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BOOK REVIEW

# A Systematic Review of Dietary Protein During Caloric Restriction in Resistance Trained Lean Athletes: A Case for Higher Intakes

**Eric R. Helms, Caryn Zinn, David S. Rowlands, and Scott R. Brown**

Caloric restriction occurs when athletes attempt to reduce body fat or make weight. There is evidence that protein needs increase when athletes restrict calories or have low body fat. ***Purpose:*** The aims of this review were to evaluate the effects of dietary protein on body composition in energy-restricted resistance-trained athletes and to provide protein recommendations for these athletes. ***Methods:*** Database searches were performed from earliest record to July 2013 using the terms *protein,* and *intake,* or *diet,* and *weight,* or *train,* or *restrict,* or *energy,* or *strength,* and *athlete.* Studies ($N$ = 6) needed to use adult (≥ 18 yrs), energy-restricted, resistance-trained (> 6 months) humans of lower body fat (males ≤ 23% and females ≤ 35%) performing resistance training. Protein intake, fat free mass (FFM) and body fat had to be reported. ***Results:*** Body fat percentage decreased (0.5–6.6%) in all study groups ($N$ = 13) and FFM decreased (0.3–2.7kg) in nine of 13. Six groups gained, did not lose, or lost nonsignificant amounts of FFM. Five out of these six groups were among the highest in body fat, lowest in caloric restriction, or underwent novel resistance training stimuli. However, the one group that was not high in body fat that underwent substantial caloric restriction, without novel training stimuli, consumed the highest protein intake out of all the groups in this review (2.5–2.6g/kg). ***Conclusions:*** Protein needs for energy-restricted resistance-trained athletes are likely 2.3–3.1g/kg of FFM scaled upwards with severity of caloric restriction and leanness.

***Keywords:*** body composition, strength training, metabolism, nutrition, strength, sport

Caloric restriction during weight training is common among lean athletes attempting to make weight or improve body composition for competition. As frequently seen among wrestlers, bodybuilders, power lifters, Olympic weight lifters, boxers and martial artists (Buford et al., 2006; Mourier et al., 1997; Slater & Phillips, 2011; Umeda et al., 2004; Walberg et al., 1988). Despite the high frequency of lean athletes restricting calories while training, studies in which these conditions are examined are rare (Garthe et al., 2011a; Mettler et al., 2010; Walberg et al., 1988). Protein guidelines to optimize body composition and performance during these periods have not yet been established.

Sport and nutrition scientists have supplied a range of recommendations for protein intake over the years. Differentiations in recommendations exist between endurance and strength athletes due to the metabolic demands of the sport and the adaptations desired from training (Butterfield, 1987; Lemon, 2000; Phillips, 2006; Phillips et al., 2007; Phillips & Van Loon, 2011). Less commonly, researchers point out that these requirements increase while athletes consume energy restricted diets (Butterfield, 1987; Garthe et al., 2011a; Mero et al., 2010; Mettler et al., 2010; Millward, 2004; Phillips & Van Loon, 2011; Stiegler & Cunliffe, 2006; Walberg et al., 1988).

When in negative energy balance, the anabolic response to protein is enhanced (Saudek & Felig, 1976), which can be erroneously interpreted to mean that less protein is needed during weight loss. A more accurate explanation might be that this increase in efficiency is an adaptive mechanism to preserve fat free mass (FFM) during starvation. When supply is limited, efficiency is increased, indicating the body's increased need for protein in states of negative energy balance (Fielding & Parkington, 2002). When significant weight loss occurs, FFM tends to be lost in greater amounts that correlate with the severity of energy restriction (Chaston et al., 2007; Garthe et al., 2011a).

Slight energy deficits increase protein requirements which are further increased with exercise. Butterfield (1987) found that male athletes running 5–10 miles per day during a slight caloric deficit were in a significant negative nitrogen balance (NBAL), despite consuming 2g of protein per kilogram of body mass. Celejowa et

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al. (1970) found that 5 out of 10 intermediate competitive weight lifters achieved a negative NBAL over the course of a training camp while consuming an average protein intake of 2g/kg. Three of which were in a slight caloric deficit.

In addition to the presence of a caloric deficit, its magnitude has an impact on FFM changes as well. Greater caloric restriction (1100kcal/day versus 550kcal/day) can lead to declines in anabolic hormones and decrements in performance (Mero et al., 2010), and a smaller proportion of total mass lost coming from body fat (Garthe et al., 2011a). Fast rates of weight loss in athletes with low body fat often results in FFM losses (Mettler et al., 2010; Mourier et al., 1997) and in some cases, coincides with decreases in performance (Buford et al., 2006; Umeda et al., 2004; Walberg et al., 1988).

Besides the presence and magnitude of an energy deficit, the availability of stored body fat also impacts changes in FFM (Elia et al., 1999; Forbes, 2000; Hall, 2007). Forbes' theory states that during caloric restriction, reductions in body fat will increase the risk of FFM loss (Forbes, 2000; Hall, 2007). Elia, et al., (1999) observed significant differences in protein metabolism across subjects ranging from 6% to 50% body fat during negative energy balance. Subjects on the lower end of this spectrum derived two- to threefold more energy from protein and excreted twice as much urinary nitrogen than the subjects on the higher end of this spectrum. In the initial days of starvation, leucine oxidation increased among the leanest individuals but not among the subjects highest in body fat.

