, $P < 0.01$). Regarding specific exercise types, there was an inverse association of change in aerobic exercise and resistance exercise with subsequent fat mass and %BF ($P < 0.01$). Change in resistance exercise additionally affected lean mass ($P < 0.01$). There were no significant effects of change in time spent in other exercise on any adiposity measures at follow-up.

TABLE 1. Baseline characteristics along with 12-month change in measures of adiposity and energy expenditure by fat category.

	Total Sample	Healthy Range	Overfat	Obese
	(n = 348)	(n = 135)	(n = 99)	(n = 114)
Male (%)	49.1	42.2	46.5	59.6
White (%)	66.1	74.8	59.6	61.4
College degree (%)	86.2	88.9	83.8	85.1
Age at baseline (yr)	27.7 ± 3.7	27.2 ± 3.6	27.6 ± 3.9	28.5 ± 3.7
Height (cm)	171.9 ± 9.5	171.9 ± 9.8	171.7 ± 9.8	172.0 ± 8.9
Weight (kg)*	74.7 ± 13.7	67.5 ± 11.2	74.0 ± 12.0	84.0 ± 12.5
BMI ($kg \cdot m^{-2}$)*	25.2 ± 3.8	22.7 ± 2.2	25.1 ± 3.2	28.4 ± 3.6
Fat mass (kg)*	21.5 ± 8.8	14.4 ± 4.0	21.6 ± 6.1	29.7 ± 7.7
Fat-free mass (kg)	51.2 ± 10.6	51.1 ± 11.9	50.3 ± 10.4	52.0 ± 8.9
BF (%)*	28.5 ± 9.1	22.0 ± 7.2	29.5 ± 7.5	35.3 ± 6.9
TDEE ($kcal \cdot d^{-1}$)	2726 ± 495	2688 ± 532	2713 ± 499	2784 ± 440
RMR ($kcal \cdot d^{-1}$)	1581 ± 266	1546 ± 278	1562 ± 256	1640 ± 254
Calculated EI ($kcal \cdot d^{-1}$)	2704 ± 512	2675 ± 550	2664 ± 501	2773 ± 473

Values are prevalence or mean ± SD.

*Significant difference between all fat categories, controlling for sex, ethnicity, and age ($P < 0.01$).

EI, energy intake.

EPIDEMIOLOGY

TABLE 2. Exercise participation rate, exercise time, and frequency of exercise engagement per week at baseline.

	Total Sample	Healthy Range	Overfat	Obese
Meeting PA guidelines (%)[a]	59.8	82.2	58.6	34.2
Never any exercise (%)	6.9	2.2	4.0	14.9
Never endurance exercise (%)	16.4	8.1	16.2	26.3
Never resistance exercise (%)	30.7	21.5	29.3	43.0
Never other exercise (%)	19.5	10.4	19.2	30.7
Total exercise time ($\text{min}\cdot\text{wk}^{-1}$)[b,*,**]	346.5 ± 267.6	408.3 ± 286.7	353.7 ± 280.2	251.6 ± 192.8
Total exercise (sessions per week)[b,***]	6.2 ± 4.4	7.5 ± 4.4	6.1 ± 4.4	4.7 ± 4.0
Endurance exercise time ($\text{min}\cdot\text{wk}^{-1}$)[b,*]	135.5 ± 135.2	155.7 ± 155.6	136.5 ± 139.5	103.6 ± 82.8
Endurance exercise (sessions per week)[b]	3.4 ± 2.3	3.6 ± 2.7	3.4 ± 2.1	3.2 ± 1.9
Resistance exercise time ($\text{min}\cdot\text{wk}^{-1}$)[b]	143.2 ± 115.7	142.9 ± 107.3	163.9 ± 144.2	120.4 ± 90.1
Resistance exercise (sessions per week)[b]	3.7 ± 1.4	3.9 ± 1.3	3.7 ± 1.6	3.4 ± 1.4
Other exercise time ($\text{min}\cdot\text{wk}^{-1}$)[b,*]	192.7 ± 169.9	212.2 ± 166.6	202.3 ± 186.5	149.3 ± 150.8
Other exercise (sessions per week)[b,*]	3.4 ± 2.3	3.8 ± 2.4	3.4 ± 2.4	2.9 ± 2.0
PAL (TDEE/RMR)	1.73 ± 0.20	1.74 ± 0.20	1.74 ± 0.22	1.71 ± 0.19

