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Comparisons of vegetarian and beef-containing diets on hematological indexes and iron stores during a period of resistive training in older men

Amanda M. Wells, MS, RD,
A research dietitian for the General Clinical Research Center at the University of Arkansas for Medical Sciences, Little Rock, AR

Mark D. Haub, PhD,
An assistant professor, Department of Human Nutrition, Kansas State University, Manhattan, KS

James Fluckey, PhD,
An assistant professor, Donald W. Reynolds Center on Aging, University of Arkansas for Medical Sciences, Little Rock, AR

D. Keith Williams, PhD,
An assistant professor, Department of Biostatistics, University of Arkansas for Medical Sciences, Little Rock, AR

Ronni Chernoff, PhD, RD, and
Co-director, Geriatric, Research, Education and Clinical Center, Central Arkansas Veterans Healthcare System, and professor, Department of Dietetics and Nutrition, University of Arkansas for Medical Sciences, Little Rock, AR

Wayne W. Campbell, PhD
An assistant professor, Department of Foods and Nutrition, Purdue University, West Lafayette, IN

Abstract

Objective—To test the hypothesis that older men who consumed a vegetarian (lacto-ovo) diet would develop a lower iron status compared with older men who consumed a beef-containing diet during a period of resistive training (RT).

Design—Experimental, repeated measures study.

Subjects—Twenty-one healthy men aged 59 to 78 years, with a BMI range of 24 to 33 kg/m^2, completed the study.

Intervention—All men consumed a vegetarian diet for 2 weeks (baseline). After this, the men were randomly assigned to one of two dietary groups. Eleven men consumed a beef-containing diet, and 10 men continued to consume a vegetarian diet for 12 weeks. During this time all subjects participated in RT three days per week, designated as RT1 to RT12.

Main outcome measures—Serum ferritin and serum iron concentrations, transferrin saturation, transferrin receptor, total iron binding capacity, and selected hematological variables, as well as

Address correspondence to: Wayne W. Campbell, PhD, Department of Foods and Nutrition, Purdue University, 700 West State St, West Lafayette, IN 47907. E-mail: campbellw@cfs.purdue.edu.

Consumption of a beef-containing diet, having greater iron bioavailability, increases hematological parameters during resistive training; however, consumption of a lacto-ovo vegetarian diet did not adversely affect hematological profile

selected nutrient intakes and estimated iron bioavailability from three-day diet records, were determined at baseline, RT5, and RT12.

Statistical analyses—A general linear model repeated-measures ANOVA was used to examine the effects of group, time, and group×time interactions for iron status and dietary data.

Results—Total iron intake was not different between the two groups; however, the beef group had a three to four times greater intake of bioavailable iron ($P<.01$) than the vegetarian group. Serum iron, total iron binding capacity, transferrin saturation, and transferrin receptor were not significantly different between the beef and vegetarian groups, or changed over time with RT. Serum ferritin decreased over time in both the beef and vegetarian groups during RT ($P<.01$). Re-introduction of beef into the diets of the beef group increased hemoglobin concentration and hematocrit compared with the vegetarian group during the 12 weeks of RT (group×time, $P<.05$). These changes were within clinically normal limits.

Applications/Conclusions—Older men who consume a beef-containing, higher-bioavailable-iron diet, compared with a vegetarian, lower-bioavailable-iron diet, have an increased hematological profile during a 12-week period of RT. Older men who consume either a beef-containing or a vegetarian diet maintain a hematological profile within clinically normal limits during 12 weeks of RT.

In the absence of disease or blood loss, iron status is primarily controlled by dietary iron absorption (1,2), which is regulated by current iron stores and the iron bioavailability of the diet (2,3). Iron bioavailability, the degree to which dietary iron is absorbed and is available for use or storage, varies based on the total iron content, type of iron (heme or nonheme), and the presence or absence of specific dietary enhancing and inhibiting factors (1,4).

Meat-containing diets have greater iron bioavailability than meat-free diets with the same total iron content (5) because of the presence of heme iron and an unidentified enhancing factor. This results in a greater percentage of iron absorption or retention from meat-containing diets (6). Consumption of meat, fish, and poultry (MFP) is positively associated with measures of iron status in older adults (7). Comparisons of those who habitually consume meat with those who do not have indicated that consumption of a meat-free diet is associated with lower iron status indexes (8,9).

