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Section II - Exercise Physiology & Sports Medicine

Effects of Different Dietary Energy Intake Following Resistance Training on Muscle Mass and Body Fat in Bodybuilders: A Pilot Study

by
Alex S. Ribeiro[1], João Pedro Nunes[2], Brad J. Schoenfeld[3], Andreo F. Aguiar[1], Edilson S. Cyrino[2]

The purpose of this study was to determine the effects of different amounts of energy intake in combination with progressive resistance training on muscle mass and body fat in bodybuilders. Eleven male bodybuilders (26.8 ± 2.3 years, 90.1 ± 9.7 kg, and 176.9 ± 7.1 cm) were randomly assigned into one of two groups: a group that ingested higher amounts of energy (G1, 67.5 ± 1.7 kcal/kg/d, n = 6), and a group that ingested moderate amounts of energy (G2, 50.1 ± 0.51 kcal/kg/d, n = 5). Both groups performed resistance training 6 days per week over a 4-week study period. Measures of body composition were assessed before and after the intervention period. For body fat, only the G1 presented significant changes from pre- to post-training (G1 = +7.4% vs. G2 = +0.8%). For muscle mass, both groups showed significant increases after the intervention period, with G1 presenting a greater increase compared to G2 (G1 = +2.7% vs. G2 = +1.1%). Results suggest that greater energy intake in combination with resistance training induces greater increases in both muscle mass and body fat in competitive male bodybuilders.

Key words: *strength training; bodybuilding; muscle mass; body fat; split routine.*

Introduction

Bodybuilding is an aesthetic sport whereby competitors aspire to achieve a combination of high levels of muscularity, symmetry between muscles, and very low levels of body fat (Hackett et al., 2013). Provided similar muscular symmetry, proportion and definition, the competitor with the largest muscles necessarily has a decided advantage over his opponents.

Bodybuilding preparation generally involves two phases. An off-season phase, in which hypertrophy is the primary goal, and a pre-contest phase, where the main objective is to reduce body fat levels while maintaining muscle mass. Thus, maximizing muscle growth, especially during the first phase, is critical for success in the sport. Accordingly, the proper manipulation of resistance training variables as well as precise attention to nutrient and energy intake are essential off-season considerations.

Energy intake has an important effect on the capacity to build muscle (Millward et al., 1994). For example, studies have shown that caloric restriction induces a chronic decrease in muscle protein synthesis (McIver et al., 2012; Pasiakos and Carbone, 2014), which necessarily would limit muscle growth given that a positive muscle protein balance over time is what ultimately drives hypertrophic changes. On the other hand, a positive energy balance, even in the absence of strength training, is a potent stimulator of anabolism (Churchward-Venne et al., 2013; Millward et al., 1994).

[1] - *Center for Research in Health Sciences. University of Northern Paraná, Londrina, Brazil.*
[2] - *Metabolism, Nutrition, and Exercise Laboratory, Physical Education and Sport Center. Londrina State University, Londrina, Brazil.*
[3] - *Exercise Science Department, CUNY Lehman College, Bronx, New York, USA.*

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Several studies have shown that higher energy intake in combination with progressive resistance training induces greater increases in hypertrophy when compared to lower caloric conditions (Garthe et al., 2013; Rozenek et al., 2002). However, overconsumption of energy also can be accompanied by an increased fat deposition (Garthe et al., 2013). Therefore, elucidating a caloric surplus threshold that would induce maximal hypertrophy with minimal increases in body fat would be beneficial for coaches and athletes to optimize body composition. However, such a threshold remains undetermined. Moreover, the adaptive response to resistance training is dependent on an individual's training experience, whereby untrained individuals are more responsive to resistance exercise compared to those with resistance training experience, displaying a higher hypertrophic potential and a faster rate of muscle growth (Ahtiainen et al., 2003). Thus, highly trained individuals conceivably would need more energy for building muscle.

Despite the aforementioned information, there is a dearth of research as to how energy consumption impacts body composition in highly trained individuals. Therefore, the purpose of this study was to investigate the effects of distinct levels of energy intake in combination with resistance training on muscle mass and body fat in elite male bodybuilders.

