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# The Impact of Protein Content on Athletes' Body Composition

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***Abstract*—**Several factors contribute to success in sport and diet is one of them. Evidence-based sport nutrition guidelines underline the importance of macro- and micro-nutrients' balance and timing in order to improve athlete's physical status and performance. Nevertheless, a high content of proteins is commonly found in resistance training athletes' diet with carbohydrate intake that is not enough or not well planned. The aim of the study was to evaluate the impact of different protein and carbohydrate diet contents on body composition and sport performance on a group of resistance training athletes. Subjects were divided as study group (n=16) and control group (n=14). For a period of 4 months, both groups were subjected to the same resistance training fitness program with study group following a specific diet and control group following an *ab libitum* diet. Body compositions were evaluated trough anthropometric measurement (weight, height, body circumferences and skinfolds) and Bioimpedence Analysis. Physical strength and training status of individuals were evaluated through the One Repetition Maximum test (RM1). Protein intake in studied group was found to be lower than in control group. There was a statistically significant increase of body weight, free fat mass and body mass cell of studied group respect to the control group. Fat mass remains almost constant. Statistically significant changes were observed in quadriceps and biceps circumferences, with an increase in studied group. The MR1 test showed improvement in study group's strength but no changes in control group. Usually people consume hyper-proteic diet to achieve muscle mass development. Through this study, it was possible to show that protein intake fixed at 1,7 g/kg/d can meet the individual's needs. In parallel, the increased intake of carbohydrates, focusing on quality and timing of assumption, has enabled the obtainment of desired results with a training protocol supporting a hypertrophic strategy. Therefore, the key point seems related to the planning of a structured program both from a nutritional and training point of view.

***Keywords*—**Body composition, diet, exercise, protein.

## I. Introduction

IT is becoming increasingly clear that diet is one of the most influential factors on athletes' health and performance [1]. Different arranged proportions of macro- and micro-nutrients depending on athlete characteristics and all the variables related to the sport practiced seem to directly influence the performance. Moreover, athlete's nutrition will indirectly affect performance by leading to significant changes in body composition. During the past 50 years, there were strong efforts and great progresses in the scientific understanding of the role of nutrition in health and physical performance [1], [2]. Science of nutrition related to sports performance and physical achievements has progressed from empirical studies investigating the effect of dietary manipulations to the direct investigation of the physiological basis of specific demands related to sport-specific metabolic (biochemical) implications [3]. Starting from increased knowledge of exercise physiology and increased number of reports and studies, it was possible to construct specific sport nutrition guidelines in recent years [3] [4]. It is known that exercise adaptations can be both amplified or reduced by nutritional strategies. Sport nutrition professionals and sport nutritionist are now able to structure individualized dietary advice with specific macro- and micro-nutrients intake and timing of assumption. The International Society of Sport Nutrition (ISSN)'s guidelines published in 2010 represent one of the reference documents in this field [4]. First of all, athletes must consume enough calories to balance energy expenditure to optimize training and performance.

Secondly, macronutrients must be optimized to improve training and performance [4]. In sport nutrition, carbohydrates are essential to replenish muscle glycogen storage. Moreover, protein daily intake should increase due to amino acids oxidation during the exercise [4].

Other investigations report how it is also important to "periodize" nutrition according to season period and athlete goals [5]. Hawley et al. showed how carbohydrate loading (depletion phase followed by high intake) results in improvements of glycogen stores prior to an endurance exercise [6].

As far as protein intake, there are many and controversial studies that have tried to find the right daily intake depending on training and specific goals. A positive net protein balance is related to an increase in skeletal muscle mass. [7]. Several studies suggest how increased mechanical loading (well formulated resistance training program) and provision of high quality amino acids (right protein ratio and quality) are potent and independent stimulators of muscle protein synthesis through activation of key cell signaling pathways involving the mTOR-p70S6K signaling axis [7].

Usually in strength, power and/or resistance training disciplines, health professionals, media and popular diet books/papers gave the advice to consume high-protein diet despite lack of scientific data on the safety and right amount to achieve muscular development and without considering other variables and nutrients intake [8]. For example, a recent study reported how is common in gym to overreach daily protein needs both by consumption of high-protein foods especially poultry and meat and by utilization of protein powders (food supplements) [9].

