Twice-Weekly Progressive Resistance Training Decreases Abdominal Fat and Improves Insulin Sensitivity in Older Men With Type 2 Diabetes

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OBJECTIVE — To evaluate the influence of a twice-weekly progressive resistance training (PRT) program, without a concomitant weight loss diet, on abdominal fat and insulin sensitivity in older men with type 2 diabetes.

RESEARCH DESIGN AND METHODS — Nine older men (aged 66.6 ± 3.1) with type 2 diabetes participated in a 16-week PRT supervised program (50–80% of the one repetition maximum), for all main muscle groups. Basal glycemia, HbA_{1c}, diet, habitual physical activity, body composition, and upper/lower maximal strength were measured. Insulin sensitivity was determined according to Bergman's minimal model procedure and abdominal fat was obtained by computed tomography. The measurements were taken 4 weeks before training (−4), immediately before training (0), and at 8-week intervals (i.e., weeks 8 and 16) during the 16-week training period.

RESULTS — No significant variation was observed in any of the above selected parameters during the 4-week control period. After PRT, both leg and arm maximal strength increased significantly by 17.1 and 18.2%, respectively. Visceral and subcutaneous abdominal fat decreased significantly by 10.3% (from 249.5 ± 97.9 to 225.6 ± 96.6 cm^3, $P < 0.01$) and by 11.2% (from 356.0 ± 127.5 to 308.6 ± 118.8 cm^3, $P < 0.01$), respectively, while no changes were observed in body mass. PRT significantly increased insulin sensitivity by 46.3% (from 2.0 ± 1.2 to 2.8 ± 1.6 $\cdot 10^4 \cdot min^{-1} \cdot \mu U^{-1} \cdot ml^{-1}$, $P < 0.01$), whereas it significantly decreased (−7.1%, $P < 0.05$) fasting blood glucose (from 146.6 ± 28.3 to 135.0 ± 29.3 mg/dl). Finally, a 15.5% increase in energy intake (from 2,287.1 ± 354.7 to 2,619.0 ± 472.1 kcal/day, $P < 0.05$) was observed.

CONCLUSIONS — Two sessions per week of PRT, without a concomitant weight loss diet, significantly improves insulin sensitivity and fasting glycemia and decreases abdominal fat in older men with type 2 diabetes.

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Abbreviations: 1-RM, one repetition concentric maximum; ACSM, American College of Sport Medicine; ADA, American Diabetes Association; CT, computed tomography; FSIVGTT, frequently sampled intravenous glucose tolerance test; PRT, progressive resistance training.

Type 2 diabetes is a common disease in the elderly (1). Older people tend to have a decline in insulin sensitivity because of their decreased physical activity and increased central obesity (2). Indeed, increased abdominal adipose tissue has been linked to different metabolic perturbations, especially insulin resistance (3). The beneficial effect of physical conditioning on insulin sensitivity has been well established (4). Exercise training results in preferential loss of fat from the central regions, and it seems that this loss of visceral adipose tissue is closely related to an improvement in insulin sensitivity (5). Moreover, exercise alone in the absence of body composition change is able to enhance glucose homeostasis (6).

Aerobic endurance exercise has traditionally been advocated as the most suitable exercise mode in the treatment for patients with type 2 diabetes (4). Recently, the American College of Sports Medicine (ACSM) has recommended the use of progressive resistance training (PRT) as part of a well-rounded exercise program for individuals with type 2 diabetes (7). The ACSM defines PRT as training in which the resistance against which a muscle generates force is progressively increased over time (8). On the other hand, due to the limited information on the role of resistance training for older patients with type 2 diabetes, the American Diabetes Association (ADA) recommends PRT only for young individuals with diabetes but not for older individuals or those with long-standing diabetes (9). However, it is known that the progressive loss of muscle mass and strength with aging is an important cause of frailty, disability, and loss of independence in the elderly, and that older adults with diabetes are at increased risk of impaired physical function (10). Exercise interventions that improve neuromuscular performance in older people are becoming recognized as an effective strategy to increase