Resistive training (RT), which is recommended to older adults for the maintenance or enhancement of muscle mass and strength (10), has also been noted to have an effect on iron status indexes. RT by younger adults resulted in a decrease in iron stores as indicated by a decrease in serum ferritin concentration (11,12). Yet when the effects of RT in older men were examined, a decrease in total iron binding capacity (TIBC), consistent with enhanced iron transport, was found (13). Previous research comparing meat-free and meat-containing diets during RT found that a meat-containing diet contributed to greater gains in muscle mass (14). One difference between these two diets may have been the iron content and/or iron bioavailability. It is not known whether a meat-free diet, in addition to contributing to lesser gains in muscle mass during RT, may contribute to a lowered iron status compared with a meat-containing diet.

The broad goal of this study was to continue to examine the effects of diet and RT on body composition and iron status in older adults (13-15). The specific goal of this study was to compare iron bioavailability and iron status of older men who consumed either a beef or a vegetarian diet (lacto-ovo) during a period of RT. The following hypotheses were tested: (a) In a comparison of vegetarian and beef-containing diets of older men during RT, the vegetarian diets would have lower iron bioavailability as estimated using the Monsen and Balintfy (16) and Tseng and colleagues (17) methods; (b) older men who consumed a vegetarian diet would

develop a lower iron status compared with older men who consumed a beef-containing diet during a period of RT.

Materials and Methods

Subjects

Men between the ages of 59 and 78 years and who had a body mass index (BMI) between 24 and 33 kg/m^2 were recruited through newspaper advertisements. Each subject signed a written informed consent agreement. The study protocol and consent form were reviewed and approved by the Human Research Advisory Committee at the University of Arkansas for Medical Sciences, Little Rock, AR. A medical history, physical examination, resting electrocardiogram, and routine blood and urine chemistries were performed and used to exclude men with medical conditions that might place them at risk for participating in the study or might interfere with the successful completion of the study protocol. Specific exclusion criteria included diabetes, hypothyroidism or hyperthyroidism, abnormal electrocardiogram results, BMI $\geq$35 kg/m^2, or participation in RT within the past year. Twenty-six men began the study. Four men did not complete the study because of conflicts of time, interest, or illness (unrelated to the study protocol). Twenty-two men successfully completed the study protocol. Of these 22 men, data from one man were excluded from statistical analyses after evaluation of iron status and hematological indexes revealed that the subject's indexes were consistent with a state of iron deficiency anemia throughout the study. Therefore the data presented are from 21 men.

Experimental Design

An experimental repeated-measures study design was used for this 14-week study. The data presented were collected from subjects to determine dietary intake and hematological and iron status indexes. The study intervention started with a 2-week baseline period, during which time all of the men were counseled to consume a self-selected lacto-ovo vegetarian diet supplemented with 0.6 g protein $\cdot kg^{-1} \cdot d^{-1}$ texturized vegetable protein meat-analog products (TVP products). The purpose of this 2-week period was to familiarize subjects with the diet protocol that would be used and to attempt to standardize the major source of protein and type of iron consumed. This allowed all men to begin the diet and RT intervention after following a similar diet pattern. Baseline data were collected during week 2 of baseline to determine the men's iron status and dietary intake. At the end of the 2-week baseline period, the men also completed initial strength measurements and then began to participate in RT three days per week for 12 weeks (RT1-RT12). At RT1 (after baseline), the men were randomly divided into one of two dietary groups. The beef group (n=10) received 0.6 g protein $\cdot kg^{-1} \cdot d^{-1}$ beef products, and the vegetarian group (n=11) continued to receive TVP products. Both groups continued to self-select a vegetarian diet for the remainder of their dietary intake. Dietary intake and iron and hematological status data were collected at the midpoint (RT5) and at the completion (RT12) of the protocol. These data were used to assess any changes in indexes of iron status or nutrient intake with consumption of either a beef-containing or vegetarian diet and participation in RT. Maximal strength measures were also completed at RT5 and RT12.

Diet

A registered dietitian planned a three-day cycle for the provided TVP and/or beef products. All products were supplied in uncooked form on a weekly basis, with all foods provided for a given day to be prepared by the subject and consumed during that day. The TVP products included Morningstar Farms Grillers, Chik Patties, Breakfast Patties, and Veggie Dogs (Worthington Foods, Inc., Worthington, OH). Beef products were provided in the form of cube steak, beef burger patties, and beef tips.

