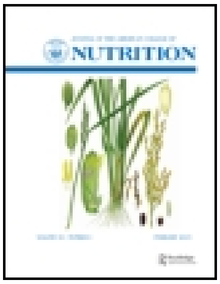

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Dietary Protein and Resistance Training Effects on Muscle and Body Composition in Older Persons

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Review

Dietary Protein and Resistance Training Effects on Muscle and Body Composition in Older Persons

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Key words: aging, amino acids, elderly, nutritional supplementation, sarcopenia, strength exercise and training

The regular performance of resistance exercises and the habitual ingestion of adequate amounts of dietary protein from high-quality sources are two important ways for older persons to slow the progression of and treat sarcopenia, the age-related loss of skeletal muscle mass and function. Resistance training can help older people gain muscle strength, hypertrophy muscle, and increase whole body fat-free mass. It can also help frail elderly people improve balance and physical functioning capabilities. Inadequate protein intake will cause adverse metabolic and physiological accommodation responses that include the loss of fat-free mass and muscle strength and size. Findings from controlled feeding studies show that older persons retain the capacity to metabolically adjust to lower protein intakes by increasing the efficiency of nitrogen retention and amino acid utilization. However, they also suggest that the recommended dietary allowance of 0.8 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1} might not be sufficient to prevent subtle accommodations and blunt desired changes in body composition and muscle size with resistance training. Most of the limited research suggests that resistance training-induced improvements in body composition, muscle strength and size, and physical functioning are not enhanced when older people who habitually consume adequate protein (modestly above the RDA) increase their protein intake by either increasing the ingestion of higher-protein foods or consuming protein-enriched nutritional supplements.

INTRODUCTION

The habitual consumption of adequate amounts of high-quality dietary protein and the inclusion of resistance exercise training as part of a physically active lifestyle are considered important contributors to an adult person's skeletal muscle size and strength, whole body fat-free mass, and health and well-being as they progress through the lifespan. Recent evidence suggests that protein intakes above the recommended dietary allowance (RDA) might promote resistance-training-induced muscle hypertrophy. If true, this would provide older persons with an effective strategy to counter sarcopenia, the age-related loss of muscle mass, strength, and function that occurs in all persons and contributes to the need for about 15% of persons 65 to 75 years of age and 50% of persons over age 85 years to require assistance with activities of daily living [1,2]. This review describes current understanding of the synergistic effects of dietary protein and resistance training on body composition and skeletal muscle size, strength, and function in older persons.

ACUTE DIETARY PROTEIN INTAKE AND RESISTANCE EXERCISE

Research primarily done in younger adult men and women provides a strong foundation for how dietary protein and resistance exercise might synergistically work to ultimately promote muscle hypertrophy and increased whole body fat-free mass. Review articles by Tipton and Wolfe [3] and Phillips [4] describe these interactions in more detail. However, in general, proteins are constantly being formed (synthesized) and broken down and these processes are influenced by external cues including feeding and physical activity. On a daily to weekly

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Abbreviation: RDA = Recommended Dietary Allowance.

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basis the cumulative rates of protein synthesis and breakdown are in equilibrium; consequently, muscle and lean tissue mass are maintained. Measurements of the rates of protein synthesis and breakdown during short-term (acute) experiments have established the following knowledge: 1) In a post-absorptive (fasting) state, the rate of protein synthesis is slower than the rate of protein breakdown, which results in a net catabolic state. 2) In a postprandial (fed) state that includes the ingestion of proteins or mixtures of amino acids, the rate of protein synthesis increases and is faster than the rate of protein breakdown (which is not appreciably changed); a net anabolic state results. As previously stated, these events typically balance each other over time and skeletal muscle and fat-free mass are unchanged. 3) In a post-absorptive state during the period soon after resistance exercise is performed, the rate of protein synthesis increases modestly more that the rate of protein breakdown increases. While this increases net protein balance, a catabolic state still remains. 4) The combination of feeding proteins or mixtures of amino acids and resistance exercise result in the greatest net anabolic state. This is achieved via amino acid and exercise-induced increases in protein synthesis and minimal or no change in protein breakdown. The effects of ingesting proteins and resistance exercise on muscle protein synthesis are considered to be independent and additive. Muscle hypertrophy theoretically is achieved from the cumulative periods of positive protein balance that occur after resistance exercise when protein is consumed. While this knowledge has resulted from studies in younger adults, several acute studies in older persons also document that amino acid feeding [5] and resistance exercise [6] increase muscle protein synthesis, findings that support the combined use of dietary protein and resistance training to hypertrophy muscle and offset sarcopenia.