Parallel to this information, study like that published by

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Antonio et al., underline how high-protein diet (4.4 g/kg/d) compared to suggested intake from sport nutrition guidelines (1.4-2.0 g/kg/d) in individuals involved in resistance training protocol do not report significant changes over time in terms of body composition [10]. In addition, high protein consumption is reported to be related to different negative outcomes like disorders of bone and calcium homeostasis, impaired renal functions, increased cancer risk, disorders of liver function and progression of coronary artery disease especially in a caloric surplus state and with high carbohydrate intake [11]. For athletes (both involved in resistance training or endurance), proteins represent a key factor to improve body composition. Moreover, in resistance training/strength and power disciplines, proteins' importance, in terms of muscle mass gain, is reflected on increased daily intake requirements [12]. Exercise physiology studies report how alternating cycles of high-volume to cycles of high intensity workouts will provide a complete range of muscle fibers activation providing a satisfactory stimulus/recovery for all the different types of muscle fibers in the human body [13]. In this regard, it is important to underline the role of carbohydrate as the predominant fuel source for moderate to high intensity activities. When muscle glycogen stores are diminished, fatigue is eminent. Inadequate glycogen stores will decrease the exercisers' ability to maintain appropriate exercise intensities. Muscle glycogen can decrease of about 25-40% during multiple set of resistance exercise [14]. The role of carbohydrates in resistance training programs is indirect. First of all, they will constitute the fuel to give the maximum during the training, secondly the importance of recovery of energy storage will function as a signal that there is enough energy to start the recovery process (muscle anabolism and muscle protein synthesis). From this, it is important to underline that to achieve muscular development goals, after planning a well-structured training plan, it will be important to provide high biological value protein and carbohydrates in the right amount and timing and fat from high quality sources.

## II. Material and Methods

### A. Study Design

30 subjects participated to the study divided as study group and control group both subjected to a specific resistance training for 4 months. Study group followed also a specific diet (Fig. 1).

Body composition was evaluated at the beginning and every month (t0, t1, t2, t3 and t4).

The one repetition maximum test (1RM) was performed at the beginning (t0) and at the end of the study (t4). In addition to this, at the beginning of the study and at the end, participants were invited to write a weekly daily food record, both qualitative and quantitative, specifying type and quantity of foods and drinks consumed, physical activity level and use of drugs (Fig. 2). Food records were analysed through WinFood® software and evaluated using "Mediterranean Diet Adherence Screener" (MEDAS) dietary score (0-14 score) to get the Mediterranean Diet adherence value of each participant [15].

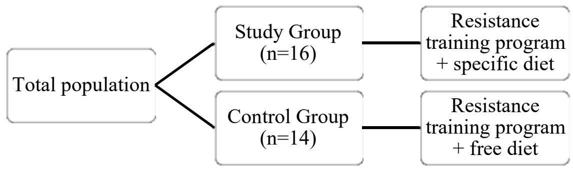


Fig. 1 Study design

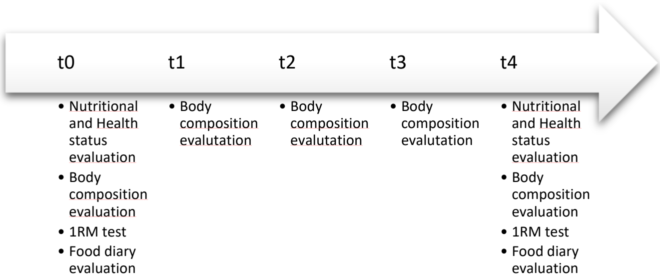


Fig. 2 Study protocol

### B. Subjects

30 male subjects (aged 18-50) took part in the study.

All participants were physically active and free from musculoskeletal injury.

Participants were excluded if they were involved in other training programs or consuming sport supplements.

### C. Body Composition Evaluation

Body Anthropometric data were collected following standardized international procedures and guidelines described in the NHANES manual [16], [17].

Weight, height, body circumferences and skinfolds were collected for each subject. Weights were measured using a mechanical balance scale (Wunder RB200) with a precision of 0.01 kg. Heights were measured shoeless using a stadiometer (Wunder HR1) with a precision of 0.1 cm. The measure was taken checking the correct position of the head in the standard position of reference Frankfurt plane.

Body circumferences were taken using a non-stretchable fiberglass insertion tape with a precision of 0.1 mm in different sites: abdominal, chest, left and right arms (both relaxed and contracted), left and right tight (Proximal, Mid and distal) and left and right calf.

