Exercise and Protein Effects on Strength and Function with Weight Loss in Older Women

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[1]Department of Kinesiology, University of Georgia, Athens, GA; [2]Department of Foods and Nutrition, University of Georgia, Athens, GA; [3]School of Psychological Sciences and Health, University of Strathclyde, Glasgow, UNITED KINGDOM; and [4]Department of Nutrition and Health Sciences, University of Nebraska Lincoln, Lincoln, NE

ABSTRACT

EVANS, E. M., C. R. STRAIGHT, R. A. REED, A. C. BERG, D. A. ROWE, and M. A. JOHNSON. Exercise and Protein Effects on Strength and Function with Weight Loss in Older Women. *Med. Sci. Sports Exerc.*, Vol. 53, No. 1, pp. 183–191, 2021. Obesity negatively affects lower extremity physical function (LEPF) in older adults. Exercise and a higher protein diet are both known to positively and independently affect body composition, muscle strength, and LEPF during weight loss; however, their potential interactive effects have not been well characterized in older women. **Purpose:** The aim of this study was to determine the relative efficacy of a higher protein diet with or without exercise to improve body composition, muscle strength, and LEPF in older inactive overweight/obese women after weight loss. **Methods:** Postmenopausal women (body mass index = 31.1 ± 5.1 kg·m^{-2}, 69.2 ± 3.6 yr) completed a 6-month weight loss program after randomization to three groups (n = 72 randomized; 15% dropout): 1) higher protein diet (PRO, ~30% energy from protein; n = 20), 2) PRO plus exercise (PRO + EX; n = 19), or 3) a conventional protein control diet plus EX (CON + EX, ~18% energy from protein; n = 22). EX was supervised, multicomponent (aerobic, muscle strengthening, balance, and flexibility), and three sessions per week. Body composition was measured via dual-energy x-ray absorptiometry, leg strength by isokinetic dynamometry, and LEPF via 6-min walk, 8-ft up and go, and 30-s chair stand tests. **Results:** Changes in weight (−7.5 ± 4.1 kg; −9.2% ± 4.8%), fat mass, and leg lean mass did not differ among groups (all P > 0.50). Despite weight loss, muscle strength improved in the exercise groups (PRO + EX and CON + EX) but it declined in the PRO group (P = 0.008). For all LEPF measures, the PRO group had attenuated improvements compared with both PRO + EX and CON + EX (all P < 0.01). **Conclusion:** Exercise during weight loss is critical to preserve strength and enhance LEPF; however, a higher protein diet does not appear to influence body composition, muscle strength, or LEPF changes when combined with multicomponent exercise. **Key Words:** MULTICOMPONENT EXERCISE TRAINING, PHYSICAL FUNCTION, DIETARY PROTEIN

Obesity in older adults is of great concern as it is associated with reductions in physical function and an increased risk for physical disability (1), especially in older women (2,3). It has been established that weight loss and exercise/physical activity interventions are effective behavioral strategies for attenuating functional decline and reducing risk for disability in older adults (3). However, weight loss in older adults typically causes concurrent reductions in lean mass and strength, thereby exacerbating the risk for sarcopenia and dynapenia (1). The inclusion of exercise in a calorically restricted weight loss regimen attenuates lean mass and strength loss and is advocated as a critical component of weight loss programs for older adults (1). Regarding the latter, Villareal and colleagues (4) were one of the first to report that calorically restricted weight loss and exercise combined resulted in greater improvements in physical function compared with weight loss or exercise alone in older adults.

In addition to exercise training, emerging literature also suggests that increased dietary protein is another strategy to enhance favorable body composition changes under weight loss conditions, specifically preservation of muscle mass (5) and greater reductions in fat mass (6). However, the effect of protein intake on body composition changes, and relatedly strength and physical function, in response to a calorically restricted weight loss regimen remains an active area of investigation as the current literature focused on older adults is equivocal (7–11). Further, the literature is lacking controlled trials balanced in internal and external validity that (a) explore the potential additive benefits of multicomponent exercise training (i.e., aerobic/endurance, resistance training, functional/balance) and dietary protein; (b) are of a longer duration (>3 months); (c) have outcome measures of body composition, strength, and physical function; and (d) use readily available food (i.e., dietary food not supplied; minimal/no use of protein powders/supplements) in older women known to be at higher risk for

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obesity and physical disability compared with their male counterparts (3).

Multicomponent exercise training and dietary protein may have complicated, interactive implications for changes in lower extremity physical function (LEPF) in older adults because of differential effects on weight change, individual body composition components (i.e., fat and lean mass), and muscle strength. Specifically, conceptually framed, reducing the load to be moved (i.e., weight and fat mass), and maintaining or enhancing the ability to move the load (i.e., preserving high-quality muscle mass) theoretically should confer the greatest improvements in LEPF. The literature in this area remains equivocal, although promising, and reviews call for additional clinical trial research before best practice guidelines can be established (1,11,12).

In this context, the aim of this study was to determine the relative efficacy of a higher protein diet with or without exercise to improve body composition, muscle strength, and LEPF in older inactive overweight/obese women enrolled in a 6-month weight loss program. We hypothesized that although all treatments would confer favorable effects on weight status, body composition, and LEPF, the higher protein diet combined with exercise group would experience the greatest benefit in all outcomes of interest, especially LEPF, compared with the conventional protein control diet with exercise or protein diet alone groups.

