Resistance training and intra-abdominal adipose tissue in older men and women

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ABSTRACT

HUNTER, G. R., D. R. BRYAN, C. J. WETZSTEIN, P. A. ZUCKERMAN, and M. M. BAMMAN. Resistance training and intra-abdominal adipose tissue in older men and women. *Med. Sci. Sports Exerc.*, Vol. 34, No. 6, pp. 1023–1028, 2002. **Purpose:** Little is known concerning the effects of resistance-exercise training (RT) on older adult's intra-abdominal adipose tissue (IAAT). The purpose of this study was to determine the effects of RT on fat distribution in 12 women and 14 men, aged 61–77 yr. **Methods:** Computed tomography IAAT and abdominal subcutaneous adipose tissue (SAT), densitometry-determined body composition, one-repetition maximum (1-RM), and isometric strength were measured before and after 25 wk of RT. Training consisted of two sets of 10 repetitions at 65–80% of 1-RM, three times each week. **Results:** There were similar increases in strength for both the men and women. Women improved 22% and 38% in the isometric strength test and 1-RM test, respectively, whereas the men improved 21% and 36%, respectively. A significant increase in fat-free mass (FFM) was found for both men and women. However, there was a significant gender × time interaction, which indicated that men increased FFM more than women (2.8 kg vs 1.0 kg, respectively). Similar decreases in fat mass (FM) were found for the men (1.8 kg) and women (1.7 kg). However, women lost a significant amount of IAAT (131 to 116 cm^2), whereas the men did not (143 to 152 cm^2). Similarly, women also lost a significant amount of SAT (254 to 239 cm^2), but men did not (165 to 165 cm^2). **Conclusion:** Despite similar decreases in FM after a 25-wk RT program, older women lost significant amounts of IAAT and SAT, whereas the older men did not. **Key Words:** FAT DISTRIBUTION, EXERCISE, BODY WEIGHT

The incidence of obesity continues to be one of our nation's most serious health problems (23). However, where fat is distributed may be more important to health than the total amount of body fat. It is well established that fat distributed in the trunk and especially intra-abdominal adipose tissue (IAAT) is related to the development of diabetes and heart disease, as well as mortality (3,10,16,34,40). Whereas on the other hand, fat distributed in the legs appears to impose little or no risk (16,18,40).

Strategies for decreasing elevated IAAT levels are considered to be beneficial to overall health risk, especially in older adults. Younger women have lower IAAT than younger men (16,17). However, men and especially women increase IAAT with age until absolute amounts of IAAT are similar between men and women in their 7th decade (16,17). In addition, available data suggest that at least part of the increased cardiovascular risk observed in older adults may be mediated by increased IAAT (16,17,40,41). Several studies have shown that more active individuals have lower IAAT after adjusting for total body fat. This suggests physical activity may be related to a proportionately larger decrease in fat stored in the intra-abdominal cavity (16,17).

Several aerobic exercise-training studies suggest that IAAT is reduced in both men (5,28,33) and women (8,28) after training. However, few studies have reported changes in IAAT after resistance-exercise training (RT) (38). In one study, a 10% reduction in computed tomography (CT)–determined IAAT was reported in older women (>60 yr) after 16 wk of RT (38), and in an unpublished dissertation, Smith (36) surprisingly reported no significant change in IAAT in older men after 16 wk of resistance training despite significant decreases in fat mass (FM). Resistance training may hold promise for decreasing IAAT in older adults, however. These limited prior findings raise the possibility of gender specificity. Therefore, the purpose of this study was to determine the effect of gender on RT-induced changes in IAAT among adults 60 yr and older.

