Published in final edited form as:

J Nutr Gerontol Geriatr. 2018 ; 37(2): 117–129. doi:10.1080/21551197.2018.1478696.

Markers of Renal Function in Older Adults Completing a Higher Protein Obesity Intervention and One Year Later: Findings from the MEASUR-UP Trial

Kathryn N. Porter Starr, PhD, RD^{1,2,3}, Shelley R. McDonald, DO, PhD^{1,2}, Aubrey Jarman, BS, RD¹, Melissa Orenduff, BS¹, Richard Sloane, MS^{1,4}, Carl F Pieper, DrPH^{1,4}, and Connie W. Bales, PhD, RD^{1,2,3}

¹Center for the Study of Aging, Duke University Medical Center

²Department of Medicine, Duke University Medical Center

³Geriatric Research, Education, and Clinical Center, Durham VA Medical Center

⁴Department of Biostatistics and Bioinformatics, Duke University Medical Center

Abstract

Increases in rates of obesity in the older population are hastening the development of chronic illnesses, including chronic kidney disease (CKD). However, obesity reduction in older adults is besought with concerns about the long-term benefit/risk, especially regarding loss of muscle mass and its impact on function. Higher protein intakes have been advocated to help offset the tendency for loss of muscle during weight reduction but this raises concerns about possible negative effects on older kidneys. We assessed markers of renal function in venous blood samples collected during a 6-month randomized controlled weight loss trial of higher protein intake in obese ($n = 67$; BMI 30 kg/m^2) older (> 60 years) adults with physical frailty and age-normal renal status (glomerular filtration rate (GFR) > 45); the Control diet (0.8 g protein/kg body weight/day; $n = 21$) was compared to a protein-enhanced (1.2 g /g protein/kg body weight/day with 30 g protein/meal; $n = 41$; Protein) diet. Results showed no group effect of the Protein treatment on markers of renal function (estimated GFR, blood urea nitrogen, and creatinine), either upon intervention completion or one year later. Our findings align with literature support for the benefits of higher protein in the diets of older individuals during obesity reduction and help to confirm the safety of moderate increases in protein intake during weight loss in this population.

Keywords

Protein intake; renal function; glomerular filtration rate; weight reduction; obesity; older adults; Protein; function

INTRODUCTION

The convergence of the obesity epidemic and the “aging boom”(1) is likely to increase the incidence and severity of many chronic diseases that are dually exacerbated by obesity and aging: chronic kidney disease (CKD) is one such condition. Age-related decrements in renal function are some of the most dramatic observed in any organ system and include progressive decreases in glomerular filtration rate and renal blood flow that can predispose the older kidney to acute injury as well as CKD (2). Obesity, a more recent concern in the geriatrics realm, is also a key contributor to renal disease, because it markedly enhances the risk of development of Type 2 diabetes and hypertension, both well-known precipitators of kidney damage (3, 4). Moreover, obesity is also directly responsible for damage to the kidneys, further increasing the risk for CKD (5, 6).

With the obesity rate in older adults surpassing 33% (1), efforts to establish appropriate weight loss interventions in this population have mounted. Several trials have shown success in improving a variety of obesity-related outcomes (7–9). However, concerns remain about the benefit/risk trade off of weight reduction in older adults (10), including fears that the resulting loss of lean mass could impair physical function in the long-term (11). This concern has provoked interest in the use of higher protein intakes to protect against the challenge to muscle mass of a calorie deficit (12, 13). This is one of several justifications for recent recommendations that protein intakes for older individuals should exceed the RDA of 0.8 g/kg body weight/day (14, 15). Based upon studies showing higher protein intake thresholds for optimal anabolism in aging skeletal muscle, published advice now advocates for “protein-centric” meals for older adults, with a target intake of ~30 grams of protein per meal (16, 17).