METHODS

Study Design, Overview, and Participants

Relatively healthy but overweight/obese inactive older women were recruited with the following primary inclusion criteria: 65 to 80 yr old, body mass index (BMI) ≥25.0 $kg \cdot m^{-2}$, and physically inactive (<1 $h \cdot wk^{-1}$ of physical activity or less than two exercise sessions per week) over the past 6 months. The primary exclusion criteria were as follows: habitual smoker, dietary restrictions that precluded adherence to the dietary protocol, history of unstable cardiovascular disease, self-report of active cancer or treatment within previous 5 yr, psychiatric or cognitive disorder that precluded the ability to adhere to study protocols, severe arthritis, or other conditions that precluded safe adherence to the exercise prescription. Women randomized to the exercise interventions were also required to complete a graded exercise test administered by the study physician to ensure safety for exercise participation. All participants obtained medical clearance from their personal physician. Participants were stratified by age and BMI and randomized using an online program (www.randomnumbergenerator.com) to one of three treatment groups: high-protein diet with exercise (PRO + EX), high-protein diet without exercise (PRO), or conventional protein control diet with exercise (CON + EX). The study coordinator who was not involved with the intervention or data collection, reduction, or analysis completed the stratification and randomization procedures. All procedures of this study were approved by the University of Georgia's Institutional Review Board (protocol ID no. 2012109023), and participants provided written informed consent before enrollment.

Dietary Intervention and Dietary Intake

Energy goals and macronutrient distribution. All individuals, regardless of randomized group, were prescribed diet programs supervised by a registered dietitian nutritionist (RDN) based on a reduction of ~500 kcal from calculated energy needs (Mifflin St. Jeor equation using baseline body weight; activity factor 1.3) to promote loss of ~0.25 to ~1 $kg \cdot wk^{-1}$ (13). The recommended PRO diet was designed to provide 30% of daily energy from protein, targeting at a minimum 1.0 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$ (1) with a prescribed level of ~1.6 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$, and the recommended CON diet was designed to provide 18% of daily energy from protein (0.8 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$). Both diets were designed to provide 30% of energy from fat, and the remainder of energy from carbohydrate (PRO = ~40%, CON = ~52%). Participants in the PRO intervention groups were instructed to consume at least one serving of cooked lean beef (3 oz) per day. In addition, they were recommended to select high-quality low-fat protein foods as preferred including other lean meats (e.g., poultry, pork), low-fat/fat-free dairy, eggs, and protein bars and powder supplements as preferred for adherence to protein goals, the latter being less encouraged than whole foods. Based on recommended clinical practice given the risk for deficiencies with calorie restriction and under direct oversight by the RDN, all participants were provided a multivitamin mineral supplement (Centrum® Silver® Women, Pfizer, Inc., Madison, NJ). Similarly, additional calcium supplements (Regular Strength TUMS®, 200 mg elemental calcium; GlaxoSmithKline, St. Louis, MO) were prescribed on an individual basis to meet the RDA (1200 $mg \cdot d^{-1}$).

Dietary counseling sessions. At the beginning of the intervention, participants attended a minimum of two individual sessions with the RDN or nutrition graduate student under supervision of the RDN for instruction regarding energy restriction, macronutrient distribution of the intervention diet, and self-monitoring methods. For the remainder of the study, participants attended weekly educational and/or motivational group sessions (45–60 min) and individual sessions as necessary to meet weight loss goals. The group session topics included both general nutrition education and behavioral strategies for weight management. All participants attended one individual session at the midpoint of the intervention to assess progress toward weight loss and dietary goals. Participants were instructed to use a free online dietary intake monitoring application (MyFitnessPal.com) to enhance adherence. Interventionists set up the program with the individualized energy restriction goal and macronutrient distribution per protocol. Entries were monitored weekly, along with weight changes, and participants were provided individualized feedback to help meet weight loss and nutrient goals.

Dietary intake assessment. Participants completed diet records for 3 d, including two weekdays and one weekend day, recording all food and beverages consumed each 24-h period, at baseline, midpoint, and postintervention. The RDN or the trained interviewer reviewed the record with the participant to clarify information provided, allowing the participant multiple opportunities to recall food and beverage intake. Food models were used as needed to verify portion sizes. Dietary intake data were assessed using the Nutrition Data System for Research (NDSR 2013, Minneapolis, MN) to determine 3-d average energy intake and diet composition at each data collection time. Note that the MyFitnessPal dietary intake records acquired above were for adherence enhancing purposes only and were not research outcomes.

Exercise Intervention

All participants in the PRO + EX and CON + EX groups were asked to complete 3 × 75-min sessions of supervised exercise on nonconsecutive days during each week of the intervention for 6 months. The exercise intervention was a multicomponent program that integrated cardiorespiratory training (30 min at moderate intensity), resistance training for all major muscle groups (two sets of 8–10 repetitions at 65% of 1-repetition maximum), and balance and functional exercises per established recommendations (14). All participants were asked to maintain usual activities outside the intervention. Habitual physical activity was assessed objectively using an accelerometer (NL-1000; New Lifestyles, Inc., Lee's Summit, MO) at baseline, midpoint, and postintervention. Step counts and moderate-to-vigorous physical activity (MVPA) minutes were calculated using the average step count from valid wear days.

Outcome Measures

NCT01893684; clinicaltrials.gov. The authors acknowledge the following deviations from our registered protocol: (a) omission of body composition outcomes assessed using MRI due to common knee implants in our older adult sample, which were not deemed safe for scanning on our university magnet, and (b) reporting on the secondary outcome measure, physical functional performance (LEPF), within the primary aim in the present manuscript due to increased interest in these end points in recent literature.

Weight status and body composition. Standing height and weight were measured using conventional clinical methods. Whole-body and regional soft tissue composition (absolute [kg] and relative fat mass [%Fat] and mineral-free lean mass) was assessed via dual-energy x-ray absorptiometry (iDXA; GE Healthcare-Lunar, Madison, WI). Regional analyses were performed per manufacturer's guidelines and involved bisecting the femoral neck and patella to measure mineral-free lean mass of the upper leg.