All products were supplied in amounts to provide 0.6 g protein · kg^{-1} · d^{-1} based on each subject's prestudy body weight. Each man's body weight was measured weekly, and he was encouraged to adjust his food intake as necessary to maintain a constant body weight throughout the study period. The provided protein amount of 0.6 g protein · kg^{-1} · d^{-1} was chosen because it is equal to the mean reference protein requirement for adults on which the Recommended Dietary Allowance (18) is based and because it could be provided in portions of food easily incorporated into a person's daily meals (about three servings per day). The total protein intake of the men was expected to be 1.0 to 1.3 g protein · kg^{-1} · d^{-1} from their self-selected diet and provided food combined. The macronutrient and iron content of the provided products are presented in Table 1.

Body Composition

Subject height without shoes was measured using a wall-mounted stadiometer. Whole body weight, percent body fat, and fat-free mass were determined by whole body densitometry (19) using the Bod Pod Body Composition System (Life Measurements Instruments, Concord, CA) and the two-compartment model equation of Siri (20). The subjects were dressed only in shorts and a swim cap for the body density measurements. BMI was calculated as weight/height^2 (kg/m^2).

RT and Strength Measurement

From RT1 to RT12, all of the men participated in RT on three nonconsecutive days per week. After a warm-up of cycling and stretching, five exercises were used to train the major muscle groups of the upper and lower body using Keiser pneumatic RT equipment (Keiser Sports Health Equipment, Fresno, CA). Lower body exercises included knee extension, seated leg curl, and double leg press. Upper body exercises included a seated arm pull and seated chest press. The intensity of the resistive exercises was set at 80% of the maximum load the subject could lift through the full range of motion of a joint one time only (one repetition maximum, 1RM). Each man completed two sets of eight repetitions and a third set with repetitions to volitional fatigue for each exercise. When the men were able to complete 12 repetitions for the third set, a 5% increase in resistance was applied to the next exercise session. Maximal strength, determined as 1RM, was measured for each exercise at RT1, RT5, and RT12.

Iron and Hematological Status Indexes

A 35- to 40-mL fasting blood sample was taken at baseline, RT5, and RT12. A vacutainer containing potassium ethylenediaminotetracetic acid (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) was used to collect whole blood, which was used for measurement of complete blood count (CBC) (including white blood cell count, red blood cell count, hemoglobin concentration, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration) to determine whether any clinically defined anemia was present. CBC analyses were completed by the Central Arkansas Veterans Healthcare System's Pathology and Laboratory Medicine Service with a Coulter MaxM counter (Coulter Electronics Inc., Hialeah, FL) using standard methods.

Blood was collected in a vacutainer containing serum separator gel and clot activator transport (Becton Dickinson Vacutainer Systems). After collection, the blood sat at room temperature for 30 to 45 minutes, then was centrifuged for 10 minutes to separate the serum. Serum was separated into aliquots in cryotubes and stored frozen at −70°C until analyses. Analyses included serum iron concentration, TIBC, transferrin receptor content, and serum ferritin concentration. These indicators allow detection of possible changes in iron stores (ferritin), iron transport to tissues (serum iron, TIBC, and transferrin saturation percentage), and adequacy of iron delivery (transferrin receptor). Serum iron and TIBC were determined using Sigma Iron and Total Iron-Binding Capacity assay kit 565 (Sigma Diagnostics, St. Louis, MO).

Transferrin saturation was calculated as [(serum iron÷TIBC)×100]. Transferrin receptor was determined by enzyme immunoassay using Ramco TfR transferrin receptor assay kit TR-94 (Ramco Laboratories, Houston, TX). Serum ferritin was determined by the Central Arkansas Veterans Healthcare System's Pathology and Laboratory Medicine Service by immunoassay using Ferritin Flex reagent cartridge RF440 (Dade Behring Inc, Newark, DE).

Assessment of Dietary Intake and Iron Bioavailability

Each man completed three-day diet records during baseline, RT5, and RT12. The men were instructed to record the timing and amounts of foods consumed for three consecutive days (two weekdays and one weekend day). The three-day diet records were then analyzed using Nutritionist Five (First Databank Inc, San Bruno, CA) version 1.5, a computerized dietary analysis system, to provide a nutrient analysis of individual foods and the composite diet. Any meat-containing mixed dishes were separated into basic food components before analysis to allow later estimation of heme and nonheme iron. The composite nutrient analysis report served as an index of energy, macronutrient, vitamin C, and iron intakes.