FFM is more metabolically active than fat, and muscle gain is dependent upon skeletal muscle metabolism. Muscle is the site at which dietary protein aids resistance training adaptation; thus, optimal protein intake is likely relative to FFM. Therefore, protein intakes established by total body weight result in higher protein intakes relative to FFM in obese subjects. This may help to explain why energy restricted diets with comparable protein intakes (when established by total body weight) are more apt to produce FFM gains in overweight subjects performing resistance training (Demling & DeSanti, 2000; Stiegler & Cunliffe, 2006) compared with those at normal body fat levels (Mero et al., 2010). It also could be one reason as to why leaner subjects are more likely to lose FFM during energy restricted diets (Forbes, 2000; Hall, 2007; Stiegler & Cunliffe, 2006).

There are also significantly different endocrine responses between normal weight and obese individuals in response to energy deficits. Nair et al., (1987) found that unlike the morbidly obese (Suryanarayana et al., 1969), subjects of healthy weight experience a lowering of total testosterone production (–608.5 ± 254.8 nmol/L $p < .05$) and free testosterone (–30.5 ± 11.1 nmol/L $p = .055$) in response to fasting. A decline in this anabolic hormone could contribute to losses in FFM. Collectively the endocrine, metabolic, and body composition differences in lean versus overweight populations may indicate that lean dieters might benefit from a higher protein intake in an attempt to offset losses in FFM.

Traditional protein requirement studies have inherent methodological limitations. The most common technique used is NBAL; the process of comparing the amount of nitrogen entering the body via dietary protein, to that leaving the body via urine, feces, sweat and other processes. Protein recommendations are based on the minimal intake required to prevent nitrogen loses. NBAL does not measure protein synthesis nor tissue specific breakdown (Nair et al., 1987; Oddoye & Margen, 1979). In two studies subjects were observed to maintain NBAL while losing FFM (Pikosky et al., 2008; Walberg et al., 1988). These discrepancies likely occur because NBAL tends to overestimate nitrogen intake, underestimate excretion (Kopple, 1987) and is inaccurate at high protein intakes showing impossible levels of retention (Lemon et al., 1992; Oddoye & Margen, 1979; Phillips, 2006; Tarnopolsky et al., 1992; Tarnopolsky et al., 1988; Tipton, 2008).

The more modern technique of isotopic amino acid tracing can be used to track tissue-specific protein synthesis and breakdown (Zak et al., 1979). However, most studies only measure synthesis (Wolfe, 2006). Phenylalanine tracing is often used as it is not synthesized endogenously or oxidized by muscle (Liu & Barrett, 2002; Smith et al., 2007), but is not without limitations (Marchini et al., 1993; Pikosky et al., 2008; Short et al., 1999). Isolated amino acids may not represent the broad picture of protein metabolism; therefore multiple amino acids should be traced (Pikosky et al., 2008; Smith et al., 2007; Wagenmakers, 1999; Wolfe et al., 1984). Even properly designed, tracer studies are acute in nature. They provide "snapshots" of protein turnover (Pikosky et al., 2008) and their results are not always indicative of long term changes in FFM (Aragon & Schoenfeld, 2013; Pasiakos et al., 2013). This may be because amino acids have other impacts related to metabolic pathways and immune function (Phillips et al., 2007) and before oxidation exert a regulatory influence on maintenance and growth (Millward & Rivers, 1988, 1989).

Tracer studies can be used to make mechanistic inferences but they do not measure FFM or performance over time. NBAL can determine a minimum protein requirement, but what optimizes accrual of FFM may be higher (Lemon, 2000; Phillips et al., 2007; Tipton & Wolfe, 2004; Wilson & Wilson, 2006). Establishing minimums is important, but sports nutrition should focus on determining intakes that optimize performance. Finding the optimal protein intake range during caloric restriction is especially valuable because if one macronutrient is set too high it can force another too low, potentially resulting in decreased performance (Mettler et al., 2010; Millward, 2004; Phillips et al., 2007; Tipton, 2011; Walberg et al., 1988). Therefore, to determine optimal intakes during caloric restriction, this review examines research that measures changes in body composition and performance over time.

To establish protein recommendations for resistance-trained athletes during weight loss, a review of the current body of knowledge on protein intakes in energy restricted athletes must be performed. This review examines the effect of protein intake on FFM when the subjects in question: 1) are engaged in regular weight training and have resistance training experience, 2) in a negative energy balance and 3) of a healthy or leaner body fat percentage (males 23% or lower and females 35% or lower) as defined by Gallagher et al., (2000).

# Methods

## Search Parameters and Inclusion Criteria

PubMed, MEDLINE, SPORTDiscus and CINAHL electronic databases were searched online. Various combinations of the keywords *protein* and *intake,* or *diet* and *weight,* or *train**, or *restrict**, or *energy,* OR *strength,* AND *athlete** were searched in conjunction with limiting database results to academic journals, reviews and human subjects when applicable. Inclusion criteria included articles involving: (i) resistance-trained (6 months experience or more); (ii) adults (at least 18 years old); (iii) of healthy or leaner body fat percentage (males 23% or lower and females 35% or lower); (iv) during caloric restriction; and (v) providing body-fat percentages; (vi) fat-free mass; and (vii) dietary protein intake.