METHODS

Subjects. Fifteen women and 15 men, 61–77 yr old, participated in a 25-wk RT program. Although all the subjects completed the study, data from one woman and one man were not reported due to injury from unrelated activities, which resulted in the subjects missing over 20% of the training sessions. Additionally, two women were not included in the analyses because of unreadable CT images. Subjects were of normal body mass index (BMI) and were free of any metabolic disorders and medications that may affect energy expenditure. All subjects were nonsmokers and weight stable (defined as within 1% body weight during the previous 4 wk before the onset of training). None of the

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subjects had ever participated in RT before, and all subjects, except one, were sedentary (defined as exercising less than once per week for the past year). One male subject was a runner and ran between 6 and 7 miles per week in three to four exercise sessions. He continued running at the same level throughout the course of the study. All the women were postmenopausal. Institutional Review Board–approved written informed consent was obtained before participation in the study in compliance with the Department of Health and Human Services Regulations for Protection of Human Research Subjects and the policy statement of Medicine and Science in Sports and Exercise regarding the use of human subjects. Subjects were evaluated before and after 25 wk of RT.

One-repetition maximum (1-RM). For the first three exercise sessions, subjects trained with a resistance that allowed them to become familiar with both the equipment and the exercises. On the fourth session, the subjects performed a 1-RM test on the leg press, leg extension, leg curl, chest press, elbow flexion, and seated press using methods previously described (15,20,21,39). One-RM testing was repeated after the completion of the 25 wk of training. Summation of the upper body (chest press, elbow flexion, and seated press) and lower body (leg press, leg extension, and leg curl) are reported.

Isometric strength tests. To evaluate isometric strength, changes in maximal isometric elbow flexion and knee extension strength was measured using previously described methods (19). During the elbow flexion test, the subject stood with arms fixed to the side wearing a harness designed to limit shoulder movement during the task. Force was measured on the right forearm at the level of the styloid process. Subjects were asked to attempt to flex the elbow as hard as possible with the elbow fixed at a position of 110°. Isometric knee extension strength was obtained at 110° extension while subjects were seated and the legs and upper torso were strapped to the chair to prevent hip movement. Force was measured at the ankle. Subjects were instructed to attempt to straighten the leg as hard as possible. Force was measured with a universal shear beam load cell (LCC 500, Omega, Stamford, CT). A digital transducer (DP2000, Omega Engineering) gave instantaneous force measurement feedback to the subjects. After three practice trials, three maximal isometric contractions were recorded. Sixty seconds of rest was allowed between trials. The average of the two highest maximal forces generated was used for statistical purposes.

Body density. Body density was evaluated with the BOD POD version 1.69 (Body Composition System; Life Measurement Instruments, Concord, CA) as previously described (9). Calibration of chamber pressure amplitudes occurred before all tests by using a 50-L calibration cylinder. While wearing a tight-fitting swimsuit, the subject's raw body volume was determined in the chamber. In a separate step, thoracic gas volume was measured. Thoracic gas volume measurement required the subject to sit quietly in the BOD POD and breath through a disposable tube and filter that was connected to the reference chamber in the rear of the BOD POD. After four or five normal breaths, the airway was occluded during mid-exhalation, and the subject was instructed to make two quick light pants. The Db from the BOD POD was calculated as follows: Db = subject mass/(raw body volume + 0.40 thoracic gas volume − SAA) where SAA (surface area artifact) and 0.40 thoracic gas volume are used to correct for the isothermic conditions within the chamber. Percentage body fat was calculated from body density according to the equation of Siri (35). The repeated measures between consecutive days for Db derived from the BOD POD in eight healthy women has an intraclass correlation of r = 0.98 and a SEE of 0.004 $g \cdot cm^{-3}$ in our laboratory. In addition, we have previously demonstrated good agreement between BOD POD and hydrostatic weight determined density, r = 0.97 and SEE = 0.005 $g \cdot cm^{-2}$ (9).

Computerized tomography (CT). CT scanning was performed on a General Electric HiLight/HTD Advantage Scanner (GEC, Milwaukee, WI). Radiographic factors were 120 kVp and 40 mAs. Examination took place in a supine position with the arms stretched above the heads. Because visceral fat area from a single scan is highly correlated with total visceral fat volume (24,29), IAAT was measured using a single 5-mm scan for 2 s at the umbilicus level. We have previously reported that in individuals who are not overweight, the level of the umbilicus will be within 0.5 cm of the 5th lumbar vertebra (29). Attenuation of circles containing approximately 50% adipose tissue and 50% muscle were measured to determine the upper attenuation limit of adipose tissue. Because it is impossible to know the absolute percentages of adipose tissue and muscle in each of the circles, the intersection of adipose tissue and muscle was determined according to the method of Kvist et al. (25). A total of 20 samples were measured establishing an upper limit of −30 HU and a lower limit of −190 HU. Cross-sectional areas of adipose tissue were determined by using a fat tissue highlighting technique. Test-retest reliability was r = 0.99 for 20 scans, with a coefficient of variation of less than 2%.