Selected nutrients from the nutrient analysis of individual foods, including amount, weight, protein, iron, and vitamin C content for each food item consumed, were exported into a Microsoft Excel (Excel 97, 1997, Microsoft Corporation, Redmond, WA) spreadsheet. The iron content of each food was then separated into heme and nonheme components. The heme iron content was assumed to be equal to 40% of the total iron found in meat, fish, and poultry (16). Nonheme iron content was calculated as total iron minus heme iron content.

A computer program was created that adjusted iron intake for bioavailability using the algorithms developed by Monsen and Balintfy (16) and Tseng and colleagues (17). All iron bioavailability calculations were based on absorption assuming normal iron stores. The Monsen and Balintfy algorithm adjusts for the presence of two enhancing factors, the effects of meat, fish, and poultry, and vitamin C on a per meal basis. The method developed by Tseng and colleagues (17) is an expansion of the Monsen and Balintfy (16) method and was used for comparison. It further adjusts nonheme iron availability for the inhibiting factors of phytate and tea consumption. The phytate content of food items was estimated using values from Harland (21) and Harland and Oberleas (22). The phytate content of the provided TVP products was estimated as 1,200 mg phytate per 100 g product based on similar products (21,22).

For both methods, the total bioavailable iron was equal to the sum of the available heme and available nonheme iron per meal. Amounts from each meal were totaled for a daily total bioavailable iron, and a daily average was determined for each recording period.

Statistical Analyses

Statistical analyses were completed using a general linear model with JMP statistical software (version 3.2, 1997, SAS Institute Inc, Cary, NC) for all dietary, hematological, iron status, iron bioavailability, and strength data. Because of a non-normal distribution, a common $\log_{10}$ transformation of the serum ferritin data was performed. The distribution of the $\log_{10}$ transformed data was normal. Comparisons for any differences between the beef and vegetarian groups were assessed by one-way ANOVA for any group effects at baseline. A two-way repeated-measures ANOVA was used for comparisons of baseline, RT5, and RT12 for the effects of group, time, and group×time interactions. A two-way repeated-measures ANOVA was also used for analyses of strength and body composition for the effects of group, time, and group×time interactions between pre-RT and post-RT (RT1 and RT12) measures. Significance was established at the $P<.05$ level (two-tailed). All values are reported as mean ± standard deviation unless otherwise noted. Given the sample size in the study, we had 80% power to

detect differences of 70.0, 9.0, 13.0, 17.7, and 4.4 units for the measures of serum ferritin, iron, TIBC, transferrin saturation, and transferrin receptor, respectively.

Results

At baseline there were no significant differences between the beef and vegetarian groups for age, height, weight, percent body fat, fat free mass, and muscle strength (Table 2). There were also no significant differences between groups for any of the diet, estimated bioavailable iron, hematological, or iron status parameters at baseline (Tables 3 and 4).

Over the course of the intervention, there were no significant differences within or between the beef and vegetarian groups for weight, percent body fat, or fat free mass. Maximal strength increased in all of the muscle groups that were trained and ranged from 14% to 38% (Table 2). Overall, the consumption of the beef vs vegetarian diet did not affect the RT-induced increase in strength, as indicated by no group×time interactions for four of the five exercises (leg press, seated leg curl, chest press, and arm pull). The vegetarian group had a greater increase in strength for the knee extension exercise (group×time interaction [$P<.01$]).

During the intervention, protein, carbohydrate, alcohol, and vitamin C intake were not different between groups (Table 3). There was a significant group×time interaction ($P<.01$) for fat intake, with the beef group increasing fat intake. Total iron intake was not different between groups. However, the beef group consumed more heme iron ($P<.01$) and less nonheme iron ($P<.05$) than the vegetarian group. This pattern of iron intake resulted in increased iron bioavailability, as determined by the Tseng and colleagues method (17), for the beef group (significant group×time interaction [$P<.01$]), a finding expected based on re-introduction of meat in the form of beef. However, when iron bioavailability was determined by the Monsen and Balintfy (16) method, there was only a significant effect of time ($P<.05$). As at baseline, the Tseng and colleagues (17) method consistently predicted lower bioavailable iron intakes for both groups compared with the Monsen and Balintfy method (16).