Muscle strength. Concentric isokinetic knee torque was assessed via isokinetic dynamometry (System 4 Pro; Biodex Medical Systems Inc., Shirley, NY) at $60°\cdot s^{-1}$ using 2 sets of 4 extension and flexion repetitions. The greatest extension and flexion peak torque values for each leg were summed to calculate maximal isokinetic knee torque (IK-60).

LEPF. Objective LEPF was measured using three well-established functional tests: the 8-ft up and go (UPGO), 30-s chair stand (CHAIR), and 6-min walk (WALK) (15).

Statistical Analysis

All statistical analyses were conducted using SPSS for Windows version 22.0 (IBM Corp., Armonk, NY) and/or SAS Version 9.4 (SAS Institute, Inc., Cary, NC). Data were examined for distributional characteristics via skewness and kurtosis, and visual inspection of histograms and box plots was used to identify outliers (defined as 3 × the semi-interquartile range from the median). One-way independent-groups ANOVA was used to test for group differences at baseline, and chi-square tests were used to compare groups on categorical variables. Two-way 3 (group) × 3 (time) mixed factorial ANOVA was used to compare change over time among the three study groups. Where the sphericity assumption was violated, the Greenhouse–Geisser adjustment of the degrees of freedom was used to correct for the violation. Statistical significance was set at $P < 0.05$ for all tests. Where interaction effects were deemed to be significant, the pattern of interaction effects was interpreted using Cohen's d effect sizes (16) with suggested criteria being used to interpret effect sizes as being small (d = 0.2), medium (d = 0.5), or large (d = 0.8). Furthermore, in the presence of a significant interaction effect for a primary outcome, both a per-protocol/completer analysis (n = 61) and an intention-to-treat (ITT) analysis (n = 72) with a last value/observation carried forward approach were used to compare group changes from baseline to posttest using ANOVA and *post hoc* analysis, LSD.

Power calculation. Although changes in body composition and muscle strength were of interest, the overarching goal of this study was to assess the relative efficacy of the treatments for obesity to prevent risk of physical disability in older women. Based on their excellent translational meaning regarding daily LEPF and subsequent risk for disability, UPGO and CHAIR were deemed as the primary outcomes of interest for power calculations. Accepted clinically meaningful change in LEPF varies based on type of objective; therefore, similar to other health outcome research, it was accepted that a moderate effect (Cohen's d = 0.5) is the minimal effect to be of meaning. Based on our pilot data (9), it was determined that a sample of 25 per group with a retention of 80% providing 20 participants per group would provide power of ~0.85 to detect a group–time interaction effect size of 0.50 SD with the three measurement time points (0, 3, and 6 months), an alpha level of 0.05, and an average correlation between repeated measurements of ≥0.80.

RESULTS

Participant Characteristics

Of the 254 individuals assessed for eligibility, 81 were randomized postscreening to the three treatment groups (n = 27 each) with nine withdrawing before baseline testing and/or interventions for a total of 72 (PRO + EX = 23; PRO = 25; CON + EX = 24) (Fig. 1; Table 1). Throughout the intervention,

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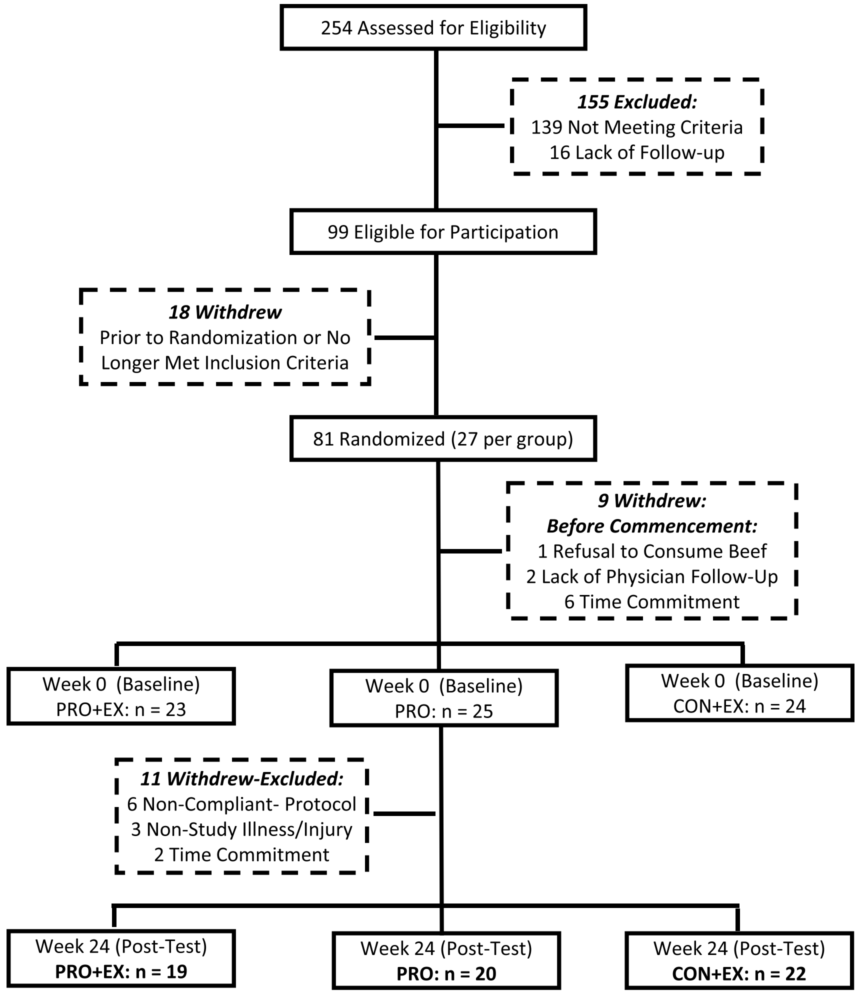

FIGURE 1—Consort table summarizing recruitment, enrollment, and retention of participants.