Methods

Participants

Eleven male bodybuilders (26.8 ± 2.3 years) volunteered to participate in the study; all athletes were competitors in Brazil, affiliated with an amateur bodybuilding federation (IFBB Brazil). The participants were randomly assigned into one of two groups: a group that ingested higher amounts of energy (G1, n = 6), and a group that ingested moderate amounts of energy (G2, n = 5). The following inclusion criteria were required for participation: bodybuilding competitors for at least one year; reported to having abstained from anabolic steroid use for a minimum of 3 months leading up to the study; non-smokers; and currently abstained from consumption of alcoholic beverages. All participants were in their off-season period aiming to increase muscular hypertrophy, and all had been regularly training 6 days per week with varied routines. Written informed consent was obtained from all participants after a detailed description of study procedures. This study was performed in accordance with the declaration of Helsinki, and the experimental protocol was approved by the Londrina State University Ethics Committee.

Measures

Body composition

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, PR, Brazil), with participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached to the scale; values were obtained to the nearest 0.1 cm with participants standing shoeless and head aligned in the horizontal Frankfurt plane. The body mass index was calculated as body mass in kilograms divided by the square of height in meters.

Skeletal muscle mass was estimated using the prediction equation of Lee et al. (2000), validated by Gobbo et al. (2013) as follows:

$$\text{SMM (kg)} = 0.244 \times BW + 7.8 \times H + 6.6 \times S - 0.098 \times A + R - 3.3$$

where BW = body weight (kg), H = height (m), S = sex (male = 1, female = 0), A = age (years), R = race (−1.2 for Asians, 1.4 for African-Americans and 0 for Caucasians).

Body fat was estimated by the skinfold technique using a Lange skinfold caliper at 7 sites (chest, axilla, triceps, sub-scapula, abdomen, supra-iliac, and thigh). The equation of Jackson and Pollock (1978) was used to estimate body density. Three measures were taken by the same evaluator at each point, in a rational sequence, on the right side of the body. The median value was recorded. The equation of Brozek et al. (1963) was then used to determine body fat.

Resistance training program

Resistance training was carried out for 4 weeks employing a program designed to promote muscular hypertrophy. All participants were personally supervised by physical education professionals throughout each training session to reduce deviations from the study protocol and to ensure participant's safety.

Resistance training was performed six times a week parceled into three routines (A, B, and C). Routine A was carried out on Mondays and Thursdays and included exercises for the chest, shoulders, triceps, and abdomen in the following order: bench press, incline dumbbell fly, cable crossover, barbell military press, lateral raise, lying triceps French press, triceps pushdown, crunch, and cable crunch. Routine B was performed on Tuesdays and Fridays and consisted of exercises for the back, biceps, and forearms in the following order: lat pulldown, bent over barbell row, seated cable row, arm curl, inclined dumbbell curl, seated palm-up barbell wrist curl, and seated palm-down barbell wrist curl. Routine C was carried out on Wednesdays and Saturdays and comprised exercises for the thigh and calf in the following order: squat, leg press, knee extension, stiff leg deadlift, lying leg curl, standing calf raise, and seated calf raise. All exercises consisted of 4 sets with the magnitude of load increasing and the number of repetitions decreasing simultaneously for each set (ascending pyramid method). The number of repetitions for each set was 12/10/8/6 repetition maximum (RM), respectively. In accordance with the ascending pyramid routine, training loads were progressively increased for each set by 2-4 kg for upper body exercises and 4-10 kg for lower body exercises. The number of repetitions per set was higher for exercises of the wrist and calves (15-20 RM), and the abdominals (150 to 300 repetitions per session). The greater volume of repetitions for the wrist, calves and abdominals was based on the premise that these muscles are more endurance-oriented and thus need a greater time under tension to maximize muscular development. Participants were instructed to perform each repetition with a velocity of 1 and 2 s in the concentric and eccentric phases, respectively. Participants were afforded a rest interval of 1-2 min between sets and 2-3 min between each exercise.

Dietary control

All diets were individually prescribed by a nutritionist. The diets, in printed sheets, were delivered to the athletes before the first week of training. The diet plans were weekly readjusted according to body weight changes. Participants were oriented to distribute the meals every 3-4 h. Foods included: rice, bean, potato, manioc, pasta, fruits, vegetables, nuts, oats, juices, meats, eggs, milk, yogurt, and oils. Total dietary energy, protein, carbohydrate and fat content were calculated using nutrition analysis software (Avanutri Processor Nutrition Software, Rio de Janeiro, Brasil; Version 3.1.4).