Resistance training. Resistance training took place at a local fitness center where the subjects exercised for 25 wk, 3 times per week, for approximately 45 min per session. Investigators trained in the procedures supervised each session. Three initial training sessions were to allow subjects to become familiar with the equipment and exercises. Average adherence rate of the subjects was over 90% and was not significantly different between exercise groups. Each exercise session began with a 5-min warm-up (bicycle ergometer or treadmill) at a low work level followed by 10 static stretches. The resistance exercises were elbow flexion, elbow extension, seated row, seated overhead press, back extension on Cybex Systems equipment (Ronkonkoma, NY) and leg extension, leg curl, and bench press on Keiser K-300 pneumatic variable resistance machines (Fresno, CA). Fifteen to 25 bent leg sit-ups were also performed. In addition, six women and seven men did leg press, and six women and seven men did squats. Subjects were instructed to complete two sets of 10 repetitions (or until failure, which

TABLE 1. Descriptive variables.

Variable	Pretraining		Posttraining	
	Women (N = 12)	Men (N = 14)	Women (N = 12)	Men (N = 14)
Age (yr)	65.9 ± 4.4	67.9 ± 4.4		
Height (cm)*	165.1 ± 4.1	177.5 ± 5.2		
Body mass (kg)†	65.9 ± 9.1	78.5 ± 12.2	65.2 ± 8.5	79.3 ± 12.1
BMI (kg·m^{-2})	24.4 ± 3.1	25.1 ± 3.4	23.9 ± 3.0	25.2 ± 3.4

* Significant paired *t*-test difference, $P < 0.05$.
† Significant gender effect in a time × gender two-way ANOVA with repeated measures for time.
BMI, body mass index (body weight (kg)/height^2 (m)).

ever came first) in all exercises with a 2-min rest between each set. Progression was incorporated into the program with daily training log evaluations. Resistance was increased the subsequent training session if two sets of 10 repetitions were completed for any exercise performed at 80% 1-RM. One-RM testing was performed every 25 d to ensure appropriate progression.

Statistics. A 2 (time) × 2 (gender) analysis of variance (ANOVA) with repeated measures on time was used to evaluate the effects of training on body composition and strength variables. Because the pretraining strength and fat-free mass (FFM) variables were different between men and women, analysis of the time by gender interaction may have been confounded. Therefore, *t*-test gender comparisons were also conducted on the percent change for these variables. *Post hoc* analyses were run between before and after values for each gender for variables in which significant time by gender interaction occurred (1-RM upper-body strength, IAAT, and SAT). To determine whether men and women who had greater amounts of initial IAAT also tended to lose more IAAT, zero-order Pearson product correlations were run between pretraining IAAT and change in IAAT. All analyses were completed using SPSS (SPSS Inc, Chicago, IL) with an alpha of 0.05 for all tests.

RESULTS

Table 1 contains the descriptive variables. Men were taller and had more body mass than women. No significant differences were observed for age or BMI.

Time and gender effects were significant for isometric and 1-RM strength tests for upper and lower body (Table 2). A significant time × gender interaction for upper-body 1-RM strength indicated the men increased strength more than the women (419 N for men as compared with 296 N for women). However, no gender differences in percent changes in any of the strength measures were observed using a *t*-test (Table 2).