11 withdrew or were excluded after baseline measures (n = 8) or after midpoint measures (n = 3) due to noncompliance with the protocol (lack of exercise training attendance or nutritional meetings; n = 6), non–study-related illness/injury (n = 3) or other reasons (time commitment; n = 2). Thus, a total of 61 participants completed the trial (PRO + EX = 19; PRO = 20; CON + EX = 22) with 75% and 85% retention rates from the randomization and intervention commencement, respectively. In comparison with the completers (n = 61), noncompleters (n = 11) were not different at baseline on age, body weight, relative adiposity, total energy intake, or protein intake ($P > 0.05$). The sample that completed the intervention (n = 61) was 92% White, and based on study design, the cohort was on average obese (BMI = 31.1 ± 5.1 kg·m^{-2}). The completed intervention groups (three groups; n = 61) did not significantly differ on age, height, weight, BMI, or relative adiposity at baseline ($P > 0.05$). All primary outcomes of interest were normally distributed except the UPGO functional test, which was not normally distributed at two different time points and did not resolve with transformation. Thus, these outliers were removed (PRO + EX, n = 1; CON + EX, n = 1).

TABLE 1. Participant characteristics

Outcome	Pro + EX (n = 19)	Pro (n = 20)	CON + EX (n = 22)
Age (yr)	69.7 ± 4.3	69.3 ± 2.4	68.7 ± 4.0
Height (cm)	162.5 ± 5.4	162.0 ± 4.8	163.4 ± 6.7
Weight (kg)	83.0 ± 13.1	85.4 ± 12.4	78.1 ± 10.0
BMI (kg·m^{-2})	31.7 ± 6.4	32.6 ± 4.8	29.2 ± 3.2
Relative Adiposity (%Fat)	49.0 ± 3.7	49.0 ± 4.3	47.1 ± 4.0

Data are presented as mean ± SD. No statistically significant differences between groups on any outcome.

Intervention Adherence

Energy and macronutrient intake. At baseline, groups did not differ in energy intake or macronutrient intake, expressed in grams per day or as percent of energy intake (all $P > 0.05$) (Table 2). All groups reduced their reported energy intake similarly ($P > 0.05$) throughout the intervention with an average reduction of ~2093 kJ (~500 kcal·d^{-1}) or ~30%. Per the protocol, the higher protein groups, PRO + EX and PRO, reported intakes of 29.1% ± 5.6% of energy from protein, 39.6% ± 4.6% from carbohydrate, and 30.2% ± 5.3% of energy from fat. The conventional protein control diet group (CON + EX) reported consuming 19.3% ± 2.2% of energy from protein, 49.2% ± 6.5%

TABLE 2. Dietary intake at baseline and in response to the intervention at 3 months (midpoint) and 6 months (posttest).

	Pro + EX (*n* = 19)	Pro (*n* = 20)	CON + EX (*n* = 22)
Energy intake (kJ·d^{-1}; kcal·d^{-1})			
Baseline	7300.8 ± 2204.3 (1744.1 ± 526.6)	7013.2 ± 1667.3 (1675.4 ± 398.3)	7027.0 ± 1547.6 (1678.7 ± 369.7)
Midpoint	5270.2 ± 931.0 (1259.0 ± 222.4)	5144.2 ± 984.5 (1228.9 ± 235.2)	4974.6 ± 858.1 (1188.4 ± 205.0)
Posttest	5255.9 ± 905.0 (1255.6 ± 216.2)	4948.7 ± 1064.9 (1182.2 ± 254.4)	4786.7 ± 840.5 (1143.5 ± 200.8)
Protein (g·d^{-1}; g·kg^{-1} BW·d^{-1}; g·kg^{-1} LM·d^{-1})[a]			
Baseline	73.8 ± 22.8	70.0 ± 19.1	67.5 ± 14.6
	0.94 ± 0.29	0.83 ± 0.24	0.87 ± 0.19
	1.82 ± 0.57	1.70 ± 0.48	1.71 ± 0.46
Midpoint	85.7 ± 18.9*	82.1 ± 17.9*	56.2 ± 11.1
	1.11 ± 0.26*	1.14 ± 0.24*	0.77 ± 0.16
	2.12 ± 0.47*	2.00 ± 0.38*	1.42 ± 0.23
Posttest	85.4 ± 16.7*	84.0 ± 14.6*	55.7 ± 8.5
	1.14 ± 0.24*	1.12 ± 0.31*	0.80 ± 0.10
	2.12 ± 0.40*	2.10 ± 0.47*	1.42 ± 0.21
Carbohydrate (g·d^{-1})			
Baseline	200.3 ± 64.2	184.9 ± 50.8	199.5 ± 54.2
Midpoint	129.2 ± 21.5*	124.6 ± 28.6*	156.0 ± 30.3
Posttest	131.9 ± 21.2*	123.5 ± 34.2*	146.5 ± 26.8
Total fat (g·d^{-1})			
Baseline	74.5 ± 27.8	71.0 ± 21.8	64.5 ± 20.3
Midpoint	46.3 ± 12.3	44.7 ± 14.7	39.6 ± 11.2
Posttest	44.9 ± 13.0	40.5 ± 14.0	38.6 ± 11.7

Data are presented as mean ± SD.
*Different from CON + EX at same time point ($P < 0.05$).
[a]Protein intake expressed as grams per kilogram of body weight (BW) and whole-body lean mass (LM).

of energy from carbohydrate, and 29.1% ± 4.8% of energy from fat. Also, per the protocol, PRO + EX and PRO had greater protein intake, regardless of whether expressed as absolute or relative to body weight or lean body mass (P < 0.001), lower carbohydrate (P < 0.05), and similar dietary fat intakes (P > 0.05) compared with CON + EX.