DIETARY PROTEIN NEEDS OF OLDER ADULTS WHO PERFORM RESTANCE TRAINING

Adequate dietary protein is critical to promote the maintenance of skeletal muscle and treat sarcopenia [1]. The RDA for protein is set at 0.8 g protein · kg^{-1} · d^{-1} for all men and women age 19 years and above, independent of physical activity status [7]. For younger adults, the American College of Sports Medicine, American Dietetic Association and Dietitians of Canada joint position statement on nutrition and athletic performance indicates that athletes might need to consume 50–100% more protein for exercise-related energy production, post-exercise muscle damage repair, and muscle hypertrophy [8]. The protein needs of older persons who perform resistance training are not known with confidence. Sarcopenia and reductions in the intensity and volume of training might modestly reduce the need for protein in older versus younger resistance-trained persons.

The influence of resistance training on nitrogen balance and amino acid utilization was evaluated in a strictly controlled diet study where the 54–78 year-old subjects either remained sedentary or performed lower-body or whole-body resistance exercise 3 d/wk for 12 weeks [9]. All of the subjects consumed diets that contained the RDA for protein and sufficient energy for weight maintenance throughout the study. During the first six weeks of intervention, urinary nitrogen excretion decreased and nitrogen balance increased comparably in all three groups, findings that support metabolic adaptation to the constant protein intake and the achievement of increased efficiency of nitrogen retention and amino acid utilization. Over the next six weeks of intervention, the two resistance training groups experienced a modest increase in urinary nitrogen excretion, compared to a continued progressive decline in the sedentary group. While being cautious not to over-interpret these findings, they are consistent with an increased protein requirement for the resistance-training older persons.

PROTEIN INTAKE AND RESISTANCE TRAINING TO COUNTER SARCOPENIA

Controlled Feeding Studies

The potential interactive effects of dietary protein and resistance training on protein metabolism and body composition was evaluated in 12 men and women, age 56–80 years, who participated in a 14-week strictly controlled diet and exercise study [10]. Each subject was provided with a basal lacto-ovo vegetarian diet with 0.6 g protein · kg^{-1} · d^{-1}, as well as milk-based beverages that contained either 0.2 or 1.0 g protein · kg^{-1} · d^{-1}, which resulted in total protein intakes of either the RDA or twice the RDA (0.8 and 1.6 g protein · kg^{-1} · d^{-1}, respectively). Strengths of this study included the strict dietary control and comprehensive assessments of whole body nitrogen balance, amino acid kinetics, and body composition, while the study was weakened by the very small sample size. All baseline measurements were made after the subjects had consumed the controlled diets for two weeks while remaining sedentary. Several group-specific differences in nitrogen balance and amino acid kinetics highlighted the dietary protein-related differences in whole body protein metabolism. At baseline, nitrogen balance was negative in the lower protein group and positive in the higher protein group, and the rates of leucine turnover, oxidation, and uptake for protein synthesis were slower in the lower-protein group. Over time, nitrogen retention increased by about 13 mg nitrogen · kg^{-1} · d^{-1} and leucine turnover increased by about 4–7% in both groups. In the lower-protein group, 91% of the change in leucine turnover was due to an increase in protein synthesis and only 9% due to increased leucine oxidation, while 72% of the change in the higher-protein group was due to an increase in leucine oxidation and only 18% due to increased protein synthesis. While the overall nitrogen balance and rates of leucine turnover and uptake for protein synthesis were greater in the higher-protein group, the efficiencies of nitrogen retention and utilization for protein synthesis were greater in the lower-protein group. These findings are consistent with adaptive metabolic responses to changes in dietary protein intake to successfully achieve and maintain physiological homeostasis. Correlation analyses using data from both groups combined support that the changes in protein metabolism, especially in skeletal muscle, were related to changes over time in body composition. For example, the change in whole body protein-mineral mass was related to changes in leucine turnover ($r = 0.75$, $P = 0.005$) and leucine oxidation ($r = 0.81$, $P = 0.002$). The relationships between the change in 24-hour urinary 3-methylhistidine excretion (a marker of muscle protein breakdown) and changes in protein-mineral mass ($r = 0.72$, $P = 0.008$), leucine oxidation ($r = 0.72$, $P = 0.008$), and mid-thigh muscle area ($r = 0.64$, $P = 0.026$) suggest that changes at the whole body level were due to changes that occurred in skeletal muscle.

