Alterations in body weight and composition consequent to 20 wk of endurance training: the HERITAGE Family Study[1–3]

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ABSTRACT

Background: Obesity is a major public health problem in the United States. The role of physical activity and formal exercise in controlling body weight has not been clearly determined.

Objective: This study determined the magnitude of change in body weight and composition across sex, race, and age in response to 20 wk of endurance training.

Design: Men and women (*n* = 557) of various ages (16–65 y) and 2 races (black and white) exercised on cycle ergometers 3 d/wk for a total of 60 exercise sessions starting at 55% of maximal oxygen consumption ($\dot{V}O_2$max) for 30 min/session and building to 75% of $\dot{V}O_2$max for 50 min/session, where it was maintatined during the last 6 wk. Skinfold-thickness measurements, circumferences, body composition (by hydrostatic weighing), and body fat distribution (by computed tomography scan at L4-L5 and the waist-hip ratio) were determined before and after training.

Results: All skinfold-thickness and circumference measures, waist-hip ratio, body mass index, total body mass, fat mass, percentage body fat, and computed tomography scan measures of total, subcutaneous, and visceral abdominal fat decreased with training, whereas total body density and fat-free mass increased. These changes were significant, but small. There were several differences in training response by sex and race, but not by age.

Conclusions: A short-term exercise intervention can induce favorable changes in body composition, but the magnitude of these changes is of limited biological significance. Increasing physical activity likely has a major effect on body-composition and fat distribution characteristics only when it is of a greater magnitude and sustained for much longer periods *Am J Clin Nutr* 1999;70:346–52.

KEY WORDS Body composition, fat mass, fat-free mass, visceral fat, skinfold thicknesses, endurance training, weight control, obesity, HERITAGE Family Study

INTRODUCTION

In 1990, the US Department of Health and Human Services set a goal of reducing the prevalence of overweight in the United States to not >20% in people aged ≥20 y, and not >15% in adolescents 12–19 y of age by the year 2000 (1). These goals were based on an existing prevalence of overweight in the US adult population of 25.4%, with overweight being defined at that time as a body mass index (BMI; in kg/m^2) ≥27.8 for men and ≥27.3 for women [second National Health and Nutrition Examination Survey (NHANES II) 1976–1980 (2)]. In 1994, Kuczmarski et al (2) reported that the prevalence of obesity in the US, using these same BMI standards, had increased to 33.4% on the basis of initial data from NHANES III obtained between 1988 and 1991. More recent data from NHANES III, obtained between 1988 and 1994, indicate that the prevalence of obesity has increased to nearly 35% for US adults (3). Even more remarkable, the prevalence of overweight in Hispanic women and non-Hispanic black women was 46.7% and 48.6%, respectively (2). Similar data were reported for children and adolescents (4). Of great significance is the fact that the prevalence data remained very consistent between 1960 and 1980, with this big increase occurring after 1980—a trend that is consistent across age, sex, and race.

These data represent a population trend of positive energy balance, because there was an increase in the mean body weight of 3.6 kg between NHANES II (1976–1980) and NHANES III (1988–1991) for men and women (2). This weight gain is attributed to an increasingly sedentary lifestyle, a failure to increase energy expenditure to match energy intake, or both. Less clear, however, is the role that a formal exercise-training program plays in promoting weight loss and the loss of body fat in a previously

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TABLE 1
Physical characteristics of the HERITAGE Family Study subjects[1]

	Age	Height	Weight	BMI
	y	*cm*	*kg*	*kg/m²*
All subjects (*n* = 557)	34.0 ± 13.6	170.1 ± 9.3	73.9 ± 16.1	25.4 ± 4.6
By sex				
Men (*n* = 258)	35.2 ± 14.2	177.4 ± 6.4	82.1 ± 14.7	26.0 ± 4.3
Women (*n* = 299)	33.1 ± 13.1	163.8 ± 6.3	66.9 ± 13.7	24.9 ± 4.8
By race				
Blacks (*n* = 159)	32.3 ± 11.5	168.7 ± 9.1	75.7 ± 16.0	26.6 ± 5.0
Whites (*n* = 398)	34.8 ± 14.3	170.7 ± 9.4	73.2 ± 16.1	25.0 ± 4.4
By age				
Children (*n* = 383)[2]	25.9 ± 6.5	170.5 ± 9.5	72.3 ± 16.3	24.7 ± 4.6
Parents (*n* = 174)	52.0 ± 5.8	169.1 ± 8.9	77.6 ± 14.9	27.0 ± 4.1

[1] $\bar{x}$ ± SD.
[2] Offspring of parents; were required to be ≥17 y of age.

sedentary population. Several studies have shown losses in total body mass of >10 kg as a result of formal exercise training without dieting over a period ≤20 wk (5, 6), whereas others have reported no weight loss with 12 wk of exercise training without dieting (7), or even a weight gain with 12 mo of exercise training without dieting (8). In a recent review of exercise training and weight loss, Wilmore (9) took the average changes in body weight per week from several hundred studies and concluded that the average weight loss over 12 mo of exercise training would amount to only 3.2 kg.

