Original Paper DOI: 10.5604/947457 Biol. Sport 2011;28:145-150

CHANGES IN MAXIMAL STRENGTH AND BODY COMPOSITION AFTER DIFFERENT METHODS OF DEVELOPING MUSCLE STRENGTH AND SUPPLEMENTATION WITH CREATINE, L-CARNITINE AND HMB

■ Accepted for publication 21.08.2008

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ABSTRACT: The aim of the present study was to assess the effects of bodybuilding training combined with administration of L-carnitine, weightlifting training combined with administration of creatine, and isometric training combined with administration of β-hydroxy-β-methylbutyrate (HMB) on maximal strength and body composition of athletes. The studies were conducted on groups of beginners practising bodybuilding training (n=63) and isometric training (n=69) as well as on a group of advanced powerlifters (n=50) practising weightlifting training. The obtained results indicate that the most desirable and beneficial supportive effect in strength sports was exhibited by HMB. No significant differences in body composition of subjects practising bodybuilding training were detected between those who were given L-carnitine and those who received placebo, an observation confirming controversies over the capacity of the former to reduce fat content. However, significant differences in maximal strength were demonstrated between the examined groups of athletes. Significant differences in the examined parameters were also detected within the group of advanced powerlifters practising weightlifting between those who were supplemented with creatine and those who were given placebo. Thus, the use of creatine in the development of physical capacity in advanced athletes may be advisable.

KEY WORDS: **maximal strength, body building training, weightlifting training, isometric training, creatine, L-carnitine, HMB, body composition**

INTRODUCTION

Sport achievements, maximal strength, and body composition of athletes practising strength sports appear to be affected not only by conventional changes in training loads and methods, but also by supportive administration of legally approved nutritional supplements. Until recently “training assistance” was often associated with the use of prohibited substances, a practice that some athletes and trainers regarded as almost essential for augmentation of the physical capacity of the former [2,6,26,27,35,36,49].

The Strasburg Anti-Doping Convention of 16 November 1989 followed by the foundation of the World Anti-Doping Agency (WADA) resulted in increased frequency of anti-doping surveillance and enabled detection of the majority of forbidden substances even a year after the time of their intake. This situation stimulated research on the allowable anabolic substances since the level of competitiveness and exercise performance depend, to a large extent, on efficient protein anabolism. The enhanced demand for legally approved supportive substances and their relatively free turnover resulted in the market being flooded with supplements of uncertain origin and reputation [3,35,36,43,49]. Until now, only a few such compounds have survived on the market (e.g., creatine, L-carnitine, HMB), although the results of the conducted studies did not always unequivocally confirm their properties touted by the manufacturers [10,17,27,35,49]. Indeed, analysis of the available reports reveals numerous reservations related to the studies of these compounds. These reservations relate to the usually conventional and fragmentary assumptions made by the authors, which prevents them from drawing informative conclusions about the many aspects of the effects of these substances on the human organism [9,13, 24,37,41,50]. Particularly questionable are: short time (usually 6-9 days) of administration of the supplements, differences in the recommended doses and combination with other substances, recruitment of competitors doing sports other than strength sports, and lack of discussion of the obtained results in view of the training loads applied, which may undoubtedly affect the former. Hence, a study design corrected for the aforementioned reservations and aimed at clarifying our understanding of the beneficial effects of nutritional supplementation in strength sports seems to be highly recommended.

MATERIALS AND METHODS

Young male competitors recruited to participate in the investigation were divided into the following groups: L-CAR – beginners (n=63) practising body building training and receiving L-carnitine (n=30) or placebo (n=33); CRE – advanced powerlifters from the Polish National Team (n=38) practising weightlifting training and receiving creatine (n=16) or placebo (n=22); and HMB – beginners practising isometric training (n=69) and receiving HMB (n=35) or placebo (n=34) (Table 1). The subjects from the examined groups did not differ significantly with respect to body mass, height, or age.