Collectively, findings from this strictly controlled diet study [10] suggest that older people who perform resistance training adapt their metabolism to meet the metabolic demands for amino acids, and that dietary protein intake influences these adaptive responses. The increased efficiencies of nitrogen retention and amino acid utilization observed in the older people who consumed the lower-protein diet may provide some insight as to why differences in protein intake might not have as a dramatic effect on resistance-training-induced body composition changes in older people as would theoretically be expected. The very small sample size compromised the opportunity to evaluate the effects of dietary protein intake on body composition and skeletal muscle size.

Quantity and Sources of Protein Intake and Resistance Training

While everyone consumes proteins from a variety of sources, it is of interest to know if the predominant source of protein consumed might differentially affect the physiological responses to resistance training in older people. Very limited research has been conducted to address this issue. Campbell et al. [11] evaluated the effects of ingesting an omnivorous (meat-containing) diet vs. lactoovovegetarian (meat-free) diet on whole body composition and skeletal muscle size in older men after completing a 12-week resistance training period. The groups of men who consumed the omnivorous and vegetarian diets had total protein intakes of about 1.0 (125% of RDA) and 0.8 (100% of RDA) g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}, respectively. The omnivorous meal plan was achieved by asking the subjects to continue to consume their usual diets, which contained about 50% of their total protein intake from meats (beef, poultry, pork and fish), 17% from dairy, 4% from eggs, and 37% from other sources. The vegetarian meal plan was achieved by counseling the subjects to self-select a meat-free diet (i.e., no foods that contained striated tissues), which resulted in 35% of total protein intake from dairy, 4% from eggs, and 61% from other sources. Consistent with an effective resistance training response, maximal strength of the muscle groups trained increased by 10–38%; these responses were not different between the omnivorous and vegetarian groups. Over time with training, whole body density, fat-free mass, and muscle mass increased in the men who consumed the omnivorous diet, but these parameters decreased in the men who consumed the vegetarian diet (group-by-time interactions, $P < 0.05$). Resistance training increased the size (area) of the type II fibers in the vastus lateralis, and the hypertrophy response tended to be greater in the omnivorous group vs. vegetarian group, $16 \pm 4\%$ vs. $7 \pm 5\%$, respectively. While this study is limited by the uncontrolled nature of the dietary interventions and the lack of control groups to distinguish between the effects of protein quantity and source, the results indicate that ingestion of a higher-protein, meat-containing diet promoted larger resistance-training-induced gains in fat-free and skeletal muscle masses in older men than when lower-protein, meat-free diets were consumed.

The potential influence of protein source was also investigated by Haub et al. [12], who counseled 21 men, mean age 65 years, to self-select a basal meat-free diet along with 0.6 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1} from either texturized vegetable protein (soy, $n = 11$) or beef ($n = 10$). All of the men participated in a 12-week resistance training program and the total protein intakes were not different between the two groups and ranged from 129 to 146% of the RDA (1.03 to 1.17 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}). The soy and beef groups experienced comparable increase in maximal strength (14 to 38%) among the muscle groups that were exercised, as well as increases in vastus lateralis cross-sectional muscle area; 4.2 ± 3.0 and $6.0 \pm 2.6\%$ in the soy and beef groups, respectively. Haub et al. [12] concluded that when older men consume adequate amounts of total protein, resistance-training induced muscle hypertrophy is not influenced by whether the predominant protein source is from soy versus beef sources.