Exercise and physical activity. Per established protocol, participants randomized to the PRO + EX and CON + EX groups were individually progressed with optimal training overloads for the components of the exercise intervention being achieved by week 8 (data not shown). The two EX groups did not differ in adherence to the supervised EX program and achieved ~75% attendance. Physical activity outside the supervised intervention did not differ at baseline among the groups (P > 0.05) for either daily steps or daily minutes of MVPA. Across the intervention period, PRO + EX and CON + EX increased steps and MVPA compared with PRO, as expected based on the research design and protocol (P < 0.05; data not shown).

Weight and Body Composition

Weight. Participants who completed the intervention (n = 61) lost −9.2% ± 4.8% of initial body weight, and 42.6% met the weight loss goal of 10% of initial body weight (Table 3). There was no significant group–time interaction effect for body weight ($F_{2.4,70.3}$ = 0.7, P > 0.05, η^2 = 0.024), and no significant main effect for group ($F_{2,58}$ = 2.2, P > 0.05, η^2 = 0.070). The main effect for time was significant and large ($F_{1.2,70.3}$ = 183.8, P < 0.001, η^2 = 0.760). The percent of participants who met the weight loss goal of 10% in the PRO + EX, PRO, and CON + EX groups was 31.6%, 45.0%, and 50.0%, respectively, and did not differ significantly among groups ($\chi^2_{(2)}$ = 1.5, P > 0.05).

Body composition. Body composition outcomes showed a similar pattern to weight loss. Both fat mass and %Fat showed no significant interaction ($F_{2.9,83.6}$ = 0.4, P > 0.05, η^2 = 0.014; and $F_{4,116}$ = 2.0, P > 0.05, η^2 = 0.066, respectively), and no significant group main effect ($F_{2,58}$ = 2.2, P > 0.05, η^2 = 0.070; and $F_{2,58}$ = 1.6, P > 0.05, η^2 = 0.051, respectively). Time main effects were significant for both variables ($F_{1.4,83.6}$ = 149.1, P < 0.001, η^2 = 0.720; and $F_{1.5,88.8}$ = 123.0, P < 0.001, η^2 = 0.680 for fat mass and relative adiposity, respectively). Results for lean mass (both whole-body and leg lean mass) were the same, with interaction effects being nonsignificant ($F_{4,116}$ = 2.0, P > 0.05, η^2 = 0.066 and $F_{3.3,95.7}$ = 0.7, P > 0.05, η^2 = 0.025 for whole-body and leg lean mass, respectively), and the main effects for group also nonsignificant ($F_{2,58}$ = 0.3, P > 0.05, η^2 = 0.038; and $F_{2,58}$ = 0.2, P > 0.05, η^2 = 0.007). Main effects for time were significant for both lean mass variables ($F_{2,116}$ = 7.7, P < 0.001, η^2 = 0.117; and $F_{1.7,95.7}$ = 7.4, P < 0.01, η^2 = 0.114).

Muscle Strength and Physical Function

Muscle strength. There was a significant group–time interaction effect for IK-60 ($F_{4,116}$ = 5.1, P < 0.001, η^2 = 0.148), which was decomposed using Cohen's d effect sizes, focusing on changes across time within each group (Fig. 2; Table 4). Comparatively, the net difference in IK-60 change over time represented a medium-to-large effect in favor of the two EX groups (d = 0.68 and d = 0.76 for CON + EX and PRO + EX, respectively) compared with the PRO group. The per-protocol analyses (n = 61) indicated that improvements in IK-60 from

TABLE 3. Weight and body composition at baseline and in response to the intervention at 3 months (midpoint) and 6 months (posttest).

	Pro + EX (*n* = 19)	Pro (*n* = 20)	CON + EX (*n* = 22)
Weight (kg)*			
Baseline	83.0 ± 13.2	85.4 ± 12.4	78.1 ± 10.0
Midpoint	79.3 ± 12.4	80.0 ± 12.2	73.4 ± 9.1
Posttest	76.2 ± 12.7	77.3 ± 12.4	70.5 ± 9.4
Posttest (%)	−8.2 ± 4.3	−9.4 ± 6.2	−9.8 ± 3.6
Fat mass (kg)*			
Baseline	39.9 ± 8.8	41.0 ± 9.0	35.7 ± 6.8
Midpoint	36.1 ± 8.9	36.7 ± 9.2	31.8 ± 6.9
Posttest	33.1 ± 8.1	34.3 ± 9.2	29.8 ± 7.3
Adiposity (%Fat)*			
Baseline	49.0 ± 3.7	49.0 ± 4.3	47.1 ± 4.0
Midpoint	46.4 ± 4.2	46.7 ± 4.8	44.5 ± 4.9
Posttest	44.5 ± 4.7	45.1 ± 5.3	42.7 ± 5.5
Lean mass (kg)*			
Baseline	40.7 ± 4.2	42.0 ± 4.0	39.7 ± 4.4
Midpoint	40.8 ± 4.6	40.9 ± 4.0	39.5 ± 3.4
Posttest	40.3 ± 3.7	40.8 ± 4.1	39.2 ± 3.8
Leg lean mass (kg)*			
Baseline	13.8 ± 1.7	14.2 ± 1.5	13.7 ± 1.8
Midpoint	13.9 ± 2.1	13.8 ± 1.5	13.5 ± 1.5
Posttest	13.4 ± 1.4	13.6 ± 1.5	13.4 ± 1.6

Data are presented as mean ± SD.
*Time effect (P < 0.05).