Design and Procedures

The study was carried out over a period of 6 weeks, with 4 weeks dedicated to the resistance-training program and 2 weeks allocated for measurements and evaluations. Anthropometric and body composition measurements were performed at weeks 1 and 6, while the resistance training program was carried out during weeks 2-5. All sessions were directly supervised by trained fitness personnel. Participants refrained from performing any other type of exercise during the entire study period. The resting metabolic rate was individually predicted for each athlete using the Harris and Benedict equation (Harris and Benedict, 1918).

Statistical analysis

Two-way analysis of variance (ANOVA) for repeated measures was used for intra- and inter-group comparisons followed by Fisher's post hoc. Baseline scores as well as the relative change differences between groups were explored with an independent t-test. Effect size (ES) was calculated as post-training mean minus pre-training mean divided by the pooled pre-training standard deviation (Cohen, 1992), where an ES of 0.00 - 0.19 was considered trivial, 0.20-0.49 small, 0.50-0.79 moderate and ≥ 0.80 large (Cohen, 1992). For all statistical analyses, significance was accepted at $p \leq 0.05$. The data were analyzed using STATISTICA software version 10.0 (Statsoft Inc., Tulsa, OK, USA).

Results

Table 1 displays participant characteristics at baseline. No significant differences were observed between groups ($p > 0.05$) for age, body mass, height, and resting metabolic rate at baseline. However, as expected, the G1 had a greater surplus of energy beyond the resting metabolic rating compared to the G2.

Total macronutrients and energy intake of both groups are displayed in Table 2. The G1 ingested significantly ($p < 0.001$) higher relative amounts of carbohydrate, energy, and non-protein kcal, but lower relative amounts of protein ($p < 0.01$) and lipids compared to the G2.

Table 2 shows the pre- and post-training values for muscle mass and body fat according to the group. For body fat, only the G1 showed significant ($p < 0.01$) changes from pre- to post-training, in which an increase was observed. Both groups significantly increased measures of muscle mass after the intervention period, with the G1 showing greater increases ($p = 0.03$) compared to the G2.

Table 4 presents the effect size and values for groups as well as the difference between groups. A difference of small magnitude was observed for muscle mass and body fat.

Pre- to post-study percentage changes in body fat and muscle mass for each group are presented in Figure 1. The G2 presented greater changes than the G2 both for muscle mass ($p = 0.04$) and body fat ($p = 0.04$). Figure 2 illustrates the individual percentage changes from pre- to post-training in muscle mass and body fat according to the group.

Table 1

General characteristics of the participants at baseline. Data are presented as mean and standard deviation.

	G1 (n = 6)	G2 (n = 5)	*p*
Age (years)	26.5 ± 2.8	27.2 ± 1.7	0.64
Body mass (kg)	90.2 ± 13.3	89.8 ± 3.8	0.94
Height (cm)	179.1 ± 9.2	174.2 ± 2.3	0.27
RMR (kcal)	2025.0 ± 218.1	1989.9 ± 69.5	0.73
Energy above RMR (kcal)	4062.6 ± 635.6	2511.6 ± 109.5	< 0.001

Note: RMR = resting metabolic rate. G1 = higher energy intake. G2 = moderate energy intake

Table 2

Dietary intake of bodybuilders according to groups. Data are presented as mean and standard deviation.

	G1 (n = 6)	G2 (n = 5)	*p*
Carbohydrates			
Grams	1170.2 ± 161.5	726.0 ± 30.8	< 0.05
g/kg	12.9 ± 0.32	8.0 ± 0.05	< 0.05
Energy (kcal)	4681.0 ± 646.2	2904.2 ± 123.4	< 0.05
Energy (%)	76.9 ± 0.99	64.5 ± 0.81	< 0.05
Proteins			
Grams	162.2 ± 26.1	185.0 ± 6.9	0.08
g/kg	1.8 ± 0.15	2.0 ± 0.05	< 0.05
Energy (kcal)	648.8 ± 104.4	740.1 ± 27.7	0.08
Energy (%)	10.6 ± 0.80	16.4 ± 0.39	< 0.05
Lipids			
Grams	84.1 ± 13.5	95.2 ± 5.8	0.12
g/kg	0.93 ± 0.05	1.06 ± 0.05	< 0.05
Energy (kcal)	757.7 ± 121.6	857.0 ± 52.3	0.12
Energy (%)	12.4 ± 0.59	19.0 ± 0.81	< 0.05
Energy			
kcal	6087.6 ± 853.3	4501.4 ± 177.9	0.05
kcal/kg	67.5 ± 1.7	50.1 ± 0.51	< 0.05
Non-protein kcal/g protein	33.7 ± 3.1	20.3 ± 0.6	< 0.05

Note: G1 = higher energy intake. G2 = moderate energy intake.