Study design

The following assumptions were made and the following tests were performed:

- maximal strength was estimated in powerlifting exercises (squat, bench press, deadlift) and by measurements of static maximal muscle torques;
- for estimation of the maximal strength in powerlifting, maximal weights that the subjects lifted with one repetition maximum (RM) were considered and their statistical significance within the groups as well as inter group interactions were assessed;
- strength of the muscles participating in powerlifting was estimated through measurements of the static maximal muscle torques of the extensors of the trunk, the right hip, the right knee, and the right elbow, as well as of the flexors of the right knee during their maximal contraction;
- the subjects were fed a standard diet containing 2 g of protein per kg body mass;
- the subjects declared that they would not take any supportive substances throughout the investigation other than those selected for the study;
- body composition was evaluated using three indices: lean body mass (LBM), fat content (FAT), and water content, all of which were estimated using bioelectrical impedance analysis (BIA);
- for statistical analyses mean values of the maximal strength (both relative and absolute) estimated during the exercises, of the muscle torques and of somatic features were used;
- the L-CAR subjects were divided into two subgroups practising bodybuilding training of the same volume and with the same training measures; the first subgroup was given L-carnitine (L-carnitine tartrate in sucking tablets) and the second subgroup received placebo, both at 900 mg per day (3 x 300 mg before main meals). The bodybuilding training was executed as “circuit training” performed three times per week at 5 p.m. and each time it was repeated three times. Each exercise consisted of 12 repetitions and started at 50% of RM. Intervals between exercises were long enough (about 120 s) to normalize breathing. During the last series of exercises the maximal number of repetitions (until exhaustion) was performed in order to indicate the weight progression for the next training;
- the CRE subjects were divided into two subgroups practising weightlifting training of the same volume and with the same training measures. The first and second subgroups were given a creatine-carbohydrate preparation (50% creatine and 50% dextrose) and placebo, respectively, at 20 mg per day (4 x 5 mg between meals). The weightlifting training was carried out from 4 to 6 p.m., five times per week. In each of the three powerlifting exercises, which started at 60% of RM, the weight load was increased by 10% and three repetitions were performed until the record level (RM) was reached;
- the HMB subjects practised isometric training and were divided into two subgroups: the first and second subgroup were given HMB (swallow tablets) and placebo, respectively, at 2 g per day (500 mg in the morning, before and after the training, and before bedtime). The isometric training was performed from 4 to 6 p.m., five times per week, and three types of exercises were done during each training session: holding the bar halfway up during the bench press, holding the bar halfway down during the squat (the angle between the thigh and the shank was equal to 120^{o}), and holding the bar halfway up during the deadlift (the bar at knee level). The following two variants of the training were performed on alternate days (first day – variant I, second day – variant II, third day – variant I, etc.):

Variant I – after a warm-up the subjects would reach their record levels indicated by the results of the weightlifting. Then, in each exercise they would do three series of lifting three times (isometric contractions) the RM. Both the repetition (time of a contraction) and the interval between consecutive contractions would last 8 s, whereas the interval between the series of exercises would last 60 s.

Variant II – after a warm-up the subjects would reach their record levels indicated by the results of the weightlifting. Then, in each exercise they would perform three series of four repetitions (isometric contractions) lifting the weight at 80% of RM. The repetition (time of a contraction) would last 15 s, the intervals between consecutive contractions would last 60 s, and the intervals between the series of exercises would last 180 s.

Methods of development of muscle strength

Three methods of development of muscle strength were used (bodybuilding, weightlifting, and isometric training) according to the methodology described earlier by Kruszewski [29,31].

Registration and estimation of training loads

The applied training loads were calculated every day individually for each athlete based on the analysis of the applied exercises, as registered in the training record books. Evaluation of the training loads was carried out according to the method of Saksonow et al. [40] modified by Kruszewski [29].

Evaluation of maximum strength capabilities during training

Evaluation of the absolute and relative strength in powerlifting exercises was based on the maximum weight lifted in the test exercises (squat, bench press, deadlift) according to the “International Powerlifting Federation Technical Rules Book” [39].

Evaluation of body composition

Evaluation of body composition was assessed using bioelectrical impedance analysis (BIA) at the Department of Physiology, University School of Physical Education in Warsaw, according to a protocol described by Kruszewski et al. [30]. For the final analysis mean values from two measurements were used.

Estimation of static maximal muscle torques

Estimations of the maximal muscle torques of the selected muscle groups were performed using measuring devices at the Department of Biomechanics, Faculty of Rehabilitation, University School of Physical Education in Warsaw, according to a protocol described by Fidelus [16].