Many of the studies that have investigated the effect of exercise training on weight loss were not well controlled. Some used a moderately active population and most had a small sample size, the latter being heavily influenced by individual variability in response to the exercise stimulus. Consequently, it is not entirely clear how effective exercise training is in free-living people in reducing body weight and favorably altering body composition. Therefore, the purpose of this study was to determine the effects of a highly controlled exercise-training stimulus over a period of 20 wk on body weight and composition in a previously sedentary population of >500 participants. These data were obtained as a part of the HERITAGE Family Study.

The HERITAGE Family Study is a large multicenter clinical trial investigating the possible genetic basis for the variability in the responses of physiologic measures and risk factors for cardiovascular disease and type 2 diabetes mellitus to endurance exercise training. Details of the aims, experimental design, and measurement protocols of the HERITAGE Family Study were presented in detail in a previous publication (10).

SUBJECTS AND METHODS

Subjects

Subjects were recruited from 4 clinical centers [Indiana University (formerly at Arizona State University), Laval University in Québec, the University of Minnesota at Minneapolis, and the University of Texas at Austin]. The Data Coordinating Center is located at Washington University Medical School, St Louis. The HERITAGE Family Study subject population consists of families, including the natural fathers and mothers (less than or equal to 65 y of age) and ≥3 offspring aged ≥17 y of age for white families, and the natural parents and ≥2 offspring aged ≥17 y of age for black families. Inclusion and exclusion criteria were summarized in detail in a prior publication (10). Specific criteria of importance to this paper included the fact that participants were sedentary at baseline and had a BMI <40. Several participants with BMIs slightly in excess of this value were included in the study if they were considered by the supervising physician at one of the Clinical Centers to be relatively healthy and able to exercise at the intensities and for the durations required in the study. A total of 744 participants finished all HERITAGE testing and training protocols. Of this total, 557 had complete body-composition data and constitute the sample of this study. Their characteristics are presented in **Table 1**. The study protocol had been previously approved by each clinical center's institutional review board and informed consent was obtained from each participant.

Experimental design

Participants were screened by the clinical center's supervising physician and staff; only those who were previously sedentary, free of preexisting disease, and not taking any medications that would affect any of the outcome variables were allowed to enter the study (10). The following comprehensive battery of tests was administered before subjects started the training program: health, medical, and nutrition questionnaires; maximal and submaximal exercise tests; blood tests for lipids, lipoproteins, and sex steroids; an intravenous-glucose-tolerance test; measurement of resting blood pressure; and body-composition tests. After the initial battery of tests, subjects completed a 20-wk endurance-training program (3 d/wk for a total of 60 exercise sessions) on cycle ergometers that were computer controlled to maintain the participants' heart rates at fixed percentages of their aerobic capacity ($\dot{V}O_2$max). The training program started at 55% of $\dot{V}O_2$max for 30 min/session and gradually increased to 75% of $\dot{V}O_2$max for 50 min/session, where it was maintained during the last 6 wk of training. The test battery was administered again at the conclusion of the training program.

For the body-composition assessment, participants reported to the laboratory ≥4 h after eating, having performed no formal exercise in the previous 4 h. The entire anthropometric and body-composition test battery was administered on a single day, except for the computed tomography scan for abdominal visceral adipose tissue, which was usually scheduled for a different day. Participants changed into their bathing suits and voided their bladders and evacuated their bowels, if necessary. Height and weight, hip and waist circumferences, subcutaneous skinfold thicknesses, residual lung volume, and underwater weight were measured. Identical measurement protocols were used pre- and posttraining.