Table 3

Participants' scores at baseline (pre) and post the 4-week intervention period. Data are expressed as mean and standard deviation

	G1 (n = 6)			G2 (n = 5)			*p*
	Pre	Post	Δ%	Pre	Post	Δ%	
Muscle mass (kg)	36.7 ± 3.7	37.7 ± 3.9*	+2.7	36.1 ± 1.1	36.5 ± 1.2*	+1.1	< 0.05
Body fat (%)	16.2 ± 4.6	17.4 ± 4.6*	+7.4	13.3 ± 2.7	13.4 ± 2.6	+0.8	< 0.05

*Note: * $p < 0.05$ pre vs post. G1 = higher energy intake. G2 = moderate energy intake.*

Table 4

Effects size values according to groups

	G1 (n = 6)	G2 (n = 5)	Differences
Skeletal muscle mass	0.42	0.17	0.25
Body fat	0.33	0.03	0.30

G1 = higher energy intake. G2 = moderate energy intake

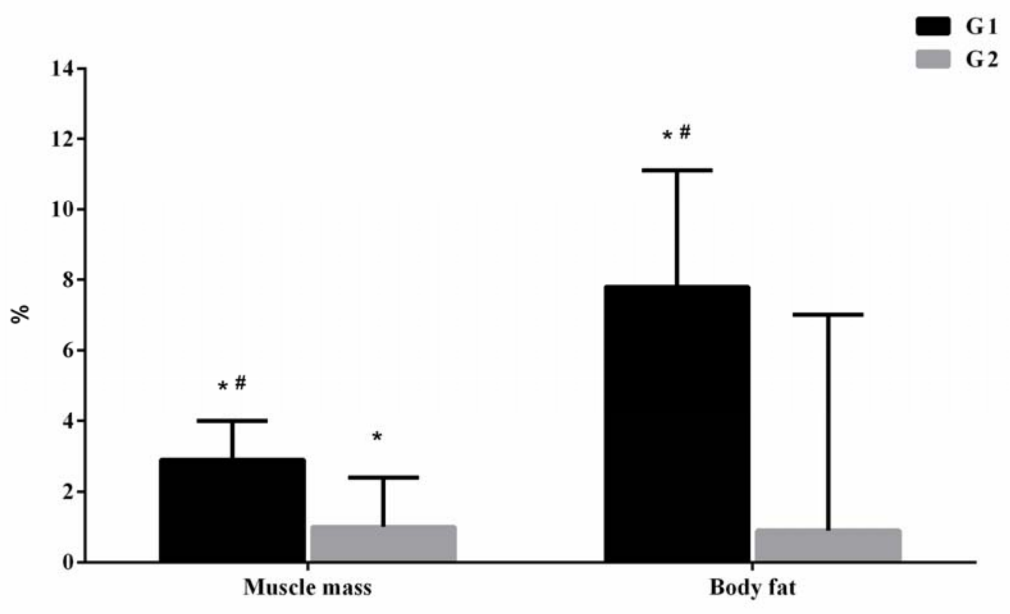

Figure 1

*Percentage changes from pre- to post-training according to groups. G1 = higher energy intake. G2 = moderate energy intake. * $p < 0.05$ pre- vs post-training. # $p < 0.05$ G1 vs. G2. Data are presented as mean and standard deviation.*

