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ORIGINAL RESEARCH

High-Protein, Low-Fat, Short-Term Diet Results in Less Stress and Fatigue Than Moderate-Protein, Moderate-Fat Diet During Weight Loss in Male Weightlifters: A Pilot Study

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Purpose: Athletes risk performance and muscle loss when dieting. Strategies to prevent losses are unclear. This study examined the effects of two diets on anthropometrics, strength, and stress in athletes. ***Methods***: This double-blind crossover pilot study began with 14 resistance-trained males (20–43 yr) and incurred one dropout. Participants followed carbohydrate-matched, high-protein low-fat (HPLF) or moderate-protein moderate-fat (MPMF) diets of 60% habitual calories for 2 weeks. Protein intakes were 2.8g/kg and 1.6g/kg and mean fat intakes were 15.4% and 36.5% of calories, respectively. Isometric midthigh pull (IMTP) and anthropometrics were measured at baseline and completion. The Daily Analysis of Life Demands of Athletes (DALDA) and Profile of Mood States (POMS) were completed daily. Outcomes were presented statistically as probability of clinical benefit, triviality, or harm with effect sizes (ES) and qualitative assessments. ***Results***: Differences of effect between diets on IMTP and anthropometrics were likely or almost certainly trivial, respectively. *Worse than normal* scores on DALDA part A, part B and the part A "diet" item were likely more harmful (ES 0.32, 0.4 and 0.65, respectively) during MPMF than HPLF. The POMS fatigue score was likely more harmful (ES 0.37) and the POMS total mood disturbance score (TMDS) was possibly more harmful (ES 0.29) during MPMF than HPLF. ***Conclusions***: For the 2 weeks observed, strength and anthropometric differences were minimal while stress, fatigue, and diet-dissatisfaction were higher during MPMF. A HPLF diet during short-term weight loss may be more effective at mitigating mood disturbance, fatigue, diet dissatisfaction, and stress than a MPMF diet.

Keywords: macronutrient; anthropometry; resistance training; isometric exercise; athlete.

Caloric restriction during resistance training is common practice for athletes in weight-class restricted or aesthetic sport. This is frequently seen among bodybuilders, power lifters, weight lifters, and combat athletes (Slater & Phillips, 2011; Umeda et al., 2004), the goal being to improve performance either via increased power-to-weight ratio in performance sports, or via aesthetic improvement in physique competitions. These performance or aesthetic improvements are optimized when fat-free mass (FFM) contributes as little as possible to the mass lost during energy restriction. However, weight loss and caloric restriction can lead to losses of FFM and performance (Buford et al., 2006; Koral & Dosseville, 2009; Umeda et al., 2004). Thus, strategies to minimize potential losses of FFM and performance during weight loss warrant study.

While it is well established that body composition is most favorably improved in overweight populations performing resistance training in combination with an increased protein intake (Demling & DeSanti, 2000; Layman et al., 2005; Stiegler & Cunliffe, 2006), similar research in resistance-trained athletes is sparse. To date, two studies have measured performance and body composition in resistance-trained athletes while they consumed energy-matched hypocaloric diets of differing protein levels (Mettler et al., 2010; Walberg et al., 1988). The data available from these studies provide insight into the FFM-sparing potential of high-protein diets in athletes. However, only a handful of intake levels have been examined (0.8g/kg, 1g/kg, 1.6g/kg and 2.3g/kg per day) which limits the ability to determine thresholds at which benefits are obtained. However, it seems that as protein increases FFM retention increases as well.

While upon first glance it appears that a linear relationship with protein intake and FFM preservation exists, in Pasiakos et al. (2013) a nonsignificant trend of greater FFM retention was observed in a group consuming 1.6g/

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kg of protein compared with a group consuming 2.4g/kg. However, this trend could have been related to a low carbohydrate-mediated (27% of calories) performance decrease in the resistance training protocol (Walberg et al., 1988), or because the protocol did not increase protein demands as it was specifically designed to not provide an anabolic stimulus. Thus, uncertainty remains for thresholds of beneficial protein intakes in resistance-trained athletes during weight loss.

