Postexercise protein supplementation improves health and muscle soreness during basic military training in marine recruits

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Flakoll, Paul J., Tom Judy, Kim Flinn, Christopher Carr, and Scott Flinn. Postexercise protein supplementation improves health and muscle soreness during basic military training in marine recruits. *J Appl Physiol* 96: 951–956, 2004. First published December 2, 2003; 10.1152/japplphysiol.00811.2003.—Elevated postexercise amino acid availability has been demonstrated to enhance muscle protein synthesis acutely, but the long-term impact of postexercise protein supplementation on variables such as health, muscle soreness, and function are unclear. Healthy male US Marine recruits from six platoons (US Marine Corps Base, Parris Island, SC; $n = 387$; 18.9 ± 0.1 yr, 74.7 ± 1.1 kg, $13.8 \pm 0.4\%$ body fat) were randomly assigned to three treatments within each platoon. Nutrients supplemented immediately postexercise during the 54-day basic training were either placebo (0 g carbohydrate, 0 g protein, 0 g fat), control (8, 0, 3), or protein supplement (8, 10, 3). Subjects and observers making measurements and data analysis were blinded to subject groupings. Compared with placebo and control groups, the protein-supplemented group had an average of 33% fewer total medical visits, 28% fewer visits due to bacterial/viral infections, 37% fewer visits due to muscle/joint problems, and 83% fewer visits due to heat exhaustion. Recruits experiencing heat exhaustion had greater body mass, lean, fat, and water losses. Muscle soreness immediately postexercise was reduced by protein supplementation vs. placebo and control groups on both *days 34* and *54*. Postexercise protein supplementation may not only enhance muscle protein deposition but it also has significant potential to positively impact health, muscle soreness, and tissue hydration during prolonged intense exercise training, suggesting a potential therapeutic approach for the prevention of health problems in severely stressed exercising populations.

nutrient supplementation; infections; heat exhaustion; body composition; stress

US MARINE CORP recruits initiate their career with an intense period of basic exercise and discipline training, which is associated with considerable physical, mental, and emotional stress. This training instigates changes in metabolic events, increasing net catabolism, resulting in a loss of total and lean body mass (8, 13, 24). Lean body mass losses under a variety of conditions have been associated with immunosuppression, poor wound healing, decreased strength and activity, and functional impairment (32). Chronic strenuous exercise itself has been demonstrated to promote impaired immune function (5, 11).

Intense exercise training leads to muscle fatigue and soreness, as well as dehydration, muscle structural damage, free radical damage, lactic acid buildup, neutrophilia, muscle swelling, central nervous tissue fatigue, and catabolism of nutrient stores (2). Specifically, rigorous training in relatively "untrained" individuals leads to elevated counterregulatory hormones, increased metabolic flux and oxidation of carbohydrate, fat, and protein, depletion of muscle glycogen, net release of amino acids from muscle, stimulated hepatic gluconeogenesis, and negative nitrogen balance (30). Postexercise muscle recovery, repair, and growth, which ultimately determines the benefits of exercise to lean body mass, is reliant on glucose, amino acid, and energy availability for optimal rates of muscle glycogen and protein synthesis (3, 6, 14, 19, 20). However, links between postexercise nutrient availability and health, muscle soreness, and function have not been established. Therefore, the purpose of this study was to determine the impact of postexercise protein supplementation on recruit health, muscle soreness, and function during the stress of Marine basic training.

METHODS

Subject selection. Healthy adult male subjects ($n = 387$; 18.9 ± 0.1 yr of age) were recruited from six platoons at the Marine Corps Recruit Depot (Parris Island, SC). The subjects were required to be at least 18 yr of age and free from hepatic, pulmonary, thyroid, renal, or metabolic dysfunction as determined by a complete physical examination and medical history. Of the eligible individuals, 99.9% in each platoon participated. Each subject was provided with an explanation of the study, and informed, written consent was obtained for procedures to be performed. Experimental protocols and procedures were approved by the Naval Hospital (Beaufort, SC) and the Institutional Review Board of Clinical Investigation and Research, Naval Medical Center (Portsmouth, VA).