All hematological and iron status indicators were within clinically normal ranges. Hematological parameters of hemoglobin (Hgb) and hematocrit (Hct) differed between groups over time, indicated by significant group×time interactions ($P<.01$). The Hgb and Hct of the beef group increased after the re-introduction of meat in the form of beef (Table 4), and remained stable in the vegetarian group, as shown by post-hoc testing using Bonferroni Familywise 95% confidence intervals. During RT, serum ferritin declined over time in both the beef group and vegetarian groups ($P<.01$). There were no group or group×time interactions for other iron status indexes (serum iron, TIBC, serum transferrin, transferrin saturation, and transferrin receptor).

Discussion

Our study examined the effects of diets of differing iron bioavailabilities during RT on iron status in older men. The findings indicate that consumption of a beef-containing diet, having greater iron bioavailability, increases hematological parameters during RT. However, consumption of a lacto-ovo vegetarian diet did not adversely affect hematological profile.

The difference noted in heme iron intake between the vegetarian and beef groups over time reflects the inclusion of beef in the beef group during the RT period. This coincided with a decrease in nonheme iron intake in the beef group, because the TVP products were no longer provided to this group. The increasing fat intake of the beef group compared with the vegetarian group over time may reflect the relative contribution of fat from the beef vs the TVP products. A comparison of the two groups' diets without the inclusion of the provided beef and TVP products revealed no significant difference in fat intake ($P=0.78$).

Serum transferrin receptor trended downward in the beef group and upward in the vegetarian group from baseline to RT5 and RT12. This trend in serum transferrin receptor is consistent with the change that would be expected based on the differences in iron bioavailability between the two groups; however, this group-specific response only achieved a *P* value of .07.

There was a significant decrease in serum ferritin for both groups from baseline, RT5, and RT12 despite the differences in bioavailable iron intake between groups. An explanation for this decrease may be an effect of RT. A decrease in serum ferritin has been noted in previous studies (11,12) involving younger men with no dietary control, suggesting that RT causes a reduction in iron stores. In contrast, Campbell and colleagues (13) found no significant change in serum ferritin over time in older men who participated in 12 weeks of RT. All of these studies, including ours, differed in length and intensity of the RT protocol, timing of phlebotomy, and age of participants, making definitive comparisons difficult.

Hgb and Hct are frequently used clinically to identify iron status. The increase of Hgb and Hct in the beef group once meat, in the form of beef, was re-introduced to the beef group suggests that there may have been some change in erythropoiesis or expression of erythropoiesis with the transition to a beef-containing diet. The increased Hgb and Hct noted when subjects consumed beef is similar to the findings of Ortega and colleagues (23) and Worthington-Roberts and colleagues (24). In a study of young women, Ortega and colleagues (23) found higher levels of Hgb and Hct in those who consumed ≥100 g (3.5 oz) of meat per day. Worthington-Roberts and colleagues (24) found that young women whose habitual predominant source of protein came from red meat had greater Hgb and Hct concentrations than women whose predominant source of protein was fish and poultry or lacto-ovo vegetarian.

The observed changes of increasing Hgb and Hct of the beef group are more consistent with the iron bioavailability as predicted by the Tseng et al method (17), which showed an increase in bioavailable iron density in the beef group and a decrease in bioavailable iron density in the vegetarian group. The Tseng et al method (17), which expands the Monsen and Balintfy method (16), may more closely estimate iron bioavailability, because it includes the additional inhibiting factors of iron absorption.

The recommended dietary allowance (RDA) of iron for the older adult is 10 mg/d (18). According to nutrient analyses of reported intakes, both vegetarian and beef groups exceeded this requirement at all measured time points. It is generally accepted that a reference man must absorb approximately 1 mg of iron per day to account for iron losses and maintain iron balance. An inability to meet the requirements for iron balance over time would negatively impact iron stores and status. Although iron balance was not measured in the present study, the bioavailable iron density necessary to maintain iron balance can be estimated using the RDA for recommended energy intakes of men aged 51 and above (2,300 kcal) and the iron absorption needs (1 mg absorbed iron). Assuming energy needs are met (consistent with the maintenance of body weight in the present study), for the older adult man, a bioavailable iron density of 0.43mg/1,000 kcal should be adequate to meet iron balance requirements based on the RDA for energy and absorbed iron requirements (1 mg absorbed iron/2,300 kcal). The mean energy intake of the beef and vegetarian groups was estimated from food records to range from approximately 2,100 to 2,300 kcal, and 2,150 to 2,300 kcal, respectively, throughout the study period. When mean bioavailable iron density was determined according to the Monsen and Balintfy (16) method, both groups exceeded 0.43mg/1,000 kcal at all time points. However, when mean bioavailable iron density was determined by the Tseng and colleagues method (17), although the beef group approached the 0.43mg/1,000 kcal level when beef was included in their diet, neither the beef nor the vegetarian group met this bioavailable iron density level.