[a]At least 150 $\text{min}\cdot\text{wk}^{-1}$ of MVPA in 10-min bouts for 5 $\text{d}\cdot\text{wk}^{-1}$.
[b]Excluding participants not reporting this type of exercise.
*Data from obese participants are significantly different from those from the healthy range after controlling for sex, age, and ethnicity ($P < 0.05$).
**Data from obese participants are significantly different from those from the overfat participants after controlling for sex, age, and ethnicity ($P < 0.05$).
***Significant difference across all fat categories, controlling for sex, ethnicity, and age ($P < 0.05$).

Additionally adjusting for change in PAL did not change the previously reported results.

The effects of change in exercise time separately for normal-fat, overfat, and obese participants are shown in Table 4. Change in total exercise time or any specific exercise type was directly associated with subsequent lean mass in normal-fat participants ($P < 0.05$), whereas there was no effect of total exercise or specific exercise types on fat mass, %BF, and BMI. In overfat and obese participants, there was an inverse effect of change in total exercise time on fat mass and %BF ($P < 0.05$). Particularly, change in resistance exercise affected subsequent fat mass and %BF, with results being more pronounced in obese participants compared with those in overfat participants. Aerobic exercise affected only %BF in overfat participants ($P < 0.05$), and there was no significant effect of aerobic exercise in obese participants. There was no effect of change in total exercise time or any specific exercise time on lean mass in overfat and obese participants. No significant effects on measures of adiposity were observed for time spent in other exercise. As shown for the total sample, change in exercise did not affect subsequent BMI and results remained essentially unchanged after additionally controlling for PAL.

DISCUSSION

Health benefits of regular exercise are well documented (1), but research on differential effects of various exercise types on measures of adiposity has been limited. To evaluate the growing number of exercise programs in various settings, scientific evidence on the effects of specific exercise types on body weight and body composition is warranted. Results of the present study show that habitual exercise engagement predominantly affects fat mass and lean mass, whereas the effect on BMI is minimal. An increase in resistance exercise was associated with increase of lean mass and decrease of fat mass. An increase in aerobic exercise, on the other hand, was only associated with reduction of fat mass. Effects of various exercise types, however, differed by adiposity level. In normal-fat participants, exercise predominantly affected lean mass, independent of exercise type. In overfat and obese participants, change in exercise engagement predominantly affected fat mass. Interestingly, resistance exercise had a greater effect on fat mass in overfat and obese participants than aerobic exercise. In fact, aerobic exercise affected %BF only in overfat participants but not in obese participants.

The limited effect of exercise on BMI has been addressed previously (39), and results of the present study support the argument for energy restriction as an important component for weight loss (10). Caloric restriction, however, has been associated with a decline in lean body mass (31) and habitual PA (23,32). The corresponding decline in energy expenditure could make it difficult to achieve sustainable weight loss relying entirely on low energy intake. The present study further showed no difference in energy intake between normal-fat, overfat, and obese participants, which emphasizes the importance of exercise or PA in long-term

TABLE 3. Effect of baseline exercise levels and change in exercise on measures of BF at 12 months.