Statistical analysis

For statistical analysis of the results, Student's t-test for dependent variables was used. Statistical significance of the differences between the mean values of the analysed variables in consecutive examinations was assessed using analysis of variance (ANOVA) with repeated measurements. Statistical significance of the changes between repetitions (differences in the mean values obtained in both groups between the first and second measurement) was estimated using the Wilcoxon test, whereas statistical significance of the increments depending on the group (interaction between the group and the repetition was estimated using the Mann-Whitney U test). All the calculations were performed using the STATISTICATM 5.5 package (StatSoft, USA).

RESULTS

Mean changes of the sport results, muscle torques, body mass, and body composition of competitors from the three investigated groups who developed their muscle strength with different methods of training and who were supplemented with L-carnitine, creatine, or HMB as well as the characteristics of the groups are presented in Table 1. The changes described for the muscle torques and body composition both within and between the groups relate to the groups of subjects who were given the supplements and placebo.

DISCUSSION

The present study demonstrated that some beneficial effects of the tested supplements, as highlighted by the manufacturers, may not always be true. Indeed, although the most popular, seemingly the most effective and the most often used legally approved substances were selected for the present investigation, it was impossible to confirm their effectiveness within the whole spectrum of their advertised activities.

In the case of L-carnitine, contrary to it being hailed as a "fat burner" contributing to the combustion of, predominantly, the fat reserve in the body [1,4,7,8,19], no such effect was observed in the present study. Evaluation of the body composition with the BIA method did not reveal any significant changes in the fat and water contents of the bodies of young males after the five-week bodybuilding training and supplementation with L-carnitine at doses recommended by the manufacturers. The lack of such changes should encourage potential consumers to treat advertisements of this compound with

TABLE 1. CHANGES IN MAXIMAL STRENGTH (SPORT RESULTS AND MUSCLE TORQUES), BODY MASS AND BODY COMPOSITION (MEAN VALUES), AND CHARACTERISTICS OF THE SUBJECTS (MEAN GROUP VALUES) DEVELOPING MUSCLE STRENGTH THROUGH BODYBUILDING, WEIGHTLIFTING OR ISOMETRIC TRAINING, AND SUPPLEMENTED WITH L-CARNITINE, CREATINE OR HMB.

TRAINING METHODS	CHANGES (mean values)				GROUP CHARACTERISTICS (mean values)			
	Sport results [kg]	Muscle Torques [Nm]	Body Mass [kg]	Body Composition	Number of trainings	Body mass [kg]	Training practice [months]	Duration of experiment [months]
Body building + L - CARNITINE	13.7* power-lifting	Significant changes within groups, no interaction between groups	ns	BIA ns changes in fat and water content	15	76.8	0	1.2
Weightlifting + CREATINE	15.6* power-lifting	Significant changes within groups, interaction only in case of trunk extensors*	ns	BIA* significant loss of fat content and elevation of water content	20	77.1	66	0.9
Isometric training + HMB	17.7* power-lifting	Significant changes within groups, significantly higher in HMB group*	1,31*	BIA* significant increase of LBM, significant loss of water	20	76.6	0	0.9

Note: ns – difference not significant; * – significant difference; BIA – bioelectrical impedance analysis; LBM – lean body mass; changes within groups and interaction between groups – refer to groups of subjects who were given supplementation and placebo.

reserve. The obtained results also suggest that the effect of L-carnitine may be highly selective and depend on individual responses to this supplement [14,15]. It is possible that individuals with inherited or acquired L-carnitine deficiency manifested by increased deposition of fat in the body may benefit from such supplementation and improve their body composition by consuming appropriate amounts of this substance accompanied by proper (predominantly aerobic) exercising. However, additional L-carnitine supplementation in individuals with normal production and concentration of this substance in the body is superfluous. Such an impact of L-carnitine may be suggested by the cases observed in the present study, albeit statistically insignificant. The significantly elevated results demonstrated in the present investigation in the powerlifting exercises, as compared to the control group, are surprising in view of the fact that such an effect of L-carnitine has very rarely been reported and emphasized. Perhaps it is associated with the variable impact of this substance on the general physical fitness of the organism [5,12,33,35,42], which can also be manifested by improvement of the maximal strength attained through specific exercises. Such a function of L-carnitine seems to be confirmed in the present investigation by the lack of significant inter group differences in the values of the static muscle torques.