Percent fat decreased significantly for both men and women (>2%) (Table 3). Although the men were significantly leaner than the women, no significant time × gender interaction for percent fat was found. FFM had significant time, gender, and time × gender effects. This suggests both groups increased FFM, with the men initially having greater FFM and increasing FFM more than the women. Because men were larger (taller and heavier) and had more FFM before training, it would be expected that they would have more potential for increasing absolute FFM than women. Therefore, it might be important to evaluate FFM changes relative to initial FFM. Percent change in FFM was not significantly different between the genders. However, the 4.7% change in FFM for the men approached being significantly greater than the 2.3% change for the women (P = 0.06). The significant time and gender effects in the ANOVA analysis suggest that FM was reduced in both groups after the training program. Additionally, the men had less FM than the women both before and after training (Table 3). Absence of a time × gender interaction indicates that both genders reduced FM similarly.

No main effects were found for either IAAT or SAT. However, a significant interaction was found for both dependent variables. *Post hoc* analyses indicate that the women significantly reduced both IAAT and SAT, whereas the men did not. No significant time or time by gender interaction was observed for the IAAT/SAT ratio. However, men did have a significantly larger ratio than the women (Table 3). There were no significant zero-order Pearson product correlations between pretraining IAAT and change in IAAT for men and women combined (r = 0.06, P = 0.76) or for men alone (r = −0.02, P = 0.96). However, there was a significant correlation between pretraining IAAT and change in IAAT in the women (r = 0.55, P = 0.04).

TABLE 2. Strength measures before and after 25 wk of resistance training in older men and women.

Variable	Pretraining		Posttraining		Percent Change	
	Women (N = 12)	Men (N = 14)	Women (N = 12)	Men (N = 14)	Women	Men
Isometric elbow flexion (N)*†	163 ± 24	286 ± 58	185 ± 26	319 ± 74	15 ± 8	12 ± 16
Isometric knee extension (N)*†	323 ± 69	565 ± 197	410 ± 67	695 ± 181	29 ± 16	29 ± 25
1 RM upper-body strength (N)*†‡	408 ± 118	704 ± 138	525 ± 132	944 ± 204	30 ± 14	35 ± 18
1 RM lower-body strength (N)*†	900 ± 263	1445 ± 265	1317 ± 409	1954 ± 411	47 ± 15	36 ± 19

Time × gender ANOVA with repeated measures for time.
* Significant time effect ($P < 0.05$).
† Significant gender effect ($P < 0.05$).
‡ Significant time × gender interaction ($P < 0.05$).

TABLE 3. Body composition and fat distribution measures before and after 25 wk of resistance training in older men and women.

	Pretraining		Posttraining	
Variables	Women ($N = 12$)	Men ($N = 14$)	Women ($N = 12$)	Men ($N = 14$)
Percent fat*†	40.1 ± 8.7	24.4 ± 6.3	38.0 ± 8.7	21.7 ± 6.8
Fat-free mass (kg)*†‡	38.9 ± 3.9	58.8 ± 6.4	39.9 ± 6.4	61.6 ± 6.4
Fat mass (kg)*†	27.0 ± 9.3	19.6 ± 7.8	25.3 ± 8.9	17.8 ± 8.2
IAAT (cm^2)‡	131.2 ± 52.3	143.4 ± 68.5	115.8 ± 45.8	152.3 ± 74.6
SAT (cm^2)‡	253.6 ± 85.6	165.4 ± 56.0	238.8 ± 97.8	165.2 ± 84.4
IAAT/SAT†	0.54 ± 0.19	0.91 ± 0.40	0.52 ± 0.20	0.95 ± 0.30

Time × gender ANOVA with repeated measures for time.
* Significant time effect ($P < 0.05$).
† Significant gender effect ($P < 0.05$).
‡ Significant time × gender interaction ($P < 0.05$).

DISCUSSION

Consistent with our previously reported results (38), we demonstrated that women decrease IAAT consequent to RT despite no significant changes in body mass. Although there were similar and significant reductions in FM for both the older men and women (1.8 kg and 1.7 kg, respectively) after RT, there was only a significant change in IAAT for the older women. We are aware of only one other study that measured IAAT before and after RT in older men (36). Similar to the results for the men in this study, Smith (36) did not find a significant change in IAAT in older men after a 16-wk RT program despite 1.7-kg loss of FM. In the present study, there was a relationship between initial levels of IAAT and the amount of IAAT lost. This relationship was not found in the men, suggesting that more viscerally obese women but not men may be better able to improve fat distribution than less viscerally obese women.