Table 1—*Selected anthropometrics, abdominal fat, metabolic and energy intake, expenditure variables, hormonal concentrations, and upper- and lower-body strength during the control period (week −4 to 0) and after the 16-week training period (weeks 8 and 16)*

	Week −4	Week 0	Week 8	Week 16
Age	66.6 ± 3.1	—	—	—
Anthropometrics				
Body weight (kg)	80.6 ± 9.8	80.3 ± 10.0	80.3 ± 10.3	79.8 ± 10.2
BMI (kg/m^{-2})	28.3 ± 2.7	28.2 ± 2.7	28.1 ± 2.8	28.3 ± 2.7
Sum of skinfold (mm)	141.3 ± 35.3	138.9 ± 36.5	135.7 ± 35.9	127.1 ± 35.1*
Body fat (%)	24.0 ± 3.9	23.7 ± 4.0	23.4 ± 3.9	22.4 ± 3.9*
Abdominal fat				
Subcutaneous fat (cm^3)	364.9 ± 137.3	356.0 ± 127.5	—	308.6 ± 118.8†
Visceral fat (cm^3)	255.4 ± 94.1	249.5 ± 97.9	—	225.6 ± 96.6*
Energy intake (kcal/day)	2,332.7 ± 346.0	2,287.1 ± 354.7	—	2,619.0 ± 472.1†
Habitual physical activity (kcal/day)	2,344.5 ± 485.5	2,261.3 ± 361.4	—	2,437.7 ± 393.3 (P = 0.07)
Metabolic variables				
Fasting plasma glucose levels (mg/dl)	150.6 ± 28.1	146.6 ± 28.3	147.3 ± 33.7	135.0 ± 29.3†
HbA_{1c} levels (%)	6.2 ± 0.9	6.2 ± 0.9	5.8 ± 1.2 (P = 0.06)	6.2 ± 0.9
Insulin sensitivity index ($\cdot 10^{-4} \cdot min^{-1} \cdot \mu U^{-1} \cdot ml^{-1}$)	—	2.0 ± 1.2	—	2.8 ± 1.6*
Hormonal concentrations				
Total testosterone (μg/ml)	4.0 ± 1.6	3.1 ± 0.8	2.9 ± 1.3	3.0 ± 1.3
Free testosterone (pg/ml)	15.5 ± 7.3	13.2 ± 4.5	13.9 ± 8.1	12.5 ± 6.8
Cortisol (μg/ml)	13.6 ± 4.6	12.4 ± 3.6	13.8 ± 3.4	11.4 ± 2.5
Muscle strength performance				
1-RM bench press (kg)	62.7 ± 7.1	63.3 ± 6.9	68.4 ± 6.7*	74.1 ± 7.6*
1-RM half squat (kg)	103.0 ± 9.7	104.5 ± 8.0	116.7 ± 8.2*	124.2 ± 8.0*

Values are means ± SD. *$P < 0.001$ and †$P < 0.05$ vs. the corresponding pretraining value.

functional independence and to decrease the prevalence of many age-associated diseases, such as type 2 diabetes (8). In this context, it has been shown that three to four sessions per week of PRT increase both muscle mass and strength (8) and improve glycemic control (11,12) in older adults. Although recent studies also indicate that in healthy older adults, a low frequency PRT program (two times per week) led to great gains in maximal dynamic strength (13), to date no studies in older adults with type 2 diabetes have compared the effects of a twice-weekly PRT on abdominal fat and insulin sensitivity, as well as on neuromuscular performance. As optimization of gain in physical fitness is critical for older adults based on adherence and social cost, it is important to ascertain whether these low-frequency PRT programs will obtain significant improvement in glycemic control and in strength development in this population. These low-frequency training regimens may have higher exercise adherence and be more practical for sedentary populations.

Therefore, the main purpose of this study was to evaluate the influence of two sessions per week of a whole-body PRT, without a concomitant weight loss diet, on abdominal fat and insulin sensitivity in older men with type 2 diabetes.