Exclusion criteria included articles that: (i) were only available as case studies, conference proceedings or in abstract from; (ii) did not involve participants performing regular progressive resistance training; (iii) included any ergogenic dietary supplementation; or (iv) did not add to the progressive knowledge of the review by not consisting of original work or where the data were not reported. A comprehensive search through references and citation tracking on Google Scholar was used to identify any additional material. Following the search, two authors from the current review independently screened each article for inclusion. The screening process consisted of (i) screening for duplicates; (ii) screening the title; (iii) screening the abstract; (iv) screening the full paper using the inclusion and exclusion criteria. If a discrepancy occurred between authors on the inclusion of a study, a third author independently reviewed the article using the inclusion and exclusion criteria and a discussion occurred until a consensus was reached.

## Assessment of Study Quality

Two authors from the current review independently assessed the methodological quality of each article. This assessment consisted of a 10-item custom methodological quality assessment scale (Table 1) involving a 20-point scoring system (ranging from 0 to 20) where 0 = *clearly no*; 1 = *maybe, inadequate information or partially yes*; and 2 = *clearly yes*. Determining appropriate anthropometric measurements in item six follows the work of (Ayvaz & Çimen, 2011) where 0 = *not appropriate or unknown*; 1 = *appropriate but performed incorrectly or with limitations*; and 2 = *appropriate and correctly performed*. This scale was designed to assess the methodological quality of studies examining anthropometric changes and was adopted from the qualitative scoring system used by Brughelli et al. (2008). If consensus was not reached on an article's score by the two authors, a third author from the current review assessed the article in question to rectify differences and to help determine the final score.

## Data Extraction and Analysis

Data were first extracted and categorized as body fat percentage and fat-free mass in kilograms and then separated into groups by low-protein, high-protein, low-loss or slow-loss, high-loss or fast-loss and energy-restricted. Due to the heterogeneity of the study design and subject characteristics, data were not pooled together but instead analyzed individually in a qualitatively descriptive method.

If standard deviations (*SD*) were not reported, data were imputed in as follows: (1) available SDs were individually squared; (2) summed and averaged; (3) and square rooted to impute missing SDs. Similarly, missing p values were imputed as follows: (1) *SD* change of the mean was imputed based on similar study characteristics; (2) *SD* change of the mean was divided by the square root of the *n* to obtain the standard error of the mean change; (3) mean change was divided by the standard error of the mean change to obtain the t-statistic; (4) a two-tailed Student's t-distribution was used to impute missing p values. Finally, mean differences (the mean of the post variable minus the mean of the pre variable) and 90% confidence intervals were computed using the two-tailed inverse of the Student's t-distribution. All data were analyzed using Excel (2010, Microsoft, Redmond, WA, USA) software.

# Results

A large number of studies were located examining resistance training during weight loss with quantified protein intakes; however the vast majority were performed with overweight participants. Among the studies located, nine were identified in which athletic and nonoverweight participants performed resistance training during negative energy balance. The full texts were further analyzed to determine if they fit the inclusion and exclusion criteria. Three studies did not fit the criteria and were excluded. One was excluded because body composition was not measured (Celejowa & Homa, 1970). A second was excluded because branch chain amino acid supplementation was used by one experimental group and not the others (Mourier et al., 1997). The final study was excluded because the participants were not required to have resistance training experience (Pasiakos et al., 2013). Figure 1 represents the search and selection process in a graphical flowchart.

In our methodological quality assessment of the six included studies there was a range of scores from 13 to 18 out of 20 with a mean score of 16. Of particular note was that only one study performed a power analysis for sample size calculation and only half the studies performed test-retest reliability on at least one of their measurements. Scoring details of the studies are provided in Table 1.

**Table 1 Methodological Quality Assessment**

| Question | Criteria | Maestu et al., 2010 | Mettler et al., 2010 | Garthe et al., 2011a | Walberg et al., 1988 | Mero et al., 2010 | Umeda et al., 2004 |
|---|---|---|---|---|---|---|---|
| 1 | Power analysis was performed and justification of study sample size given. | 2 | 0 | 0 | 0 | 0 | 0 |
| 2 | Participant demographics were clearly defined: Gender, age, body composition and mass at the time of the test. | 2 | 2 | 2 | 2 | 2 | 1 |
| 3 | Participant characteristics were clearly defined: sport or activity and experience level at the time of the study. | 2 | 2 | 2 | 2 | 1 | 2 |
| 4 | Inclusion and exclusion criteria were clearly stated for participants. | 2 | 2 | 2 | 1 | 2 | 1 |
| 5 | Participants or groups of participants were similar at baseline or differences were accounted for and explained. | 2 | 2 | 2 | 2 | 2 | 2 |
| 6 | Anthropometric measurement methods were appropriate and discussion or conclusions acknowledged measurement limitations when applicable. | 2 | 2 | 2 | 2 | 2 | 2 |
| 7 | Methods were described in great detail to allow replication of the study. | 2 | 2 | 2 | 2 | 1 | 1 |
| 8 | Test retest reliability of measurement device(s) reported. | 0 | 1 | 1 | 0 | 1 | 0 |
| 9 | Outcome variables were clearly defined. | 2 | 2 | 2 | 2 | 2 | 2 |
| 10 | Statistical analyses were appropriate | 2 | 2 | 2 | 2 | 2 | 2 |
| | Total score out of 20 | 18 | 17 | 17 | 15 | 15 | 13 |

*Note*. 0 = clearly no; 1 = maybe, inadequate information or partially yes; 2 = clearly yes.