Dependent Variable	Baseline Exercise ($\text{min}\cdot\text{wk}^{-1}$)								ΔExercise ($\text{min}\cdot\text{wk}^{-1}$)							
	Total EX[a]		Aerobic EX[b]		Resistance EX[b]		Other EX[b]		Total EX[a]		Aerobic EX[b]		Resistance EX[b]		Other EX[b]	
	β	P	β	P	β	P	β	P	β	P	β	P	β	P	β	P
BMI ($\text{kg}\cdot\text{m}^{-2}$)	0.029	0.173	−0.028	0.200	0.040	0.101	.016	0.541	−0.007	0.747	−0.026	0.219	0.013	0.539	0.001	0.995
%BF	−0.071	<0.001	−0.037	0.057	−0.052	0.013	−0.019	0.409	−0.100	<0.001	−0.063	0.001	−0.075	<0.001	−0.019	0.356
Fat mass (kg)	−0.046	0.031	−0.039	0.067	−0.051	0.032	0.012	0.639	−0.097	<0.001	−0.060	0.004	−0.081	<0.001	−0.011	0.640
Lean mass (kg)	0.053	<0.001	−0.004	0.715	0.050	<0.001	0.025	0.052	0.036	0.001	0.010	0.330	0.028	0.007	0.015	0.194

Values are standardized coefficients, adjusted for baseline sex, ethnicity, age, and baseline measures of BF.
[a,b]Separate regression models.
EX, exercise; ΔExercise, change in exercise over 12 months based on LMM.

TABLE 4. Effect of baseline exercise levels and change in exercise on measures of BF at 12 months separately for normal-fat, overfat and obese participants.

Dependent Variable	Baseline Exercise (min·wk^{-1})								Δ Exercise (min·wk^{-1})							
	Total EX[a]		Aerobic EX[b]		Resistance EX[b]		Other EX[b]		Total EX[a]		Aerobic EX[b]		Resistance EX[b]		Other EX[b]	
	β	P	β	P	β	P	β	P	β	P	β	P	β	P	β	P
Normal fat																
BMI (kg·m^{-2})	0.113	0.040	0.001	0.994	0.088	0.158	0.100	0.159	0.092	0.078	0.026	0.574	0.054	0.285	0.097	0.138
%BF	−0.053	0.194	−0.035	0.324	0.023	0.619	−0.075	0.270	−0.071	0.077	−0.061	0.094	0.004	0.915	−0.061	0.237
Fat mass (kg)	−0.020	0.731	−0.045	0.374	0.052	0.445	−0.039	0.625	−0.055	0.342	−0.060	0.253	0.031	0.592	−0.043	0.563
Lean mass (kg)	0.088	<0.001	0.013	0.422	0.056	0.012	0.072	0.006	0.071	<0.001	0.036	0.036	0.038	0.038	0.056	0.020
Overfat																
BMI (kg·m^{-2})	0.030	0.498	−0.046	0.336	−0.020	0.756	0.060	0.413	−0.037	0.392	−0.057	0.577	−0.083	0.092	0.042	0.355
%BF	−0.076	0.104	−0.060	0.235	−0.114	0.098	0.026	0.657	−0.098	0.033	−0.101	0.045	−0.127	0.015	0.018	0.703
Fat mass (kg)	−0.082	0.141	−0.078	0.202	−0.144	0.082	0.040	0.568	−0.118	0.032	−0.101	0.090	−0.144	0.021	−0.001	0.980
Lean mass (kg)	0.058	0.001	−0.002	0.903	0.047	0.067	0.027	0.229	0.025	0.131	0.015	0.430	0.005	0.802	0.019	0.290
Obese																
BMI (kg·m^{-2})	0.007	0.874	−0.081	0.116	0.068	0.123	−0.011	0.812	−0.043	0.320	−0.052	0.326	0.038	0.393	−0.073	0.112
%BF	−0.093	0.009	−0.033	0.417	−0.081	0.021	−0.019	0.601	−0.180	<0.001	−0.041	0.330	−0.142	<0.001	−0.065	0.080
Fat mass (kg)	−0.075	0.068	−0.064	0.173	−0.063	0.121	0.006	0.879	−0.186	<0.001	−0.083	0.091	−0.146	0.001	−0.039	0.360
Lean mass (kg)	0.030	0.137	−0.027	0.223	0.059	0.002	0.001	0.968	0.012	0.540	−0.016	0.485	0.031	0.113	−0.014	0.487