Recommendations for higher protein intakes in older individuals bring to the forefront concerns about the possible impact of protein on renal function, reflecting the debate about the benefit/risk of higher protein diets (18). These concerns are based on the assumption that higher protein intake increases the burden on the kidney and thus accelerates progression of renal dysfunction (18, 19). Additionally, higher protein intake is known to be associated with an accelerated decline in renal function in those with baseline renal compromise. Results of the Women’s Health Study associated higher protein intake (assessed by food frequency) over a long interval (11 years) with greater decline in estimated glomerular filtration rate (GFR) in women with pre-existing renal disease (20). This study also found an indication that animal source protein might be more detrimental than plant-based protein, but there was no adverse effect of any type of protein on women with normal renal function. This agrees with the bulk of the published literature, which finds no detrimental effect of protein in those with normal kidney function. Beasley et al. (21) found no association of protein intake with change in GFR in 3,623 participants in the Cardiovascular Health study over a mean follow-up interval of 6.4 yrs; they also found no difference between protein sources. Likewise, in a comparative study of 24 months of a low-carbohydrate, high protein diet versus a low-fat diet, Friedman et al. (22) reported no reduction of surrogate markers of GFR by the high protein diet. Brinkworth et al. found a similar result in middle-aged men and women following a 35% protein diet for one year (23).

Based upon the available evidence, the “conventional wisdom” is that higher protein intakes are not detrimental in those with normal renal function (18, 24), but there is a shortage of high quality studies such as randomized controlled trials (RCTs) on the topic. A recent systematic review and meta-analysis on high and low protein diets (25) found only 6 of 74 trials assessed kidney health (serum creatinine), although no indication of detrimental changes in this surrogate marker of renal health were noted in this small group of trials. The state of the science to date leaves questions regarding the safety of higher protein for older adults essentially unresolved. This is because there is a gradual decrement in renal filtration with aging that typically begins in middle age and continues to progress so that by older ages the “age-expected” level of renal function is often categorized as being in the mild to moderate stages of CKD. The availability of RCTs on protein intake and renal function in older adults is especially limited. In a 12-week program of resistance training with post-exercise protein ingestion in a large ($n = 237$) community-based study, Ramel et al (26) found no decline in GFR with higher protein intake. However, this study achieved only a modest increase in protein intake, as supplements were taken only 3 times per week and this was not a weight loss study. We are aware of only one RCT that examined a moderate protein versus a standard protein weight loss diet in “older” adults (mean age ~60 yrs). This trial included overweight individuals who had type 2 diabetes and renal disease and found that weight loss improved renal function, with no effect of protein treatment (27). To address the scarcity of causal studies on the topic, we assessed renal function by GFR via a venous blood sampling in a 6-month RCT of weight loss with a higher protein intake in obese ($n = 67$; BMI ≥ 30 kg/m²) older (≥ 60 years) adults with physical frailty (SPPB 4 – 10) and age-normal renal status (GFR ≥ 45). This study provided the unique opportunity to assess GFR in older participants who received generous amounts of high quality protein on a daily basis (1.2 g/kg body weight/day; primarily from lean and very lean beef), and to compare their findings to those for an RDA-level protein intake control group after a 6-month weight loss intervention, as well as at a follow-up assessment one year later.

METHODS

Results from the parent trial (**Measuring Eating, Activity and Strength: Understanding the Response-Using Protein; MEASUR-UP**) of a protein-enhanced diet versus a traditional weight loss regimen in obese, physically frail older adults were examined for possible group differences in markers of renal function at the end of the 6-month intervention and again after a year of free living (18-month time point).