Iglay et al. [13] recently continued to investigate the combined influences of protein quantity and source by evaluating whether the ingestion of higher amounts of high-quality, animal-based protein would influence changes in body composition in older men and women who participated in a resistance training program. Thirty-six men and women, mean age 61 years, were randomly assigned to groups that consumed either 0.9 ± 0.1 (lower protein group) or 1.2 ± 0.1 (higher protein group) g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}, which equate to 113% and 150% of the RDA for protein, respectively, during the 12-week period of training. Both groups were counseled to consume omnivorous diets, with the higher protein intake achieved by asking these subjects to consume more eggs, meats, and dairy foods. At the end of the training period, both diet groups had remained weight stable and experienced significant increases in fat-free mass (lower protein group 3.6%; higher protein group 3.1%), protein mass (lower protein group 2.6%; higher protein group 8.4%), and total body water (lower protein group 4.1%; higher protein group 2.3%), and decreases in fat mass (lower protein group −6.8%; higher protein group −7.4%), waist circumference (lower protein group −1.5%; higher protein group −1.5%), and waist to hip ratio (lower protein group −1.2%; higher protein group −1.2%). Strength increases over time were significant and not different between the two groups (composite maximum strength gain, lower protein group 28%; higher protein group 34%). Iglay et al. [13] concluded that favorable body composition responses to resistance training can be achieved by older adults when they consume adequate amounts of total protein (i.e., above the RDA), and that these responses are not enhanced by a further increase in protein intakes. The contrasting findings from the Haub et al. [12], Campbell et al. [11] and Iglay et al. [13] studies tentatively suggest that protein quantity is a more important determinant of body composition and muscle hypertrophy responses to resistance training in older men than is the predominant source of protein.

Dietary Protein Adequacy and Resistance Training

The loss of whole-body fat-free mass in the men who consumed the RDA for protein during a 12-week period of resistance training suggests that this amount of protein intake is marginally inadequate [11]. These findings might also suggest that the exercise-induced muscle hypertrophy occurred at the expense of other protein stores; the possible source of these stores was not investigated. To more fully evaluate whether the RDA for protein is adequate for older persons, Campbell et al. [14,15] conducted a strictly controlled feeding, metabolic balance study in 29 men and women who were 54–78 years old and recreationally active at the start of the interventions. Throughout the 14-week study period all of the subjects consumed precisely portioned foods that provided the RDA for protein, and were randomly assigned to groups that performed resistance training 3 d/wk using lower-body or lower- and upper-body (whole-body) exercises, or maintained their usual levels of physical activity (sedentary). Body weight was purposefully maintained by adjusting the amount of total energy provided to each subject [9]. Consistent with an expected training response, maximal strength increased in the muscle groups trained, and did not change in non-exercised muscle groups. Mid-thigh muscle area increased comparably in the lower body and whole body training groups [14]. However, mid-thigh muscle area decreased in the sedentary group [15]. This unexpected finding supports that an adverse accommodation response, as opposed to a desired adaptive response, occurred when sedentary older people habitually consumed the RDA for protein. Whole body fat-free mass and total body water decreased and body fat % increased in all three groups. Collectively, these observations suggest that while muscle hypertrophy can occur in older people who consume the RDA for protein while resistance training, physiological accommodations might occur at the whole body level (decreased fat-free mass) and that this amount of protein is marginally inadequate to maintain skeletal muscle.

Retrospective Re-assessment of Dietary Protein and Resistance Training Studies

The descriptions above of the studies by Campbell and colleagues [10–14] indicate that no individual study has definitively assessed the effects of dietary protein to influence changes in fat-free mass and muscle hypertrophy in older people who resistance train. Each study has weaknesses and strengths with regard to experimental designs, dietary controls, subject sample sizes, and measurement techniques. However, a retrospective re-assessment of data from these and other resistance training studies conducted by the Campbell research group might provide additional insight as to whether protein intake influences fat-free mass accretion with resistance training among older people. To this end, data from 106 men and women age 50–80 years who have participated in diet and resistance training studies conducted by Campbell and colleagues over the past 15 years were compiled [10,11,13,14, 16,17]. The common measurements among the studies included dietary protein intake and whole body density (from hydrostatic weighing or plethysmography) before and after the subjects completed the period of resistance training. The whole body density measurements were converted to fat-free mass estimates using the two-compartment equation of Siri [18]. The training programs for all of these studies were comparable in duration (12 weeks), intensity (2 sets of 8 repetitions and 1 set of repetitions to voluntary muscle fatigue or 12 repetitions at 80% of maximal strength), use of exercises that train larger muscle groups (leg press, leg extension, leg flexion, chest press, and arm pull exercises), frequency (training 2 or 3 days per week), and equipment (pneumatic resistance exercise equipment, Keiser Sports Health Equipment Company, Fresno, CA). Dietary protein intakes among the subjects ranged from about 0.4 to 1.7 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}. As shown in Fig. 1, a