RESEARCH DESIGN AND METHODS

— Ten untrained, sedentary older men (aged 66.6 ± 3.1) with newly diagnosed type 2 diabetes volunteered to participate in a 20-week supervised PRT study, two times per week. All of them had a fasting plasma glucose consistent with type 2 diabetes by the ADA criteria (14) and had previously received advice about the benefits of diet and physical exercise by their primary care physicians. No study patient had ever been treated with hypoglycemic agents or insulin. Nine of the volunteers completed the study protocol. The investigative team excluded one subject for not adhering to the protocol. Before inclusion in the study, all candidates were thoroughly screened using an extensive medical history as well as resting and maximal exercise electrocardiogram and blood pressure measurements. Cardiovascular, neuromuscular, arthritic, pulmonary, or other debilitating diseases as determined via one or all of the screening tools were reasons for exclusion from the study. All subjects were carefully informed about the possible risks and benefits of the project, which was approved by the ethics committee of the regional Health Department. The subjects then signed a written consent form before participating in the study. The physical characteristics of the subjects are presented in Table 1. The subjects were tested on four different occasions using identical protocols. Baseline testing was completed during the first 4 weeks of the study (between the measurements at week −4 and at week 0) during which no strength training was carried out, but the subjects maintained their customary recreational physical activities (e.g., walking). This was followed by a 16-week period of supervised experimental strength training. The measurements were repeated during the actual experimental training period at 8-week intervals (i.e., weeks 8 and 16).

Anthropometric variables

Height of the barefoot subjects was measured to the nearest 0.1 cm. Body mass was measured on the same standard medical scale with an accuracy of ±100 g. Whole-body fat was estimated according to the skinfold thickness method developed by Jackson and Pollock (15). Skinfold measurements were taken from seven sites: at the subscapular, tricipital, midaxillary, suprailiac, pectoral, abdominal, and anterior thigh levels using a Harpenden skinfold caliper. A minimum of two measurements were made at each skinfold site by the same highly experienced investigator for each measurement.

Computed tomography

Visceral and subcutaneous adipose tissue volumes were measured by computed tomography (CT) with a Siemens Helicoidal Somatom Balance Scanner (Siemens, Erlangen, Germany). Radiographic factors were 130 kVp and 195 mAs. Examination took place in a supine position with the arms stretched above the head. Total visceral fat volume was measured using a single 10-mm scan for 2 s at the L4–L5 vertebrae level, using a scout image of the body to establish the precise scanning position. Visceral adipose tissue volume was quantified by drawing a line within the inner portion of delineating the intra-abdominal cavity at the innermost aspect of the abdominal and oblique muscle walls surrounding the cavity and the anterior aspect of the vertebral body with the computer interface of the scanner. Adipose tissue was highlighted and computed using an attenuation range from −190 to −30 Hounsfield units. Subcutaneous adipose tissue volume was quantified by highlighting adipose tissue located between the skin and the outermost aspect of the abdominal muscle wall. The same individual analyzed all scans. Test-retest reliability was $r = 0.99$ for 18 scans, with a coefficient of variation of <2%.

Energy intake and energy expenditure analysis

All subjects were interviewed by an experienced dietitian and given instructions on how to complete food records accurately. Three-day dietary food records (including 1 weekend day) were completed. All food records were analyzed by the DIETSOURCE (DietSource program, Version 1.0; Novartis, Barcelona, Spain). Habitual physical activity was evaluated by accelerometry (TriTrac-R3D System, Software Version 2.04; Madison, WI). The TriTrac-R3D was worn on a belt that was firmly attached to the anterior torso of the subject at the level of the waist. TriTrac monitoring was recorded on a minute-by-minute basis during 2 weekdays and 2 weekend days.

Frequently sampled intravenous glucose tolerance test

Subjects reclined comfortably throughout the procedure. An indwelling catheter was placed in the antecubital vein of each arm. One catheter was used for blood collection, whereas the glucose bolus was injected into the other catheter. After the placement of the catheters, 30 min was allowed before initial blood sampling. Basal samples were collected in Vacuette tubes (Greiner, Kremsmuenster, Germany) at −15 and −5 min, after which glucose (Glucosmon R50, BYK ELMU S.A.; Madrid, Spain) (300 mg/kg body wt, 50% aqueous solution) was injected over 1 min starting at time 0. At 20 min, regular insulin (0.03 units/kg) was injected as a bolus. Additional samples were obtained from a contralateral antecubital vein at times 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 19, 20, 22, 23, 24, 25, 27, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, and 180 min. Blood samples were centrifuged, and the resultant plasma was stored at −80°C until it was analyzed.