Values are standardized coefficients, adjusted for sex, ethnicity, age, and baseline measures of BF.
EX, exercise; ΔExercise, change in exercise over 12 months based on LMM.
[a,b]Separate regression models.

weight management. It should also be considered that the proportion of lean mass lost during caloric restriction is greater than the amount regained, resulting in a lean mass deficit, which negatively affects various health outcomes (3,31). Exercise engagement during weight loss, on the other hand, has been shown to attenuate the loss in lean mass (27), which would allow individuals to maintain RMR (45). This sustained energy expenditure during sedentary pursuits could facilitate long-term weight maintenance. In addition, exercise is associated with increased cardiorespiratory fitness and functional capacity, which increases quality of life and improves health (35). It should also be considered that adiposity has a stronger association with health outcomes than BMI (29). Both aerobic and resistance exercise have beneficial effects on visceral adiposity, which is associated with cardiovascular disease risk, independent of change in body weight (25). Therefore, a stronger focus on change in body composition, rather than on weight or BMI, is warranted when evaluating health effects of exercise-based interventions (33).

This study further shows that the association between exercise and body composition differs by BF categories. In normal-fat participants, any type of exercise affected lean mass, but there was no significant effect on fat mass. This may partly be explained by the observational nature of the study. Without an attempt to lose weight, participants potentially compensated for a change in exercise regimen by dietary adjustments. Particularly in lean individuals, energy intake has been shown to increase in response to long-term exercise, whereas such compensatory changes in energy intake are less likely in overweight and obese adults (20). With a lack of compensatory adjustments in dietary intake, an increase in exercise induces negative energy balance resulting in fat loss. This was observed in participants with excess BF who lost fat mass with increased exercise while maintaining lean mass. Interestingly, resistance exercise had a greater effect on fat mass than did aerobic exercise. A 12-yr cohort study also showed a stronger effect of resistance exercise on waist circumference compared with moderate-to-vigorous aerobic exercise (25). The lower effect of aerobic exercise on adiposity, particularly in overfat and obese participants, may be due to limited ability of achieving a sufficient exercise intensity and volume (28,44). Despite the positive effects of moderate-intensity aerobic exercise on various health outcomes (25), higher exercise intensities may be necessary to induce changes in body composition (4). Accordingly, high-intensity interval training has been shown to induce significant loss in fat mass whereas continuous moderate-intensity exercise had a limited effect on various measures of adiposity (5,42). Resistance exercise may result in similar physiological responses, as it is similar in nature to high-intensity interval training. Resistance exercise has been associated with increase in fat oxidation (21), which potentially contributes to greater reduction in fat mass while maintaining lean mass. The positive effects of resistance exercise on nonexercise activity thermogenesis may further contribute to changes in body composition (15) despite the lower energy expenditure during resistance exercise compared with that during aerobic exercise (38).

In contrast to the results of this study, clinical exercise studies in overweight/obese adults generally show a greater effect of aerobic exercise on fat mass, whereas resistance exercise induces greater changes in lean mass (35). DiPietro (9), however, argues that effects of self-selected exercise regimen in a free-living population (as in the present study) most likely differ from those in the controlled environment of intervention studies. With most individuals participating in clinical studies not being able to maintain exercise-induced changes in body composition (17), results of observational studies could provide valuable insights into the role of exercise for long-term weight management. In a 12-yr cohort study, a greater effect of resistance exercise on waist circumference was observed compared with that of aerobic exercise (25). Furthermore, resistance exercise has been shown to be better tolerated and more enjoyable in overweight adults (46), which could facilitate sustained exercise engagement.