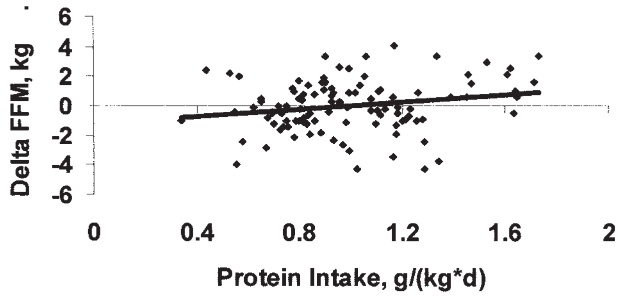

Fig. 1. Protein intake and fat-free mass changes after three months of resistance training in 50–80 year-old people. Regression equation: ΔFFM = (1.19955 × protein intake (kg)) − 1.172; r = 0.202, P = 0.038, n = 106 men and women.

modest, but statistically significant positive relationship ($r = 0.202$, $P = 0.038$) was established between dietary protein intake and the change in whole body fat-free mass. It is interesting to note that the regression line crosses the line of neutrality (no change in fat-free mass) at a protein intake of about 1 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}. The apparent loss of fat-free mass by many of these older persons when they consumed the RDA for protein of 0.8 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}, despite the anabolic stimulus of resistance training [10,11,14,15], is consistent with this being a marginally inadequate amount of protein to habitually consume. Based on the linear regression, theoretically an older person who consumed the RDA for protein would lose about 0.2 kg fat-free mass after the 12-week period of resistance training. At protein intakes of 1.0, 1.2, 1.4 and 1.6 g protein $\cdot$ kg^{-1} $\cdot$ d^{-1}, the changes in fat-free mass would be 0.0, 0.3, 0.5, and 0.8 kg, respectively.

NUTRITIONAL SUPPLEMENTATION AND RESISTANCE TRAINING IN OLDER PERSONS

Much of the research described above involved increasing dietary protein intake by manipulating the distribution of macronutrients without purposefully changing energy intake. Nutritional supplementation represents another approach to provide older persons with additional protein, most often in conjunction with other macro and micro nutrients. Research on the interactive effects of nutritional supplementation and resistance training on body composition and muscle size in older people started with a 12-week intervention study in 11 men age 61–72 years. [19] All of the men performed leg extension and flexion exercises (lower-body training) 3 d/wk, 3 sets/d at 80% of their individualized maximal strength capacity for each exercise. Each subject maintained their usual, unrestricted diet throughout the training period and six of the subjects ingested a liquid dietary supplement daily that contained 560 kcal and a macronutrient distribution of 17% protein, 43% carbohydrate, and 40% fat. The group of men who consumed the supplement increased their total energy, fat, and protein intakes and gained 2.2 kg of body weight, while the group of men who were not provided the supplement did not significantly change their energy and macronutrient intakes and body weight. Computed tomography scans performed at the start and end of the resistance training period documented that the increase in mid-thigh muscle area over time with training was greater in the supplemented group (13%) versus un-supplemented group (5%). Among all 11 subjects, the change in mid-thigh muscle area from the start to end of the training period was related to the change in energy ($r = 0.69$, $P = 0.02$), fat ($r = 0.72$, $P = 0.01$) and protein ($r = 0.63$, $P = 0.04$) intakes. The authors discussed that these findings support that nutrition can affect resistance-training-induced muscle hypertrophy in older men [19].

Over the past 15 years several studies were conducted to evaluate the effectiveness of nutritional supplementation, resistance training, and the combined therapies to positively influence muscle strength, body composition, and other indicators of metabolic and physiological health and functioning in older and elderly persons. The results have been very supportive of the therapeutic value of resistance training, but mixed for nutritional supplementation. Fiatarone et al. [20] conducted a randomized, placebo-controlled, 10-week clinical trial in a long-term nursing care facility near Boston, MA, USA. One hundred elderly persons, mean age 87 years, were assigned to one of four groups: 1) lower-body resistance training program 3 days per week (3 sets of 8 repetitions at 80% of maximal strength); 2) nutritional supplementation (360 kcal/d with energy provided as 17% soy-based protein, 60% carbohydrate, and 23% fat, given daily in the evening); 3) both treatments, or 4) a placebo activity and low-energy supplement. Compliances to the exercise sessions (97%), control activities (100%), and ingestion of the nutritional (99%) or placebo (100%) supplement were excellent. Resistance training significantly increased strength of the exercised muscles (26 to 215%), increased cross-sectional area of the mid-thigh muscles (2.0 to 3.4%), and improved habitual gait velocity, stair-climbing ability, and the overall level of physical activity. Daily ingestion of the nutritional supplement did not influence these responses to training, but did independently cause modest (1.5 to 1.8%) increases in body weight that were much less than expected from a cumulative 25,200 kcal added over a 10-week period of time. The authors speculated that the ineffectiveness of the nutritional supplement might be related to the subject's generally good nutritional status prior to the interventions. Also, the supplement was actually a meal replacement because many of the subjects, especially those who did not participate in the resistance training, compensated by reducing their ad libitum food intakes.