Subjects recorded the last meal on the evening before the test and they were asked to replicate that meal on the evening before the posttraining frequently sampled intravenous glucose tolerance test (FSIVGTT). In addition, the subjects were asked to fast overnight for 12 h before each FSIVGTT. The postexercise FSIVGTT was performed 24 h after the last training session.

Biological variables

Resting blood samples were drawn at week −4 (4 weeks before the start of training) and at weeks 0, 8, and 16 during the training period. The subjects reported to the laboratory and sat quietly for 10–15 min before giving a blood sample. Venous blood samples were obtained at rest between 8:00 and 9:00 A.M. from the antecubital vein to determine concentrations of serum total testosterone, free testosterone, and cortisol. Blood samples were taken at the same time of day to reduce the effects of diurnal variation on hormonal concentrations. Blood was drawn after 12 h of fasting and 1 day of minimal physical activity. Basal glycemia and HbA_{1c} were analyzed using an enzymatic hexokinase method (Roche Diagnostics, Mannheim, Germany) and ion exchange high-performance liquid chromotagraphy (Menarini Diagnostics, Hi AUTO 8140 DCCT, Caliber), respectively. The samples for hormone analysis were centrifuged, and the serum was removed and frozen at −20°C for later analysis. The assays of serum cortisol and testosterone were performed by radioimmunoassays. Serum total and free testosterone and cortisol concentrations were measured using reagent kits from Diagnostic Product Corporation and INCSTAR Corporation (Coat-A-Count Total/Free Testosterone TKTT11CS and GammaCoat Cortisol Radioimmunoassay Kit). The sensitivity of the total testosterone and free testosterone assay was 0.14 nmol/l and 0.15 pmol/l, respectively. The sensitivity of the cortisol assay was 0.21 μg/dl. All samples were analyzed in the same assay for each hormone according to the manufacturer's instructions.

Exercise testing

Maximal strength was examined because it has been previously postulated that age-related decrease in maximal strength is an important cause of frailty and disability, closely related to loss of muscle mass (8). Lower- and upper-body maximal strength was assessed using one repetition concentric maximum (1-RM) action in a half-squat and in a bench-press position, respectively. A detailed description of the 1-RM testing procedure can be found elsewhere (12). In brief, in the half squat, the subjects began the test by lifting a bar in contact with the shoulders with weight plates added to both ends of the bar. On command, the subject performed a concentric extension (as fast as possible) of the leg muscles starting from a knee angle of 90° to reach the full extension of 180°. In the bench press, the bar was positioned 1 cm above the subject's chest and supported by the bottom stops of the measurement device. Maximal strength half squat was defined as the maximum weight that could be lifted through a full range of motion with proper form. In all tests, strong verbal encouragement was given to each subject to motivate them to perform each test action as maximally and as rapidly as possible.

Training protocol

The strength training program utilized in the present study was similar to that reported previously (13) and was a combination of heavy resistance and "explosive" strength training. This type of combined resistance training was chosen because performance of daily activities requires both strength and muscle power, so that heavy resistance training might be combined with explosive types of exercises by also emphasizing higher action velocities of the exercises performed. Thus, it has been previously reported as an effective strategy to minimize age-related decreases in muscle mass, maximal strength, and muscle power output (13) in older men without type 2 diabetes. The subjects were asked to report to the training facility two times per week for 16 weeks to perform dynamic resistance exercise, for 45–60 min per session. A minimum of 2 days elapsed between two consecutive training sessions. Each training session included two exercises for the leg extensor muscles (bilateral leg press and bilateral knee extension exercises), one exercise for the arm extensor muscle (the bench press), and four to five exercises for the main muscle groups of the body. Only resistance machines (Technogym, Gambettola, Italy) were used throughout the training period. Resistance in this study was progressively increased or decreased every week for the 16-week training period using a repetition maximum approach, so that the loads that brought about a given relative intensity remained unchanged from week to week.

