Regional Fat Changes Induced by Localized Muscle Endurance Resistance Training

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Abstract

Ramírez-Campillo, R, Andrade, DC, Campos-Jara, C, Henríquez-Olguín, C, Alvarez-Lepín, C, and Izquierdo, M. Regional fat changes induced by localized muscle endurance resistance training. *J Strength Cond Res* 27(8): 2219–2224, 2013—The purpose of this study was to examine the effects of a localized muscle endurance resistance training program on total body and regional tissue composition. Seven men and 4 women (aged 23 ± 1 years) were trained with their nondominant leg during 12 weeks, 3 sessions per week. Each session consisted of 1 set of 960–1,200 repetitions (leg press exercise), at 10–30% 1 repetition maximum. Before and after training, body mass, bone mass, bone mineral density (BMD), lean mass, fat mass, and fat percentage were determined by dual-emission x-ray absorptiometry. Energy intakes were registered using a food recall questionnaire. At the whole-body level, body mass, bone mass, BMD, lean mass, or body fat percentage were not significantly changed. However, body fat mass significantly decreased by 5.1% (preexercise: 13.5 ± 6.3 kg; postexercise: 12.8 ± 5.4 kg, $p < 0.05$). No significant changes in bone mass, lean mass, fat mass, or fat percentage were observed in both the control and trained leg. A significant ($p < 0.05$) decrease in fat mass was observed in the upper extremities and trunk (10.2 and 6.9%, respectively, $p < 0.05$). The reduction of fat mass in the upper extremities and trunk was significantly greater ($p < 0.05$) than the fat mass change observed in the trained leg but not in the control leg. No significant changes were observed in energy intake pre- and postexercise intervention (2,646 ± 444 $kcal \cdot d^{-1}$ and 2,677 ± 617 $kcal \cdot d^{-1}$, respectively). In conclusion, the training program was effective in reducing fat mass, but this reduction was not achieved in the trained body segment. The present results expand the limited knowledge available about the plastic heterogeneity of regional body tissues when a localized resistance training program is applied.

Key Words spot reduction, DXA, corporal composition, exercise

Introduction

Exercise programs (aerobic or resistance training) may lead to differential regional adipose tissue depot loss, possibly by differential regional alterations of adipose tissue depot metabolism (i.e., mobilization of free fatty acids) (8). Several studies have shown that exercise-induced relative loss of fat seems to be higher in the abdominal region (16) or in the arms (17) than in the femoral region. This suggests that training-induced adipose tissue depot changes differ between body regions. Indeed, whether specific exercises can reduce local adipose tissue depots and thus modify fat distribution is still open to discussion.

The term *spot reduction* refers to the localized loss of fat as a result of exercising a particular part of the body (10). Several studies have evaluated the effects of specific localized exercise on whole-body and regional tissue composition, with contradicting results. Some studies have reported that after exercise intervention, localized mobilization of subcutaneous fat may be observed (15,18,19,21), whereas others have not found these changes (6,9,10,12,17,23). The conflicting results may be accounted for by the methodology used in the studies cited. A valid study design to test the hypothesis of spot reduction would be one in which the muscles in one part of the body are trained, whereas the muscles in the contralateral side are not. In addition, the size of the adipose tissue depots adjacent to the trained and respective sedentary muscles should be carefully monitored before and after the intervention period (21) using valid measurement techniques, such as fat biopsy, dual-emission x-ray absorptiometry (DXA), or magnetic resonance image techniques (10). Some of the previous studies cited met these criteria (10,12); nevertheless, because of the training protocol used (i.e., low training volume), localized blood flow and

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lipolysis possibly remained limited in the adipose tissue depot adjacent to the trained muscle group (21). Thus, it remains to be determined whether spot reduction is possible through localized exercise sessions with a sufficient training volume component after a longitudinal exercise intervention.

If the notion of spot reduction is correct, then performing a regimen of unilateral leg extension exercises should affect adipose content in that leg region to a greater extent than that in the other leg or any other body area. To the best of the our knowledge, no studies have examined the effect of high-volume localized muscle endurance resistance training on whole-body and regional tissue composition, using valid measurement techniques such as DXA, while controlling energy intake. Therefore, the aim of the present study was to examine the effects of 12 weeks of localized muscle endurance resistance training of nondominant leg muscles, on the whole-body and regional tissue composition. Our hypothesis is that the trained leg and the nontrained leg would exhibit similar fat changes.