Participant populations included male and female adults with a mean age of 23.4 years. Training experience ranged from elite athletes and competitive bodybuilders to healthy adults performing resistance training. Table 2 outlines the subject and design characteristics of the studies included.

In all study populations body fat percentage was decreased with reductions ranging from 0.5% to 6.6%. From Figure 2 and Table 3 it can be observed that only the female and slow-loss groups in Garthe et al. (2011a) were able to both reduce body fat and increase their FFM (increases ranging from 0.6 to 1.1kg). In nine out of 13 study populations the FFM of participants was decreased with reductions ranging from 0.3 to 2.7kg (Figure 2). The slow-loss group in Mero et al., (2010) did not undergo a change in FFM and the FL group underwent a nonsignificant decrease of 0.3kg. The participants in Maestu et al. (2010) experienced a FFM reduction of 0.4kg but this change was also nonsignificant.

## Discussion

The aim of this review was to establish protein recommendations for resistance-trained, lean participants who are restricting calories. Six published studies met the inclusion criteria for analysis while relevant manuscripts provided additional information and context. In addition to protein intake, the rate of weight loss, resistance

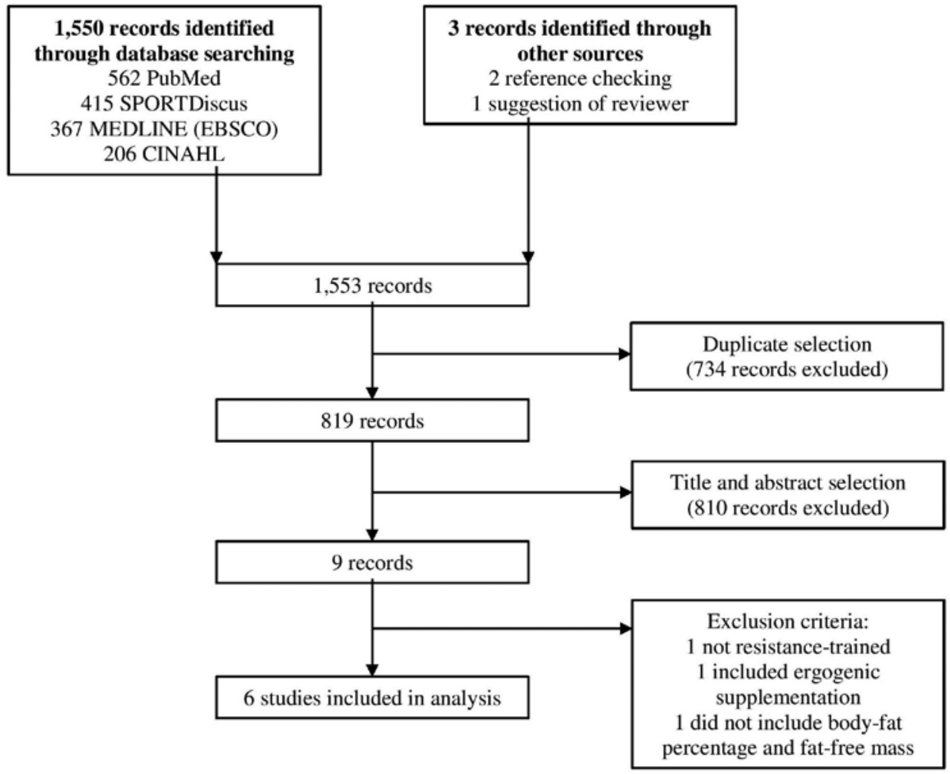


**Figure 1** — Summary of the search strategy and selection process for inclusion.

training experience, and initial body fat levels may have a significant influence on changes in FFM and body fat when restricting calories.

The female athletes in Garthe et al. (2011a) and female participants in Mero et al. (2010) that were able to avoid losses of FFM (actually gaining FFM in the former) had specific similarities which likely allowed this to occur. In Mero et al. (2010), the women had the highest body fat percentage out of all populations included in this analysis and the female athletes in Garthe et al. (2011a) had the second highest. In addition, the slow-loss groups in both studies had the least aggressive energy restriction of all populations included. In contrast, the leanest men in Garthe et al. (2011a), which were in the faster weight loss group experienced a loss of FFM. Another similarity between the two was the participants in Mero et al. (2010) were the least experienced resistance-trained population in this review and although the participants in Garthe et al. (2011a) had prior weight lifting experience it was not a main component of their regular training. This may have contributed to the results, as novice weight lifters experience accelerated gains in FFM (Peterson et al., 2005). Supporting this hypothesis, Garthe et al. (2011a) noted that gains in FFM and performance came predominantly in the upper body and that the athletes already had a high volume of lower body training in their sport specific conditioning. Thus, the upper body may have experienced this novice effect. A follow-up study examining the long term results in the same group of athletes six to 12 months later found the athletes had returned to their normal resistance training volume (half of that in the previous study) and their FFM had decreased back to baseline (Garthe et al., 2011b). Thus, it may be unrealistic to expect a lack of FFM loss or FFM gain in leaner more experienced weight lifters at protein levels similar to Garthe et al., (2011a) and Mero et al., (2010).