Marked differences in IAAT exist between men and premenopausal women. We have previously reported in a sample of over 200 women that IAAT cross-section is 2 times greater in postmenopausal women, despite only 7% greater percent body fat than premenopausal women (17). Similar to the IAAT results reported in this study, older men and women tend to have comparable IAAT levels (17,22). The amount of IAAT found in the subjects in this study seems to be consistent with other older nonobese Caucasian men and women.

By design, the subjects in this study maintained weight. The study was originally designed to observe what effects RT has on energy expenditure, FFM, and strength. We weighed them at each exercise session and counseled them to maintain weight any time weight varied more than 2 pounds from their initial weights. Because body weight was maintained any changes in FM had to be accompanied by inverse changes in FFM. Therefore, the changes in IAAT may be smaller in this study of relatively lean older adults than would occur with a fatter group of men and women who also lost weight during the program. Both men and women lost similar amounts of FM. It is well established that diet-induced weight and fat loss is associated with a greater proportional reduction of IAAT compared with fat in other parts of the body (31). For example, the available evidence suggests that a 10% loss of total fat would be associated with an approximate 35% loss of visceral fat. Similar trends in fat loss have been reported in the few exercise studies that have examined visceral fat changes after aerobic training. The women in this study lost about 6% of their total FM and almost 12% of their IAAT. This suggests a similar trend for women as that found in diet and aerobic training weight loss studies. The men in this study were leaner than the women and experienced greater than 9% loss of FM after the 25 wk of RT. This suggests that the absence of a reduction in IAAT was not related to an insufficient loss of FM. Because the losses in IAAT for the women were similar to what might be expected from the loss in FM, the results for the women in this study support Ross's suggestion that visceral fat loss will be a function of total fat loss whether the loss is due to exercise or to diet.

Observed changes in body fat distribution may have been affected by differences in hormones, i.e., cortisol, growth hormone, estradial, and sex hormone binding globulin. For example, cortisol may increase fat storage in the abdominal region (27), high testosterone levels are associated with increased abdominal obesity and reduced sex hormone binding globulin (4), and growth hormone and insulin-like growth factor are inversely related to abdominal obesity (2,27). Cortisol levels are known to increase in older men and women after resistance training (13), but growth hormone, insulin-like growth factor I, and testosterone did not change in older men after resistance training (32). Men produce much more androgen and women produce much more estradial and progesterone. In addition, it appears that elevated estrogen and progesterone levels in women are related to increased lipid oxidation rates during exercise (6). The interaction of these different hormones may have contributed to the different fat distribution changes found in the older women and men; however, because these hormones were not measured in this study, we cannot determine what role hormones had in altering fat distribution in the men and women.

We measured IAAT at the level of the 4th and 5th lumbar vertebrae because we (29) as well as Kvist et al. (24) have previously shown that this is the site that is most highly correlated with total volume of intra-abdominal adipose tissue. However, our work was done on premenopausal women, and Kvist et al.'s work was done on men and women younger than those found in this study (mean age of 44 and 43 yr for the men and women in the Kvist et al.

study). It is possible that older men may distribute fat differently in the abdomen than younger men and women. Thus, the 4th/5th lumbar vertebrae may not have been the best single site for detecting losses of visceral fat in this group of older men. Measurement of total visceral fat across the abdomen with serial CT scans may have resulted in different results. The results of this study are thus limited to IAAT measured at the level of the 4th/5th lumbar vertebrae.