Therefore, in the context of isocaloric, carbohydrate-matched diets of a 40% energy deficit, the current study compared 2.8g/kg to 1.6g/kg of protein per day; 2.8g/kg representing what many strength athletes habitually consume and 1.6g/kg falling within standard sports nutrition guidelines (Slater & Phillips, 2011). The aim of this pilot study was to see whether a high protein intake above what is typically recommended, yet which represents what many strength athletes habitually consume, provides any measureable benefit in terms of mood state, maximal strength or body composition during short-term energy restriction in resistance trained males.

Methods

Fourteen resistance-trained males gave their written informed consent to participate in this double-blind cross-over pilot study approved by the AUT University Ethics Committee (approval number 12/313). Thirteen participants completed the study. Participants were required to be: (i) regularly (³ 2 days per week) resistance training with at least one year of experience; (ii) weight stable (± 2%) for at least one month; (iii) healthy as assessed by the Physical Activity Readiness Questionnaire; (iv) not using anabolic steroids or other illegal performance enhancing drugs; and (v) below 20% body fat (Durnin & Womersley, 1974) as assessed by an International Society for the Advancement of Kinanthropometry certified anthropometrist. Participants were recruited from gyms, weight lifting and crossfit clubs, supplement stores, and AUT University sports science and nutrition classes. Participant characteristics are provided in Table 1.

Eligible participants were taught to track their diets with multiple one on one sessions with a researcher and once familiarized they each completed a one-week online food diary. Digital food scales were provided to participants who did not have their own. This diary was analyzed by the researchers, one of whom is a New Zealand Registered Dietitian, to determine habitual energy intakes. Diets were developed based on 60% of the energy intake recorded in the diaries, which was 3049 ± 414kcal per day. Mean protein intake recorded in the food diaries for the group was 169.4 ± 36.8g or 2.1 ± 0.4g/kg per day when expressed relative to bodyweight. Participants were randomly assigned to the 14 day dietary intervention, which was either a high-protein low-fat (HPLF) or moderate-protein moderate-fat (MPMF) intervention diet. The design of each dietary intervention is shown in Table 2. Fat intake as a percentage of calories provided by HPLF and MPMF was 15.4% and 36.5% of calories, respectively and the relative intake of fat was 0.4 ± 0.2g/kg and 0.9 ± 0.2g/kg per day, respectively. Carbohydrate intake relative to bodyweight during both diets was 2.0 ± 0.2g/kg per day. Six of the participants began with HPLF and finished with MPMF and seven had the opposite order. Food preference questionnaires were used to develop meal plans for each dietary intervention. Each participant was provided with three meal plans with equal macronutrients, for variety, and either a pea-protein isolate (Clean Lean Protein Vanilla; NuZest, New Zealand) only or a pea-protein and maltodextrin mix to make up the daily intake during each intervention. Pea protein was selected to assist in blinding because of its thicker texture and infrequent commercial use compared with whey, casein or soy protein. Similarly, maltodextrin was selected because of its bland flavor. Participants were not permitted to consume any new supplements or supplements with caloric value, but were instructed to maintain their existing (zero caloric value) supplementation regimen throughout the two interventions. Details of the intervention diets are provided in Table 2.

The dietitian, who was not involved in data collection or analysis mixed the powders, labeled them "a"

Table 1 Predietary Intervention Participant Characteristics (*n* = 13)

Characteristic	HPLF	MPMF
Age (yr)	27.4 ± 7.9	27.4 ± 7.9
Height (cm)	177.9 ± 10.4	177.9 ± 10.4
Weight (kg)	80.6 ± 8.4	80.7 ± 8.0
BMI (kg/m^2)	25.5 ± 1.7	25.5 ± 1.6
Sum of Eight Skinfolds (mm)[a]	71.7 ± 18.3	76.7 ± 21.0
Body Fat Percentage (%)b	13.2 ± 4.2	14.1 ± 3.7
FFM (kg)b	70.0 ± 8.0	69.3 ± 7.5

Note. Values are means ± *SD*. HPLF = high-protein low-fat; MPMF = moderate-protein moderate-fat; BMI = body mass index; FFM = fat free mass.