Methods

Experimental Approach to the Problem

This study was designed to address the question of how 12 weeks of a localized muscle endurance resistance training program for the nondominant leg affects local and regional body tissue composition. To this end, a group of 11 subjects were recruited. Anthropometric tests were carried out to establish a baseline. After the initial measurements, subjects were enrolled in 12 weeks of training. Before initiating the training period, the subjects were instructed on how to properly execute the exercise to be done during this period. The training protocol only included the leg press exercise. None of the subjects had performed regular resistance training previously. All training sessions were supervised. The subjects were instructed to maintain their usual physical activity during the experimental period and to maintain their dietary habits for the duration of the study.

Subjects

Eleven physical education students (7 men and 4 women), with an average age ($\pm SD$) of 23 $\pm$ 1 years and body mass index of 25 $\pm$ 2 $kg \cdot m^{-2}$, volunteered to participate in the study (more detailed initial anthropometric characteristics are given in Table 1). All subjects were carefully informed about the experimental procedures and about the possible risks and benefits associated with participation in the study and signed an informed consent document before any of the tests were performed. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the department responsible. All subjects who took part in the training program (nondominant leg) served as their own control (dominant leg). Sample size was computed according to changes observed in fat mass percentage ($\delta = 9.8\%$; SD = 10.9) in a group of subjects submitted to training for 14 weeks (17). A total of 11 participants per group would yield a power of 80% and a α of 0.05.

None of the members participated in any formal exercise programs. Before the training program, there were no significant differences between the experimental and control leg in any of the dependent study variables. The general experimental procedure was a pre- and posttest design.

Anthropometric Characteristics and Testing Procedures

Total body and regional estimates of bone mass, bone mineral density (BMD), fat mass, lean mass, and fat percentage were determined by DXA using manufacturer-supplied algorithms (Total Body Analysis, version 3.6; Lunar, Madison, WI, USA). Precision for this measurement is greater than $\pm$0.5% for body fat. For this procedure, the subjects dressed in underwear and lay face-up on a DXA scanner table. The body was carefully positioned so that it was laterally centered on the table with hands palm downward. Velcro straps were used to keep the knees together and support the feet so that they tilted 45° from the vertical. Scanning was in 1-cm slices from head to toe using a 20-minute scanning speed. Regional measurements (arm, leg, and trunk) were determined on the basis of bony landmarks via manual analysis. The boundary between the arms and trunk was vertical (at shoulder level), whereas the boundary between the legs and trunk was angled. The precision of the measurement reported in these 3 regions is 1.5, 0.8, and 1.1% for the arms, legs, and trunk, respectively (17). Dual-emission x-ray absorptiometry measurements for total body and regional tissue composition were obtained before the study began (pre) and the day after the training period. The intraclass correlation coefficient was 0.97 (0.96–0.98) for arm fat, 0.97 (0.96–0.98) for leg fat, and 0.97 (0.96–0.98) for trunk fat.

Treatment

Subjects completed a 12-week localized muscle endurance resistance training program for the leg muscles of their nondominant leg. Training sessions were performed 3 $d \cdot wk^{-1}$. Each session lasted 80 minutes. Subjects completed one set of one exercise (i.e., leg press) per session, at 10–30% of 1 repetition maximum (1RM) (10% during weeks 1–4, 20% during weeks 5–6, and 30% during weeks 7–12). Subjects completed 960–1,200 consecutive repetitions for their set (no rest between repetitions), with 4–5 seconds per repetition (if subjects could not maintain the established rate of muscular work, weight was reduced), for a total of 80 minutes of continuous leg press exercise. During training, subjects completed a very high training volume, reaching a total of 34,560–43,200 muscle contractions in 12 weeks, a volume 10 times greater than that used in studies by other authors (23) that examined the impact of a localized muscle endurance resistance training program on body tissue composition. This high volume of training was necessary to induce important energy expenditure, with the objective of altering body tissue composition. During each training session, subjects were recommended to maintain