Experimental design. The subjects were randomly assigned within each of the six platoons to one of three treatment groups. Each group participated in the same activities for daily living (exercise, dietary intake, and training activities) throughout the 54 days of basic training, except for the nutrients provided after each of 27 training sessions. The training sessions consisted of 3 days of conditioning hikes (3-, 5-, and 10-mile hikes) and 24 days of conditioning using running (1–3 miles), sit-ups, push-ups, and pull-ups. In addition, the recruits were exposed to additional physical activity interspersed throughout the training days. This activity included 6 days of Marine Corps martial arts training, 4 days of swimming conditioning, and daily walking of >3 miles.

The first group ($n = 128$) received one nonnutritive placebo tablet (Breath Savers, Nabisco, Chicago, IL) as a single serving. This pill

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contained no protein, carbohydrate, or fat and was provided as a placebo (Pla). The second group ($n = 129$) received no protein, 8 g of carbohydrate, and 3 g of fat in a single serving (Orange Slice Confection, Brach Confections, Chicago, IL). This group received exactly the same amount of carbohydrate and fat as the group receiving protein and provided a nonprotein control (Con). Finally, the third group ($n = 130$) received 10 g of protein, 8 g of carbohydrate, and 3 g of lipid in a single serving (Pro; JogMate, Pharmavite, Mission Hills, CA). The subjects were not informed as to which treatments were Pla, Con, or Pro and were told that each of the treatments had equal potential to produce effects.

We did not formally assess whether subjects knew which group they were in, but we did ask them to rate their perceived fitness on a scale of 1–100 before the start of the study and at 34 days into the study. The perceived fitness values were not different between groups at the beginning of the study. Each of the groups rated their perceived fitness as higher after 34 days of training, but this improvement was not perceived to be different between groups (numeric increases of 7.6 ± 1.8, 7.5 ± 1.3, and 7.3 ± 1.9 for Pro, Con, and Pla, respectively). This suggests that the subjects did not appear to equate the physical appearance of their treatment with more improved fitness.

Members in each platoon were treated similarly, performing activities such as exercise and meal consumption together. There were an approximately equal number of subjects on each treatment within each platoon (*platoon 1*: 21, 21, 21; *platoon 2*: 23, 23, 23; *platoon 3*: 19, 19, 18; *platoon 4*: 20, 19, 20; *platoon 5*: 24, 25, 25; and *platoon 6*: 23, 22, 21 for Pla, Con, Pro, respectively), so exercise frequency and intensity were maintained constant between each treatment group. An exercise training event occurred every other day with a total of 27 events for each group. Additionally, each platoon participated together in activities not associated with exercise as well, maintaining consistency for nonexercise activities between groups. Food intake during regular meals was not controlled, but each treatment group had equal access to food. Nor were measurements of food intake made because of *1*) problems in defining the appropriate time over the course of the study to estimate intake, *2*) the lack of a definitive method to make this assessment, and *3*) difficulties associated with application of any such determination.

In each treatment group, the subjects were categorized into two subgroups on the basis of body mass, allowing those with greater mass to receive a greater treatment intake. Subjects initially <81.8 kg received one-serving portion, whereas those >81.8 kg received two-serving portions of their respective treatments. The protein, carbohydrate, and fat provided after each exercise session averaged 0, 0, and 0 g for Pla; 0, 9.6, and 3.6 g for Con; and 12, 9.6, and 3.6 g for Pro, respectively. The majority of protein, carbohydrate, and fat in the nutrient supplements were derived from casein, regular corn sugar, and milk fat, respectively. The subjects, drill instructors, data recorders, and data analyzers were not told which treatment contained protein, carbohydrates, or fat and were blinded to assigned treatment groups. Self-reported blinded exit surveys at the conclusion of the study suggested that compliance was excellent and similar between groups (99.7%).

Body composition. Total body mass (nearest 0.1 kg), height (nearest 0.5 cm), and composition measurements were made on the days before the initiation and at conclusion of the study. Subjects were measured in the same order within a 2-h period to maintain consistency between initial and final measurements. Body composition was estimated by bioelectrical impedance analysis determining whole body electrical resistance with a standard single-frequency (50 kHz) bioelectrical impedance analyzer (Body Composition Analyzer Quantum II, RJL Systems, Clinton Township, MI) and standard electrode placements (23). Three measures of resistance and reactance to a small current (~800 µA) were recorded to the nearest 1 Ω. Analyzer calibration with a 500-Ω test resistor differed by <1 Ω before and after the subject tests. Intrasubject coefficient of variability was $0.11 \pm 0.02\%$ for resistance and $0.25 \pm 0.05\%$ for reactance. Phase

angle, and body water, fat, and lean masses were calculated according to previously validated equations (Fluid & Nutrition Analysis Software, version 3.1b., RJL Systems; Refs. 17, 18).

