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Effects of Resistive Training and Chromium Picolinate on Body Composition and Skeletal Muscle Size in Older Women

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This study assessed the effect of resistive training (RT), with or without high-dose chromium picolinate (Cr-pic) supplementation, on body composition and skeletal muscle size of older women. Seventeen sedentary women, age range 54–71 years, BMI 28.8 ± 2.4 kg/m^2, were randomly assigned (double-blind) to groups (Cr-pic, $n = 9$; Placebo, $n = 8$) that consumed either 924 μg Cr/d as Cr-pic or a low-Cr placebo (<0.2 μg Cr/d) during a 12-week RT program (2 day/week, 3 sets · exercise^{-1} · d^{-1}, 80% of 1 repetition maximum). Urinary chromium excretion was 60-fold higher in the Cr-pic group, compared to the Placebo group ($p < .001$), during the intervention. Resistive training increased maximal strength of the muscle groups trained by 8 to 34% ($p < .001$), and these responses were not influenced by Cr-pic supplementation. Percent body fat and fat-free mass were unchanged with RT in these weight-stable women, independent of Cr-pic supplementation. Type I and type II muscle fiber areas of the m. vastus lateralis were not changed over time and were not influenced by Cr-pic supplementation. These data demonstrate that high-dose Cr-pic supplementation did not increase maximal strength above that of resistive training alone in older women. Further, these data show that, under these experimental conditions, whole body composition and skeletal muscle size were not significantly changed due to resistive training and were not influenced by supplemental chromium picolinate.

Key Words: muscle fiber size, muscle biopsy, exercise, strength training, resistance training, hydrostatic weighing

Introduction

Chromium (Cr^{3+}) is an essential nutrient that functions to help regulate insulin-mediated carbohydrate, lipid, and protein metabolism (2, 26), possibly as a part of a

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low-molecular-weight chromium-binding substance (38). Dietary supplementation with chromium, via the organic compound chromium picolinate, was reported to positively influence body composition changes in young men (10). Subsequently, the suggested benefits of chromium picolinate related to body composition, energy expenditure, carbohydrate metabolism, and muscle strength were promoted (9, 22), in part, based on the theory that chromium picolinate enhanced both insulin-mediated amino acid uptake into muscle and the plasma concentration of the androgenic hormone dehydroepiandrosterone (9). Several controlled research studies in young men and women have evaluated these suggested benefits of chromium picolinate (7, 17, 18, 27, 37). The designs of these studies frequently were structured to assess the effect of chromium picolinate during concurrent exercise training interventions. More recently, placebo-controlled evaluations of chromium picolinate in conjunction with exercise training were reported for young obese women (15) and older men (5). The vast majority of these studies concluded that chromium picolinate supplementation had no measurable effect on indexes of body composition, skeletal muscle strength, and energy metabolism (26). This conclusion is supported by some (1, 37), but not all (22, 23), chromium picolinate supplementation studies in sedentary people.

As adults age, body fat increases (8), and fat-free mass and muscle strength and size decrease (8, 13). Older people who perform resistive exercise training often experience decreased body fat, increased fat-free mass, and increased muscle strength and size (5, 6, 14, 33). We previously documented that chromium picolinate supplementation did not influence resistive training-induced changes in whole body composition, and skeletal muscle size and strength, in older men (5). The effects of chromium picolinate supplementation on resistive training-induced changes in body composition and skeletal muscle size in older women are unknown. Recent research documents that the skeletal muscle responses (strength and size) to resistive training are different in older women, compared to older men (16, 19, 21, 36). Research by Hasten et al. (18) suggested that chromium picolinate supplementation might have a greater effect on body composition of young women than young men. Thus, the purpose of the present study was to assess the effects of high-dose chromium picolinate supplementation on whole body composition and skeletal muscle strength and size in older women before and after the completion of a 12-week resistive training program. We hypothesized that resistive training-induced changes in these parameters would be augmented by chromium picolinate supplementation.