Like the publications by Mero et al., (2010) and Garthe et al., (2011a), Umeda et al., (2004) examined high and low losses of body mass, but between groups of male judoists. However unlike these studies, the participants were much leaner. As would be expected, the male judoists were a great deal leaner compared with the female participants of both Garthe et al. and Mero et al.'s works and 5–6% body fat leaner than the male subjects in the study by Garthe (2011a). This study examined judo competitors cutting weight for a competition; protein levels decreased over the length of the study as calories were decreased which can be seen in Table 1. The second and third highest amounts of FFM occurred in the high and low loss groups respectively. The high loss group lost significantly more FFM than the low loss group. However, making firm connections between the losses of FFM and protein intakes among the participants is difficult considering there was only a slight difference in protein intake between groups and more importantly due to the disparity in weight loss and thus energy intake between groups. What is clear, and what confirms the results reported by Mero et al. (2010) and Garthe et al. (2011a), is that the

**Table 2 Protein Intake During Caloric Restriction Study and Subject Characteristics**

| Study | Groups and Subjects | | Age (y) | Body Mass Pre Study (kg) | Initial Body Fat (%) | Body Fat Assessment Method | Energy Deficit | Diet Time | Protein Intake g/kg/d | Prior Training History | Training Protocol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Walberg et al., 1988 | CG | 5 M | 19.4 ± 0.7 | 74.6 ± 4.1 | 7.5 ± 1.2 | UWW | n/a | 1 wk | 1.1 | ≥2 years weight training | Weights 6/d/wk |
| | LP | 7 M | 21.4 ± 0.7 | 81.8 ± 2.9 | 11.4 ± 2.3 | | 51% baseline | | 0.8 | | |
| | HP | 7 M | 21.0 ± 0.9 | 80.2 ± 4.1 | 14.4 ± 2.3 | | 51% baseline | | 1.6 | | |
| Umeda et al., 2004 | CG | 5 M | 19.3 ± 0.6 | 78.7 ± 8.8 | 9.5 ± 8.2 | UWW | n/a | 20 d | 1.2, 1.4, 1.3 | College level judoists | Running and judo 6/d/wk and weights 2/d/wk |
| | LL | 11 M | | 80.7 ± 13.1 | 11.4 ± 5.8 | | –2.4 kg BW | | 1.3, 1.0, 0.8 | | |
| | HL | 11 M | | 78.5 ± 13.6 | 11.2 ± 6.6 | | –3.2 kg BW | | 1.5, 1.1, 0.8 | | |
| | | | | | | | by study end | | Day 20, 4, 1 | | |
| Maestu et al., 2010 | CG | 7 M | 22.4 ± 3.4 | 85.3 ± 10.5 | 12.0 ± 3.4 | DXA | n/a | 11 wk | 1.7–1.9 | Amateur level body builders | Habitual weights and aerobic training |
| | ER | 7 M | 28.3 ± 10.3 | 82.2 ± 9.3 | 9.6 ± 2.3 | | 199 ± 115 kcal/d | | 2.5–2.7 | | |
| | | | | | | | 536 ± 298 kcal/d | | | | |
| | | | | | | | 978 ± 625 kcal/d | | | | |
| | | | | | | | at start, middle and end | | | | |
| Mero et al., 2010 | SL | 7 F | 28.9 ± 6.2 | 65.7 ± 4.0 | 34.2 ± 4.0 | DXA | 550 kcal/d | 4 wk | 1.5 | ≥ 6 months weight and aerobic training | Habitual weights and aerobic training |
| | FL | 8 F | 28.0 ± 6.4 | 66.9 ± 4.3 | 31.8 ± 7.0 | | 1100 kcal/d | | 1.4 | | |
| Mettler et al., 2010 | LP | 10 M | 25.8 ± 1.7 | 78.3 ± 4.3 | 17.4 ± 1.5 | DXA | 60% baseline | 2 wk | 1.0 ± 0.0 | ≥ 6 months weight training | Habitual weights and aerobic training |
| | HP | 10 M | 24.7 ± 1.6 | 79.9 ± 2.9 | 16.1 ± 1.6 | | 60% baseline | | 2.3 ± 0.1 | | |
| Garthe et al., 2011a | FL | 6 F | 20.7 ± 6.4 | 68.9 ± 6.7 | 30.0 ± 5.0 | DXA | 791 ± 113 | 4–12 wk | 1.4 ± 0.2 | Elite athletes from various sports | Normal sport training and weights 4/d/wk |
| | FL | 5 M | 20.9 ± 4.5 | 81.9 ± 11.5 | 16.0 ± 3.0 | | kcal/d | | 1.6 ± 0.4 | | |
| | SL | 7 F | 22.4 ± 3.1 | 66.4 ± 8.8 | 27.0 ± 5.0 | | 469 ± 61 | | | | |
| | SL | 6 M | 24.9 ± 3.5 | 78.5 ± 14.1 | 17.0 ± 5.0 | | kcal/d | | | | |

Values are means ± standard deviation when applicable or available.