During the first 8 weeks of the training period, the subjects trained with loads of 50–70% of the individual 1-RM, 10–15 repetitions per set and three to four sets of each exercise. During the last 8 weeks of the training period, the loads were 70–80% of the maximum, five to six repetitions per set (higher loads) and three to five sets. In addition, from week 8 to week 16, the subjects performed a part (20%) of the leg extensor and bench-press sets with the loads ranging from 30 to 50% of the maximum. In these training occasions, the subjects now performed six to eight repetitions per set and three to four sets of each exercise, but executed all of these repetitions as rapidly as possible. In all the individual exercise sessions performed, one of the researchers was present to direct and assist each subject toward performing the appropriate work rates and loads.

Statistical analysis

Standard statistical methods were used for the calculation of the mean and standard deviations (SDs). Statistical comparison during the control period (from week −4 to week 0) was performed by Student's paired *t* test. The training-related effects were assessed using a two-way ANOVA with repeated measures (groups × time). When a significant *F* value was achieved, Sheffé's post hoc procedures were performed to locate the pairwise differences between the means. Statistical power calculations for this study ranged from 0.75 to 0.80. The $P \leq 0.05$ criterion was used for establishing statistical significance.

RESULTS

Baseline measurements

Body composition, maximal strength, basal glycemia, HbA_{1c}, caloric intake, and habitual physical activity, as well as serum cortisol or total and free testosterone, remained unaltered during the 4-week control period (from week −4 to week 0) (Table 1).

Compliance and adverse events

One hundred percent adherence to the exercise sessions was set at 32 training sessions (two times per week for 16 weeks). In nine subjects, average attendance at exercise sessions was 99.3% (range 97–100%). One subject was excluded because of attendance at exercise sessions of only 65%. Other than transient musculoskeletal soreness, no major complications or injuries were reported.

Anthropometrics and body composition

Body mass was not significantly changed after the 16-week training period, while the sum of seven skinfold thickness significantly decreased from 138.9 ± 36.5 to 127.1 ± 35.1 mm (−8.5%, $P < 0.001$) (Table 1). Intra-abdominal adipose tissue significantly decreased by 10.3% (249.5 ± 97.9 to 225.6 ± 96.6 cm^3, $P < 0.01$) (Fig. 1), and abdominal subcutaneous fat decreased by 11.2% (356.0 ± 127.5 to 308.6 ± 118.8 cm^3, $P < 0.01$) (Table 1).

Muscle strength and serum hormones

After 16 weeks of PRT, large increases took place in maximal leg strength of 17.1% (from 104.5 ± 8.0 to 124.2 ± 8.0 kg, $P < 0.001$) and in arm strength of 18.2% (from 63.3 ± 6.9 to 74.1 ± 7.6 kg, $P < 0.001$) (Table 1). Serum levels of total testosterone, free testosterone, and cortisol remained unchanged throughout the training (Table 1).

Metabolic variables

As shown in Table 1, after 16 weeks of PRT, insulin sensitivity was significantly improved by 46.3% (2.0 ± 1.2 to 2.8 ± $1.6 \cdot 10^4 \cdot \mathrm{min}^{-1} \cdot \mu\mathrm{U}^{-1} \cdot \mathrm{ml}^{-1}$, $P < 0.01$) (Fig. 1) and fasting blood glucose significantly decreased by −7.1% (from 146.6 ± 28.3 to 135.0 ± 29.3 mg/dl, $P < 0.05$), whereas HbA_{1c} remained unchanged (from 6.2 ± 0.9 to 6.2 ± 0.9%). For glycosylated hemoglobin, an almost significant decrease of 6.2% ($P = 0.06$) was observed during the first 8 weeks of training.

Energy intake and habitual physical activity

Analysis of dietary records indicated that after resistance training caloric intake significantly increased by 15.5% (from 2,287.1 ± 354.7 to 2,619.0 ± 472.1 kcal/day, $P < 0.05$), whereas no changes were recorded in habitual physical activity (from 2,261.3 ± 361.4 to 2,437.7 ± 393.3 kcal/day, $P = 0.07$).