Accordingly, resistance exercise was the second most reported exercise type following walking in overweight/obese participants in the National Weight Control Registry (6). Aerobic exercise, however, provides valuable health benefits (14), and a combined exercise regimen (i.e., aerobic and resistance exercise) has been suggested as the optimal approach to induce positive changes in body composition (25,35). A combined exercise approach would also provide the largest health benefits because there is no single exercise type that provides the best benefit for every health indicator (36).

Some limitations of the present study, however, should be considered when interpreting the results. Even though overall activity level (PAL) was assessed objectively, participants self-reported their exercise participation and there was limited information on specific exercise intensities. The lack of more detailed information on specific sports (i.e., soccer vs golf) may also have contributed to the limited effect of other exercise types. Relying on multiple measures of exercise and the use of LMM to determine change in exercise behavior should mitigate the limitations associated with self-report, and the inclusion of an objective measure of total PA and energy intake further strengthens the results. The sample, however, consisted of predominantly well-educated adults with a high activity level (average PAL, 1.7). Despite these limitations regarding generalizability, this study provides valuable information on the effects of various exercise types on adiposity.

Exercise has been emphasized as an important component of a healthy lifestyle because of the well-documented benefits for various health outcomes (1). Uncertainty remains, however, on the role of exercise in weight loss and weight management because of potential compensatory adaptations in energy intake and/or other components contributing to TDEE. The present study shows that exercise induces positive changes in body composition even in the absence of weight loss. Of greater interest, however, is that the effects of exercise on body composition vary by BF. Any type of exercise positively affected lean mass in normal-fat participants, whereas resistance exercise was particularly shown to reduce fat mass in overfat and obese young adults. This should be considered in the development of weight management programs, as aerobic exercise is generally the most commonly prescribed form of exercise. More research on separate effects of volume, intensity, type, and pattern of exercise in various subpopulations, however, is needed to clarify the benefits of exercise regarding weight loss and weight management. Population-specific, evidence-based recommendations for exercise participation along with reasonable expectations may help with the promotion of exercise participation that can be sustained over a prolonged period.

The authors wish to thank the advisory board, staff, and participants of the Energy Balance study.

The funding for this project was provided through an unrestricted grant from the Coca-Cola Company. The funder had no role in any aspect of the study design, collection, or analysis.

Steven N. Blair has received research funding from the following organizations/companies: National Institutes of Health, Department of Defense, Body Media, and the Coca-Cola Company. He is on the scientific/medical advisory boards for the following organizations/companies: Technogym, Santech, Clarity, International Council on Active Aging, and Cancer Fit Steps for Life. The remaining authors have no conflict to declare.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