Skinfold thicknesses were measured using a GIMA Skinfold Calliper with a precision of 0.2 mm, at different sites on the right site of the body: triceps, biceps, mid-axillary, chest, subscapular, abdominal, suprailiac, thigh, calf.

Percentages of fat mass were estimated using Jackson & Pollock equations (both 3- and 7-sites) [18].

Bioelectrical Impedence Test (BIA) was performed to evaluate tri-compartimental body composition using a BIA AKERN 101 (AKERN, Florence, Italy). Both conventional and vectorial analyses were performed. Resistance (Rz) and Reactance (Xc) were measured through tetrapolar impedance method applying a constant, low level alternating current (50 kHz).

BIA measure was taken with subjects in supine position using two current-introducing electrodes in the middle of the dorsal surfaces of the right hand and foot [19], [20].

Conventional analysis was performed evaluating the value of Resistence and Reactance and using BodyGram Plus© software. Total Body Water (TBW), Free Fat Mass (FFM), Body Cell Mass (BCM) and Body Cell Mass Index (BCMI) were considered.

BIA vectorial analysis was performed using BodyGram Plus© software [21].

### *D. Physical Strength Evaluation*

One repetition maximum test (1RM) was performed at the beginning and at the end of the study to assess strength and fitness levels. 1RM is defined as the highest resistance at which one repetition could be successfully completed with acceptable form [22].

The 1RM determination started with 2 separate sessions dedicated to the understanding of the proper exercise technique. Then, after a warm-up of 8 repetitions, 3 repetitions were performed (with 1 minute of rest). At the end, the weight was increased until only one repetition was performed with the right technique. The tests were conducted for four exercises namely leg press, bench press, lat-machine and shoulder press.

### *E. Diet*

For the study group, the diet was planned taking into account both the "Italian Nutrients and Caloric References of Intake" guidelines and The ISSN guidelines [23], [24]. In this regard, the protein requirement has been fixed between 1.6 and 1.7 g/kg/d, carbohydrates at 6.0-6.2 g/kg/day and lipids at 30-35% of the total diet's kcal.

### *F. Training Sessions*

Both groups took part in a supervised, progressive 16 weeks' strength/hypertrophy resistance training program structured in two different "mesocycles", with 45–90 minutes sessions, three to five days a week, performing three-four sets of 60-85% of 1RM, 6-12 repetition with one to two-minute rest between sets.

Each training session was divided in 4 parts: warm-up, stretching, conditioning (resistance training) and cool-down according to the recommendation by the American College of Sports Medicine (ACSM)'s guidelines [25], [26]. The training sessions consisted of 10 minutes warm up on stationary bicycles, running on treadmill, followed by stretching exercises targeting larger muscles groups. Then, resistance training exercises on the resistance machines and free weights exercises targeting large muscle groups were performed. At the end, five to seven minutes of cool down were performed.

Daily records of performance by each subject were collected. In particular, loading used for each exercise, number of repetitions completed for each of the three sets and sensation were registered.

### *G. Statistical Analysis*

Statistical Analysis were performed using SigmaStat 4.0© performing Student's t-tests and ANOVA test.

Results are presented as means ± SD. Significance level was set at $p \leq 0.05$.

## III. RESULTS

A total of 30 subjects were involved in the study. Subjects were divided as study group (n=16) and control group (n=14). Groups were balanced by age, height, and body weight (Table I).

TABLE I
PARTICIPANT CHARACTERISTICS AT BASELINE (TO)

| | Study group (n=16) | Control group (n=14) |
|---|---|---|
| Age | 28.43 ± 8.53 | 31.16 ± 11.04 |
| Height (cm) | 173.87 ± 8.26 | 171.23 ± 7.54 |
| Body Weight (kg) | 67.13 ± 8.98 | 72.96 ± 15.58 |

Data are shown as mean (±standard deviation).

The characteristics of the diet at t0 are shown in Table II.

TABLE II
DIET CHARACTERISTICS AT BASELINE (T0)

| | Study group (n=16) | Control group (n=14) |
|---|---|---|
| Energy (kcal/day) | 2584.00 ± 506.03 | 2780.00 ± 386.34 |
| Carbohydrates (g/kg B.W./day) | 5.58 ± 0.89 | 5.13 ± 0.32 |
| Proteins (g/kg B.W./day) | 2.24 ± 0.29 | 2.26 ± 0.27 |
| Fat (g/kg B.W./day) | 1.24 ± 0.12 | 1.20 ± 0.15 |

Data are shown as mean (±standard deviation).