[a] Triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh and medial calf skinfolds.

[b] Durnin & Womersley (1974).

Table 2 Nutritional Profiles of Dietary Interventions

Intervention Development	HPLF	MPMF
Protein (g/kg)	2.8	1.6
Carbohydrate (% of total calories)	35%	35%
Fat	remaining	remaining
Calories	60% habitual intake	60% habitual intake
Total Intakes (Meal Plans Plus Powders)	**HPLF**	**MPMF**
Protein (g/day)	225.7 ± 24.5	129.0 ± 14.0
Carbohydrate (g/day)	159.5 ± 21.9	159.5 ± 21.9
Fat (g/day)	31.4 ± 14.2	74.2 ± 15.0
Calories (kcal/day)	1829.3 ± 248.3	1829.3 ± 248.3
Intakes from Meal Plans Alone	**HPLF**	**MPMF**
Protein (g/day)	115.3 ± 24.5	108.8 ± 14.0
Carbohydrate (g/day)	151.8 ± 21.9	64.1 ± 21.9
Fat (g/day)	29.7 ± 14.2	73.9 ± 15.0
Calories (kcal/day)	1341.6 ± 248.3	1364.0 ± 248.3
Intakes from Supplement Powders Alone	**HPLF**	**MPMF**
Protein (g/day)	110.4	20.2
Carbohydrate (g/day)	7.7	95.4
Fat (g/day)	1.7	0.3
Calories (kcal/day)	487.7	465.3

Note. Values are means ± *SD* when applicable. HPLF = high-protein low-fat; MPMF = moderate-protein moderate-fat.

or "b" for blinding and retained the blinding key. The primary researcher was unblinded to the supplement key only after data analysis was complete. Exit surveys were not performed to determine the success of the blinding strategy. The participants were instructed to approach the dietitian for any assistance with dietary matters.

Three participants inadvertently consumed extra or incorrect food items on one occasion each, and immediately communicated this with the dietitian. Meals for the remainder of the day were adjusted where possible to ensure that the macronutrient and energy contributions were not compromised. When the communication was made the day following the error, meals on that day were adjusted to account for the nutrient shortfall or excess the day prior, and thereby ensuring an accurate nutrient intake over a two-day period. Examples of errors included inadvertently adding milk to tea, and consumption of a full-sugar beverage and full-sugar peppermints, rather than their nonsugar counterparts. All meal plans were successfully adjusted, thereby maintaining nutrient integrity throughout the study.

After completing the first diet, participants were assigned to a wash out that lasted approximately twice the length of the intervention diet or longer (25–49 days) based on the scheduling needs of the participant. During the wash out participants were instructed to eat normally, initially allowing weight regain. Two weeks before starting the second intervention they were instructed to return to their habitual caloric intake as recorded in their initial food diaries which they completed before beginning their first intervention. Fourteen participants started the study; however, one dropped out during the first intervention, which for this participant was MPMF, complaining of fatigue, depression and mental stress.

The day before starting and the day after completing each intervention, participants had their height, weight, eight-site (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf) skinfold thicknesses, waist, hip, calf, relaxed and flexed arm girths, and femur and humerus breadths measured. The anthropometrist had a technical error of measurement for skinfolds of ± 0.4mm (mean error of six sites).

Three equations were used to analyze FFM (Durnin & Womersley, 1974; Peterson et al., 2003; Yuhasz, 1974).

Pre and post testing occurred as close to the same time of day as possible for each individual. On the day of post testing before assessment, participants were instructed to repeat the eating pattern they followed the day of pre testing before assessment. Participants were informed of this requirement the day of pre testing and then reminded again the day before post testing. Participants were instructed to maintain their normal training regimen during both dietary intervention periods. In addition, the same exercise and dietary regimen was maintained before both pre and post testing. Strength assessment testing peak force using the isometric midthigh pull (IMTP) exercise (Stone et al., 2003) followed anthropometry. Vertical ground reaction force data were collected at a sample rate of 200 Hz with a commercially available force plate (400 Series Performance Force Plate; FitnessTechnology, Australia) connected to computer software (Ballistic Measurement System, FitnessTechnology, Australia). The force plate was calibrated before each testing session. Participants used cloth-lifting straps to avoid grip-strength limitations. Participants were instructed on the performance of the assessment, given a visual demonstration, allowed a practice attempt, and then the best of three IMTP's was recorded. One participant during one pretest was unable to properly use the lifting straps and was excluded from the IMTP analysis for that arm of the crossover. Thus, 12 pre and posttests were included for the IMTP analysis for that arm of the crossover.