Muscle soreness. Perceived muscle soreness was estimated by using a continuous-range evaluation (15, 16). The subjects self-reported their soreness on a scale from 1 to 10 (1 representing "no soreness—no impact on my training," 3 representing "soreness—minimal impact on training," 5 representing "sore—noticeable during training," 7 representing "very sore—uncomfortable to train", and 10 representing "so sore—I am unable to train"). It has been demonstrated that a linear relationship exists between a continuous-scale measurement, such as was used in our study, and a seven-point Likert scale that uses multiple questions to assess soreness (29). Soreness was assessed on the day of and the day after three events during the study. The first pair of assessments was made immediately after and 24 h after the recruit's initial strength testing (IST) on the initial day. The IST, which consisted of each recruit's maximum number of sit-ups and pull-ups as well as a 1.5-mile run, was conducted the day before study initiation. The second pair of assessments was made after a 6-mile full-gear hike on *day 34*. The third pair of assessments was made after the recruit's final physical fitness testing (PFT) event on *day 54*. The final PFT consisted of each recruit's maximum number of sit-ups and pull-ups as well as a 3-mile run.

Health assessment. General health was assessed by recording each visit made to the Branch Medical Clinic or Battalion Aid Station, with professional medical diagnosis and treatment being required for each event to be placed into the following categorizes: *1*) bacterial/viral-based infections, *2*) muscle/joint-based problems not due to impact with external objects, *3*) heat exhaustion, *4*) preexisting problems, *5*) heart anomalies, *6*) rashes, *7*) abrasions, *8*) nose bleed/tooth eruption, and *9*) mental health problems. Heat exhaustion was defined as elevated body temperature (>39.2°C) without a related illness, such as an infection. When patients were examined, medical personnel did not know whether they were or were not participating in the study and thus were blinded to each subject's treatment. Furthermore, tabulation of the medical visits was done in a blinded fashion.

Rifle scores. Previous research at the Naval Medical Research Institute measured changes in marksmanship performance with marine sharpshooters as a measure of mental and physical function (26). In the present study, rifle (M-16) range scores of each of the recruits during a formal competition were recorded as a surrogate for function according to standard US Marine Corps procedures. Marine personnel were blinded to whether subjects were on treatment, and tabulation and recording of the scores were blinded.

Statistical analysis. Values presented in the text, figure, and tables are means ± SE. Differences between treatments for the initial variables, final variables, and changes between initial and final variables were assessed by using an ANOVA with the general linear models procedure of the Statistical Analysis System (SAS; Statistical Analysis System for Windows, 1996, Release 6.12, SAS Institute, Cary, NC) with the main effect being the supplementation treatment. The interaction of treatment effects with body mass subgroups was not significant, and thus data are reported excluding subgroup analysis. The comparisons of Pro vs. Pla or Pro vs. Con were selected a priori to apply post hoc *t*-test analysis. Differences between the treatment groups for variables of health were assessed by using χ^2 analysis (SAS). Statistical significance was set at $P < 0.05$, and a trend was declared if $0.10 < P > 0.05$.

RESULTS

Subject demographic data were not different between treatment groups, and thus overall means are reported. Ethnicity was as follows: 70.5% Caucasian, 13.7% African American, 8.0% Hispanic, 1.0% American Indian, and 5.2% either unknown or not reporting. Forty-two percent of the subjects reported a history of smoking an average of 0.9 ± 0.1 packs of

cigarettes daily over an average period of 2.8 ± 0.3 yr, and 17% reported previously using chewing tobacco. The self-reported fitness of the subjects before the study was 5.1 ± 0.2 on a scale of 1 (highest) to 10 (lowest). Before the study, the subjects reported a frequency of exercise as follows: 16.9% less than once per month, 22.1% less than once per week, and 61.0% greater than once per week. Only 36.8% exercised at that particular frequency for >6 mo.