Study group diet was modified as reported in Table III. Proteins of the study group were set at 1.78 ± 0.12 g/kg/day vs 2.24 ± 0.28 g/kg/day in control group with the free diet.

TABLE III
STUDY GROUP'S DIET CHARACTERISTICS AT BASELINE AND DURING THE STUDY

| | Study group diet at baseline (t0) | Modified Study group diet |
|---|---|---|
| Energy (kcal/day) | 2584.00 ± 506.03 | 3043.00 ± 532.92 |
| Carbohydrates (g/kg B.W./day) | 5.58 ± 0.89 | 6.51 ± 0.74 |
| Proteins (g/kg B.W./day) | 2.24 ± 0.29 | 1.78 ± 0.12 |
| Fats (g/kg B.W./day) | 1.24 ± 0.12 | 1.40 ± 0.07 |

Data are shown as mean (±standard deviation).

Body composition measurements are shown in Table IV. From anthropometric data, body weight increased in study group respect to baseline ($p < 0.05$). This is also reflected in an increase of BCM ($p < 0.05$), BCMI ($p < 0.05$) and Phase Angle ($p < 0.05$) obtained from bioimpedence analysis. TBW slightly increased in study group ($p < 0.05$) as intracellular water. No significant changes were observed in extra cellular water.

At the end of the study, body weight increase result is significantly different between study group and control group ($p < 0.05$, treatment over 4 months). This is also found in BCM, BCMI and phase angle. No significant differences were found in fat mass and TBW between the 2 groups. Bicep circumferences increased both in study group and in control group, on the other hand quadricep circumferences increased significantly only in study group.

TABLE IV
BODY COMPOSITION MEASUREMENTS

| | Study group (n=16) | | Control group (n=14) | |
|---|---|---|---|---|
| | t0 | t4 | t0 | t4 |
| Body Weight (kg) | 67.14 ± 8.99 | 69.96 ± 10.36* | 72.96 ± 15.58 | 73.05 ± 15.73† |
| BCM (Kg) | 33.60 ± 5.45 | 39.97 ± 3.21* | 34.44 ± 6.90 | 35.13 ± 6.62† |
| BCMI (Kg/m) | 11.08 ± 1.33 | 12.03 ± 1.47* | 10.61 ± 0.86 | 10.65 ± 1.01† |
| BMI (Kg/m$^2$) | 22.25 ± 2.02 | 23.06 ± 1.94* | 23.41 ± 3.05 | 23.43 ± 3.29† |
| BMR (kcal) | 1715.62 ± 157.64 | 1824.37 ± 175.53* | 1742.50 ± 162.67 | 1763.57 ± 164.48*† |
| FM (%) | 11.17 ± 4.29 | 10.29 ± 4.04 | 8.55 ± 6.16 | 8.36 ± 6.43 |
| TBW (L) | 42.26 ± 6.87 | 43.68 ± 7.19* | 43.68 ± 6.91 | 44.43 ± 7.39 |
| ECW (L) | 17.12 ± 2.98 | 17.13 ± 2.61 | 18.71 ± 3.83 | 19.07 ± 4.85 |
| ICW (L) | 24.53 ± 4.33 | 26.01 ± 4.52* | 25.02 ± 4.20 | 25.16 ± 4.08† |
| PA | 7.10 ± 0.53 | 7.48 ± 0.52* | 7.02 ± 0.51 | 7.20 ±0.61 |
| Bicep circumference (cm) | 30.56 ± 3.54 | 33.86 ± 3.93* | 30.82 ± 4.13 | 31.27 ± 3.87*† |
| Quadricep circumference (cm) | 50.58 ± 2.91 | 53.66 ± 3.40* | 52.92 ± 3.50 | 52.92 ± 3.50† |

Data are expressed as mean (±standard deviation).

BMI= Body Mass Index, BMR= Basal Metabolic Rate, FM= Fat Mass, ECW= extracellular water, ICW= intracellular water, PA= phase angle.*significantly different from T0 ($p < 0.05$), † significantly different between the 2 groups

Strength significantly increased in all the 4 exercises in study group (Table V) but not in control group.