M, male; F, female; CG, control group; ER, energy restricted group; HP, high protein group; LP, low protein group; HL, high weight loss group; FL, fast weight loss group; LL, low weight loss group; SL, slow weight loss group; UWW, underwater weighing; DXA, dual-energy X-ray absorptiometry.

**Table 3 Protein Intake During Caloric Restriction Anthropometric Changes**

| | | Body Fat (%) | | | Fat Free Mass (kg) | | |
|---|---|---|---|---|---|---|---|
| **Study** | **Group** | **Pre** | **Post** | **Change** | **Pre** | **Post** | **Change** |
| Walberg et al., 1988 | CG M | 7.5 ± 1.2 | 6.6 ± 1.3 | -0.9 | 68.9 ± 3.9 | 68.9 ± 3.7 | 0.0 |
| | LP M | 11.4 ± 2.3 | 9.3 ± 1.7 | -2.1 | 72.7 ± 3.1 | 70.0 ± 2.7 | -2.7 |
| | HP M | 14.4 ± 2.3 | 12.4 ± 2.3 | -2.0 | 68.4 ± 4.0 | 67.0 ± 3.8 | -1.4 |
| Umeda et al., 2004 | CG M | 9.5 ± 8.2 | 9.7 ± 4.5 | 0.2 | 70.9 ± 5.4 | 71.2 ± 5.6 | 0.3 |
| | LL M | 11.4 ± 5.8 | 10.9 ± 6.4 | -0.5 | 70.9 ± 8.6 | 69.2 ± 8.6 | -1.7* |
| | HL M | 11.2 ± 6.6 | 10.5 ± 6.4 | -0.7*# | 68.9 ± 7.0 | 66.7 ± 6.4 | -2.2*# |
| Maestu et al., 2010 | CG M | 12.0 ± 3.4 | 11.8 ± 3.0 | -0.2 | 70.5 ± 8.6 | 72.2 ± 7.8 | 1.7 |
| | ER M | 9.6 ± 2.3 | 6.5 ± 1.5 | -3.1*# | 72.9 ± 8.4 | 72.5 ± 8.1 | -0.4 |
| Mero et al., 2010 | SL F | 34.2 ± 4.0 | 32.3 ± 4.6 | -1.9* | 40.6 ± 3.4 | 40.3 ± 3.8 | -0.3 |
| | FL F | 31.8 ± 7.0 | 27.6 ± 7.9 | -4.2*# | 42.8 ± 5.4 | 42.8 ± 5.4 | 0.0 |
| Mettler et al., 2010 | LP M | 17.4 ± 1.5 | 16.4 ± n/a | -1.0 | 64.7 ± n/a | 63.1 ± n/a | -1.6 |
| | HP M | 16.1 ± 1.6 | 14.9 ± n/a | -1.2 | 67.0 ± n/a | 66.7 ± n/a | -0.3# |
| Garthe et al., 2011a | FL F | 30.0 ± 5.0 | 28.0 ± 4.3 | -2.0* | 44.6 ± 3.6 | 45.2 ± 3.6 | 0.6* |
| | FL M | 16.0 ± 3.0 | 13.3 ± 7.7 | -2.7*# | 65.5 ± 3.3 | 64.1 ± 6.8 | -1.4 |
| | SL F | 27.0 ± 5.0 | 20.4 ± 4.5 | -6.6 | 46.3 ± 5.5 | 47.4 ± 5.1 | 1.1# |
| | SL M | 17.0 ± 5.0 | 11.9 ± 3.3 | -5.1 | 62.3 ± 10.3 | 63.3 ± 10.3 | 1.0 |

Pre and post values are means ± standard deviation when available.

* Significantly different from baseline value.

# Significantly different from comparative group(s).

M, male; F, female; CG, control group; ER, energy restricted group; HP, high protein group; LP, low protein group; HL, high weight loss group; FL, fast weight loss group; LL, low weight loss group; SL, slow weight loss group.

magnitude of the caloric deficit imposed is likely one of the most powerful variables that impacts FFM loss, potentially being more important than protein intake.

In Walberg, et al., (1988), the effects of two energy restricted isocaloric diets of differing protein intakes were compared. Carbohydrate was reduced in the 1.6g/kg group to keep the interventions isocaloric. NBAL was negative in the 1g/kg group while it was positive in the 1.6g/kg group (despite losses of FFM). It should also be noted that the 1.6g/kg group displayed decreased muscular endurance compared with the 0.8g/kg group. The authors suggested this was possibly due to the caloric balance between the diets being established by a reduction in carbohydrate in the higher protein diet. This likely reduced muscle glycogen levels precipitating a reduction in muscular endurance. The authors noted this would likely compromise the effectiveness of the participants habitual bodybuilding training characterized by high volume and moderate repetition ranges. In regards to the anthropometric changes, the authors stated that with such a short time period of intervention (1 week), and considering the inherent 2% margin of error in hydrostatic weighing, conclusive changes to FFM were difficult to detect.