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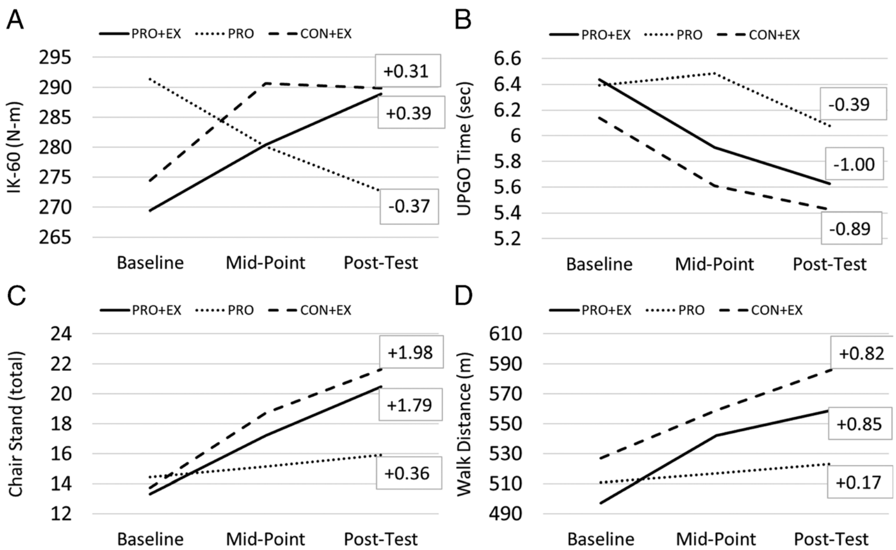

FIGURE 2—A–D, Changes in muscle strength and physical function in response to the intervention. Numbers indicate effect size from baseline to posttest within group. IK-60, isokinetic knee torque at 60°·s^{-1}; CHAIR, 30-s chair stand test; WALK, 6-min walk test.

baseline to posttest were similar in PRO + EX and CON + EX (P > 0.05) and greater than PRO (both P < 0.05). The ITT analyses (n = 72) produced similar significance results (i.e., PRO + EX = CON + EX > PRO). Notably, neither the baseline nor the changes in weight or adiposity were related to changes in strength (all P > 0.05).

Physical function. Group–time interactions were significant for all physical function variables (UPGO $F_{3.1,\ 86.3}$ = 4.4, P < 0.01, η^2 = 0.136; CHAIR $F_{3.3,\ 95.1}$ = 11.2, P < 0.001, η^2 = 0.278; WALK $F_{3.2,\ 92.2}$ = 10.3, P < 0.001, η^2 = 0.262). Patterns of Cohen's d for UPGO revealed that in comparison with the PRO group, there was a net medium improvement for the two EX groups (d = −0.49 and −0.61 for CON + EX and PRO + EX, respectively). CHAIR scores were similar with the net difference being substantial when comparing the PRO to the improvements in both CON + EX (d = 1.62) and PRO + EX (d = 1.43). Finally, a similar pattern was seen for WALK with the EX groups exhibiting a moderate-to-large improvement compared with the PRO group (CON + EX d = 0.66 and PRO + EX d = 0.69, respectively). The per-protocol analyses (n = 61) indicated that improvements in UPGO, CHAIR, and WALK from baseline to posttest were similar in PRO + EX and CON + EX (P > 0.05) and greater than PRO (both P < 0.05). The ITT analyses (n = 72) produced similar significance results in all physical function outcomes (i.e., PRO + EX = CON + EX > PRO).

TABLE 4. Muscle strength and physical function at baseline and in response to the intervention at 3 months (midpoint) and 6 months (posttest).

	Pro + EX (n = 19)[b]	Pro (n = 20)	CON + EX (n = 22)[b]
IK-60 (N·m)*			
Baseline	269.4 ± 58.8	291.3 ± 49.7	274.5 ± 44.2
Midpoint	280.4 ± 52.1	280.1 ± 40.5	290.7 ± 58.7
Posttest	288.9 ± 51.6	272.7 ± 39.8[a]	289.9 ± 53.2
UPGO (s)*			
Baseline	6.4 ± 0.9	6.4 ± 1.0	6.2 ± 0.9
Midpoint	5.9 ± 0.6	6.5 ± 0.9	5.6 ± 0.7
Posttest	5.6 ± 0.5	6.1 ± 0.9[a]	5.4 ± 0.7
CHAIR (total)*			
Baseline	13.3 ± 2.4	14.5 ± 2.9	13.7 ± 2.3
Midpoint	17.2 ± 3.3	15.2 ± 2.9	18.7 ± 5.0
Posttest	20.5 ± 4.5	15.9 ± 3.0[a]	21.6 ± 6.9
WALK (m)*			
Baseline	496.8 ± 88.7	511.0 ± 65.6	526.5 ± 67.2
Midpoint	542.8 ± 75.1	516.7 ± 71.0	558.6 ± 65.5
Posttest	558.7 ± 85.0	523.0 ± 70.8[a]	586.4 ± 64.8

Data are presented as mean ± SD.
[a]Significant change from baseline to posttest compared with PRO + EX and CON + EX (P < 0.05) from both per-protocol/completer analysis and ITT analysis.
[b]Reduction in sample size for UPGO due to outlier (PRO + EX, n = 1; CON + EX, n = 1).
*Significant group–time interaction (P < 0.05).
IK-60, isokinetic knee torque at 60°·s^{-1}; CHAIR, 30-s chair stand test; WALK, 6-min walk test.