The Profile of Mood States (POMS) short form (Shacham, 1983) and the Daily Analysis of Life Demands of Athletes (DALDA) (Rushall, 1990) questionnaires were chosen to quantify the psychological-response to the diets because of their wide use in sport and exercise research (Halson et al., 2002; Mettler et al., 2010; Morgan et al., 1988). Every day participants completed the POMS and both part A and B of the DALDA questionnaire, which represent the general stress sources and the resulting signs and symptoms, respectively. Each source of stress in part A and each sign or symptom in part B could be graded as follows: a = *worse than normal*, b = *normal* and c = *better than normal*. Total *worse than normal* scores were calculated for part A and part B and total *worse than normal* scores for the "diet" item in part A were calculated to assess the diet-related stress, representing the satiety and enjoyment of each dietary intervention. Participants were instructed to complete questionnaires at the same time on a daily basis. If a participant missed a day of completing the DALDA in one 14-day dietary intervention, the same day of the following 14-day dietary intervention was discarded. The POMS questionnaire provides a measure of the tension/anxiety, depression, anger, vigor, fatigue and confusion levels of the participant. Each mood item in the POMS was rated on a 5-point scale as follows: 0 = *not at all*, 1 = *a little*, 2 = *moderately*, 3 = *quite a bit* and 4 = *extremely*. For each participant a mean of all days reported was calculated for the total mood disturbance score (TMDS) and fatigue score. The fatigue score was specifically chosen to help differentiate any effects on TMDS that might have been caused by satiety or diet preference rather than energy levels, which are of primary concern to athletes. TMDS was calculated by adding the five negative mood states together and subtracting the positive mood state, vigor. One participant after one arm of the crossover lost their POMS and DALDA forms and thus their data for that arm of the crossover was not included, resulting in 12 completed sets of psychometric forms for that portion of the study.

All variables except the POMS TMDS, fatigue score and the DALDA "worse than normal" diet scores were log transformed before analysis to reduce nonuniformity of error and to express effects as percent changes (Hopkins et al., 2009). POMS TMDS and fatigue scores were averaged over the days reported to provide uniformity and the DALDA diet score is a single item Likert scale.

A spreadsheet for analysis of a post only crossover trial (Hopkins, 2012a) was used to determine differences between the two groups on the POMS and DALDA scores. A spreadsheet for analysis of a pre and post crossover trial (Hopkins, 2012b) was used to determine differences between the two groups on the IMTP and all anthropometric variables. IMTP data were analyzed with bodyweight at the start of the dietary intervention as a covariate. Mean percentage changes with 90% confidence limits (CL) were presented for pre and posttest variables (IMTP and anthropometric data) and mean scores with 90% CL were presented for post only variables (psychometric data). The chances (% and qualitative) that the true value of each statistic was practically beneficial, trivial, or harmful were calculated using the spreadsheets. To determine the threshold for an effect, the smallest standardized change was assumed to be 0.2. For all variables that were measured, thresholds used to determine the magnitude of effect sizes were based on a modified Cohen's scale. Standardized thresholds of <0.2, <0.6, <1.2, and <2.0 were interpreted as trivial, small, moderate, and large effects, respectively (Batterham & Hopkins, 2006). This approach using probability statistics allows the reader to make decisions around the use of feedback based on its predicted beneficial or harmful effects (Batterham & Hopkins, 2006; Hopkins et al., 2009). Readers unfamiliar with this statistical paradigm and its merits are referred to Batterham and Hopkins (2006) and Hopkins et al. (2009) for a more in-depth discussion.

Results

Results of all variables measured are provided in Table 3.