In a study by Mettler, et al., (2010) the same basic premise and methodology was employed as in that of Walberg et al., (1988). However, different protein intakes were used, the subjects were not as lean and a larger number of measurements were taken. Unlike Walberg et al. (1988), the calorie balance between the diets was maintained by a reduction in dietary fat as opposed to carbohydrate. Performance and most blood parameters did not vary between the two groups. Unlike Walberg, et al., (1988), the avoidance of carbohydrate restriction appeared to prevent reductions in performance. Similarly, the participants in Garthe et al. (2011a) established the majority of their caloric deficit via a reduction in fat and all groups in improved their one repetition maximum on squats, bench press, bench pull and their counter movement jump height. Despite maintenance of performance in the high protein group in Mettler et al. (2010), this group reported slightly but significantly reduced feelings of well-being as assessed by the Daily Analysis of Life Demands for Athletes questionnaire. It is unknown if this was caused by the increased intake of protein, the dietary fat reduction to allow for this increase or other factors. Therefore, while maintaining carbohydrate levels may aid performance, it is not known to what degree fat can be safely and pragmatically reduced. A comprehensive discussion of dietary fat in the context of dieting athletes is beyond the scope of this review. However, 20% of total calories which is the low end of some fat intake recommendations for resistance trained athletes (Bird,

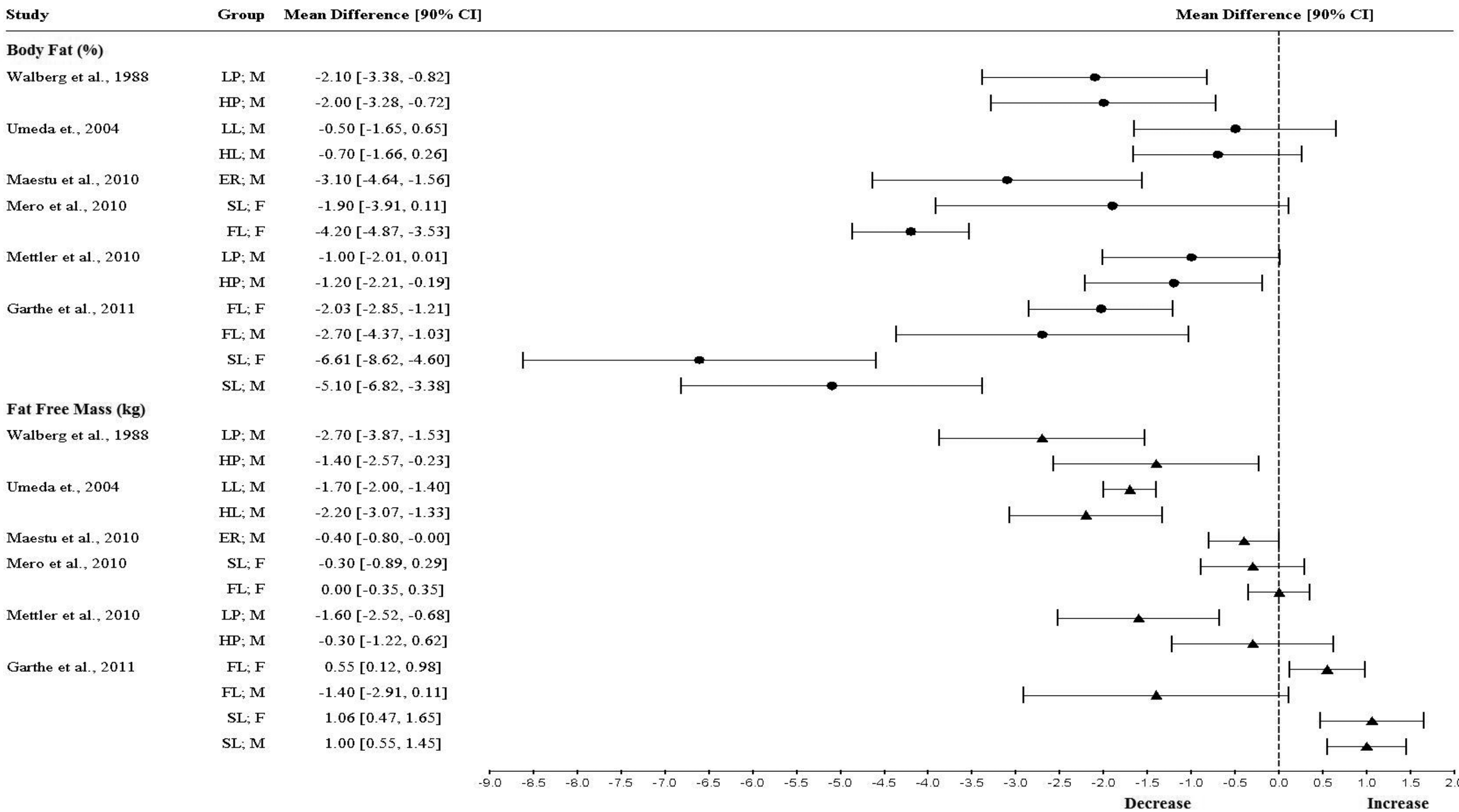


**Figure 2** — Forest plot summarizing the anthropometric changes within each group presented as pre versus post (mean difference [90% CI]). M, male; F, female; ER, energy restricted group; HP, high protein group; LP, low protein group; HL, high weight loss group; FL, fast weight loss group; LL, low weight loss group; SL, slow weight loss group; CI, confidence interval.

2010), may serve as a reasonable lower limit until more research is done.