The number of subjects discontinuing participation ($n = 26$) was distributed similarly across treatment groups (Pla = 8, Con = 8, Pro = 10). Fourteen were reassigned to another platoon, 10 were removed from the US Marine Corps because of discipline problems, 1 did not like the taste of the placebo, and 1 was removed due to a mental health-related problem.

Initial body mass, stature, and body composition measurements were not different between treatment groups, and thus overall means are displayed (Table 1). In addition, initial determinations of resistance (426.4 ± 4.5 Ω), reactance (57.5 ± 0.7 Ω), and phase angle ($7.74 \pm 0.7°$) were not different between groups. Body composition measurements suggested that recruits initially were of normal hydration and not obese (range of body fat from 4.2 to 24.0%).

Over the 54-day training period, there were 296 visits to the Branch Medical Clinic and Battalion Aid Stations for treatment of diagnosed bacterial/viral diseases (Table 2) with the number of visits with Pro being 14% less than Pla and 40% less than Con. Furthermore, there were 121 visits for treatment of muscle/joint pain with the number of visits with Pro being 49% less than Pla and 17% less than Con. There were a total of 13 heat exhaustion cases reported during the 54-day period with only 1 from the Pro group. Therefore, total medical visits due to bacterial/viral diseases, muscle/joint pain, and heat exhaustion were 430, and the cases from Pro were 36% less than Pla and 29% less than Con. The number of cases due to preexisting conditions ($n = 4$), heart anomalies ($n = 6$), rash ($n = 35$), abrasions ($n = 24$), wisdom tooth eruptions/nose bleeds ($n = 5$), and mental health problems ($n = 3$) were not different between the treatment groups.

Initial muscle soreness was not different between the three groups on the day of (2.67 ± 0.14 units on the muscle soreness scale) or the day after the IST (3.24 ± 0.16 units). At 34 days into the training period, muscle soreness immediately after a

Table 1. *Initial body composition*

	Placebo	Control	Protein Supplement
Body mass, kg	74.4 ± 1.1	74.8 ± 0.9	74.9 ± 1.2
Height, cm	177.6 ± 0.6	177.1 ± 0.6	177.0 ± 0.6
BMI, kg/m^2	23.1 ± 0.3	23.4 ± 0.3	23.4 ± 0.3
Lean mass, kg	63.7 ± 0.7	64.0 ± 0.6	64.0 ± 0.7
Fat mass, kg	10.6 ± 0.5	10.8 ± 0.4	10.9 ± 0.5
Fat mass, %	13.7 ± 0.4	14.0 ± 0.4	13.9 ± 0.4
Cell mass, kg	30.9 ± 0.3	31.3 ± 0.3	31.5 ± 0.3
Extracellular mass, kg	29.7 ± 0.3	29.7 ± 0.3	29.8 ± 0.3
Total water, liters	44.4 ± 0.4	44.8 ± 0.4	45.0 ± 0.5
Intracellular water, liters	28.2 ± 0.3	28.6 ± 0.3	28.8 ± 0.3
Extracellular water, liters	16.2 ± 0.3	16.2 ± 0.2	16.3 ± 0.2

Values are means $\pm$ SE of initial body composition measurements made on the day before the study initiation. BMI, body mass index. There were no significant differences ($P > 0.05$) between treatment groups for any of the variables.

Table 2. *Summary of medical visits*

	Placebo	Control	Protein Supplement
Number of visits for bacterial/viral treatment	127‡	91*	78
Number of visits for muscle/joint treatment	35†	57‡	29
Number of visits for heat exhaustion treatment	7†	5*	1
Total number of visits	169‡	153‡	108

Values are means $\pm$ SE of number of visits made by the recruits for medical treatment in each groups. *Statistical trend ($P < 0.1$), †statistical difference ($P < 0.05$), ‡statistical difference ($P < 0.001$) between the placebo or control treatments vs. the protein supplement treatment.