Trial Design and Study Participants

MEASUR-UP was a two-armed RCT with outcomes assessed at 0, 3, and 6 months; detailed methods (28) and the primary outcomes of an intent-to-treat analysis have been previously reported (29). The study was approved by the Duke University Health System Institutional Review Board before recruitment was initiated and written informed consent was obtained from all study participants. Obese (BMI ≥ 30 kg/m²), physically frail men and women aged ≥ 60 years living in or near Durham, North Carolina, were recruited. Physical frailty at baseline was qualified by having a score of 4–10 on the Short Physical Performance Battery (30), which has three component domains (balance, strength, and gait speed) yielding a total

score of 0 (poor) to 12 (high). Most participants had a GFR ≥ 60 ; but, as illustrated in Figure 1, those with a GFR of 45 to 59 ml/min/1.73 m² had the measurement repeated every 2 months. Those with a baseline GFR of <45 ml/min/1.73 m² were excluded from study participation. Other exclusions included dementia, neurological conditions causing functional limitations, and unstable or terminal medical conditions. Blocking by gender and marital/partner status, eligible participants were randomly assigned to a traditional weight loss (Control) or a protein-enhanced weight loss (Protein) study arm in a 1:2 allocation, using a computerized centralized randomization scheme generated by the study statistician. The 40 participants who completed 6 months in the parent trial were invited for a repeat assessment 12 months later; 21 (6 Control and 15 Protein) were available and returned to be assessed.

Interventions

Participants in both study arms received a supervised weight loss treatment program (hypo-caloric (500 kcal deficit) diet with goal of 10% weight loss over 6 months) delivered by Registered Dietitians (Interventionists). Interventionists provided individualized kcal prescriptions and meal plans, led weekly group meetings for counseling and peer support and supervised weekly weigh-ins. Control participants were prescribed a 15% protein, 30% fat, 55% carbohydrate diet with a protein intake of the Recommended Dietary Allowance (0.8 g/kg body weight). Protein participants were prescribed 30% protein, 30% fat, 40% carbohydrate and their protein intake was 1.2 g/kg body weight/day; their meal plans included 30 grams of lean, high-quality protein three times a day. Portions of lean and very lean beef protein (ground sirloin, deli roast beef, and flank steak) were provided to the Protein group for two of three meals each day to aid intervention compliance. For the remaining meal, interventionists instructed participants to consume lean high quality protein such as, chicken breast, salmon, pork tenderloin, whey protein powder, eggs and egg whites.

Assessments

Estimated glomerular filtration rate (GFR), blood urea nitrogen (BUN), and creatinine were measured in venous blood samples at baseline, the completion of 6 month's intervention, and one year later (LabCorp, Inc, Burlington, NC). The estimated GFR, which measures renal filtering capacity, is a calculated value based on age, sex, race, and serum creatinine using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (31). Body weight was measured at each time point using the BODPOD™ (Life Measurement, Inc., Concord, CA). Diet compliance was determined from three-day food records analyzed using Food Processor Nutrition Analysis Software (ESHA Research, Salem, OR) for daily intakes of kcal and protein at 0 and 6 months for all participants and one year after intervention for 10 participants.

Statistical Analysis

In choosing the statistical approach, we recognized the lack of consensus in the literature regarding the effects of higher protein diets on renal function. Moreover, we also needed to take into account the well-established benefit of obesity reduction to renal function (including GFR) (32). Thus, we lacked sufficient information to make an a priori prediction of differences in the direction of the change in GFR between the Control and Protein groups

and selected a two-tailed superiority test for the analysis. Overall change in both arms and differences in that change between arms over time were tested for all variables. Measurements were collected at baseline, 6 and 18 months. A Mixed Models repeated measures approach was used to assess change from baseline to 6 and 18 months, controlling for baseline values. The main effect of the outcomes over time was tested by the Time effect, while the group difference over time was assessed by statistical significance of the Group and the Group X Time interaction. Statistical significance was declared at level alpha of 0.05 (two-tailed).

RESULTS

Of the 150 individuals screened prior to baseline in the parent trial, 83 were excluded or declined participation, as shown in Figure 2; 27 participants either dropped out before the end of the trial or did not meet criteria for this analysis, leaving 40 completers at the 6-month time point. Baseline characteristics for these participants (Control, $n = 14$; Protein, $n = 26$) are shown in Table 1. The study population was predominantly female (82%) and 30% African American, with a mean BMI of 37.7 kg/m^2 (Class 2 obesity). Based on reported medical history, 20% had Type 2 diabetes and 67% had hypertension. Of the 40 parent trial finishers, 6 Controls (43%) and 15 Protein (58%) participants returned for the post-intervention assessment one year later.