Rosendahl et al. [21] also evaluated the efficacy of exercise training and nutritional supplementation on physical functioning in persons age 65 years and older who resided in assisted care facilities in Umeå, Sweden, due to their dependence on help to accomplish activities of daily living. One-hundred ninety-one persons, many of whom were cognitively impaired, were assigned to one of four groups: 1) exercise/protein group, high-intensity functional exercise program (29 sessions over 3 months) and protein-enriched energy supplement (200 mL milk-based beverage, 7.4 g protein and 100 kcal per 100 g); 2) exercise/placebo group, high-intensity functional exercise program and low-protein supplement (200 mL beverage, 0.2 g protein and 45 kcal per 100 g); 3) control/protein group, social activities performed while sitting (29 sessions over 3 months) and protein beverage supplementation; and 4) control/placebo group. The protein and placebo supplements were provided to the subjects immediately after each exercise session. The compliances to the interventions were as follows: 72% of exercise sessions attended; 70% of control activity sessions attended; 82% of protein supplements consumed; and 78% of placebo drinks consumed. After three months of intervention, the groups that exercised improved their self-paced gait speed and after six months their balance, self-paced gait speed, and lower-limb strength. These parameters were not changed over time in the control groups and the results were not influenced by the nutritional supplementation interventions. Measures of body weight, body composition, and muscle mass were not reported. The authors [21] speculated that the apparent lack of efficacy of ingesting the protein supplement immediately after the exercise sessions related to the poor nutritional status of the subjects (causing the ingested protein to be used for energy) and that most of the subjects were women with many diseases and drug treatments. It is interesting to note that the suggestion that the protein-containing nutritional supplement did not work because the subjects were poorly nourished contrasts with the speculation by Fiatarone et al. [20] that their protein-containing nutritional supplement did not work because their subjects were well-nourished.

Applying integrated nutritional supplementation and resistance training strategies to elderly persons in community settings is important, but challenging to accomplish. Bunout et al. [22] conducted a one-year-long community-based, randomized study with 149 persons aged 70 years and older who regularly attended a preventative geriatric program at public outpatient clinics in Santiago, Chile. The participants were assigned to groups that 1) performed moderate-intensity resistance exercises (twice weekly, 3–5 sets of 10 repetitions for functional movements against rubber exercise bands); 2) nutritional supplementation (two daily between meal snacks, total daily intakes 400 kcal, 13 g protein, 62 g carbohydrate, 11 g fat, 10–25% of daily reference values for multiple vitamins and minerals); 3) both interventions; and 4) neither intervention. Over time, walking capacity and most of the muscle strength measures improved more in the two training groups than in the non-training groups, and among the trained subjects, greater increases in leg strength was associated with greater improvements in walking capacity. Neither intervention appreciably changed measures of body weight or fat-free mass. The lack of body weight change in the supplemented subjects is consistent with the supplement actually functioning as a meal replacement. In contrast with the high levels of compliance to the nutritional supplementation and resistance training interventions in the 10 to 12-week in-patient clinical trials conducted by Fiatarone et al. [20], (≥97%) and Rosendahl et al. [21] (70–82%), compliances to the supplements and training in this community-based intervention were 48 and 56%, respectively. Retrospective assessments of the data based on high and low compliance did not influence the apparent lack of efficacy for the nutritional supplement, and documented greater muscle strength gains by persons who exercised more. Interestingly, hand grip strength (a potential functional marker of nutritional status in hospitalized patients) and maximal inspiratory pressure (an indicator of respiratory muscle function) improved the most in the group that consumed the supplement and exercised. The authors discussed that these findings support that elderly persons are most likely to benefit from a program of functional resistance training when adequately nourished.