A previous controlled diet study by Hunt and Roughead (25) found an insensitivity of blood iron indexes to differences in iron absorption from lacto-ovo vegetarian and nonvegetarian diets over eight weeks. Perhaps the length of time for dietary intervention in the present study was too short to result in a change in iron status indexes. In contrast, iron status indexes did respond to dietary intervention (26) in a seven-week crossover design study in postmenopausal women comparing controlled high meat, low meat, and low meat plus mineral supplement diets, all similar in phytate content. Opposite of what would have been expected, that a high meat diet would increase iron stores and/or positively affect iron status, the high meat diet resulted in decreased ferritin and increased TIBC.

The lack of significant change in iron indexes by Hunt and Roughead (25) and in our study may be a reflection of an adaptation of nonheme iron absorption, as found in a recent study (27) in which men adapted over time to diets of high and low iron bioavailabilities. This adaptive response was noted by decreased nonheme iron absorption of the men who consumed high bioavailable iron diets and an increased nonheme iron absorption in men who consumed low bioavailable iron diets over time. We concluded that although dietary iron bioavailability influences iron stores, the effects are long-term and are not as great as predicted from short-term absorption studies. Therefore, in short-term considerations, it seems that iron stores may influence iron bioavailability to a greater extent than iron bioavailability influences iron stores.

Limitations of this study include small sample size and inability to separate the effects of diet and RT on iron and hematological status indicators. For each response, the study had 80% power to detect 2.64 standard deviation between means. According to most references, this is a very large effect size, which implies that power to detect small effects was limited. Despite this, significant group×time effects were found for both Hgb and Hct.

Applications

- Older men who consume a beef-containing higher bioavailable iron diet, compared with a vegetarian, lower bioavailable iron diet, increase hematological profile parameters during a 12-week period of RT. These results suggest that a beef-containing diet may better maintain or improve hematological indexes during RT.
- The vegetarian group's hematological profile was maintained within normal ranges and did not decline over time with RT and continued consumption of a meat-free diet.
- As dietitians and health care professionals, we should encourage eating patterns consistent with a high level of iron bioavailability with those who consume either a vegetarian diet or meat-containing diet and participate in RT.

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Table 1

Three-day average macronutrient and iron contents of provided food items (beef and texturized vegetable protein products) for a 75 kg reference male[a]

	Energy (kcal)	Protein (g)	Carbohydrate (g)	Fat (g)	Iron (mg)
Beef group	609	53.3	0	46.3	5.0
Vegetarian group	549	53.3	32.9	20.2	9.0

[a] All products were provided in amounts adjusted to yield 0.6 g protein·kg^{-1}·d^{-1}.

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Table 2

Body composition and strength measures of older men who consumed beef-containing vs vegetarian diets during a 12-week period of resistive training[a]

	Baseline	Week RT12[b]	Percentage change
Weight (kg)			
Beef	89.8±7.9	89.6±7.6	0.2±0.7
Vegetarian	89.0±8.3	89.3±9.6	−0.1±0.5
Percent body fat			
Beef	30.5±6.0	30.6±6.6	0.2±0.2
Vegetarian	30.4±6.6	31.4±6.9	0.1±0.2
Fat-free mass (kg)			
Beef	62.1±4.1	61.9±5.1	−0.4±0.9
Vegetarian	61.7±4.9	60.8±4.9	−1.4±2.8
Knee extension[x] (Nm[c])			
Beef	111±22	138±28	25±4
Vegetarian	121±29	164±28	38±5
Seated leg curl[y] (Nm)			
Beef	109±25	139±23	30±6
Vegetarian	111±24	140±20	29±5
Seated chest press[y] (N[d])			
Beef	450±103	554±76	27±8
Vegetarian	449±58	511±61	14±2
Double leg press[z] (N)			
Beef	1,280±357	1,544±481	21±8
Vegetarian	1,339±212	1,589±161	20±3
Seated arm pull[y] (N)			
Beef	606±123	744±84	26±7
Vegetarian	603±68	741±84	23±2

[a] Beef, n=10; vegetarian, n=11. Baseline and Week RT12 values reported as mean±standard deviation; percent change values reported as mean±standard error of the mean.