Assessment of diet intakes showed the Protein group increased protein intake in g/kg body weight per day from 0.8 to 1.1 ($p < 0.001$) and as a percent of calories from 20 to 31% ($p < 0.0001$), as shown in Table 2. Protein intake for Control was unchanged when expressed as g/kg body weight per day ($p = 0.67$) but increased slightly when expressed as percent of calories (from 18 to 22%; $p < 0.01$). For the 10 participants (Control = 3; Protein = 7) who provided 3-day diet records one year following the intervention, mean intakes of kcal, protein in g/kg body weight/day and percent kcal from protein carbohydrate and fat had all returned to baseline levels (data not shown). As previously reported and shown in Table 3, both treatment groups decreased their body weights in absolute and relative terms at 6 months, with no group difference. Upon follow-up evaluation one year later, only the Protein group retained a body weight significantly lower than at baseline ($p < 0.001$), although the test for group difference was not significant ($p = 0.21$). At 6-months, physical function significantly improved in the Control (1.4 ± 1.9 SPPB score; $p < 0.001$) and Protein (2.2 ± 1.9 SPPB score; $p < 0.0001$) group.

Renal function did not differ between Control and Protein groups at baseline and there were no significant group differences in GFR, BUN or creatinine at 6 months (Table 3). There were some small, within-group changes from baseline to 6 months for GFR (in Protein group -3.7 ; $p < 0.05$), BUN (in Control group 1.8 mg/dL ; $p < 0.04$; in Protein group 2.4 mg/dL ; $p < 0.001$) and Creatinine (in Protein 0.04 mg/dL ; $p < 0.04$); these changes were numerically but not clinically significant. Two participants with a baseline GFR in the 45 to $59 \text{ mL/min/1.73m}^2$ range completed the trial with GFR monitored every two months. One (Protein group) had GFR levels as follows for 0, 2, 4, and 6 months: 56, 56, 57 and 61 mL/min/1.73m^2 . The other (Control group) had these GFR levels for 0, 2, 4, and 6 months:

53, 47, 46, and 41 mL/min/1.73m². For participants assessed one year after the intervention ($n = 21$), mean levels of GFR, BUN, and creatinine were not different from baseline values.

DISCUSSION

This study is the first to examine the renal impact of meal-based enhancement of protein intake during weight reduction in a long-term intervention with functionally frail obese older adults. We found that markers of renal function were unchanged by the Protein treatment upon intervention completion or at one year following the intervention. Although these findings cannot answer questions about the effects of longer-term intakes of higher protein, they do support the renal safety of a higher protein intake during a period of intentional calorie restriction in obese older adults. This has considerable practical relevance, since the 6-month intervention interval is typical for weight loss interventions. The relative strength of our findings is based upon several advantages, including (1) carefully supervised RCT study design, (2) sufficient difference in protein intakes of Control (0.8 g/kg body weight/day) and Protein (1.2 g/kg body weight/day) for comparison, and (3) strong likelihood of consistent protein intake in Protein group due to daily provision of high protein foods for two of three meals for entire 6-month trial. The inclusion of 18-month observations for 21 Protein participants is also a strength, supporting the absence of any longer-term impact of higher protein intake on markers of renal function.