Body-composition assessment and anthropometric methods

Height and body weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, by using a balance-beam scale and a stadiometer. Waist and hip circumferences were measured to the nearest 0.1 cm by using an anthropometric fiber glass tape (model 17-1340-2; Grafco Fiberglass Tape, Grahams-Fields, Inc, Hauppauge, NY). Skinfold-thickness measurements were then obtained at the subscapular, biceps, triceps, midaxillary, suprailiac, abdominal, thigh, and calf skinfold sites by using a Harpenden skinfold caliper (no. 03496-001; Quinton Instruments Co, Bothell, WA). The height, weight, circumference, and skinfold-thickness measurements were taken in accordance with the procedures recommended by Lohman et al (11). All measurements were taken in duplicate. A third measurement was taken if the first 2 measurements differed by a predetermined amount: height by >0.5 cm, weight by >200 g, circumference by >1.0 cm, and skinfold thicknesses by >1.0 mm. When it was necessary to take a third measurement, the 2 closest measurements were averaged. When the third measurement fell equally between the first 2, all 3 were averaged.

Hydrostatic weighing was used to assess body density according to the method of Behnke and Wilmore (12). The subjects was instructed to exhale completely to the point of residual lung volume, at which point a load cell interfaced with a computer was used to obtain the underwater measurement of body weight. Ten measurements were obtained and the 3 highest values were averaged. Residual lung volume was assessed out of the water in a seated position by using the oxygen-dilution principle, as described by Wilmore (13) and modified by Wilmore et al (14), at the Indiana, Minnesota, and Texas clinical centers. A minimum of 2 measurements were obtained and a third measurement was taken if the first 2 differed by >150 mL. An average of the first 2 trials, or the 2 closest trials, was used in the correction for the residual lung volume in the estimation of body density. At the Québec clinical center, residual lung volume was measured in the water by using the helium-dilution technique (15, 16). Percentage body fat was estimated from body density by using the equations of Siri (17) for white men, Lohman (18) for white women, Schutte et al (19) for black men, and Ortiz et al (20) for black women.

Computed tomography methods

Computed axial tomography (CT) was used to provide an estimate of abdominal visceral adipose tissue at the level of the vertebral disc between the fourth and fifth lumbar vertebrae (L4-L5 space) by using either a Siemens Somatom DRH scanner (Erlangen, Germany) or a General Electric model CT 9800 scanner (Waukesha, WI). The general procedures described by Sjöström et al (21) were followed. Participants were clothed only in loose-fitting gowns because restrictive clothing had been determined to alter the distribution of fat. They were examined in the supine position, with their arms stretched above their heads. One scan was performed by using a lateral view radiograph of the skeleton (abdominal area) to establish the position of the L4-L5 space within 1.0 mm. A second scan was then performed at the L4-L5 space (at 125 kV and with a slice thickness of 8 mm). A single, standardized calibration unit was developed by using lard carefully sealed within a plexiglass cylinder. This unit was transported to each clinical center every 6–12 mo to ensure the reliability and consistency of the method between the 4 clinical centers. Pre- and posttraining measurements were conducted at the same time by the same technician to minimize technical error. Total and visceral fat areas were calculated by delineating those areas with an electronic graph pen and then computing the adipose tissue surfaces by using an attenuation range of −30 to −190 Hounsfield units. The subcutaneous abdominal fat area was calculated as the difference between the total and visceral fat areas.

Quality-assurance, quality-control, and statistical methods

Important quality-assurance and quality-control procedures were instituted across all 4 clinical centers, as described by Gagnon et al (22). One or 2 staff members at each clinical center was responsible for all anthropometric, hydrostatic weighing, residual volume, and CT scan measurements, and the same staff member was responsible for both pre- and posttraining measurements on any given subject. A detailed "Manual of Procedures" (MOP) was developed, and staff were required to review, every 6 mo, those sections of the MOP for which they were responsible. Finally, the reproducibility of all anthropometric and body-composition measurements were published (23).

All data were analyzed by using the SAS statistical package (version 6.12; SAS Institute Inc, Cary, NC). Data are expressed as means ± SDs except where noted otherwise. A matched-pair *t* test was used to determine the significance of differences between pre- and posttraining data. A multiple-testing analysis of variance was implemented by using the general linear models procedure to determine the influence of sex, age (children versus parents), and race (blacks versus whites) on the magnitude of change in any given variable. Statistical significance was established at the 0.05 level.

RESULTS

The reproducibility of measurements in this study was very high, as was recently reported (23). This was determined in a separate substudy of 60 participants who were representative of the characteristics of the HERITAGE Family Study subject population for skinfold-thickness measurements, circumferences, height, weight, hydrostatic weight, residual lung volume, and body density, from which percentage body fat, fat mass, and fat-free mass were determined. Participants in this substudy were tested 3 times on separate days under identical conditions over a 3-wk period. Intraclass correlations generally ranged from 0.95 to 0.99 for all variables across the 4 clinical centers. Technical errors and CVs within subjects were also low.