EPIDEMIOLOGY

REFERENCES

1. Andersen RE, Jakicic JM. Interpreting the physical activity guidelines for health and weight management. *J Phys Act Health*. 2009;6(5):651–6.
2. Archer E, Shook RP, Thomas DM, et al. 45-Year trends in women's use of time and household management energy expenditure. *PLoS One*. 2013;8(2):e56620.
3. Beavers KM, Lyles MF, Davis CC, Wang X, Beavers DP, Nicklas BJ. Is lost lean mass from intentional weight loss recovered during weight regain in postmenopausal women? *Am J Clin Nutr*. 2011; 94(3):767–74.
4. Bernstein MS, Costanza MC, Morabia A. Association of physical activity intensity levels with overweight and obesity in a population-based sample of adults. *Prev Med*. 2004;38(1):94–104.
5. Boutcher SH. High-intensity intermittent exercise and fat loss. *J Obes*. 2011;2011:868305.
6. Catenacci VA, Ogden LG, Stuht J, et al. Physical activity patterns in the National Weight Control Registry. *Obesity (Silver Spring)*. 2008;16(1):153–61.
7. Church TS, Thomas DM, Tudor-Locke C, et al. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One*. 2011;6(5):e19657.
8. Dhurandhar EJ, Kaiser KA, Dawson JA, Alcorn AS, Keating KD, Allison DB. Predicting adult weight change in the real world: a systematic review and meta-analysis accounting for compensatory changes in energy intake or expenditure. *Int J Obes (Lond)*. 2014. doi: 10.1038/ijo.2014.184.
9. DiPietro L. Physical activity in the prevention of obesity: current evidence and research issues. *Med Sci Sports Exerc*. 1999; 31(11 Suppl):S542–6.
10. Donnelly JE, Blair SN, Jakicic JM, et al. American College of Sports Medicine Position Stand: Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*. 2009;41(2):459–71.
11. Ekelund U, Särnblad S, Brage S, Ryberg J, Wareham NJ, Aman J. Does physical activity equally predict gain in fat mass among obese and nonobese young adults? *Int J Obes (Lond)*. 2007;31(1):65–71.
12. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *Am J Clin Nutr*. 2000;72(3):694–701.
13. Hand G, Shook R, Paluch A, et al. The Energy Balance Study: The design and baseline results for a longitudinal study of energy balance. *Res Q Exerc Sport*. 2013;84(3):275–86.
14. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1423–34.
15. Hunter GR, Fisher G, Neumeier WH, Carter SJ, Plaisance EP. Exercise training and energy expenditure following weight loss. *Med Sci Sports Exerc*. 2015;47(9):1950–7.
16. Hunter GR, Wetzstein CJ, Fields DA, Brown A, Bamman MM. Resistance training increases total energy expenditure and free-living