6-mile full-gear hike was increased vs. the initial day by 10% with Pla ($P < 0.05$) and 16% with Con ($P < 0.05$; Fig. 1). Pro was significantly different from the other groups because muscle soreness was reduced by 7% with Pro ($P < 0.05$). Again, Pro was significantly ($P < 0.05$) different from the other groups because muscle soreness 1 day after the 6-mile hike was slightly increased with Pla (3%) and Con (5%), but muscle soreness was decreased with Pro by 17% ($P < 0.05$). Compared with initial values, muscle soreness immediately after the final PFT was improved significantly ($P < 0.05$) more with Pro (26%) than with Pla (9%) and Con (13%). Improvement in muscle soreness on the day after the final PFT was similar for all three groups.
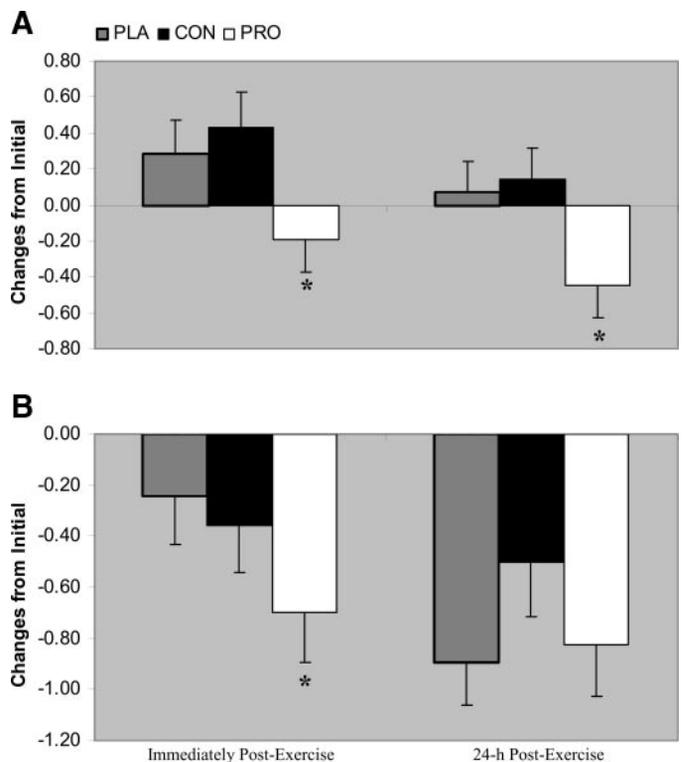

Fig. 1. Changes in muscle soreness score units from the initial day to either *day 34* (A) or the final day (B). Pla, placebo (0 g carbohydrate, 0 g protein, 0 g fat); Con, control (8 g carbohydrate, 0 g protein, 3 g fat); Pro, protein supplement (8 g carbohydrate, 10 g protein, 3 g fat). Measurements were made either immediately after exercise (*left*) or the day after exercise (*right*). Values are means $\pm$ SE. Positive values represent increased muscle soreness, and negative values represent decreased muscle soreness. *$P < 0.05$ difference for Pro vs. Pla and Con.

Table 3. *Changes in body composition*

	Placebo	Control	Protein Supplement
Total mass, kg	−5.04±0.53	−4.65±0.52	−4.49±0.60
Lean mass, kg	−3.08±0.28	−2.93±0.26	−2.74±0.29
Fat mass, kg	−1.96±0.31	−1.72±0.32	−1.75±0.35
Cell mass, kg	−2.51±0.24	−2.29±0.25	−2.23±0.27
Extracellular mass, kg	−0.57±0.19	−0.65±0.21	−0.51±0.20
Total water, liters	−2.58±0.24	−2.48±0.22	−2.30±0.24
Intracellular water, liters	−2.29±0.22	−2.08±0.23	−2.03±0.25
Extracellular water, liters	−0.29±0.15	−0.40±0.17	−0.27±0.15

Values are means ± SE of changes in body composition over the course of the 54-day study [final day vs. initial day (note Table 1) measurements]. None of the differences between the treatment groups were statistically significant ($P > 0.05$).

Rifle scores, as an estimate of functionality, averaged 207.1 ± 1.2, 209.3 ± 1.2, and 209.4 ± 1.1 for Pla, Con, and Pro, respectively. The scores with Pro were significantly greater than those with Pla, but they were not different than Con.