DISCUSSION

Aim, hypotheses, and novelty of data. Our data are novel as they are the first to compare the effects of a higher protein diet and exercise treatment with a conventional protein treatment, with or without exercise, using a longer-term protocol and participant-selected and prepared foods (i.e., not supplements) in older overweight/obese inactive women. Contrary to our hypothesis, a higher protein diet combined with exercise did not augment the beneficial effects of weight loss on body composition change, muscle strength, or LEPF in comparison with a conventional protein control diet combined with the same exercise treatment. However, the importance of exercise training, inclusive of resistance training, was apparent as the nonexercise group, despite being higher protein, experienced reductions in strength and attenuated improvements in LEPF compared with the exercise groups.

Higher protein weight loss diets, exercise training, and physical function in older women. There is a substantial literature, regarding the importance of habitual exercise, especially resistance training, for optimal body composition and strength and physical function with advancing age (14). Recently emergent paradigms suggest that a diet higher in protein may be of benefit not only to augment fat mass loss but also for lean mass preservation, especially under weight loss conditions

(5,6,11). However, a more limited literature exists regarding higher protein weight loss diets, especially when combined with exercise, in the older adult cohort. Our previous work, which informed the current study, demonstrated in middle-age adults that (a) a higher protein weight loss diet leads to greater weight and fat mass loss and a relative preservation of lean mass compared with an isocaloric conventional higher carbohydrate control diet (17) and (b) the effect of exercise and dietary protein appears to be additive in that the most beneficial body composition changes occurred with a higher protein diet and resistance exercise training (18).

Literature targeting weight loss and physical function specifically in older adults suggests variable effects of a higher protein diet. Our own data determined that a higher protein calorically restricted diet combined with a low-intensity walking protocol elicited greater weight loss but did not influence changes in lean mass, strength, or physical function compared with a conventional protein weight loss diet plus walking in older women over 6 months (9). Porter Starr and colleagues (10) assessed the potential benefit of a meal-based higher protein weight loss diet (i.e., protein intake spread throughout the day) compared with an isocaloric control diet for physical function in frail (based on the SPPB, 4–10), sedentary, and obese (BMI > 30 $kg \cdot m^{-2}$) older adults using a 6-month protocol. The older adults lost a similar amount of weight with comparable reductions in lean mass (as measured by air displacement plethysmography); however, the higher protein group had greater physical functional improvements relative to the control group. Using a shorter-term intervention, Backx et al. (7) reported, in the absence of exercise training, a higher protein diet compared with a normal protein weight loss diet over 12 wk induced similar weight and lean mass loss, reductions in leg strength, and improvements in walking speed. A design closer to the present study, Verreijen et al. (8) reported that when a higher protein weight loss diet was combined with resistance training, it produced similar reductions in weight and fat mass loss and improvements in handgrip muscle strength and physical function compared with an isocaloric control diet with the same resistance training protocol in overweight older adults. However, the higher protein diet did provide benefits to appendicular lean mass preservation compared with the control diet. The inconsistency of the results of these studies renders the viability of increased dietary protein intake in the weight loss diet as a strategy for improving physical function unclear.

Differences in key research design factors affect the integration of our results with the literature cited above. First, our study targeted only women, whereas Porter Starr et al. (10), Backx et al. (7), and Verreijen et al. (8) used a mixed-sex sample. Our previous work suggests that the protein content of the weight loss or calorically restricted diet affects regional body composition differently in middle-age men and women (19). Second, our intervention length matched Porter Starr et al. (10), whereas the Backx et al. (7) and the Verreijen et al. (8) studies were only 12 and 13 wk in duration, respectively. Third, as described above, participants in these studies also varied based on degree of frailty and baseline weight status, potentially influencing the magnitude of change in physical function that occurred. Fourth, although the cited studies included older adults, age range varied and our cohort spanned 65 to 77 yr with an average age of ~70 yr, which was older than several studies. This may be of importance given the known effect of age-related anabolic resistance in response to dietary protein and/or exercise (11).

Important characteristics of the dietary intervention also varied as many of the previous studies provided meals or used supplements, which likely strengthened internal validity but may limit translation, especially for longer-term interventions. Alternatively, whole foods may not be as effective for increasing protein intake to desired levels for adherence reasons. Porter Starr et al. (10) targeted >30 g of protein at each meal reached in part by supplying ≥420 g of protein per week in the form of cooked then frozen/chilled very lean beef. Backx et al. (7) provided 1.7 $g \cdot kg^{-1} \cdot d^{-1}$ with 90% of the diets being provided to the participants, likely enhancing dietary compliance. Alternatively, Verreijen et al. (8) provided both groups with a supplement with the higher protein group receiving a high whey protein-, leucine-, and vitamin D–enriched supplement (~20 g of protein) and the control receiving an isocaloric placebo (150 kcal) with one serving consumed before breakfast and three servings consumed immediately after exercise training. This is similar to the Mojtahedi et al. study (9), which provided a 90% whey protein isolate or isocaloric placebo in powder form with directives to consume half of the supplement in the morning and the other half in the afternoon or evening. Regarding protein intake, it is possible that (a) the protein distribution across the day, (b) the actual magnitude of protein grams per day, and (c) the variability in adherence influenced the results of our study with respect to those cited.