TABLE V
STUDY GROUP'S DIET CHARACTERISTICS AT BASELINE AND DURING THE STUDY

| | Study group | | |
|---|---|---|---|
| | t0 | t4 | Delta |
| Bench Press (Kg) | 43.73 ± 22.26 | 55.59 ± 25.93* | +12.22 |
| Leg Press (Kg) | 118.75 ± 56.55 | 152.93 ± 34.18* | +34.18 |
| Shoulder Press (Kg) | 29.31 ± 15.23 | 39.00 ± 16.76* | +9.68 |
| Lat Machine (Kg) | 47.50 ± 22.50 | 57.81 ± 24.18* | +10.31 |

Data are shown as mean (±standard deviation).
*significantly different from t0 ($p < 0.05$)

## IV. DISCUSSION

Diet is one of the main aspects that contribute to success in sport. As reported by Jeukendrup, there are several factors able to determine and influence the adaptive response to exercise training. These are both related to duration, intensity, frequency and type of exercise but also to quality and quantity of nutrition pre- and post-exercise. Nutrition and exercise resulted to be strictly connected and nutrition per se can influence and determine performance outcomes [5]. Dietary requirements of athletes depend on several factors (i.e. disciplines and goals). The importance of individualized dietary advice has been increasingly recognized, including day-to-day dietary advice with specific timing. The ISSN [27] stated that to optimize training and performance through nutrition is of fundamental importance to ensure that athletes consume the proper amounts of calories, carbohydrate, protein and fat in their diet. In particular, focusing the attention on athletes involved in moderate amounts of intense training, ISSN suggests consuming a diet consisting of 55-65% carbohydrate (i.e., 5-8 grams/kg/day or 250-1,200 grams/day for 50-150 kg athletes) to maintain liver and muscle glycogen stores. In resistance training, carbohydrates are important during the exercise as fuel but also in the recovery as energy storage function [14].

The big issue of protein intake is part of important debates. ISSN's guidelines underline how the requirements are elevated in athletes involved in strength, speed but also endurance and ultra-endurance training [28], [29].

An optimal protein and amino acid intake is strictly related to strength and hypertrophy, in particular as a plastic substrate to ensure training adaptations.

Studies confirmed that there is confusion regarding the optimal protein intake due to the fact that optimal amount is related to individual's characteristics and goals. So, protein recommendations should be adjusted in relation to several factors [30].

In case of strength and resistance training, proteins and amino acids have a key role to support muscle protein synthesis, reducing muscle protein breakdown and repairing muscle damages (training adaptations) [30].

According to the most recent position stands on nutrition and athletic performances, and in particular to the recently published new position stand on protein and exercise by ISSN, to maintain a positive muscle protein balance, a daily protein intake of 1.4–2.0 g/kg/d is suggested [29].

Proteins' and carbohydrates' role is underlined by evidences that suggest how the right training and the right nutrient ratio are the bases for muscle protein synthesis [31].

Physical adaptation and biochemical pathways in response to resistance training and nutrition was deeply analyzed by Atheron and Smith [32] suggesting that mammalian target of rapamycin (mTOR) is a key signaling pathway regulating exercise/nutrient-induced alterations in muscular protein synthesis and that essential amino acids, in particular leucine, are considered stimulators of this pathway [32].

From this study, the analysis of food diaries reported that normally individuals consume hyper-proteic diet to achieve physical strength goals and carbohydrate intake is not enough or not well planned. In addition, there is no scientific evidence related to long-term hyper-proteic diet's effect on human health status. Through this study, it was demonstrated that a protein intake fixed at 1,7 g/kg/day can meet the individual's needs, especially in a period of high caloric intake. Moreover, it was observed that the increased intake of carbohydrates, focusing on quality and timing of assumption, has enabled the consumption of more bulky and satisfactory meals leading to obtain the desired results with the training protocol supporting a hypertrophic strategy.

To maximally promote muscle protein synthesis, it is important to consider all variables related to training and nutrition. In the first case, the training program modulation and variables are fundamental to give the right stimuli to muscle fibers and to generate adaptation principles, in parallel macro- and micro-nutrients provide both energy to fully complete the workout in the proper manner sustaining all the recovery functions and plastic material to support the anabolic processes leading to improvements in terms of body composition and performance. These results underline the importance of a well balance dietetic approach in terms of macronutrients also in case of hypertrophic strategies.

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