Table 1. Dual-emission x-ray absorptiometry-assessed changes in total body and regional tissue composition over a 12-week localized muscle endurance resistance training program.*

Body region	Before	After	Before and after percentage change	Effect sizes (η_p^2)
Total body				
Body mass, kg	65.55 ± 5.7	64.59 ± 6.6	−1.5	0.091
Bone mineral density, g·cm^{-2}	1.20 ± 0.1	1.20 ± 0.1	0	0.011
Bone mass, kg	2.78 ± 0.5	2.73 ± 0.5	−1.8	0.406
Lean mass, kg	49.64 ± 9.3	49.64 ± 9.1	0	0.00001
Fat mass, kg	13.51 ± 6.3	12.82 ± 5.4†	−5.1	0.027
%Fat	21.74 ± 10.7	20.88 ± 9.1	−0.9	0.089
Trunk				
Bone mass, kg	0.93 ± 0.1	0.89 ± 0.1	−4.3	0.379
Lean mass, kg	22.72 ± 4.0	22.65 ± 3.6	−0.3	0.005
Fat mass, kg	7.24 ± 3.6	6.72 ± 3.1†	−7.2	0.060
%Fat	24.19 ± 11.4	22.71 ± 9.2	−1.5	0.115
Control leg				
Bone mass, kg	0.54 ± 0.1	0.53 ± 0.1	−1.9%	0.434
Lean mass, kg	9.20 ± 1.5	8.87 ± 1.7	−3.6	0.152
Fat mass, kg	2.43 ± 1.2	2.36 ± 1.1	−2.9	0.004
%Fat	20.48 ± 7.4	19.94 ± 6.1	−0.5	0.024
Trained leg				
Bone mass, kg	0.53 ± 0.1	0.53 ± 0.1	0	0.476
Lean mass, kg	9.16 ± 1.5	9.03 ± 1.9	−1.4	0.032
Fat mass, kg	2.41 ± 1.1	2.39 ± 1.0	−0.8‡	0.014
%Fat	20.48 ± 7.4	19.94 ± 6.1	−0.5	0.024
Arms				
Bone mass, kg	0.17 ± 0.03	0.17 ± 0.03	0	0.0007
Lean mass, kg	2.80 ± 0.6	2.73 ± 0.7	−2.5	0.083
Fat mass, kg	0.49 ± 0.2	0.44 ± 0.2†	−10.2	0.019
%Fat	16.43 ± 9.5	15.65 ± 8.7	−0.8	0.002

*Values are mean ± *SD*.
†Statistically significant ($p \leq 0.05$) difference between pre- and postintervention
‡Statistically significant ($p \leq 0.05$) difference vs. arms and trunk.

their habitual physical activity routine throughout the experiment.

Energy and Macronutrient Intake. Energy and macronutrient intake was determined before and after intervention. An experienced nutritionist performed the energy intake analysis using a food recall questionnaire. The questionnaire was completed on 3 different days (Monday, Tuesday, and Sunday). Subjects were instructed not to change their eating habits during the intervention period; this was controlled by weekly interviews between the lead researcher and the subjects. Food analyses were carried out with the online software MITABLA (MITABLA software v4.0, Santiago, Chile)

Statistical Analyses

Statistical analyses were performed using STATISTICA software (version 8.0; StatSoft, Inc., Tulsa, OK, USA). Normality and homoscedasticity assumptions for all data were checked, respectively, with Shapiro-Wilk and Levene tests. A repeated-measures analysis of variance was used to determine differences in all dependent variables. There were 2 levels of repeated measures (pre- and posttraining periods). A Sheffe post hoc follow-up test was used when significance was detected. An α level of 0.05 was used for all statistics.

Results

Total Body Composition

Significant ($p \leq 0.05$) decreases were observed in total body fat, whereas no significant changes were observed in total body mass, BMD, bone mass, or fat percentage (Table 1). A neutral/positive nitrogen balance was evidenced by the maintenance of total lean mass (Table 1).