[b] Week RT12=week 12 of resistive training.

[c] Nm=newton·meter.

[d] N=newton.

[x] Significant group×time interaction ($P<.05$).

[y] Significant time effect: $P<.01$.

[z] Significant time effect: $P<.05$.

Table 3

Dietary intake of older men who consumed beef-containing and vegetarian diets during a 12-week period of resistive training[a]

	Baseline	Week RT5[b]	Week RT12[c]
Energy (kcal/d)			
Beef	2,091±398	2,287±379	2,163±632
Vegetarian	2,282±392	2,279±442	2,155±287
Protein (g/d)			
Beef	98±17	103±19	96±32
Vegetarian	105±12	102±17	103±14
Protein/body weight (g/kg/d)			
Beef	1.1±0.2	1.0±0.4	1.1±0.2
Vegetarian	1.2±3.2	1.0±0.4	1.1±0.2
Carbohydrate (g/d)			
Beef	264±63	260±63	238±73
Vegetarian	274±66	273±60	265±51
Fat[w] (g/d)			
Beef	68±16	94±16	95±28
Vegetarian	85±25	87±32	79±28
Alcohol (g/d)			
Beef	2.0±3.5	8.0±11.1	10.1±17.1
Vegetarian	2.6±4.7	3.2±8.5	4.9±12.6
Vitamin C (mg/d)			
Beef	145±123	156±63	145±70
Vegetarian	120±63	141±110	146±85
Total iron (mg/d)			
Beef	19.0±2.8	17.5±5.4	15.2±3.8
Vegetarian	20.9±6.3	23.5±9.4	20.9±7.6
Heme iron[w] (mg/d)			
Beef	0	2.0±0.3	2.0±0.9
Vegetarian	0	0	0
Nonheme iron[x] (mg/d)			
Beef	19.0±2.8	15.5±5.4	13.2±3.5
Vegetarian	20.9±6.3	23.5±9.4	20.9±7.6
Iron density (mg/1,000 kcal)			
Beef	9.46±1.96	7.82±1.77	9.26±6.64
Vegetarian	9.56±2.18	10.19±3.19	9.64±3.60
Monsen's bioavailable iron[y] (mg/d)			
Beef	1.0±0.3	1.6±0.3	1.3±1.3
Vegetarian	1.1±0.6	1.3±0.9	1.2±0.6
Tseng's bioavailable iron[w] (mg/d)			
Beef	0.3±0.3	0.9±0.3[z]	0.8±0.3[z]
Vegetarian	0.2±0.3	0.3±0.3	0.2±0.1
Monsen's bioavailable iron density (mg/1,000 kcal)			
Beef	0.52±0.15	0.71±0.18	0.62±0.12
Vegetarian	0.65±0.23	0.55±0.17	0.52±0.26
Tseng's bioavailable iron density[w] (mg/1,000 kcal)			
Beef	0.13±0.06	0.36±0.17	0.41±0.15
Vegetarian	0.23±0.14	0.11±0.06	0.12±0.06
Monsen's percent bioavailable iron[w] (percent of total iron)			
Beef	5.50±1.30	9.15±0.72[z]	8.60±1.73[z]
Vegetarian	5.12±1.17	5.05±1.74	5.24±1.14
Tseng's percent bioavailable iron[y] (percent of total iron)			
Beef	1.33±0.76	5.26±1.08[z]	5.61±2.31[z]
Vegetarian	1.03±0.28	1.16±0.60	1.16±0.31

[a] All subjects consumed a lacto-ovo vegetarian diet at baseline. Beef, n=10; vegetarian, n=10. Values reported as mean±standard deviation.

[b] Week RT5=week 5 of resistive training.

[c] Week RT12=week 12 of resistive training.

[w] Significant group×time interaction, $P<.01$.

[x] Significant group×time interaction, $P<.05$.

[y] Significant time effect, $P<.05$.