The pre- and posttraining data for the skinfold-thickness variables are presented in **Table 2**. There was a small but significant decrease in skinfold thickness at each of the 8 sites and for the sum of all 8 sites in the total sample. For the 8 sites combined there was a 4.2% decrease posttraining. The largest changes were at the biceps (−5.5%) and suprailiac (−7.1%) sites and the smallest changes were at the calf (−3.0%) and subscapular (−2.3%) sites. The absolute change was independent of the initial size of a given site. When these data were analyzed by sex, race, and age, women and blacks showed no changes at the subscapular site, and blacks showed no change at the midaxillary, abdominal, and calf sites. Whites had greater changes than blacks at the midaxillary and abdominal sites and for the sum of all skinfold-thickness

TABLE 2
Changes in skinfold-thickness measurements pre- to posttraining

Skinfold site	Pretraining[1]	Posttraining[1]	Difference (post − pre)[2]
Subscapula (mm)			
Total	17.5 ± 8.8	17.1 ± 8.6	−0.4 ± 0.1[3]
Men	17.1 ± 8.5	16.5 ± 8.3	−0.6 ± 0.1[3]
Women	17.9 ± 8.9	17.6 ± 8.8	−0.3 ± 0.2
Blacks	20.3 ± 10.2	20.1 ± 10.3	−0.2 ± 0.3
Whites	16.4 ± 7.9	15.9 ± 7.5	−0.5 ± 0.1[3]
Children	15.9 ± 8.2	15.6 ± 8.1	−0.3 ± 0.1[3]
Parents	20.9 ± 9.0	20.4 ± 8.7	−0.6 ± 0.2[3]
Biceps (mm)			
Total	9.1 ± 6.0	8.6 ± 5.7	−0.5 ± 0.1[3]
Men	6.7 ± 4.4	6.3 ± 4.1	−0.4 ± 0.1[3]
Women	11.2 ± 6.4	10.5 ± 6.1	−0.7 ± 0.1[3]
Blacks	9.4 ± 6.6	8.8 ± 6.0	−0.6 ± 0.2[3]
Whites	9.0 ± 5.8	8.5 ± 5.6	−0.5 ± 0.1[3]
Children	8.1 ± 5.3	7.6 ± 4.8	−0.5 ± 0.1[3]
Parents	11.3 ± 7.0	10.7 ± 6.8	−0.6 ± 0.2[3]
Triceps (mm)			
Total	16.9 ± 7.6	16.4 ± 7.5	−0.6 ± 0.1[3]
Men	12.6 ± 5.7	12.1 ± 5.6	−0.5 ± 0.1[3]
Women	20.7 ± 7.0	20.1 ± 6.9	−0.6 ± 0.1[3]
Blacks	17.5 ± 8.4	17.1 ± 8.3	−0.4 ± 0.2[3]
Whites	16.7 ± 7.2	16.1 ± 7.1	−0.6 ± 0.1[3]
Children	16.0 ± 7.1	15.5 ± 7.1	−0.5 ± 0.1[3]
Parents	18.9 ± 8.1	18.3 ± 7.9	−0.7 ± 0.2[3]
Midaxillary (mm)			