The study is not without its limitations, one of the most important being the lack of generalizability to studies with a protein intake higher than 1.2 g/kg body weight/day. While our study diet provided about 30% kcal as protein, the amount of protein in grams per kg body weight in the higher protein group was lower than the maximum dose used in other studies, which is sometimes as high as 1.6 g/kg body weight/day or more. Additionally, it is possible that balancing protein intake throughout the day lessens the protein challenge to the kidneys relative to a more skewed pattern of intake. We underscore that study participants were not advised to continue their assigned diets after the trial and the limited evidence we have from participant interviews and the 10 diet records we analyzed at 18 months indicates that their diets returned to pre-study levels once the intervention ended. Thus, we cannot say if there would have been an impact on renal markers if the Protein group had continued the Protein treatment after the intervention ended. Likewise, we emphasize that our findings apply only to those with relatively modest impairment in renal function and might have been different in those more advanced chronic kidney disease. Other limitations include the relatively small number of subjects and the fact that renal function was a secondary outcome of the trial.

There is a marked shortage of high quality evidence on the influence of protein intakes higher than the RDA on renal function outcomes in older adults. While representing a very specific setting and population, our findings join others in the literature reflecting the relative safety of protein intakes exceeding the RDA. These findings align with new recommendations for older adults to have moderately increased, balanced intakes of protein and may have particular importance for supporting lean mass retention during weight loss in those who are functionally frail due to obesity.

Acknowledgments

Funding: This study was funded by the Beef Checkoff and received additional support from the National Institutes of Health (5T32 AG000029 to KNPS), United States (U.S.) Department of Veterans Affairs Rehabilitation Research and Development Service Program (CDA-2/ IK2 RX002348), Pepper Center.

References

1. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in Obesity Among Adults in the United States, 2005 to 2014. *JAMA*. 2016;315(21):2284–91. [PubMed: 27272580]
2. Weinstein JR, Anderson S. The aging kidney: physiological changes. *Adv Chronic Kidney Dis*. 2010;17(4):302–7. [PubMed: 20610357]
3. Lu JL, Molnar MZ, Naseer A, Mikkelsen MK, Kalantar-Zadeh K, Kovesdy CP. Age and Association of Body Mass Index with Loss of Kidney Function and Mortality. *The lancet. Diabetes & endocrinology*. 2015;3(9):704–14. [PubMed: 26235959]
4. Tsuboi N, Okabayashi Y, Shimizu A, Yokoo T. The Renal Pathology of Obesity. *Kidney International Reports*. 2017;2(2):251–60. [PubMed: 29142961]
5. Griffin KA, Kramer H, Bidani AK. Adverse renal consequences of obesity. *Am J Physiol Renal Physiol*. 2008;294(4):F685–96. [PubMed: 18234955]
6. Obesity Kramer H. and chronic kidney disease. *Contrib Nephrol*. 2006;151:1–18. [PubMed: 16929130]
7. Porter Starr KN, McDonald SR, Bales CW. Obesity and Physical Frailty in Older Adults: A Scoping Review of Lifestyle Intervention Trials. *J Am Med Dir Assoc*. 2014;15(4):240–50. [PubMed: 24445063]
8. Batsis JA, Gill LE, Masutani RK, Adachi-Mejia AM, Blunt HB, Bagley PJ, et al. Weight Loss Interventions in Older Adults with Obesity: A Systematic Review of Randomized Controlled Trials Since 2005. *J Am Geriatr Soc*. 2017;65(2):257–68. [PubMed: 27641543]
9. Villareal DT, Chode S, Parimi N, Sinacore DR, Hilton T, Armamento-Villareal R, et al. Weight Loss, Exercise, or Both and Physical Function in Obese Older Adults. *N Engl J Med*. 2011;364(13):1218–29. [PubMed: 21449785]
10. Locher JL, Goldsby TU, Goss AM, Kilgore ML, Gower B, Ard JD. Calorie restriction in overweight older adults: Do benefits exceed potential risks? *Exp Gerontol*. 2016;86:4–13. [PubMed: 26994938]
11. Weinheimer EM, Sands LP, Campbell WW. A Systematic Review of the Separate and Combined Effects of Energy Restriction and Exercise on Fat-free Mass in Middle-aged and Older Adults: Implications for Sarcopenic Obesity. *Nutr Rev*. 2010;68(7):375–88. [PubMed: 20591106]
12. Coker RH, Miller S, Schutzler S, Deutz N, Wolfe RR. Whey protein and essential amino acids promote the reduction of adipose tissue and increased muscle protein synthesis during caloric restriction-induced weight loss in elderly, obese individuals. *Nutr J*. 2012;11:105. [PubMed: 23231757]
13. Smith GI, Yoshino J, Kelly SC, Reeds DN, Okunade A, Patterson BW, et al. High-Protein Intake during Weight Loss Therapy Eliminates the Weight-Loss-Induced Improvement in Insulin Action in Obese Postmenopausal Women. *Cell Rep*. 2016;17(3):849–61. [PubMed: 27732859]
14. Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, et al. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. *J Am Med Dir Assoc*. 2013;14(8):542–59. [PubMed: 23867520]
15. Houston DK, Tooze JA, Garcia K, Visser M, Rubin S, Harris TB, et al. Protein Intake and Mobility Limitation in Community-Dwelling Older Adults: the Health ABC Study. *J Am Geriatr Soc*. 2017.
16. Paddon-Jones D, Campbell WW, Jacques PF, Kritchevsky SB, Moore LL, Rodriguez NR, et al. Protein and healthy aging. *Am J Clin Nutr*. 2015;101(6):1339S–45S. [PubMed: 25926511]
17. Layman DK, Anthony TG, Rasmussen BB, Adams SH, Lynch CJ, Brinkworth GD, et al. Defining meal requirements for protein to optimize metabolic roles of amino acids. *Am J Clin Nutr*. 2015.
18. Martin WF, Armstrong LE, Rodriguez NR. Dietary protein intake and renal function. *Nutr Metab (Lond)*. 2005;2:25. [PubMed: 16174292]