Over the 54-day study, significant losses in total body mass, lean mass, fat mass, and body water were noted for each group (Table 3). However, although interesting trends existed, none of the changes were statistically different between treatment groups. For example, there tended ($P < 0.1$) to be a blunting of total body mass loss with Pro (−16 and −8% vs. Pla and Con, respectively). Also, recruits in the Pro group lost 3.9 ± 0.4% of their initial lean body mass, which tended ($P < 0.1$) to approach statistical significance to be 15 and 13% less vs. both Pla (4.6 ± 0.4%) and Con (4.4 ± 0.4%), respectively. Similarly, total body water losses for Pro tended ($P < 0.01$) to be 13% less than Pla and 10% less than Con.

DISCUSSION

Basic training for US Marine Corps recruits is mentally, emotionally, and physically very stressful. Catabolism due to these demanding events has been hypothesized to cause losses in lean body mass, to compromise health, and to reduce function. Evidence from our study support this concept because the recruits had significant losses of total body mass, lean body mass, cell mass, and body water over the 54-day period. Furthermore, there was an average of 1.6 medical visits per recruit over the training period. Whereas previous studies have suggested that postexercise protein supplementation has the potential to improve muscle protein deposition (19, 20, 27, 28), the present study suggests that postexercise protein supplementation also has significant potential to impact health, muscle soreness, and hydration during intense exercise training.

During intense exercise, muscle amino acid oxidation and hepatic use of amino acid carbons for gluconeogenesis are accelerated (30). Additionally, exercise causes energy to be directed toward the needs of muscle contraction and away from the events of protein synthesis. During the postexercise recovery phase, availability of both amino acids and energy has the potential to limit the synthesis of muscle proteins. However, studies in which postexercise energy supplementation positively influenced protein synthesis are nonexistent. In fact, intake of 60 kcal of nonprotein energy immediately postexercise did not improve whole body or muscle protein synthesis vs. fasting (19). Conversely, previous studies have demonstrated a positive impact on postexercise protein synthesis for supplementation of amino acids or protein at a dose similar to that in the present study (3, 19, 20). However, data linking results for protein synthesis to muscle soreness, health, and function are limited.

Previously, a strong link has been established between impaired immune function, a high incidence of upper respiratory tract infections, and strenuous prolonged exercise (5, 11). This study demonstrates that several health parameters were better maintained with postexercise protein supplementation in marine recruits. Unfortunately, the mechanisms linking postexercise protein supplementation and the observed health improvements are only speculative. The mechanism does not appear to be due to changes in body composition. Although loss of lean body mass in a variety of settings has been demonstrated to prolong convalescence via immunosuppression and poor wound healing (31, 32), losses of total body mass, lean mass, fat mass, and water in this study were not more severe in subjects with bacterial/viral infections (Table 4). Previous studies have also shown that exercise causes significant catabolism of gastrointestinal tract protein (9), which may lead to diminished gut integrity, increased gut permeability, and elevated translocation of bacteria. Therefore, one potential mechanism is that postexercise protein intake may blunt exercise-induced gut protein catabolism (10), thereby reducing bacterial infections. Finally, a likely mechanism could involve the increased availability of specific amino acids known to modulate immune function (e.g., glutamine or arginine) with postexercise protein supplementation.

Although the reductions in losses of overall weight, lean body mass, and water mass tended to be attenuated with Pro vs. Pla or Con (average reductions of 12, 13, and 12%, respectively), method sensitivity and study length diminished the statistical significance of these differences. However, the direction of these changes in lean body mass is supported by previous short-term studies using techniques more sensitive to acute changes in whole body and muscle protein homeostasis (3, 19, 20). Conclusions can be made based on these acute studies that postexercise protein supplementation limits muscle damage and/or hastens muscle repair and recovery, supporting the observations of reduced muscle soreness and improved rifle scores. Previous studies also have focused on supplementation

Table 4. *Changes in body composition related to variables of health*

	Total Mass Loss	Lean Body Mass Loss	Fat Mass Loss	Water Volume Loss
−HE	−5.5±0.4	−4.2±0.2	−7.7±2.0	−4.8±0.3
+HE	−9.1±2.6*	−6.0±1.2*	−24.8±7.7*	−6.5±0.3*
−B/V	−5.4±0.5	−4.2±0.3	−7.7±2.4	−4.9±0.3
+B/V	−5.9±0.7	−4.3±0.3	−8.9±3.3	−4.8±0.4
−M/J	−5.4±0.4	−4.2±0.3	−6.6±2.3	−4.8±0.3
+M/J	−6.6±0.7*	−4.6±0.5	−15.0±3.6*	−5.1±0.5