Total	14.9 ± 7.6	14.3 ± 7.3	−0.6 ± 0.1[3]
Men	15.0 ± 7.6	14.3 ± 7.3	−0.8 ± 0.1[3]
Women	14.9 ± 7.6	14.4 ± 7.3	−0.5 ± 0.2[3]
Blacks	15.6 ± 7.8	15.3 ± 7.7	−0.3 ± 0.2[4]
Whites	14.7 ± 7.6	13.9 ± 7.1	−0.8 ± 0.1[3,4]
Children	13.4 ± 7.3	12.8 ± 6.9	−0.6 ± 0.1[3]
Parents	18.4 ± 7.1	17.6 ± 7.0	−0.8 ± 0.2[3]
Suprailiac (mm)			
Total	22.6 ± 10.4	21.0 ± 9.9	−1.6 ± 0.2[3]
Men	23.8 ± 11.1	21.6 ± 10.2	−2.2 ± 0.3[3,5]
Women	21.5 ± 9.7	20.5 ± 9.6	−1.1 ± 0.3[3,5]
Blacks	24.2 ± 11.2	22.9 ± 10.5	−1.3 ± 0.4[3]
Whites	22.0 ± 10.1	20.2 ± 9.5	−1.7 ± 0.2[3]
Children	21.9 ± 10.4	20.0 ± 9.8	−1.8 ± 0.2[3]
Parents	24.2 ± 10.3	23.1 ± 9.7	−1.1 ± 0.3[3]
Abdominal (mm)			
Total	25.1 ± 10.6	24.1 ± 10.5	−1.0 ± 0.2[3]
Men	24.3 ± 11.1	22.8 ± 10.6	−1.5 ± 0.2[3,5]
Women	25.8 ± 10.1	25.3 ± 10.3	−0.5 ± 0.3[3,5]
Blacks	25.5 ± 11.7	25.4 ± 11.9	−0.1 ± 0.3[4,6]
Whites	25.0 ± 10.1	23.6 ± 9.9	−1.4 ± 0.2[3,4,6]
Children	23.1 ± 10.2	22.2 ± 10.1	−0.9 ± 0.2[3]
Parents	29.7 ± 10.0	28.5 ± 10.1	−1.2 ± 0.3[3]
Thigh (mm)			
Total	25.1 ± 12.1	24.1 ± 11.6	−1.0 ± 0.1[3]
Men	16.5 ± 8.2	15.9 ± 7.8	−0.7 ± 0.1[3,5]
Women	32.6 ± 9.8	31.2 ± 9.6	−1.4 ± 0.2[3,5]
Blacks	24.8 ± 12.7	23.9 ± 12.4	−0.9 ± 0.3[3]
Whites	25.3 ± 11.8	24.2 ± 11.3	−1.1 ± 0.2[3]
Children	24.2 ± 11.3	23.3 ± 11.1	−0.9 ± 0.2[3]
Parents	27.2 ± 13.3	26.0 ± 12.7	−1.2 ± 0.3[3]
Calf (mm)			
Total	16.7 ± 8.8	16.2 ± 8.6	−0.5 ± 0.1[3]
Men	11.2 ± 5.9	10.9 ± 5.6	−0.3 ± 0.1[3]
Women	21.4 ± 8.2	20.8 ± 8.0	−0.6 ± 0.2[3]
Blacks	17.3 ± 9.7	17.0 ± 9.5	−0.3 ± 0.3
Whites	16.4 ± 8.4	15.9 ± 8.1	−0.5 ± 0.1[3]
Children	16.1 ± 8.3	15.8 ± 8.1	−0.4 ± 0.1[3]
Parents	17.9 ± 9.9	17.3 ± 9.5	−0.6 ± 0.2[3]
Sum of all (mm)			
Total	148.0 ± 59.5	141.8 ± 58.4	−6.2 ± 0.7[3]
Men	127.3 ± 54.0	120.4 ± 51.5	−6.9 ± 0.9[3]
Women	165.9 ± 58.2	160.3 ± 57.7	−5.6 ± 1.0[3]
Blacks	154.5 ± 66.9	150.4 ± 66.4	−4.1 ± 1.5[3,4]
Whites	145.5 ± 56.2	138.4 ± 54.5	−7.1 ± 0.8[3,4]
Children	138.7 ± 57.3	132.8 ± 56.4	−5.9 ± 0.8[a]
Parents	168.5 ± 59.3	161.7 ± 57.8	−6.8 ± 1.2[a]