19. Pedersen AN, Cederholm T. Health effects of protein intake in healthy elderly populations: a systematic literature review. *Food Nutr Res.* 2014;58.
20. Knight EL, Stampfer MJ, Hankinson SE, Spiegelman D, Curhan GC. The impact of protein intake on renal function decline in women with normal renal function or mild renal insufficiency. *Ann Intern Med.* 2003;138(6):460–7. [PubMed: 12639078]
21. Beasley JM, Katz R, Shlipak M, Rifkin DE, Siscovick D, Kaplan R. Dietary protein intake and change in estimated GFR in the Cardiovascular Health Study. *Nutrition.* 2014;30(7–8):794–9. [PubMed: 24984995]
22. Friedman AN, Ogden LG, Foster GD, Klein S, Stein R, Miller B, et al. Comparative effects of low-carbohydrate high-protein versus low-fat diets on the kidney. *Clin J Am Soc Nephrol.* 2012;7(7):1103–11. [PubMed: 22653255]
23. Brinkworth GD, Buckley JD, Noakes M, Clifton PM. Renal function following long-term weight loss in individuals with abdominal obesity on a very-low-carbohydrate diet vs high-carbohydrate diet. *J Am Diet Assoc.* 2010;110(4):633–8. [PubMed: 20338292]
24. Friedman AN. High-protein diets: potential effects on the kidney in renal health and disease. *Am J Kidney Dis.* 2004;44(6):950–62. [PubMed: 15558517]
25. Santesso N, Akl EA, Bianchi M, Mente A, Mustafa R, Heels-Ansdell D, et al. Effects of higher-versus lower-protein diets on health outcomes: a systematic review and meta-analysis. *Eur J Clin Nutr.* 2012;66(7):780–8. [PubMed: 22510792]
26. Ramel A, Arnarson A, Geirsdottir OG, Jonsson PV, Thorsdottir I. Glomerular filtration rate after a 12-wk resistance exercise program with post-exercise protein ingestion in community dwelling elderly. *Nutrition.* 2013;29(5):719–23. [PubMed: 23317926]
27. Jesudason DR, Pedersen E, Clifton PM. Weight-loss diets in people with type 2 diabetes and renal disease: a randomized controlled trial of the effect of different dietary protein amounts. *Am J Clin Nutr.* 2013;98(2):494–501. [PubMed: 23719550]
28. McDonald SR, Porter Starr KN, Mauceri L, Orenduff M, Granville E, Ocampo C, et al. Meal-based enhancement of protein quality and quantity during weight loss in obese older adults with mobility limitations: Rationale and design for the MEASUR-UP trial. *Contemp Clin Trials.* 2015;40:112–23. [PubMed: 25461495]
29. Porter Starr KN, Pierper CR, Orenduff M, McDonald SR, Mauceri L, Payne ME, et al. Improved function with enhanced protein intake per meal: A pilot study of weight reduction in frail, obese older adults. *J Gerontol A Biol Sci Med Sci.* 2016;71(10):1369–75. [PubMed: 26786203]
30. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol.* 1994;49(2):M85–94. [PubMed: 8126356]
31. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, 3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med.* 2009;150(9):604–12. [PubMed: 19414839]
32. Bolignano D, Zoccali C. Effects of weight loss on renal function in obese CKD patients: a systematic review. *Nephrol Dial Transplant* 2013;28 Suppl 4:iv82–98.