Although it is possible that diet may have had some role in influencing the different IAAT responses to RT, we feel it is unlikely to have played a major role in this study. First, the subjects in this study did not have a significant body mass change, indicating they were approximating caloric balance across the 25 wk. Actually they were both at a very slight caloric imbalance. By using estimates previously established (7,11,12,37), it is estimated that the energy loss for each gram FM lost is 7.7 $kcal \cdot g^{-1}$ and that the energy cost for each gram of FFM gained is 1.8 $kcal \cdot d^{-1}$. Based on these estimates, the men were at a deficit of 9180 kcal across the 25 wk (52 $kcal \cdot d^{-1}$), and the women were at a deficit of 11,290 kcal across the 25 wk (64 $kcal \cdot d^{-1}$). We did not assess diet; however, the subjects were instructed to not change macronutrient content across the 25 wk of the study, and all claimed that they did maintain their typical diet during the study. Finally, we have previously shown that macronutrient content is not related to IAAT (26), suggesting that even if the there were differences in macronutrient content between the men and women in this study, they would not have played a major role in influencing IAAT changes.

It is also possible that changes in activity-related energy expenditure and free-living physical activity may have contributed to the observed changes in body composition and fat distribution. We have previously reported data from a subset of these subjects in which we show that doubly labeled water–determined total energy expenditure, activity-related energy expenditure, and physical activity index all were increased after the 25 wk of RT (20). In addition, we show that resting energy expenditure was increased and RER decreased after the training. However, these changes were very similar in all of these variables for both men and women. Although energy metabolism analysis was only done on a subset of eight men and seven women, we have no reason to believe that they are not representative of the larger sample depicted in this paper. Thus, we feel it is unlikely that differences in changes in free-living energy expenditure and physical activity explain the different fat distribution changes observed between men and women.

Both men and women increased FFM in this study, although the men increased more than the women. Because the men were larger (taller and heavier), it might be expected that their potential for absolute FFM increases may be greater than women. Nevertheless, we have recently reported greater hypertrophy in cross-section area of Type I, IIa, and IIb fibers in nine older men than in five older women (1). Pretraining testosterone and di hydroepiandrosterone sulfate (DHEAS) serum concentrations were related to hypertrophy in the men but not the small group of women. The men as expected had higher concentrations of both testosterone and DHEAS. Although it is tempting to speculate that the higher androgen concentrations may be responsible for the greater increase in muscle cross-section area, there is danger in proposing cause and effect from correlational data. Because the men decreased FM similarly to the women, it is difficult to speculate that hormone balance would cause the women to have greater potential for IAAT loss than the men.

The means by which FM is lost in aerobic and RT studies appears to be quite different. RT is typically not associated with major changes in body mass, especially in women (14,20,38). Because body weight did not change (the sum of FM and FFM remained constant), the reductions in FM occur because of training-induced increases in FFM. Aerobic training–induced decreases in FM are associated with reductions in total body mass. We are aware of only one study that has compared the effects of equivalent aerobic training and diet induced calorie reductions on visceral fat. Ross et al. (30) reported almost identical reductions in body mass (about 7.5 kg) after a 12-wk intervention that induced a 700 kcal deficit of energy by dietary restriction in one group of men and aerobic exercise in another group of men. Using total body magnetic resonance imaging, they observed a reduction in total fat of 5.3 kg and visceral fat 1.1 kg in the aerobic training group, whereas the diet group decreased total fat 4.2 kg and visceral fat 0.8 kg.

Although a number of studies have examined the effects of aerobic training on IAAT in younger men, we are aware of only one study with older men. Schwartz et al. (33) reported a reduction of 35 cm^2 IAAT after a 7-month aerobic training program that induced a 2.5-kg loss of total FM. It appears that aerobic training can reduce IAAT in older men.

A 25-wk RT program is associated with increases in FFM and losses in FM in both older men and women. However, when weight is maintained and FFM changes are moderate as it was in this study, IAAT at the level of the 4th/5th lumbar vertebrae is significantly reduced in older women but not older men. Application of these results should be made with caution because this study did not measure visceral fat volume. However, the results are consistent with the only other studies that we are aware of that measured IAAT in older men and women before and after resistance training (36,38). Further study is needed to determine possible mechanisms of a preferential loss of IAAT and SAT in older women and to determine whether visceral fat may be lost in other parts of the abdomen of older men after RT exercise.

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