Methods

Subjects

Seventeen overweight to moderately obese women, aged 54–71 years, were recruited from the State College and surrounding Centre County, Pennsylvania, region. Prior to acceptance into the 13-week study, a medical evaluation, including a medical history, an electrocardiogram, routine blood and urine chemistries, a physician-administered physical examination, and a resistive exercise stress test, was performed to exclude women with medical conditions that might place them at risk for participation in the study or interfere with the successful completion of the study protocol. A screening 75-g oral glucose tolerance test (OGTT) was also performed to exclude women with non-insulin dependant diabetes mellitus using the criteria set in 1979 by the National Diabetics Data Group (30). None of the women were taking any form of estrogen replacement. The Institutional Review Board at the University Park campus of The Pennsylvania State University approved this study. All study participants signed informed consent forms before starting the study.

Experimental Design and Chromium Supplementation

The 13-week study was conducted at the General Clinical Research Center on the University Park campus of The Pennsylvania State University. The women were instructed to continue their normal daily activities and to halt use of all dietary supplements (if any) for 3 weeks prior to and during the 13-week study. The women who participated in the study also agreed to dietary control during weeks 1, 7, and 13, and to participate in a 12-week resistive training program, both described below.

Baseline testing and evaluations were completed during study week 1. All of the women remained sedentary and did not consume a supplement during this time. The women were then randomly assigned in a double-blind fashion to either a placebo supplementation group (Placebo, $n = 8$) or a chromium picolinate supplementation group (Cr-pic, $n = 9$), as they were declared eligible to participate in the study. Starting at study week 2, each woman participated in a 12-week period of resistive training and supplementation. Testing and evaluations were repeated at study weeks 7 and 13, designated study weeks RT6 and RT12, respectively.

From weeks RT1 to RT12, each woman consumed twice daily a supplement that was manufactured to contain either 500 μg chromium/capsule or a placebo that was manufactured to be void of chromium. Chromium analysis of the commercially prepared chromium picolinate and placebo supplements was done using a graphite furnace atomic spectrophotometer (Perkin-Elmer Model HGA 500, Norwalk, CT), as previously described (3, 17). The chromium and placebo capsules were found to contain 462 and < 0.1 μg chromium/capsule, respectively. Thus, the Cr-pic and Placebo groups received 924 and < 0.2 μg chromium/day by consuming one capsule in the morning and one capsule in the evening.

Diet

Each woman was asked to maintain her self-provided habitual diet during study weeks RT1-5 and RT7-11. For 5 days during baseline, RT6, and RT12, all of the women were provided and consumed a strictly controlled diet, as described by Campbell et al. (5). The controlled diet was used to standardize dietary intakes during the testing periods and to help control dietary chromium intake for the measurement of urinary chromium excretion. The total energy intake of each menu consisted of about 15% protein, 30% fat, and 55% carbohydrate. The women were asked to consume all of the foods and beverages provided and not to consume any other foods or beverages (other than water) during these times. The women were instructed not to purposefully attempt to gain or lose body weight during the study.

Resistive Training Protocol

From weeks RT1 to RT12, all of the women participated in a resistive training program on 2 nonconsecutive days/week. The intensity of the resistive exercises was set at 80% of the maximum load the woman can lift throughout the full range of motion of a joint one time only (one repetition maximum, 1RM). Each woman was asked to lift and lower the calculated load for 2 sets of 8 repetitions, and a 3rd set to voluntary muscular fatigue, as previously described (5). Exercise sessions were preceded and followed by warm-up and cool-down periods consisting of 5 min of stationary cycling at low resistance and slow speed (heart rate <100 beats per minute), as well as stretching of the muscle groups involved in the resistive exercises. Every 3 weeks, one training session was used for the re-measurement of the 1RM so that the training stimulus could be readjusted to maintain a constant intensity of 80% of 1RM. Five exercises were used to train the major muscle groups of both the upper and lower body. These exercises included: (a) unilateral knee extension, (b) bilateral seated leg curl, (c) double leg press, (d) seated arm pull, and (e) seated chest press. All resistive training was performed on Keiser pneumatic strength training equipment (Keiser Sports Health Equipment, Fresno, CA). Each woman successfully completed 23 supervised training sessions (100% compliance) without injury.