Maestu et al. (2010) observed only nonsignificant losses of FFM in a group of drug free bodybuilders consuming 2.5–2.6g/kg of protein during the 11 weeks before competition. When compared alongside the works by Walberg et al. (1988) and Mettler et al. (2010) and considering the 11-week time frame, these results imply that the higher the protein intake, the lower the chance for FFM loss. However, it should be noted that this study did not include a low protein control. Furthermore, two subjects did lose significant amounts of FFM (1.5kg and 1.8kg), and the authors noted that these specific bodybuilders were among the leanest of the subjects. These two subjects lost the majority of their FFM (approximately 1kg) during the latter half of the intervention as their percentage of calories from protein increased from 28% to 32% and finally to 33% by the end of the study. The participants as a whole progressively decreased their calories by reducing all three macronutrients throughout the investigation. Thus, the two subjects uniquely increased their proportion of protein, possibly reducing fat and carbohydrate to the point of detriment. Related to this point, there was a correlation between FFM losses and declines in insulin and insulin-like growth factor 1 (IGF-1). The authors suggested that an increase in carbohydrate rather than protein in the final stages of this study may have offset these hormonal declines and subsequent FFM losses. While limited conclusions can be made from this study, it appears that increases in protein are only beneficial for ameliorating losses in FFM up to the point at which sufficient fat or carbohydrate levels are not compromised.

Of these six studies, only in Walberg et al. (1988) and Mettler et al. (2010) were different protein intakes compared with one another with well-matched groups and appropriate controls in place for diet, training and time spent in the intervention. While well designed, Walberg et al. (1988) and Mettler et al. (2010) provide information on a total of only four protein intakes (0.8g/kg, 1g/kg, 1.6g/kg, and 2.3g/kg). While the time frame and range of protein intakes are limited, these two studies suggest that as protein is increased FFM retention increases as well.

In contrast, in a recent study not included in this analysis lasting three weeks a nonsignificant trend of greater FFM retention was observed in a group consuming 1.6g/kg of protein compared with a group consuming 2.4g/kg (Pasiakos et al., 2013). However, the 2.4g/kg group consumed a diet that was 27% carbohydrate while the 1.6g/kg group consumed a diet that was 44% carbohydrate. The trend for greater FFM losses in the 2.4g/kg group may have been related to decreases in insulin and IGF-1 (Maestu et al., 2010) or muscular endurance (Walberg et al., 1988). If muscular endurance was decreased in the higher protein group, it would have likely decreased performance considering the participants exclusively performed sets of 15 repetitions per exercise. In addition, the training in this study was specifically designed to not provide an anabolic stimulus and only to maintain prestudy muscular fitness levels. This presents the possibility that if the training did not provide an anabolic stimulus, there may have not been an increased demand for protein. It is unknown whether the results would have been different had the participants in the higher protein group reduced their fat intake to allow for a greater amount of carbohydrate to be consumed. More importantly, this study's applications to resistance-trained athletes are limited since the participants were not required to be resistance-trained for inclusion and were not performing progressive strength training. However, the findings highlight the need for further study comparing high protein intakes with matched carbohydrate intakes.

It appears that FFM losses can be avoided only in populations with less resistance training experience of higher body fat when following slower weight loss regimens using current sports nutrition recommendations for protein intake (1.2–2.0g/kg). To date only Phillips and Van Loon (2011) have recommended higher intakes (1.8–2.7g/kg) for athletes during periods of negative energy balance and weight loss.

## Conclusions and Recommendations

The traditional protein recommendations for strength athletes have not been determined by examining athletes in a calorically restricted state or at low body fat percentages and may be too low to minimize losses of FFM during these conditions. The recent recommendation by Phillips and Van Loon (2011) of consuming 1.8–2.7g/kg of protein is supported by the limited research available, however to further customize protein intake within this range for the individual, the body composition of the athlete should be considered. Since protein recommendations are traditionally set based on the study of individuals of a normal or high body fat percentage, it may be worthwhile to prescribe protein intake based on FFM versus total body mass in athletic populations. This may avoid giving recommendations that are too low for lean athletes.

When analyzing the six studies reviewed to determine protein intake per kilogram of FFM, it appears that the range of 2.3–3.1g/kg of FFM is the most consistently protective intake against losses of lean tissue. Furthermore, the goal of the athlete should be taken into account. Athletes with a lower body fat percentage, or a primary goal of maintaining maximal FFM should aim toward the higher end of this range. Those who are not as lean, or who are concerned primarily with strength and performance versus maintenance of FFM can safely aim for the lower end of this recommendation.

It also appears that a reduction in dietary fat versus carbohydrate to create the bulk of the caloric deficit is more effective in maintaining performance. That said, too low of a fat intake could compromise health or well-being, thus a lower limit for fat intake of 20% of total calories is recommended. Furthermore, less extreme weight loss rates (0.5kg per week or 0.7% of total body mass) may serve an even more important role than protein intake in the preservation of FFM. Slower rates of weight loss appear to be more protective of both FFM and performance and will allow a greater "caloric budget" to assign values to the three macronutrients. Future research should be designed to measure the effects of varying protein intakes on FFM and performance in athletes of various sports, body compositions and macronutrient ratios for longer time periods than have been currently studied.


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