[1] $\bar{x}$ ± SD.
[2] $\bar{x}$ ± SE.
[3–6] Significant difference, $P < 0.05$: [3]pre- compared with posttraining, [4] by race, [5]by sex, [6]for women by race.

sites. Men had greater changes than women at the suprailiac and abdominal sites, and lesser changes at the thigh site. There was a sex-by-race interaction at the abdominal site, with white women losing 1.0 cm and black women gaining 0.5 cm. Age did not affect the magnitude of change.

Pre- and posttraining data for weight and the body-composition variables are presented in **Table 3**. There were small but significant decreases in body weight, BMI, fat mass, and percentage body fat and small but significant increases in whole-body density and fat-free mass for the total sample. Fat mass and percentage fat had the greatest pre- to posttraining changes (>3%). When analyzed by group, women, blacks, and children did not lose weight. Men lost a greater amount of fat than women, but there were no other sex, race, or age differences.

The pre- to posttraining data for the CT-determined changes in fat distribution and the surrogate measure of fat distribution, waist-hip ratio, are shown in **Table 4**. There were significant decreases in all measures of fat distribution for the total sample, although the magnitude of the change was generally small. The largest change was in the abdominal visceral adipose tissue (5.9%) and the smallest change was in the waist-hip ratio (0.6%). When analyzed by group, blacks showed no changes in hip circumference or waist-hip ratio. Men had a greater change than did women in abdominal visceral fat, and white women had a greater change (1.2 mm) than black women (0.3 mm) in waist circumference.

DISCUSSION

The HERITAGE Family Study is the largest, well-controlled training study of its kind. Even when the total study population is divided into groups by age, sex, and race, there are still substantial numbers of participants per group. The magnitude of the change in each of the variables we examined was relatively small but significant. In 2 reviews, Wilmore (9, 24) estimated from the existing literature that the average change with a typical exercise intervention over a 6-mo period would be a loss of 1.6 kg total body mass, 2.6 kg fat mass, and 2.9% in percentage body fat, and a gain of 1.0 kg fat-free mass. The changes in the HERITAGE Family Study fall short of these expected changes, even when you convert 26-wk data (6 mo) to 20-wk data. The reasons for this are not entirely obvious.

TABLE 3
Changes in weight, BMI, and body composition pre- to posttraining

Body composition variables	Pretraining[1]	Posttraining[1]	Difference (post − pre)[2]
Weight (kg)			
Total	73.9 ± 16.1	73.7 ± 15.8	−0.2 ± 0.1[3]
Men	82.1 ± 14.7	81.7 ± 14.4	−0.4 ± 0.1[3]
Women	66.9 ± 13.7	66.8 ± 13.6	−0.1 ± 0.1
Blacks	75.7 ± 16.0	75.5 ± 15.8	−0.2 ± 0.2
Whites	73.2 ± 16.1	73.0 ± 15.8	−0.2 ± 0.1[3]
Children	72.3 ± 16.3	72.1 ± 16.0	−0.2 ± 0.1
Parents	77.6 ± 14.9	77.2 ± 14.8	−0.3 ± 0.2[3]
Density (kg/L)			
Total	1.0397 ± 0.0220	1.0415 ± 0.0220	0.0018 ± 0.0002[3]
Men	1.0509 ± 0.0191	1.0530 ± 0.0189	0.0021 ± 0.0002[3]
Women	1.0300 ± 0.0197	1.0316 ± 0.0195	0.0016 ± 0.0003[3]
Blacks	1.0392 ± 0.0227	1.0410 ± 0.0227	0.0018 ± 0.0004[3]
Whites	1.0399 ± 0.0218	1.0417 ± 0.0217	0.0018 ± 0.0002[3]
Children	1.0446 ± 0.0216	1.0465 ± 0.0215	0.0019 ± 0.0002[3]
Parents	1.0290 ± 0.0191	1.0306 ± 0.0190	0.0015 ± 0.0003[3]
Percentage body fat (%)			
Total	26.5 ± 9.9	25.6 ± 9.8	−0.8 ± 0.1[3]
Men	21.9 ± 8.3	20.9 ± 8.1	−0.9 ± 0.1[3]
Women	30.4 ± 9.5	29.7 ± 9.4	−0.7 ± 0.1[3]
Blacks	28.6 ± 9.7	27.8 ± 9.7	−0.7 ± 0.2[3]
Whites	25.6 ± 9.9	24.8 ± 9.8	−0.9 ± 0.1[3]
Children	24.3 ± 9.7	23.4 ± 9.6	−0.9 ± 0.1[3]
Parents	31.2 ± 8.6	30.5 ± 8.6	−0.7 ± 0.1[3]
Fat mass (kg)			
Total	20.2 ± 10.3	19.5 ± 10.1	−0.7 ± 0.1[3]
Men	18.8 ± 9.8	17.9 ± 9.5	−0.9 ± 0.1[3,4]
Women	21.4 ± 10.6	20.9 ± 10.4	−0.5 ± 0.1[3,4]
Blacks	22.2 ± 10.5	21.6 ± 10.4	−0.6 ± 0.2[3]
Whites	19.4 ± 10.1	18.7 ± 9.9	−0.7 ± 0.1[3]
Children	18.2 ± 10.1	17.5 ± 9.8	−0.7 ± 0.1[3]
Parents	24.6 ± 9.4	23.9 ± 9.2	−0.7 ± 0.1[3]
Fat-free mass (kg)			
Total	53.7 ± 11.0	54.2 ± 11.0	0.5 ± 0.1[3]
Men	63.3 ± 7.7	63.7 ± 7.8	0.5 ± 0.1[3]
Women	45.5 ± 5.2	46.0 ± 5.2	0.4 ± 0.1[3]
Blacks	53.5 ± 10.9	53.9 ± 10.8	0.4 ± 0.1[3]
Whites	53.8 ± 11.0	54.3 ± 11.1	0.5 ± 0.1[3]
Children	54.1 ± 11.2	54.6 ± 11.3	0.5 ± 0.1[3]
Parents	53.0 ± 10.4	53.3 ± 10.4	0.3 ± 0.1[3]