All anthropometric markers decreased in both groups over the course of the two-week dietary intervention. Fat loss as measured by sum of eight skinfolds was almost identical between dietary interventions. A slightly greater amount of bodyweight (0.6%) and FFM (0.4%) was lost in the MPMF group. The same relative loss of FFM was

Table 3 Effects of Dietary Interventions

Measure	HPLF Mean Change ± 90% CL (%)	MPMF Mean Change ± 90% CL (%)	Chances that True Effect of MPMF Relative to HPLF are Substantially			Qualitative Assessment of MPMF's Effect Compared with HPLF's Effect
			Harmful (%)	Trivial (%)	Beneficial (%)	
Anthropometric						
Bodyweight	–3.6 ± 0.6	-4.2 ± 0.6	<0.1	99	<0.1	almost certainly trivial
Sum of eight skinfolds	–12.5 ± 3.4	–12.6 ± 3.5	2	97	1	very likely trivial
FFM[a]	–2.1 ± 0.7	–2.5 ± 0.6	<0.1	99	<0.1	almost certainly trivial
FFM[b]	–2.9 ± 0.6	–3.3 ± 0.6	<0.1	99	<0.1	almost certainly trivial
FFM[c]	–2.1 ± 0.6	–2.5 ± 0.6	<0.1	99	<0.1	almost certainly trivial
Performance						
IMTP	–2.5 ± 1.4	–0.4 ± 3.5	<0.1	81	19	likely trivial
Psychometric	**HPLF Mean ± 90% CL**	**MPMF Mean ± 90% CL**				
DALDA *worse than normal* score	-	-	-	-	-	-
Part A total	16.7 ± 6.3	28.8 ± 10.8	83	17	<0.1	likely harmful
Part B total	37.3 ± 16.7	66.0 ± 22.2	86	14	<0.1	likely harmful
Part A "diet"	4.9 ± 1.9	7.5 ± 2.1	95	5	<0.1	likely harmful
POMS average TMDS	0.7 ± 4.1	6.5 ± 6.5	75	25	<0.1	possibly harmful
POMS average fatigue score	2.8 ± 1.5	4.7 ± 2.1	81	18	1	likely harmful

Note. Qualitative assessment was determined as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25% unlikely; 25–75% possibly; 75–95%, likely, 95–99%, very likely; >99%, almost certainly. HPLF = high-protein low-fat; MPMF = moderate-protein moderate-fat; CL = confidence limits; FFM = fat free mass; IMTP = isometric midthigh pull; DALDA = daily analysis of life demands of athletes; POMS = profile of mood states; TMDS = total mood disturbance score.

[a] Durnin & Womersley (1974)

[b] Yuhasz (1974)

[c] Peterson et al. (2003)

found when using each of the three equations that were implemented to assess body composition. However, all anthropometric differences between diets were very likely or almost certainly trivial.

IMTP strength losses were slightly less (1.1%) for the MPMF group but more than twice as variable as the HPLF group. However, differences in effect on isometric strength between diets was likely trivial.

General stress measured by part A of the DALDA, signs and symptoms of stress measured by part B of the DALDA and the part A "diet" item stress levels were higher in MPMF compared with HPLF. The effect sizes for these differences were small for part A (0.32) and B (0.4) of the DALDA and moderate for the part A "diet" item (0.65). POMS fatigue and TMDS were higher in the MPMF groups as well with small effect sizes (0.37 and 0.29, respectively) for these differences. Effects of MPMF compared with HPLF on all parts of the DALDA and POMS fatigue were assessed as likely harmful, and the effect on TMDS was assessed as possibly harmful. Grams of carbohydrate coming from maltodextrin were analyzed as a covariate separately to determine if these effects were related to carbohydrate source rather than amount; however, this analysis did not change the qualitative outcomes.

Discussion

The results of this pilot study are limited to resistance-trained males during short-term caloric restriction. In addition, the effects of this dietary intervention on performance outside of maximal isometric strength and indications of mood disturbance are unknown. Furthermore, our small sample size limits the ability to detect meaningful changes when dealing with a short-term observational period; thus the results of this pilot study should be seen as preliminary. Finally, the changes observed in FFM are subject to the inherent error present in body composition equations. In addition to its limitations, this study has a number of merits.