24-hour Urine Collections

Aliquots of 24-hour urine collections made on days 4 and 5 of the controlled dietary periods during weeks RT6 and RT12 were stored frozen at –20 °C for subsequent analysis of chromium concentration. The urinary chromium concentrations of the Placebo group at these weeks were assumed to accurately reflect the urinary chromium excretion of all subjects at baseline. Details of the collection, processing, and storage procedures aimed to eliminate contamination of these samples were described previously by Campbell et al. (5). The RT6 and RT12 urine collections were made 48–72 hours after the previous resistive exercise session. Urinary chromium concentration was measured using a graphite furnace atomic absorption spectrophotometer (model HGA500, Perkin-Elmer; 4). The chromium concentration of a pooled urine sample run as a quality control with each assay was 0.33 ± 0.02 ng/ml, a value very close to the theoretical value of 0.32 ± 0.01 ng/ml.

Body Composition

Total body density was determined via hydrostatic weighing at baseline and RT12 using the methods previously described by Campbell et al. (5). Percent body fat and fat-free mass were estimated using the two-compartment model of Siri (34). Anthropometric data were collected at baseline and RT12 of the study. Skinfold thickness was measured to the nearest 0.5 mm at eight sites: chest, thigh, biceps, triceps, subscapular, mid-axillary, abdominal, and suprailiac using standard techniques and Lange calipers (Cambridge Scientific Industries, Cambridge, MD). The sum of these eight skinfold measurements is reported. Height was measured using a wall-mounted stadiometer to the nearest 0.1 cm without shoes. Body weight was measured daily during baseline and RT12, and twice weekly during all other study weeks. Each weight measurement was made to the nearest 0.1 kg, with the woman wearing her underclothing and a robe. Nude body weight was calculated as total body weight minus the weight of the garments. Body mass index (BMI) was calculated using the equation [body weight (kg) / height^2 (m^2)].

Muscle Biopsy Technique

At baseline and RT12, a biopsy of the m. vastus lateralis was performed on the dominant leg of each woman using a 6-mm biopsy needle and syringe-applied suction, as described by Evans et al. (11). The muscle sample was quickly separated from any non-muscle tissue, and a homogeneous portion of the tissue sample was processed, stored, and subsequently analyzed for type I and type II fiber areas, using the techniques and methods described by Campbell et al. (5).

Statistical Methods

Values are reported as means ± *SEM*. Student's unpaired *t* test was used to assess differences between the Cr-pic group and Placebo group for each of the independent variables for the baseline (study week 1) data. The main effects of RT and chromium picolinate supplementation and the interaction between these dependent variables were determined by using two-way repeated-measures ANOVA for each independent variable. Statistical significance was assigned if $p < .05$ (two-sided). All data processing and calculations were performed using JMP Statistical Discovery Software (SAS Institute, Cary, NC).

Results

For the Placebo group, the mean urinary chromium excretions at weeks RT6 and RT12 were 0.20 ± 0.03 μg/d, and 0.17 ± 0.03 μg/d, respectively. In contrast, the mean urinary chromium excretions for the Cr-pic group at weeks RT6 and RT12 were 13.2 ± 2.0 μg/d, and 9.6 ± 1.7 μg/d, respectively (group difference, $p < .001$). Thus, the urinary excretion of chromium was about 60-fold higher in the Cr-pic group, compared with the Placebo group, during the period of intervention.

At baseline, the Placebo group and Cr-pic group were not different in maximum strength (1RM) for any of the exercises performed (Table 1). Maximum strength increased over time with RT for the muscles involved with each exercise ($p < .001$). Chromium supplementation did not influence these responses over time (i.e., there were no group-by-time interactions). The mean changes in 1RM for the exercises performed ranged from 13–31% in the Placebo group and 8–34% in the Cr-pic group.

At baseline, there were no differences between the two groups for mean age, height, weight, body mass index, or any measure of whole body composition (Table 2). After 12 weeks of RT in these weight-stable women, body mass index, percent body fat, fat-free mass, and sum of eight skin fold thickness were not different than at baseline (main effect of time), independent of chromium picolinate supplementation (i.e., no group-by-time interaction; Table 2).