CONCLUSIONS — The main findings of this study were that prolonged resistance training, twice weekly at intensities of 50–80% of 1-RM in older men with type 2 diabetes, led to significant *1*) increases in muscle strength, *2*) decreases in abdominal fat, and *3*) improvements in insulin sensitivity. These metabolic improvements were present even with no variation in body mass and with a significant increment in self-reported caloric intake. These observations suggest that two sessions per week of PRT are safe and could serve as a potential adjunct therapy in the management of type 2 diabetes in older men. It may have an important practical relevance for the optimal design of exercise

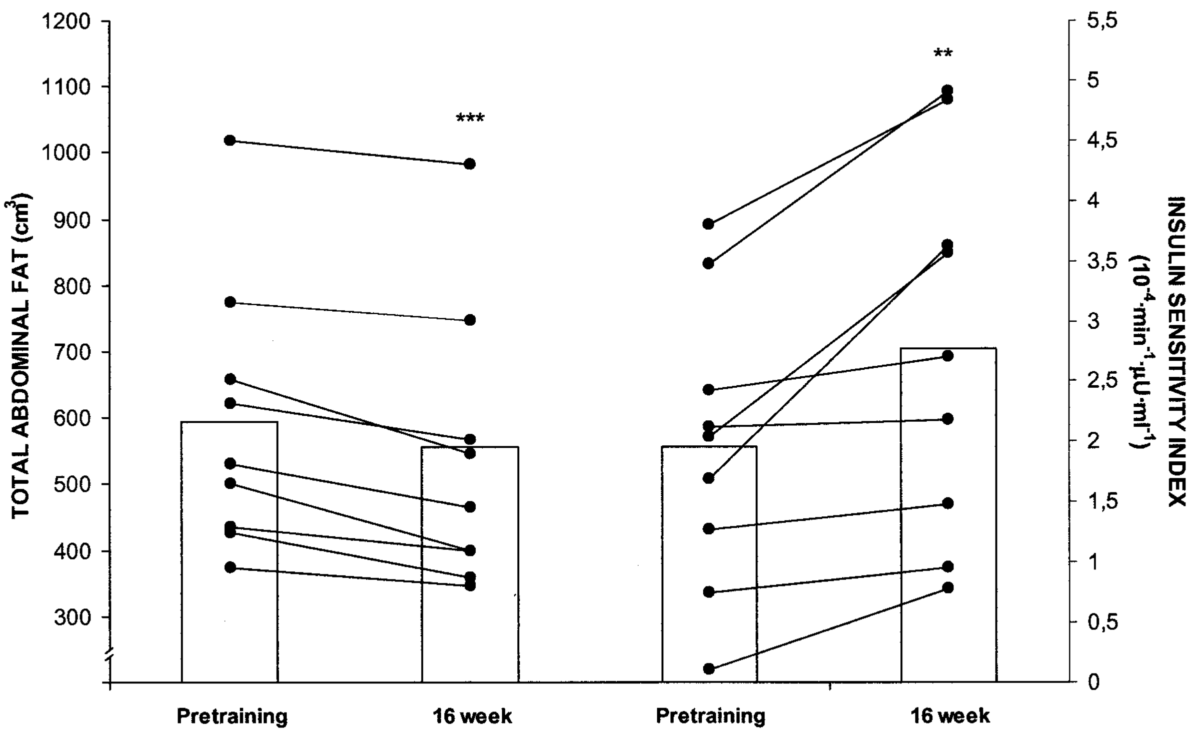

Figure 1—*Total abdominal fat and insulin sensitivity at pretraining and after a 16-week strength-training period for each subject. □, mean values; **P < 0.01 and ***P < 0.001 vs. the corresponding pretraining value.*

training programs for older men with type 2 diabetes.