Regarding protein grams per day and variability in adherence specifically, it is recognized that although our participants obtained, on average, the targeted ~30% of daily energy intake of protein, adherence was variable and grams per kilogram per day (relative to body weight) fell short of the recommended 1.6 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$ traditionally designated as "higher protein." The dietary aspects of our intervention were very well conducted with intensive educational and social support. However, notably we did not provide any supplements, food, or meals/snacks to our participants. Thus, our intervention was using participant-selected and prepared whole foods and protein supplements commonly found in the marketplace. Although more realistic and sustainable, it is recognized that this aspect of our design may have attenuated protein intake in the PRO groups. Importantly, there were significant differences between the PRO groups and the CON in protein intake regardless of expression (i.e., grams per day or expressed per body weight or lean body mass). Moreover, highly salient is that the PRO groups were above the recommended protein intake of 1.0 $g \cdot kg^{-1} \cdot d^{-1}$ advocated for older adults undergoing weight loss (1), whereas the CON group fell short. It is important to recognize that for the average older overweight/obese women in our study with an average weight (~82 kg) and body composition (i.e., ~48% fat mass; ~52% lean mass), energy intake needs to be reduced to ~1200 $kcal \cdot d^{-1}$, even with a reasonable exercise program, to disrupt energy balance enough to meet the recommended weight loss trajectory. To meet the 1.6 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$ protein intake, at the start of the weight loss protocol, this would require consuming ~131 $g \cdot d^{-1}$ with 44% of energy intake being protein. This is certainly theoretically possible; however, from a practical sustainable perspective, this goal is extremely behaviorally challenging for many individuals, particularly when selecting whole foods to meet this goal. Also, given the body composition of this cohort, it may be more appropriate to evaluate daily protein intake based on whole-body lean mass given muscle metabolic needs.

The exercise aspects of our intervention also varied greatly compared with literature cited. Regimens ranged from no prescribed exercise or physical activity (7,10) to supervised but low-intensity walking (9) to supervised muscle endurance focused resistance exercise only (8) to the present study, which used a supervised multicomponent exercise intervention. The selection of the multicomponent exercise regimen is aligned with the 2018 Physical Activity Guidelines for Americans and other current recommendations for older adults in general (14) and for weight loss in older adults specifically (1). The cardiorespiratory endurance exercise aided energy expenditure, whereas the strength training enhanced preservation of muscle mass and strength. In addition, the balance and functional exercises confer benefits for physical functional ability and fall prevention. Certainly, these intervention design factors influenced the changes in primary outcomes of interest, likely in a complicated and interactive manner.

Theoretically, based on previous work in our laboratory (9,17,18), a higher protein weight loss diet was anticipated to cause the greatest weight and fat loss while attenuating lean mass loss and subsequently enhancing the improvements in LEPF. However, for all the beneficial effects of the multicomponent exercise intervention, which included a moderate-intensity strength training regimen, it is speculated that the exercise effects, being very large, may have masked the potential dietary protein effects on body composition and LEPF. Notably, although the PRO group had greater protein, absolute and relative to body weight and lean mass, they did not achieve the functional benefits of CON + EX (Fig. 2) who exercised but actually had, on average, protein intakes lower than the recommended 1.0 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$ for older adults undergoing weight loss (1). It may be that multicomponent exercise training is more important than protein intake for improving body composition and LEPF during a weight loss program in older women, at least at the achieved protein intakes in this study. Notably, in support of the multicomponent exercise aspects of our research, recent work (20) demonstrated in obese older adults that under weight loss conditions, the greatest improvement in physical function occurred in the combined aerobic and resistance training group compared with either mode alone.

Strengths and limitations. Although our novel data are of interest in a contemporary research and clinical area of public health, it is not without limitations. First, the design has an apparent absence of a fourth group assessing a conventional protein diet with no exercise, which limits our ability for full cross-group comparisons. However, given current recommendations, it would not be considered best clinical practice to prescribe a weight loss program with a diet that is marginally adequate in protein and no exercise component to older women. Second, although the dietary intervention was prescribed to distribute protein across meals throughout the day, and there is confidence this occurred, no food products (e.g., prepared beef) or supplements (e.g., whey protein) were provided to assist adherence to this dietary prescription. Finally, although the multicomponent exercise program could be considered a strength, it might also be limited in translational value because of the comprehensive nature and high degree of supervision required. These limitations are tempered by numerous strengths of this study, including the high degree of dietary instruction and oversight, a supervised exercise program aligned with current recommendations, the length of intervention, the community-dwelling older women as participants, and the use of readily available whole foods which enhances external validity.

Conclusions and future directions. The results of this weight loss study suggest that a higher protein diet compared with a conventional protein diet when combined with exercise inclusive of resistance training does not confer additional benefits to body composition, muscle strength, and LEPF in overweight older women. Our data also reinforce the importance of exercise to prevent loss of muscle strength and to enhance improvements in LEPF under conditions of weight loss. Moreover, our results highlight that increasing dietary protein intake, especially up to the levels commonly recommended for older adults losing weight (1.0 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$) or to be designated higher protein (1.6 $g \cdot kg^{-1}$ $BW \cdot d^{-1}$) with intake spread across all meals and throughout the day (1,11,12), is behaviorally challenging using whole foods available in the marketplace and will likely require dietary prescriptions mixing animal, plant, and supplement/powder forms of protein. More research is needed to explore the potential interactions of dietary protein, from variable sources, and realistic dietary regimens and exercise or physical activity programs for optimal weight loss success and to enhance LEPF in obese older adults, especially older women at higher risk for physical disability compared with their male counterparts. Management of obesity in older adults, especially older women, remains a public health challenge.

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