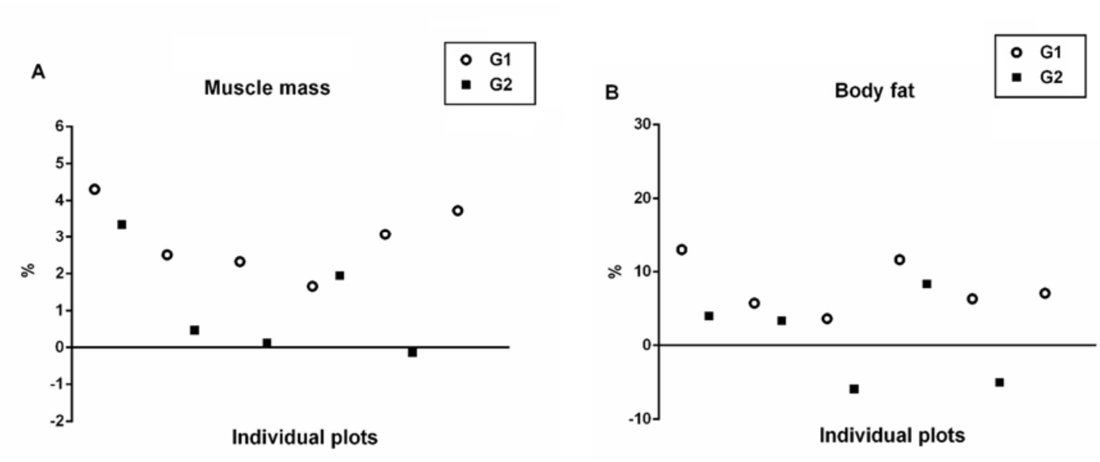

Figure 2
Individual percentage changes from pre- to post-training on muscle mass (Panel A) and body fat (Panel B) according to the group. G1 = higher energy intake. G2 = moderate energy intake.

Discussion

To our knowledge, this is the first study to investigate the effects of alterations in energy and macronutrient intake on body composition in highly trained competitive bodybuilders. The main and novel finding was that greater energy intake elicited greater increases in both muscle mass and body fat. The lack of previous literature in the population studied makes a detailed comparison with literature difficult. However, several experiments in a non-bodybuilding population indicate that energy surplus is associated with higher muscle growth (Garthe et al., 2013; Rozenek et al., 2002). Rozenek et al. (2002) reported that untrained young adult males increased fat-free mass (estimated by hydrostatic weighing) after 8 weeks of resistance training combined with an energy surplus of ~2000 kcal/d, while a control group consuming a eucaloric diet did not significantly change fat-free mass. Interestingly, the group consuming an energy surplus did not gain body fat, indicating that all of the additional calories were used for the development of fat-free mass. In a study of elite athletes participating in a variety of sports (rowing, kayaking, soccer, volleyball, taekwondo, skating, and ice hockey), Garthe et al. (2013) allocated participants to a diet providing a ~500 kcal/d surplus or ad libitum intake. All subjects participated in the same 4-day-per-week hypertrophy-type resistance training program, which was carried out over a period of 8 to 12 weeks. Results indicated a greater increase in lower body fat-free mass (estimated by dual-energy X-ray absorptiometry) favoring those consuming a caloric surplus versus those at maintenance (0.5 kg vs. 0.0 kg, respectively). However, the greater energy surplus was also accompanied by an increase in body fat deposition compared to the control condition (1.1 kg vs. 0.2 kg, respectively). The mechanism by which energy surplus induces greater hypertrophic changes is seemingly related to an augmented muscle protein synthetic response during periods of positive energy balance (Millward et al., 1994). Evidence shows that even in the absence of regimented resistance exercise, a positive energy balance alone drives increases in lean mass provided sufficient dietary protein is consumed (Churchward-Venne et al., 2013). Moreover, muscle growth is an ATP-dependent process (Lambert et al., 2004), thus adequate energy needs to be available to build muscle beyond what is expended by bodily tissues and physical activity.

The relative energy intake in our experiment was 67.5 kcal/kg/d and 50.1 kcal/kg/d for the G1 and the G2, respectively. The G2 energy intake was in accordance with previous findings in literature, but intake of the G1 was above that previously observed. For example, Slater and Phillips (2011) reviewed 7 studies that investigated relative energy intake in male bodybuilders and reported consumption ranged from ~30 to ~60 kcal/kg/d. More recently, a review by Spendlove et al. (2015) determined that energy intake in male bodybuilders across 16 studies ranged from ~24.3 to ~65.7 kcal/kg/d. This wide range of energy consumption observed in the literature may be related to the competition phases, in which energy intake is typically greater in the off-season compared to pre-contest, as well as differences in the size of subjects between studies.

Given the large inter-individual variability generally seen in exercise and nutritional trials, insight into each participants' responsiveness is of relevance to draw evidence-based inferences. Individual analysis indicated that the G2 displayed the most non-uniform variability. For example, all participants in the G1 increased muscle mass. Alternatively, one participant in the G2 lost muscle mass, while the second greatest increase in muscle mass of all individuals in the study was observed for a participant in the G2. A large inter-individual variability was also noted for body fat changes in the G2; while two participants reduced body fat from pre- to post-study, the other three participants showed an increase. Participants in the G1 displayed more consistent body composition outcomes, individually showing accretion of both muscle mass and body fat.