Trunk Region and Arms

After localized training intervention, fat mass of the trunk region and arms was significantly ($p < 0.05$) reduced (Table 1). In contrast, no significant changes were observed in bone mass, lean mass, or fat percentage of the trunk region and arms (Table 1).

Trained and Control Leg

After the intervention, neither the trained nor the control legs exhibit significant changes in bone mass, lean mass, fat mass, or fat percentage (Table 1). The fat mass reduction in arms and trunk region was significantly higher than that observed in the trained leg but not in the control leg (Table 1).

Energy and Macronutrient Intake

No significant change in energy intake (preexercise: 2,782 $\pm$ 306 $kcal \cdot d^{-1}$; postexercise: 2,677 $\pm$ 617 $kcal \cdot d^{-1}$) or macronutrient distribution ([carbohydrate, pre: 393 $\pm$ 93 $g \cdot d^{-1}$; post: 378 $\pm$ 104 $g \cdot d^{-1}$] [protein, pre: 93 $\pm$ 23 $g \cdot d^{-1}$; post: 83 $\pm$ 30 $g \cdot d^{-1}$] [fat, pre: 94 $\pm$ 23 $g \cdot d^{-1}$; post: 92 $\pm$ 29 $g \cdot d^{-1}$]) was evident over the 12-week intervention period.

Discussion

To the best of the our knowledge, the unique approach of the present study was to examine, with a valid anthropometric technique such as DXA (10), training-induced changes in lean mass, fat mass, and bone mass in total body, legs, arms, and trunk after a localized muscle endurance resistance training program of relatively high training volume (i.e., 34,560–43,200 muscle contractions). Furthermore, this unique approach included examining possible training-induced spot reduction while the subjects' energy intake was carefully controlled. The main finding of the present study showed that localized muscle endurance resistance training induces significant training-related decreases in the trunk, arms, and total body adipose tissue depots, whereas tissue composition (i.e., bone mass, lean mass, fat mass, and %fat) of the trained and untrained legs remained unchanged. These results may highlight the importance of evaluating whole-body tissue composition changes (not only localized) when this type of resistance training is executed.

An interesting finding of the present study was that 12 weeks of localized muscle endurance training induced a loss of 0.7 kg of whole-body fat, whereas subjects did not significantly modify their energy intake during the intervention period. This total fat mass reduction may be explained by the elevated training volume completed by the trained leg and the maintenance of the energy intake. In a typical training session, subjects completed 960–1,200 muscle contractions, against 10–30% of their 1RM. This, coupled with the fact that trained subjects did not modify their energy intake (preexercise: 2,782 $\pm$ 306 $kcal \cdot d^{-1}$; postexercise: 2,677 $\pm$ 617 $kcal \cdot d^{-1}$), must result in a negative energy balance, which translates into a significant total body fat loss (1,24).

In accordance with the previous findings (17), our results indicate that the localized muscle endurance resistance training program resulted in a reduction in trunk and arm fat mass, even greater than that observed in the trained leg. A negative energy balance, induced by regular exercise, may promote a reduction in fat mass (1,24), by means of a modified hormonal environment (i.e., increased adrenalin) and a subsequent increase in fatty acids mobilization from fat depots (5,22). However, one may take into consideration that the alteration in hormonal environment takes place all over the body, not only in the body segment that was exercised. In doing so, the increased hormonal stress environment induced by exercising the nondominant leg may result in fatty acids mobilization not only of the trained segment but also from the trunk region and arms. The reason why the fat mass was significantly reduced in the upper body, and not in the lower body, may be related to the initial fat content of the different body parts (17). Thus, the fact that at baseline, subjects showed 54% of their total body fat in the trunk, 36% in the legs, and 10% in the arms may explain, in part, the greater exercise induced-decrease in trunk fat mass. In this respect, other authors also indicate that the fat mass change may begin at the last place where lipids accumulated (2), although experimental evidence to justify this hypothesis is lacking. It has been shown that, during moderate exercise, fat depots from the upper body contribute with most lipids to mitochondrial oxidation, whereas fat depots from the lower body contribute little to this process (7). This may help explain the fat mass change observed from the upper-body regions vs. the lower-body regions. The increased lipid mobilization from the upper-body regions vs. the lower-body regions may be related to metabolic and morphologic factors, such as the activity of lipoprotein lipase, local blood flow, ratio between α/β-adrenoreceptors in fat cells, sympathetic nerve activity, and free fatty acids transport capacity, among others (13,14,20).