[z] Beef group significantly different than vegetarian group ($P<.01$).

Table 4

Hematological and iron status indexes of older men who consumed beef vs vegetarian diets during a 12-week period of resistive training[a]

	Baseline	Week RT5[b]	Week RT12[c]
Serum iron[d] (μmol/L)			
Beef	17±6	17±6	15±6
Vegetarian	16±3	15±3	15±6
TIBC[e] (μmol/L)			
Beef	51±6	53±6	53±9
Vegetarian	53±6	56±3	54±6
Transferrin saturation (%)			
Beef	33±9	31±9	29±9
Vegetarian	31±10	28±6	29±13
Serum transferrin receptor (μg/mL)			
Beef	4.9±2.5	4.6±2.5	4.3±1.9
Vegetarian	4.6±1.7	4.9±2.0	4.9±2.0
Ferritin[w,x] (μg/L)			
Beef	132±107	142±142	131±132
Vegetarian	95±70	76±53	72±53
WBC[f] (10^9/L)			
Beef	4.9±1.2	4.9±1.3	5.4±1.9
Vegetarian	5.7±1.0	5.6±1.0	5.5±1.0
RBC[g] (10^{12}/L)			
Beef	4.5±0.3	4.8±0.3	4.8±0.3
Vegetarian	4.7±0.3	4.7±0.3	4.6±0.3
Hgb[h,y] (g/L)			
Beef	140±6	150±12	151±9
Vegetarian	143±7	144±7	145±7
	(−0.82, 0.19)[z]	(0.14, 1.3)	(0.61, 1.01)
Hct[i,y] (l)			
Beef	0.42±0.03	0.45±0.03	0.45±0.03
Vegetarian	0.42±0.03	0.43±0.03	0.43±0.03
	(−2.22, 0.90)[z]	(0.22, 3.33)	(0.42, 3.54)
MCV[j] (fL)			
Beef	93±3	94±3	94±3
Vegetarian	91±3	92±3	91±3
MCH[k] (pg)			
Beef	31.4±1.3	31.6±1.6	31.2±1.6
Vegetarian	30.8±1.3	30.7±1.3	31.3±2.3
MCHC[l] (g/L)			
Beef	338±6	336±6	333±6
Vegetarian	339±10	334±3	335±7

[a] Beef, n=10; lacto-ovo vegetarian, n=11. Values reported as mean±SD.

[b] Week RT5=week 5 of resistive training.

[c] Week RT12=week 12 of resistive training.

[d] To convert μmol/L serum iron to μg/dL, multiply μmol/l by 5.5834. To convert μg/dL serum iron to μmol/L, multiply by μg/dL by 0.1791. Serum iron of 14 μmol/L=80 μg/dL.

[e] TIBC=total iron binding capacity. To convert μmol/L TIBC to μg/dL, multiply μmol/l by 5.5834. To convert μg/dL TIBC to μmol/L, multiply by μg/dL by 0.1791. TIBC of 45 μmol/L=250 μg/dL.

[f] WBC=white blood cell count.

[g] RBC=red blood cell count.

[h] Hgb=hemoglobin concentration. To convert g/L Hgb to g/dL, multiply by 0.1. To convert g/dL Hgb to g/L, multiply by 10. Hgb of 140 g/L=14 g/dL.

[i] Hct=hematocrit. To convert “1” Hct to %, multiply by 100. To convert % Hct to “1”, multiply by 0.01. Hct of 0.39 “1”=39%.

[j] MCV=mean corpuscular volume.

[k] MCH=mean corpuscular hemoglobin.

[l] MCHC=mean corpuscular hemoglobin concentration. To convert g/L MCHC to g/dL, multiply by 0.1. To convert g/dL MCHC to g/L, multiply by 10. MCHC of 330 g/L=33 g/dL.

[w] Statistical analyses of $\log_{10}$ transformed data. Ferritin values presented are untransformed. Minimum, median, and maximum values for ferritin at baseline, week RT5 and week RT12 were: beef: (baseline) 39, 97, 357; (RT5) 33, 76, 443; (RT12) 36, 77, 460; vegetarian: (baseline) 11, 77, 225; (RT5) 12, 83, 161; (RT12) 13, 61, 165 μg/L.

[x] Significant time effect ($P<.01$).

[y] Significant group×time interaction ($P<.01$).

[z] 95% CI for difference between means.