Adequate intake of macronutrients is of foremost importance for maximizing muscle hypertrophy. Differences observed between groups as to energy intake was chiefly due to variation in carbohydrate intake. Carbohydrates are an important substrate for maintaining training intensity in resistance exercise. Research shows that approximately 80% of ATP used in a typical hypertrophy-oriented resistance exercise session is obtained from glycolysis (Lambert and Flynn, 2002; MacDougall et al., 1999; Pascoe et al., 1993). Leveritt and Abernethy (1999) found that reductions in muscle glycogen stores significantly impaired performance in resistance exercise. Nevertheless, although dietary carbohydrate has been shown to enhance exercise performance, only moderate amounts appear to be required to achieve beneficial effects. For example, Mitchell et al. (1997) found that a diet consisting of 7.66 g/kg of CHO had no greater effect on the amount of work performed during 15 sets of 15 RM lower-body exercise when compared to consuming 0.37 g/kg. It should be noted that this was an acute finding; it is not clear whether alterations in carbohydrate intake affected training capacity between groups in the present study and, if so, whether this influenced lean mass gains.

Meeting daily needs for protein intake is a key factor for promoting an accretion of lean mass (Jager et al., 2017; Morton et al., 2018). Hypertrophy-based recommendations suggest relative protein intake ranging from 1.4 up to 2.0 g/kg/d in resistance practitioners (Jager et al., 2017; Thomas et al., 2016), where consuming beyond this amount would not induce further benefits. Specific to novice bodybuilders, Lemon et al. (1992) found that daily needs were approximately 1.6 to 1.7 g/kg/d in the early phase of training. Similar findings were reported by Tarnopolsky et al. (1992). Most recently, Bandegan et al. (2017) estimated protein needs in male bodybuilders to be 1.7 g/kg/d with an upper 95% confidence interval of 2.2 g/kg/day as determined by the indicator amino acid oxidation technique. Both groups in the present investigation met protein recommendations as outlined in the literature. However, results revealed that the G1 which ingested 1.8 g/kg/d achieved a greater increase in muscle mass than the G2 consuming 2.0 g/kg/d. This finding would seem to indicate that once adequate daily needs have been achieved (Jager et al., 2017; Morton et al., 2018), additional increases do not contribute to greater hypertrophy and non-protein kcal may be a key factor for building muscle. It is noteworthy that the difference between groups for protein intake was narrow; it is possible that wider variances may elicit different alterations in body composition (Antonio et al., 2015). The optimal protein intake for high-caliber bodybuilders to optimize body composition remains to be determined; future trials are warranted to better elucidate this topic.

The present study has some limitations that should be taken into account when drawing evidence-based inferences. First, the duration of the study was quite short, lasting only 4 weeks. Thus, it is not clear whether results would have changed had the intervention been carried out over a longer time-frame. Second, the sample size was small therefore reducing statistical power; thus, this study would best be classified as pilot work and further research is needed to clarify and quantify findings. That said, given the difficulty in recruiting highly trained competitive bodybuilders to participate as subjects in an experimental study, our findings nevertheless are quite novel despite this limitation. Third, the participants reported abstaining from anabolic steroid usage for the last 3 months via a questionnaire. However, we did not test for anabolic agents and thus cannot rule out the possibility that subjects were in fact using such agents during the study period nor can we rule out the possibility that previous use of performance-enhancing drugs may have affected results. Fourth, we did not monitor physical activity levels outside the study protocol; thus, any changes in physical activity, other than the training program, or changes in sedentary behavior may have confounded results. Fifth, we did not assess participants' eating habits prior to the intervention; it is not known how previous nutritional behaviors may have influenced the observed findings. Finally, while the anthropometric measures used to determine body composition are important and viable tools in practice, they lack the sensitivity to detect subtle changes in body composition and did not allow the ability to evaluate hypertrophic changes in specific muscles.

Our results suggest that greater energy intake in combination with regimented resistance training induces greater increases in both muscle mass and body fat in competitive male bodybuilders.

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Corresponding author:

João Pedro Nunes, BSc.
Metabolism, Nutrition and Exercise Laboratory.
Physical Education and Sport Center, Londrina State University.
Rodovia Celso Garcia Cid, km 380, Londrina, Brazil.
Phone: +5543999700301.
E-mail: joaonunes.jpn@hotmail.com
ORCID: 0000-0001-8144-5906.