[1] $\bar{x} \pm$ SD.
[2] $\bar{x} \pm$ SE.
[3,4] Siginificant difference, $P < 0.05$: [3] pre- compared with posttraining, [4] by sex.

One of the most unique features of the HERITAGE Family Study is the highly controlled exercise intervention. Each exercise session was monitored by an exercise technician and by computer. For each session, the computer obtained data on exercise heart rate and power output for each minute of exercise. This allowed careful documentation of the total work performed each day, and the grand total for all 60 training sessions. Although there was great variability between participants, the mean power output for all participants over the 60 exercise sessions was ≈75 W, which is approximately the equivalent of 0.90 L O_2 energy expenditure/min above resting levels. Over 60 exercise sessions, at an average of 42 min/session, an average of 2268 L O_2 would have been expended (≈11 340 kcal or 47 450 kJ). The expected loss in fat mass would be ≈1.3 kg, assuming no change in energy intake or in the other components of energy expenditure such as resting metabolic rate (RMR), the thermic effect of food, or spontaneous physical activity. We recently showed that there was no change in RMR after the 20-wk training program (25). Because the actual change in fat mass was only 0.7 kg, there was likely either a compensatory increase in energy intake, a decrease in spontaneous physical activity, or both. Neither was measured in this study, and few studies have attempted to measure these 2 variables because of the imprecision of the available techniques and the time and cost associated with these measures.

The changes in the abdominal visceral fat were small but important from a health perspective (26). Although there is not extensive literature on exercise training and changes in abdominal visceral fat, the results from this study are consistent with those of others and are consistent with expectations based on the loss of total body fat from exercise alone or in combination with diet (27). Both before and after training, men had substantially more abdominal visceral fat than women, whites had more than blacks, and parents had about twice as much as their children. These findings are consistent with those in the research literature (28–30).

Women lost less subcutaneous (skinfold) fat than men at 3 of 8 sites, less abdominal visceral fat, and less total fat, which is consistent with the literature (31). It is possible that women are more resistant to weight loss with exercise. In a recent study conducted in our laboratory (HK Byrne and JH Wilmore, unpublished observations, 1997), previously sedentary, moderately overweight women placed on an intense, 6-mo, resistance-training program actually gained total mass and fat mass, even though they were instructed to maintain the same diet and activity pattern that they had before starting the study, other than the formal exercise training during the experimental period. The initial percentage body fat values of these women were similar to those in the present HERITAGE Family Study. It is possible that the moderately overweight women in these 2 studies were restrained eaters before starting the exercise program and felt free to eat whatever they wanted to (ie, unrestrained) once they began formal exercise training.

In summary, the 20-wk endurance exercise-training program of the HERITAGE Family Study resulted in small but significant changes in body composition. It appears that formal exercise training of limited duration, in and of itself, is not a major factor in weight loss, or more specifically, fat loss in free-living adults. It is becoming increasingly clear from the scientific literature that formal exercise training, or simply a physically active lifestyle, makes its major contribution by preventing weight gain, but not by inducing weight loss for those individuals who already have an established pattern of energy intake and expenditure that leads to an overweight or obese state (24). It is also useful as an adjunct to dieting for management of obesity and in helping to maintain lost weight and preserving fat-free mass. Furthermore, long-term exercise habits and larger energy expenditures per exercise session should lead to greater changes in body composition and fat distribution.