physical activity in older adults. *J Appl Physiol (1985)*. 2000; 89(3):977–84.
17. Jeffery RW, Drewnowski A, Epstein LH, et al. Long-term maintenance of weight loss: current status. *Health Psychol*. 2000; 19(1 Suppl):5–16.
18. Johannsen DL, Calabro MA, Stewart J, Franke W, Rood JC, Welk GJ. Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. *Med Sci Sports Exerc*. 2010; 42(11):2134–40.
19. King N, Caudwell P, Hopkins M, et al. Metabolic and behavioral compensatory responses to exercise interventions: barriers to weight loss. *Obesity (Silver Spring)*. 2007;15:1373–83.
20. King NA, Horner K, Hills AP, et al. Exercise, appetite and weight management: understanding the compensatory responses in eating behaviour and how they contribute to variability in exercise-induced weight loss. *Br J Sports Med*. 2012;46(5):315–22.
21. Kirk EP, Donnelly JE, Smith BK, et al. Minimal resistance training improves daily energy expenditure and fat oxidation. *Med Sci Sports Exerc*. 2009;41(5):1122–9.
22. Levinger I, Goodman C, Hare DL, Jerums G, Selig S. The effect of resistance training on functional capacity and quality of life in individuals with high and low numbers of metabolic risk factors. *Diabetes Care*. 2007;30(9):2205–10.
23. Martin CK, Das SK, Lindblad L, et al. Effect of calorie restriction on the free-living physical activity levels of nonobese humans: results of three randomized trials. *J Appl Physiol (1985)*. 2011; 110(4):956–63.
24. Maurer J, Taren DL, Teixeira PJ, et al. The psychosocial and behavioral characteristics related to energy misreporting. *Nutr Rev*. 2006;64(2 Pt 1):53–66.
25. Mekary RA, Grøntved A, Despres JP, et al. Weight training, aerobic physical activities, and long-term waist circumference change in men. *Obesity (Silver Spring)*. 2015;23(2):461–7.
26. Melanson EL, Keadle SK, Donnelly JE, Braun B, King NA. Resistance to exercise-induced weight loss: compensatory behavioral adaptations. *Med Sci Sports Exerc*. 2013;45(8):1600–9.
27. Miller CT, Fraser SF, Levinger I, et al. The effects of exercise training in addition to energy restriction on functional capacities and body composition in obese adults during weight loss: a systematic review. *PLoS One*. 2013;8(11):e81692.
28. Ohkawara K, Tanaka S, Miyachi M, Ishikawa-Takata K, Tabata I. A dose–response relation between aerobic exercise and visceral fat reduction: systematic review of clinical trials. *Int J Obes (Lond)*. 2007;31(12):1786–97.
29. Oliveros E, Somers VK, Sochor O, Goel K, Lopez-Jimenez F. The concept of normal weight obesity. *Prog Cardiovasc Dis*. 2014;56(4):426–33.
30. Poslusna K, Ruprich J, de Vries JH, Jakubikova M, van't Veer P. Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice. *Br J Nutr*. 2009;101(2 Suppl):S73–85.
31. Pourhassan M, Bosy-Westphal A, Schautz B, Braun W, Glüer CC, Müller MJ. Impact of body composition during weight change on resting energy expenditure and homeostasis model assessment index in overweight nonsmoking adults. *Am J Clin Nutr*. 2014; 99(4):779–91.
32. Redman LM, Heilbronn LK, Martin CK, et al. Metabolic and behavioral compensations in response to caloric restriction: implications for the maintenance of weight loss. *PLoS One*. 2009;4(2):e4377.
33. Ross R, Janiszewski PM. Is weight loss the optimal target for obesity-related cardiovascular disease risk reduction? *Can J Cardiol*. 2008;24(24 Suppl):25D–31D.
34. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose–response meta-analysis of cohort studies. *Int J Epidemiol*. 2011;40(5):1382–400.
35. Schwingshackl L, Dias S, Strasser B, Hoffmann G. Impact of different training modalities on anthropometric and metabolic characteristics in overweight/obese subjects: a systematic review and network meta-analysis. *PLoS One*. 2013;8(12):e82853.
36. Slentz CA, Houmard JA, Kraus WE. Modest exercise prevents the progressive disease associated with physical inactivity. *Exerc Sport Sci Rev*. 2007;35(1):18–23.
37. St-Onge M, Mignault D, Allison DB, Rabasa-Lhoret R. Evaluation of a portable device to measure daily energy expenditure in free-living adults. *Am J Clin Nutr*. 2007;85(3):742–9.
38. Strasser B, Schobersberger W. Evidence for resistance training as a treatment therapy in obesity. *J Obes*. 2011;2011:482564.
39. Swift DL, Johannsen NM, Lavie CJ, Earnest CP, Church TS. The role of exercise and physical activity in weight loss and maintenance. *Prog Cardiovasc Dis*. 2014;56(4):441–7.
40. Thomas DM, Bouchard C, Church T, et al. Why do individuals not lose more weight from an exercise intervention at a defined dose? An energy balance analysis. *Obes Rev*. 2012;13(10):835–47.
41. Thomas DM, Schoeller DA, Redman LA, Martin CK, Levine JA, Heymsfield SB. A computational model to determine energy intake during weight loss. *Am J Clin Nutr*. 2010;92(6):1326–31.
42. Trapp EG, Chisholm DJ, Freund J, Boutcher SH. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *Int J Obes (Lond)*. 2008;32(4):684–91.
43. Wareham NJ, van Sluijs EM, Ekelund U. Physical activity and obesity prevention: a review of the current evidence. *Proc Nutr Soc*. 2005;64(2):229–47.
44. Westerterp KR. Obesity and physical activity. *Int J Obes Relat Metab Disord*. 1999;23(1 Suppl):59–64.
45. Westerterp KR, Meijer GA, Janssen EM, Saris WH, Ten Hoor F. Long-term effect of physical activity on energy balance and body composition. *Br J Nutr*. 1992;68(1):21–30.
46. Willey KA, Singh MA. Battling insulin resistance in elderly obese people with type 2 diabetes: bring on the heavy weights. *Diabetes Care*. 2003;26(5):1580–8.
47. World Health Organization. *Global Recommendations on Physical Activity for Health*. Geneva (Switzerland): WHO Press; 2010. pp. 24–6.