At present there is limited information on the effect of PRT on metabolic perturbations and body composition adaptation in individuals with type 2 diabetes. Three recent studies with middle-aged (16) and postmenopausal women (12) and with older men (11) have shown that both acute (16) and chronic (11,12) resistance exercises are effective in glucose control, offering an alternative to aerobic exercise in individuals with type 2 diabetes. With regard to older men, Castaneda et al. (11) found that 16 weeks of PRT (three times per week) with training intensities of 60–80% of 1-RM improved glycemic control, measured by HbA_{1c}, although mean basal glycemia did not change. In the present study, all nine subjects improved insulin sensitivity and glucose effectiveness, determined according to FSIVGTT. Additionally, all but one improved fasting plasma glucose, whereas mean HbA_{1c} values did not change. A potential mechanism that explains how resistance training might improve insulin sensitivity has not yet been reported. However, solid evidence exists that exercise on its own, in the absence of any change in body weight or composition, is able to significantly enhance insulin sensitivity and glucose homeostasis (6). Moreover, insulin resistance in aging has been closely associated with abdominal obesity (3), and it has been reported that PRT may induce a decrease in abdominal adipose tissue in older men (11,17). More recently, Rice et al. (18) suggested that improved insulin sensitivity after resistance training may be partly related to concomitant decreases in visceral and abdominal subcutaneous adipose tissue or abdominal obesity. In the present study, PRT led to reductions in both visceral and subcutaneous abdominal adipose tissue (Table 1) in all nine subjects. However, no significant relationships were observed between individual changes in insulin sensitivity or fasting glycemia and individual changes in abdominal fat or strength gains.

As to the reasons linked to these losses of abdominal fat, diet should be ruled out because a concomitant increase in mean caloric intake (~15%) was observed in the subjects at the end of the intervention program. In contrast, most studies have demonstrated an increase in resting metabolic rate in older individuals in response to strength training (19), mainly explained (60–70% of the interindividual variability) by training-induced gains in fat-free mass (FFM) (20). Unfortunately, muscle mass was not measured in the present study, although different studies developed in our laboratory using an identical PRT program with older healthy men of a similar age have been shown to promote significant increments of ~11% in a cross-sectional area of the thigh muscles (13). Thus, in the present study, although the mechanism responsible for the enhanced insulin sensitivity cannot be discerned, a significant increase of ~17% in maximal leg and arm strength, accompanied by a significant decrease in both whole-body fat (~5.5%) and abdominal adipose tissue, while body mass remained unchanged, suggests that this PRT could increase FFM and more probably muscle mass. Finally, an increase in muscle mass may have a significant effect on glucose tolerance and insulin sensitivity. Indeed, an increase in muscle mass could enhance the available glucose storage area, thereby facilitating the clearance of glucose from the circulation and reducing the amount of insulin required to maintain a normal glucose tolerance (21). Eriksson et al. (22) observed that after a 3-month PRT the improvement in glycemic control correlated strongly with muscle size. Moreover, in a recent study it has been proposed that improved insulin sensitivity after resistance training occurs through an increase in muscle mass without altering the intrinsic capacity of the muscle to respond to insulin (23).

A large individual variation in insulin sensitivity was observed in response to PRT in individuals who showed both low and higher levels of insulin sensitivity before training. One might expect a higher response to PRT in subjects with higher insulin sensitivity (24). Thus, this variation in training response, which might be related to both the small number of subjects participating in this study and non—insulin-dependent factors (23), should avoid an objective conclusion on who responds best to this type of PRT.

The present study has several limitations. First, despite the lack of a control group, the present study design was made with two baseline measurements, suggesting that the patients were stable for the critical study end points. This research design was mainly required because it was very difficult to recruit more than nine older patients with newly diagnosed type 2 diabetes without previous antidiabetic medication who were willing to perform such an extreme training program, bearing in mind that walking is the usual exercise in older men with type 2 diabetes at this stage of their lives. Second, we also assume that it should be important to confirm that a cross-sectional area of the trained muscles accompanied this type of PRT in older individuals with type 2 diabetes.

Despite these limitations, this study provides support for the safety and effectiveness of twice-weekly PRT for older men with type 2 diabetes. After 16 weeks of PRT, we observed significant improvements in muscle strength, insulin sensitivity, and glucose tolerance and a significant decrease in abdominal fat.

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