An interesting finding of the present study was that after localized training intervention, the lower extremities do not experience a significant reduction in fat mass. These results do not support a localized effect of resistance training on the fat mass content of a body segment (spot reduction). Our results agree with those of Gwinup et al. (6), showing an increased arm girth of the dominant arm vs. nondominant arm in competitive tennis players, whereas subcutaneous fat folds thickness remained similar between segments. Similarly, Krotkiewski et al. (12) showed that 5 weeks of training for the right leg (i.e., 30 maximal isokinetic leg extensions per session) resulted in muscle hypertrophy for the trained leg, in combination with a reduced subcutaneous fat thickness, whereas adipose cell size did not show a significant reduction. In this study, it was argued that geometric factors, secondary to muscle hypertrophy, may explain the reduction in subcutaneous fat thickness. In another study, 27 days of abdominal training did not induce a localized fat mobilization from the abdominal area (9). Nindl et al. (17) also showed that military training (focused primarily on legs) induced a significant increase in leg lean mass (5.5%), whereas fat mass was reduced only in arms and trunk region. Finally, 3 months of heavy resistance training of the nondominant arm in 104 subjects (10) resulted in a significant increase in muscle volume in the trained arm, but subcutaneous fat volume did not change. On the other hand, other authors reported that 30–120 minutes of unilateral knee extension exercise induced a higher adipose tissue blood flow in the exercise leg vs. the control leg (21), but this localized (blood flow) effect is not supported by other studies (3,4). Therefore, our results, in accordance with the previous studies undertaken, do not support a localized effect of resistance training on the fat mass content of a body segment (spot reduction).

Although other studies show a significant increase in lean mass after a localized resistance training program (10,12), our results did not show a significant change in lean mass in the trained leg (−1.1%) or in other body parts. The difference between our results and those reported by other authors may be related to the training methodology used. We used a muscle endurance resistance training protocol with a very high volume and very low intensity (960–1,200 muscle contractions per training session, with 10–30% 1RM), whereas other studies (10,12) used a relatively low-volume and high-intensity resistance training protocol (75–100% of maximum strength). Thus, minimum threshold intensity may be required to induce muscle and hypertrophy adaptations (11). It is also possible that, although the resistance used in the present investigation did not achieve the necessary threshold intensity to induce changes in lean mass, it was sufficient to induce a significant increase in energy expenditure and modification of fat mass. An alternative explanation may derive from the sex of the subjects. Women, in comparison with men, may not exhibit the same lean mass change after a resistance training program (10) or may need longer adaptation periods to exhibit muscular hypertrophy (17). Twenty-five percent of the subjects in this study were women, which when compared with the previously cited studies may also help explain why the lean mass of the trained leg did not increase significantly. Future studies may complement a localized muscle endurance resistance training program with high-intensity resistance training (or include preferentially male subjects), if an increase in lean mass is important to verify the investigation hypothesis.

In conclusion, the training program applied effectively reduced fat mass, but this reduction was not achieved in the trained body segment. The total training load (resistance × time) used during training was optimal to induce considerable fat mass loss but did not result in a significant muscle hypertrophy. Our results expand the limited knowledge available with regard to the plastic heterogeneity of regional body tissues when a localized resistance training program is applied.

Practical Applications

Our results show that when a muscle group is trained, changes in fat mass may take place in body areas not necessarily adjacent to the trained muscle group. Therefore, trunk body fat may be modified by training arm or leg muscles. This may be very useful in rehabilitation settings, where subjects, using their able body segment, may favorably impact the fat content in any other body part.

The present results also suggest that muscle endurance resistance training of 80 minutes per session did not result in significant muscle hypertrophy. Higher resistance will be required to induce changes in muscle mass (12). On the other hand, a training methodology, similar to that used in our study, may be sufficient to achieve a reduction in fat mass, but we recommend muscle endurance resistance training programs that include big muscle groups, which may result in more time efficient energy expenditure and corporal composition modification.

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