Take Away Points

- This randomized controlled trial is the first to assess markers of renal function in obese, physically frail older adults before and after a 6-month weight loss intervention with balanced high quality protein intake (1.2 g/kg body weight/day) throughout the day in comparison to a weight loss control group (0.8 g protein per kg body weight/day). These assessments were repeated in 21 participants who returned one year after the intervention.
- We found that markers of renal function were unaffected by the enhanced protein treatment upon intervention completion; renal markers were also unchanged one year following intervention completion.
- Our findings support the use of higher, balanced intakes of protein during an active period of obesity reduction in physically frail older adults with age-normal renal function

Figure 1.

Estimated Glomerular Filtration Rate Algorithm Flowchart This algorithm guided enrollment and monitoring of estimated glomerular filtration rate (GFR) in the parent trial. All those with a GFR of ≥ 60 ml/min/1.73 m² were study eligible. For a baseline GFR of 45–59 ml/min/1.73 m², measurements were repeated every two months; a drop of 10% or falling to <45 ml/min/1.73 m² would disqualify the individual from further study participation. Reprinted with permission from *Contemp Clin Trials*. 40:112–23.2015.

Figure 2.
Consort Diagram Consort chart for parent trial and one-year follow-up.

Table 1.Baseline Characteristics by group and for the total analysis sub-set^{*}

Variable	Control Group (n = 14) Mean±SD or n (%)	Protein Group (n = 26) Mean±SD or n (%)	Total (N = 40) Mean±SD or n (%)
Age (y)	69.2±5.4	67.9±5.3	68.4±5.3
Body Weight (kg)	103.4±16.9	107.6±23.7	106.1±21.4
BMI (kg/m ²)	37.2±5.2	38.0±7.1	37.7±6.5
Female, n (%)	11 (79)	22 (85)	33 (82)
Race, n (%)			
Black	3 (21)	9 (35)	12 (30)
White	11 (79)	16 (61)	27 (67)
Glucose, serum (mg/dL)	106.2±29.1	118.0±40.8	113.9±37.2
Energy Intake (kcal)	2090±758	1897±708	1966±722
Protein Intake (g/d)	91.2±24.9	86.6±24.2	88.2±24.2
Diabetes, n (%)	1 (7)	7 (27)	8 (20)
Hypertension, n (%)	9 (64)	18 (69)	27 (67)
Physical function (SPPB)	8.9±1.3	8.0±1.7	8.3±1.6

^{*} This analysis included 6-month finishers in the parent trial.

Table 2.