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TABLE 4

Changes in abdominal subcutaneous, visceral, and total fat (L4-L5), and hip and waist circumferences and waist-hip ratio pre- to posttraining

Fat and circumference variables	Pretraining[1]	Posttraining[1]	Difference (post − pre)[2]
Abdominal subcutaneous fat (cm^2)			
Total	245.7 ± 138.8	236.8 ± 137.3	−8.9 ± 1.1[3]
Men	208.5 ± 123.1	198.5 ± 118.8	−10.0 ± 1.4[3]
Women	277.9 ± 143.7	269.9 ± 143.7	−8.0 ± 1.7[3]
Blacks	259.3 ± 157.2	252.0 ± 157.1	−7.3 ± 2.2[3]
Whites	240.3 ± 130.5	230.8 ± 128.3	−9.6 ± 1.3[3]
Children	224.7 ± 140.8	215.3 ± 137.9	−9.3 ± 1.4[3]
Parents	292.2 ± 122.4	284.1 ± 123.8	−8.0 ± 1.8[3]
Abdominal visceral fat (cm^2)			
Total	77.9 ± 51.3	73.3 ± 48.5	−4.6 ± 0.6[3]
Men	90.7 ± 54.9	84.3 ± 52.7	−6.4 ± 1.0[3,4]
Women	66.9 ± 45.2	63.8 ± 42.3	−3.1 ± 0.7[3,4]
Blacks	64.5 ± 41.6	60.8 ± 39.7	−3.7 ± 1.0[3]
Whites	83.3 ± 53.8	78.3 ± 50.7	−5.0 ± 0.7[3]
Children	59.5 ± 35.6	55.6 ± 32.9	−3.9 ± 0.6[3]
Parents	118.4 ± 57.0	112.2 ± 54.2	−6.2 ± 1.4[3]
Abdominal total fat (cm^2)			
Total	323.7 ± 171.9	310.1 ± 168.2	−13.5 ± 1.4[3]
Men	299.2 ± 163.9	282.9 ± 158.1	−16.3 ± 1.9[3]
Women	344.7 ± 176.1	333.6 ± 173.3	−11.1 ± 2.0[3]
Blacks	323.7 ± 185.6	312.8 ± 183.6	−11.0 ± 2.7[3]
Whites	323.6 ± 166.4	309.1 ± 161.9	−14.5 ± 1.6[3]
Children	284.1 ± 164.7	271.0 ± 160.0	−13.2 ± 1.7[3]
Parents	410.6 ± 155.1	396.3 ± 153.6	−14.3 ± 2.4[3]
Hip circumference (cm)			
Total	101.9 ± 9.5	101.3 ± 9.4	−0.5 ± 0.1[3]
Men	101.7 ± 8.4	101.2 ± 8.3	−0.6 ± 0.1[3]
Women	102.0 ± 10.4	101.5 ± 10.2	−0.5 ± 0.1[3]
Blacks	102.9 ± 10.6	102.6 ± 10.5	−0.4 ± 0.2
Whites	101.4 ± 9.0	100.8 ± 8.9	−0.6 ± 0.1[3]
Children	100.8 ± 9.4	100.2 ± 9.2	−0.5 ± 0.1[3]
Parents	104.2 ± 9.3	103.7 ± 9.2	−0.5 ± 0.2[3]
Waist circumference (cm)			
Total	88.2 ± 13.8	87.3 ± 13.6	−0.9 ± 0.1[3]
Men	91.8 ± 12.6	90.8 ± 12.4	−1.0 ± 0.1[3]
Women	85.2 ± 14.0	84.2 ± 13.8	−0.9 ± 0.2[3]
Blacks	88.4 ± 13.6	87.8 ± 13.4	−0.7 ± 0.3[3,5]
Whites	88.1 ± 13.8	87.1 ± 13.7	−1.1 ± 0.1[3,5]
Children	84.9 ± 13.1	84.0 ± 12.9	−0.9 ± 0.2[3]
Parents	95.4 ± 12.4	94.4 ± 12.4	−1.0 ± 0.2[3]
Waist-hip ratio			
Total	0.863 ± 0.079	0.858 ± 0.078	−0.005 ± 0.001[3]
Men	0.900 ± 0.071	0.895 ± 0.070	−0.005 ± 0.001[3]
Women	0.832 ± 0.073	0.827 ± 0.071	−0.005 ± 0.001[3]
Blacks	0.857 ± 0.074	0.853 ± 0.072	−0.004 ± 0.002
Whites	0.866 ± 0.081	0.861 ± 0.081	−0.005 ± 0.001[3]
Children	0.840 ± 0.069	0.835 ± 0.068	−0.004 ± 0.001[3]
Parents	0.915 ± 0.077	0.909 ± 0.076	−0.006 ± 0.002[3]

[1] $\bar{x}$ ± SD.

[2] $\bar{x}$ ± SE.

[3–5] Significant difference, $P < 0.05$: [3] pre- compared with posttraining, [4] by sex, [5] women by race.

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