The participants that completed the study were among the few who originally expressed interest that were able to successfully complete the weeklong food diary. This removed potential participants who would have been the least adherent. In addition, a majority of the participants were competitive strength, physique or combat athletes and had experience with nutritional tracking and diet plans. We believe this, coupled with a nonjudgmental stance toward dietary mishaps and the encouragement of open communication, lead to a high degree of adherence. Finally, while anthropometric equations carry inherent error in regards to FFM changes, measurements of body mass and skinfold thickness when not used in an equation are reliable (± 0.4mm technical error of measurement in this study).

From the findings it is suggested that during short-term, high caloric-deficit (40%) diets, a high-protein (2.8g/kg) low-fat (mean 15.4% of calories) approach provides lower ratings of athlete-specific stress, fatigue, mood disturbance and diet dissatisfaction than a moderate-protein (1.6g/kg) moderate-fat (mean 36.5% of calories) approach. The finding of diet dissatisfaction being higher during MPMF is novel, because even though protein's satiating effect is documented (Leidy et al., 2010), rarely is it compared directly with fat. Rather, comparisons are typically made between carbohydrate and fat (Cotton et al., 2007). However, the psychometric findings cannot be attributed to satiety alone. The sole question related to nutrition appears on DALDA part A, while DALDA part B and the POMS have no questions related to diet, nutrition or hunger.

Fatigue subscale scores, TMDS and DALDA part B results indicate that athlete-specific stress and fatigue were meaningfully higher during MPMF. At high protein intakes as much as 60% of endogenous glucose production comes from gluconeogenesis (Bilsborough & Mann, 2006; Linn et al., 2000). Thus, it is possible that the HPLF group maintained higher levels of glycogen and had more readily available glucose, which could have reduced athlete-specific ratings of stress and fatigue.

Neither changes in strength nor anthropometrics were meaningfully different between diets. However, this is not entirely surprising given the length of this study, the fact that neither diet provided a low protein intake and because both diets were matched for energy and carbohydrate content. It is possible that had the diets lasted longer, the greater losses of FFM during MPMF and the greater losses of strength during HPLF could have become meaningful.

In terms of strength, there was a 19% chance that MPMF might prove to be a more beneficial approach to maintenance of peak force than HPLF, while there was practically no chance of the opposite. Intramuscular fatty acid levels are replenished to a much lesser degree when consuming 15% of calories from fat compared with 40% of calories from fat (Boesch et al., 2000). In addition, despite common perception that carbohydrate alone fuels resistance training, intramuscular triglyceride does contribute to energy expended during heavy resistance exercise of relatively short duration in men (Essen-Gustavsson & Tesch, 1990). Thus, it is possible that the low fat intake of 15% of calories in HPLF may have impacted training in some of the participants in such a way that IMTP peak force was negatively affected.

Future research should examine if body composition is an independent factor that exacerbates the effects of dieting and to what magnitude. In addition, longer periods of energy restriction may have significantly different ramifications than short-term diets and thus warrant study. Finally, study of female athletes during caloric restriction is lacking in comparison with their male counter parts and requires investigation.

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ERH conceptualized the study, determined the methods, recruited the participants, developed the diet plans, collected performance and psychometric data, analyzed the results, and wrote the manuscript. CZ assisted in conceptualizing the study, aided in diet plan development, communicated with participants regarding dietary matters, retained the blinding key and edited all parts of the manuscript. DSR assisted in conceptualizing the study and provided input on nutritional control, blinding and protein supplementation. RN collected anthropometric data and assisted with recruitment. JC assisted in conceptualizing the study and edited all parts of the manuscript. The authors would like to thank Cliff Harvey and NuZest for providing their product at a greatly reduced cost. In addition, we would like to acknowledge Seth Lenetsky for assisting in compiling data, Barbara Lyon for mixing powders and Professor Will Hopkins for his statistical guidance. Finally, we wish to sincerely thank the volunteers for undergoing such dietary interventions to help inform knowledge and practice in this field. There was no external financial support for this project.

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