Values are means ± SE of changes in body composition over the course of the 54-day study expressed as a percentage of initial body composition values. Values are for subjects without and with medical visits due to heat exhaustion (−HE and +HE), without and with medical visits due to bacterial/viral infections (−B/V and +B/V), and without and with medical visits due to muscle/joint pain (−M/J and +M/J). *Statistical difference ($P < 0.05$) between −HE and +HE, between −B/V and +B/V, or between −M/J and +M/J.

of tryptophan (22), branched-chain amino acids (12), and tyrosine (21) to alter cognitive function and neural activity. Protein supplementation would alter the availability of these amino acids, altering feelings of fatigue in humans exposed to intense exercise and extreme psychological stress. Additional research will be warranted to establish improvements in other physical and cognitive functions.

In acute and longer term studies, timing of postexercise protein supplementation has been implicated as playing an important role in enhancing protein accretion and altering body composition (7, 20). Even relatively small increases in protein intake, when given at a time when insulin sensitivity and blood flow to muscle tissue are elevated (immediately postexercise), have potential to provide a benefit to overall protein homeostasis and accretion.

Dehydration can lead to hyperthermia, nervous system imbalances, ventricular fibrillation, and death. Indeed, even slight dehydration results in diminished physical performance (1). A previous hypothesis proposed that high-protein diets may cause diuresis as a result of increased urea production and an associated excretion by the kidney (4). However, the reduced number of heat exhaustion cases in Pro was relatively dramatic in the present study. One possible explanation for this observation is that greater lean mass and water losses led to increased heat exhaustion. Overall, subjects with heat exhaustion had losses of total body weight, body lean mass, body fat, and body water that were 76, 43, 222, and 35% greater, respectively, than for subjects without heat exhaustion (Table 4). Another difference between supplementing with Pro vs. Con or Pla would be the potential for increased cellular amino acid concentrations and enhanced cell swelling (25). Increased amino acid availability also may increase the synthesis of albumin and other blood protein solutes, stabilizing body water. However, these hypotheses will require further study.

Conclusions from these data have to be made within the context of the study design. There were three possible ways to control for the protein supplement used in this study: *1)* administer a nonnutritive placebo (Pla), *2)* maintain carbohydrate and fat supplementation identical to the protein supplement (Con), or *3)* maintain energy supplementation identical to the protein supplement by increasing carbohydrate or fat supplementation above that in the protein supplemented group. We opted to use *options 1* and *2*, because whereas several studies, including those from our laboratory, have demonstrated that postexercise protein and free amino acid supplementation improved muscle protein accretion (19, 20, 27, 28), and previously our laboratory has shown that increasing postexercise supplement energy had no impact on protein metabolism (19). From the present design, we can conclude that protein supplementation did have significant effects. However, we cannot absolutely distinguish whether this is due to the amino acids being used for protein synthesis or energy. It is doubtful, however, that increasing the energy intake from 60 kcal (Con) to 100 kcal (Pro) would account for the results observed.

With the size of the population tested and the distribution of treatments across platoons, it is very likely that the random distribution of food and fluid intake was not significantly different between groups. However, even with the most sophisticated techniques available, it would have been difficult to adequately address this point. It would have been difficult to determine when, over the 54-day period, intake measurements could have been made, and furthermore, the precision of such measurements most likely would not have strengthened our conclusions. However, the data need to be interpreted, considering the remote possibility that the treatments may have altered daily food and fluid intake.

In conclusion, postexercise protein supplementation in a blinded placebo-controlled experiment with US Marine recruits during basic training resulted in reduced bacterial/viral infections, decreased medical visits due to muscle or joint problems, diminished episodes of heat exhaustion, reduced muscle soreness, and improved rifle scores. Therefore, whereas previous studies have suggested that postexercise protein supplementation has the potential to improve muscle protein deposition, this study suggests that postexercise protein supplementation also has significant potential to impact health, muscle soreness, and hydration during intense exercise training.

DISCLOSURES

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or US Government. Furthermore, the results from this study do not constitute endorsement of any product by the authors.

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