Baseline means and change scores at 6 months for calorie and macronutrient intakes by treatment group

	Control (n=14) Mean±SD	<i>P</i> value [*]	Protein (n=26) Mean±SD	<i>P</i> value [*]	<i>P</i> value [*] Control vs. Protein
Calorie Intake, kcal					
Baseline	2090±758		1897±708		
Change at 6 months	−600±600	<0.0001	−477±732	<0.0001	0.81
Protein Intake, g/d					
Baseline	91.2±24.9		86.6 (24.2)		
Change at 6 months	−7.3±21.5	0.50	21.5 (38.4)	0.01	0.01
Average Protein Intake, g/kg of body weight/day					
Baseline	0.9 (0.3)		0.8 (0.3)		
Change at 6 months	0.01 (0.2)	0.67	0.3 (0.4)	0.001	0.05
Protein Intake, % of total kcal					
Baseline,	18 (5)		20 (6)		
Change at 6 months	4 (6)	0.01	11 (7)	<0.0001	<0.0001
Carbohydrate Intake, % of total kcal					
Baseline	42 (5)		41 (8)		
Change at 6 months	4 (10)	0.09	−2 (13)	0.23	0.05
Fat Intake, % of total kcal					
Baseline	40 (4)		39 (8)		
Change at 6 months	−7 (8)	0.01	−8 (10)	<0.0001	0.59
Sodium Intake					
Baseline	3149 (1571)		2872 (1059)		
Change at 6 months	−1014 (1514)	<0.0001	−510 (1125)	0.001	0.22

* *P* values represent analysis adjusted for baseline values.

Table 3.

Baseline means and Change Scores at 6 months and 18 months for Body Weight and Renal Function Markers by Treatment Group

	Control [†] (n=6)	P value [*]	Protein [†] (n=15)	P value [*]	P value [*] Control vs. Protein
Body Weight (kg)					
Baseline, mean (SD)	103.4 (17.6)		107.6 (23.7)		
Change at 6 months, mean (SD)	-7.5 (6.0)	0.001	-8.3 (7.4)	<0.0001	0.84
Change at 18 months, mean (SD)	-2.8 (4.0)	0.24	-6.0 (5.8)	0.001	0.21
Body Weight (%)					
Change at 6 months, mean (SD)	-7.6 (6.1)	<0.0001	-7.7 (6.0)	<0.0001	0.95
Change at 18 months, mean (SD)	-3.5 (5.3)	0.13	-5.7 (5.4)	0.001	0.30
GFR^{‡§} (mL/min/1.73m²)					
Baseline, mean (SD)	79.1 (14.8)		80.8 (14.4)		
Change at 6 months, mean (SD)	0.6 (6.5)	0.83	-3.7 (10.1)	0.05	0.17
Change at 18 months, mean (SD)	0.7 (6.4)	0.86	-4.3 (10.0)	0.34	0.71
BUN (mg/dL)					
Baseline, mean (SD)	15.3 (4.6)		16.4 (3.8)		
Change at 6 months, mean (SD)	1.8 (3.7)	0.04	2.4 (2.8)	0.001	0.56
Change at 18 months, mean (SD)	1.8 (2.3)	0.07	0.4 (2.7)	0.98	0.12
Creatinine (mg/dL)					
Baseline, mean (SD)	0.85 (0.20)		0.83 (0.14)		
Change at 6 months, mean (SD)	0.001 (0.11)	0.97	0.04 (0.10)	0.04	0.20
Change at 18 months, mean (SD)	-0.01 (0.04)	0.79	0.04 (0.13)	0.77	0.95

* P values represent analysis adjusted for baseline values.

[†] Control, *n* = 14 at 6-months and *n* = 6 at 18-months; Protein *n* = 26 at 6-months and *n* = 15 at 18-months

[‡] GFR was calculated using the CKD-EPI equation.

[§] Normal GFR values were defined as ≥ 60 mL/min/1.73 m².

Notes: GFR = glomerular filtration rate; BUN = blood urea nitrogen