At baseline, type I muscle fiber area was not different between groups, while type II muscle fiber area was lower in the Cr-pic group than in the Placebo group ($p = .014$; Table 2). Type I and type II muscle fiber areas were not changed over time ($p = .719$ and .672, respectively) and were not influenced by chromium supplementation (group-by-time, $p = .372$ and .162, respectively).

Discussion

The results of this study show that supplementation of older women with 17.8 μmol chromium/day, as chromium picolinate for 12 weeks did not influence resistive training-induced responses in maximal strength, body composition, and skeletal muscle fiber size. These results concur with most (7, 15, 17, 27, 37) but not all (18,

Table 1 Maximum Muscle Strength of Older Women Before and After 12 Weeks of Resistive Training With or Without Chromium Picolinate Supplementation

	Placebo			Chromium picolinate		
Parameter	Baseline	RT12	% change	Baseline	RT12	% change
RKE* (Nm)	80 ± 9	98 ± 8	25 ± 5	78 ± 6	99 ± 9	32 ± 9
LKE* (Nm)	75 ± 10	97 ± 10	31 ± 8	73 ± 6	96 ± 6	34 ± 9
DLC* (Nm)	121 ± 13	150 ± 15	27 ± 8	123 ± 10	151 ± 7	29 ± 10
CP* (N)	287 ± 17	324 ± 19	13 ± 3	324 ± 20	361 ± 18	8 ± 3
AP* (N)	314 ± 23	367 ± 26	17 ± 3	328 ± 17	384 ± 16	19 ± 6
DLP* (N)	1010 ± 64	1220 ± 77	22 ± 7	918 ± 67	1182 ± 86	30 ± 6

Note. Values are mean ± SEM. RT12 = resistive training week 12. RKE, right knee extension; LKE, left knee extension; DLC, double leg curl; CP, chest press; AP, arm pull; DLP, double leg press.
*Significant change over time with RT for all women, $p < .001$.

Table 2 Physical Characteristics, Body Composition, and Muscle Fiber Size of Older Women Before and After 12 Weeks of Resistive Training With or Without Chromium Picolinate Supplementation

	Placebo		Chromium picolinate	
Parameter	Baseline	RT12	Baseline	RT12
Age (years)	60 ± 1 (range, 54–66)		63 ± 2 (range, 54–71)	
Height (cm)	164.1 ± 1.8		162.7 ± 1.6	
Weight (kg)	79.8 ± 3.0	80.2 ± 3.0	74.4 ± 2.3	74.7 ± 2.4
Body mass index (kg/m^2)	29.6 ± 0.8	29.8 ± 0.8	28.1 ± 0.8	28.2 ± 0.8
Body fat (%)	46.1 ± 1.1	46.8 ± 0.8	45.1 ± 0.9	44.7 ± 1.4
Fat-free mass (kg)	43.0 ± 1.7	42.6 ± 1.5	40.8 ± 1.1	41.2 ± 1.2
Sum of 8 skinfolds (mm)	244 ± 9	241 ± 9	229 ± 14	217 ± 11
Type I muscle fiber area (μm^2)	5445 ± 339	5270 ± 281	4481 ± 306	5287 ± 528
Type II muscle fiber area* (μm^2)	3760 ± 235	3467 ± 269	2790 ± 253	3325 ± 326

Note. Values are mean ± *SEM*. RT12 = resistive training week 12.
*Group difference at baseline, $p = .014$.

22, 23) double-blind, placebo-controlled chromium picolinate supplementation studies in young men and women. These results are also consistent with the results of a chromium picolinate and resistive training study in older men (5). This study expands present knowledge by studying older women and directly measuring muscle fiber size before and after a period of higher-dose chromium picolinate.

The marked increase in muscle strength supports the effectiveness of the resistive training program to elicit changes in the muscle and is consistent with findings from other resistive training studies with older women as subjects (12, 32). Given that no measurable changes in muscle size occurred with training, the gains in strength were likely largely due to neurological adaptations to training (24). The apparent lack of effect of chromium picolinate supplementation on resistive training-induced muscle strength gains supports previous research (5, 17, 27). Our findings show that neither type I nor type II muscle fiber area changed over time during resistive training, and that this lack of response was not influenced by chromium picolinate supplementation. The lack of an effect of chromium picolinate is consistent with findings in older men who consumed the same chromium supplements and experienced muscle hypertrophy after completing the same resistive training program (5). However, the results of the present study in older women may not be directly comparable with the results obtained in older men (5), since the women did not experience resistive training-induced muscle hypertrophy. While we consider it highly unlikely, the results of the present study do not rule out the possibility of chromium picolinate supplementation by older women influencing skeletal muscle size in conjunction with a training program that resulted in muscle hypertrophy.