In middle-aged and older men, protein supplementation does not appear to enhance resistance-training-induced body composition changes and muscle hypertrophy. Carter et al. [23] utilized a double-blinded, randomized, and placebo-controlled experimental design to evaluate the effects of protein and (or) creatine supplementation on whole body fat-free mass and rectus femoris cross-sectional area. The 48–72 year-old subjects all completed a 16-week whole-body resistance training program (3 d/wk, 3 sets/d, 8 repetitions/set, 80% of maximal strength), and consumed soon after finishing each exercise session 480 mL of Gatorade® (28 g sucrose; Chicago, IL, USA) alone (n = 10), with 35 g of whey protein (n = 11), with 5 g of creatine (n = 10), or with 35 g of whey protein and 5 g of creatine (n = 11). All four of the groups experienced increased fat-free mass (grand mean 1.7%) and hypertrophy of the rectus femoris (grand mean 18.7%), and these training responses were not influenced by the protein and (or) creatine supplements. Total dietary intake data and measures of compliance with regard to ingesting the supplements were not provided, which preclude knowing the subjects' usual protein intakes and whether the whey protein supplement increased total protein intake. Andrews et al. [24] evaluated the effects of protein intake on fat-free mass accretion after a 12-week resistance training program in 52 men and women, age range 60–69 years. All of the subjects ingested a liquid nutritional supplement three days per week soon after completing their resistance exercise session. The post-exercise supplement was portioned to provide 0.4 g protein/kg fat-free mass, which resulted in an effective increase in total protein intake of about 0.1 g protein · kg^{-1} · d^{-1} when considered on a weekly basis. Individual variability among the subject's habitual protein intakes, determined from food records, spanned from about 0.6 to 1.5 g protein · kg^{-1} · d^{-1}. Resistance training increased fat-free mass and this response was not influenced by the subject's total protein or branch chain amino acid intakes.

The results from Carter et al. [23] and Andrews et al. [24] suggest that the ingestion of protein-containing supplements soon after resistance exercise sessions does not influence muscle hypertrophy and increased fat-free mass responses to training. Comparable results were reported by Candow et al. [25]. They observed that the ingestion of a liquid nutrition beverage that contained 0.3 g protein · kg^{-1} immediately before, immediately after, or not before or after performing resistance exercise (3 sets of 10 repetitions at 70% of maximal strength, 3 days/week for 12 weeks) did not influence the training responses in 59–76 year-old men. The training responses included increases in muscle strength (22 to 31% increases in leg press among groups), whole-body fat-free mass (1.0 to 1.7% increases among groups), and muscle thickness (13 to 18% increases among groups). In contrast with these findings, Esmarck et al. [26] reported that older men who consumed a milk and soy-based protein supplement (10 g protein, 100 kcal energy) immediately after resistance exercise experienced increases in whole body fat-free mass (1.8%), cross-sectional area of the quadriceps femoris muscle group (7%), and mean fiber area of the vastus lateralis (24%) in response to a 12-week period of resistance training, while men who consumed the same supplement two hours after exercising experienced blunted responses (−1.5% fat-free mass, 0.2% m. quadriceps femoris cross-sectional area, −4.9% m. vastus lateralis mean fiber area). The authors [26] concluded from this small study (6 to 7 subjects per group) that the timing of protein supplementation is important for resistance training-induced muscle hypertrophy and it is potentially helpful for older people when it is consumed immediately after, but not two hours after exercise.

CONCLUSION

Consensus is building that regular performance of resistance exercise and the consumption of a diet that includes adequate amounts of high-quality proteins are important to help older adults offset the progression of sarcopenia. Resistance training can help older and elderly persons increase strength, whole body fat-free mass, and muscle mass and can improve balance and physical functioning capacities for frail elderly persons. Adequate dietary protein intake from a variety of high-quality sources is critical to prevent adverse metabolic and physiological accommodation responses, including the loss of fat-free mass and muscle mass in older persons. The findings that older persons experienced a loss of fat-free mass and muscle mass with long-term ingestion of the recommended dietary allowance of $0.8\ g \cdot kg^{-1} \cdot d^{-1}$ for protein, even when they performed resistance training, brings into question the adequacy of this level of protein intake to prevent subtle metabolic and physiological accommodation responses. While the data are currently not compelling, protein intakes moderately above the RDA may enhance fat-free mass accretion in older persons who regularly perform resistance training. The predominant source of protein (e.g., eggs, meats, dairy, soy) is not likely to influence the training responses when total protein intake is adequate. The majority of the limited data available suggest that protein-enriched nutritional supplements, whether consumed immediately after or separate from the exercise sessions, do not augment the resistance-training-induced strength, body composition, muscle hypertrophy and physical functioning improvements that are typically observed in older and elderly persons.

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