The lack of muscle hypertrophy by these older women is consistent with a more blunted initial skeletal muscle response to resistive training of women compared with men (19, 36). Tracy et al. (36) reported that quadriceps muscle volume increased more in older men than women following a 9-week unilateral knee extension resistive training program. Subsequently, Ivey et al. (19) re-presented these findings and expanded the gender-specific responses to this resistive training program to include younger adults. Joseph et al. (20) reported the gender-specific responses to resistive training from the present study for whole body composition and the lipoprotein-lipid profile. Fat-free mass increased and percent body fat decreased in the men, but not in the women, after 12 weeks of training.

One might question whether the lack of muscle hypertrophy by these women related to performing resistive training only 2 days per week compared to three or more times per week. The present study was not designed to address this issue. We used a twice-weekly training program because it was consistent with American College of Sports Medicine guidelines for including resistive training in a healthy lifestyle (29), and because it was reported to cause muscle hypertrophy in elderly men and women (31, 33). The fact that the older men who trained using the exact same twice-weekly protocol experienced hypertrophy of the vastus lateralis type II fibers (5), suggests that the protocol frequency and intensity were sufficient. However, it might take women, who perform resistive exercises twice per week, more than 12 weeks to achieve muscle hypertrophy. Staron et al. (35) reported that young women who performed resistive training twice weekly for 8 weeks did not show changes in type I, type IIa, and type IIb vastus lateralis muscle fiber areas, findings consistent with the results of the present 12-week training protocol. In contrast, Pyka et al. (33) reported significant increases in type I and type II fiber areas of the vastus lateralis in elderly men and women who performed resistive training twice weekly for 30 weeks. These authors did not report results for the men and women separately. McCartney et al. (28) reported that mid-thigh muscle area increased 5.5% in 60–80-year-old men and women who performed resistive exercises twice weekly for 42 weeks. The authors reported no difference in response between the men and women who completed the training program. Nelson et al. (31) reported that postmenopausal women who performed resistive training twice weekly for 52 weeks increased mid-thigh muscle area, as measured by computed tomography scanning. Collectively, these data suggest that older women who perform resistive exercises twice per week might experience a blunted muscle response during the first 2 to 4 months of training (i.e., little or no muscle hypertrophy), compared to older men, but can achieve muscle hypertrophy with longer-term training.

Strengths of the present study include: studying older women who might benefit from the purported positive effects of chromium picolinate supplementation on body composition and skeletal muscle size, using a high-dose of supplemental chromium, controlling diet during the periods of testing and evaluation, and directly measuring muscle fiber size from biopsied muscle samples. Weaknesses of the present study include the relatively few number of women studied and the lack of muscle hypertrophy with the resistive training program.

The urinary chromium excretion of the Cr-pic group was 60-fold higher than that of the Placebo group during the period of supplementation. This finding documents the effectiveness of the supplement to provide high levels of chromium to the women in the Cr-pic group, and is consistent with findings from older men who consumed the same high-dose chromium supplements (5). Hallmark et al. (17) showed that supplementation of young men with 3.62 μmol chromium/day as chromium picolinate (188 μg chromium/day, one-fifth of the dose used in the present study) resulted in an ~10-fold increase in urinary chromium excretion. Collectively, the results of this study, coupled with previous research findings (5, 17), suggest that urinary chromium excretion increases proportionately with increased chromium picolinate intake, and that this process is not homeostatically controlled. This conclusion is specific to supplemental chromium and does not relate to dietary chromium (25).

In conclusion, over the course of 12 weeks of progressive resistive training, women who consumed high-dose chromium picolinate supplements did not differ from women who consumed a placebo in muscle strength gains, whole body composition, and muscle fiber area. These data do not support the use of chromium picolinate by older women to augment the effects of resistive training.

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