Likewise, unexpected results were obtained in the present study with respect to creatine, the most popular legally approved supplement among professional athletes, regarded as the most effective facilitator of the short-term, intense efforts associated with phosphagen metabolism (the Lohmann reaction) [18,21,22, 38,44,45]. However, the present results indicate that supplementation with this compound led to a significant reduction in the fat content and increase in the water content of the organisms of powerlifters from the Polish National Team. These changes suggest that in professional sportsmen the effect of creatine may be much more far-reaching than that indicated in the manufacturers' leaflets. Although the increased water content in the powerlifters' bodies can be explained by its retention in muscle cells to create appropriate conditions for protein anabolism, the reduced fat content is a rare phenomenon. Record-seeking athletes, especially those categorised by body mass, have low fat content (sometimes below 6%) and it is extremely difficult and even dangerous to their health to further reduce the amount of this tissue in the body. Demonstration of the latter effect in the group of top competitors from the typical strength sports may be explained by the very pronounced reducing impact of creatine on fat content. It is possible that this substance may, in specific doses, stimulate secretion of hormones (especially somatotropin) which induce much stronger reduction of fat and, with the concomitant application of a high-protein, low-fat diet, may lead to the above-described endpoints [38,44]. Notably, unlike the effects of supplementation with L-carnitine, which is widely regarded as the best support for obesity-reducing therapy, the creatine-induced declines in fat content were statistically significant.

The significant improvement of the sport results by the creatine supplementation was not surprising and, as suggested by numerous authors, can be explained by the increased capacity of a supplemented organism to perform short-term and intense efforts typical for powerlifting [32,35,43,49]. It is symptomatic that the powerlifting-induced increments in maximal strength were reflected only in the static muscle torques of the extensors of the trunk in the hips; no significant differences in the other static muscle torques measured were found between the groups of competitors supplemented with creatine and placebo. Arguably, such a similarity resulted from the engagement of the same large, strong muscles in the measurements of the torques of extensors of the trunk and in the two powerlifting exercises (squat and deadlift). These muscles are not only large, but are also dominated by the strong and fast-twitch white fibres whose effective function depends, to a large extent, on the creatine content [18,20,25,45,48].

The most distinctive and desirable effect in strength sports seemed to be exerted by supplementation with HMB. Although this type of supplementation was used in the group of subjects who trained using the isometric method, regarded as a training system not associated with increases in lean body mass (LBM), the obtained results indicate that HMB may also affect LBM. In view of the fact that LBM involves mainly muscles containing about 70% water, the demonstrated significant elevation of LBM accompanied by the reduced water content in the bodies of the examined competitors is difficult to explain. However, strength sports, especially bodybuilding, which rely on the skilled and purposeful reduction of the so-called subcutaneous or extracellular water in the body accompanied by retention of a steady level (or even increase) of the intracellular water, generated a demand for a supplement that would enable these goals to be reached effectively [1,44]. Apparently, HMB possesses such properties, and the changes in body composition detected in the present study seem to support this assumption. The increased LBM probably resulted from the enhanced protein anabolism, whereas the loss of water probably resulted primarily from the reduction of its extracellular component that does not affect muscle mass (LBM) [11,23,24,46,47]. Thus, it was possible to demonstrate significant elevations in both the total and lean body mass accompanied by a decrease in the water (presumably extracellular) content in the body. The stimulated increase in LBM may also be related to yet another property of HMB, namely its capacity to inhibit replacement of the aging muscle cells with constantly produced new cells. As a result, owing to such specific hyperplasia, the muscle mass increases and may remain elevated long enough to enable athletes such as bodybuilders to demonstrate their enlarged muscles during two or three months of the competition period [1,28,30,34,35,44,49]. Improvements in sport results of competitors who received HMB were also significant and more pronounced compared to those of their counterparts who were supplemented with L-carnitine or even creatine. The stimulatory effect of the HMB supplementation on maximal strength is supported not only by the present results obtained in powerlifters, but also by the significantly greater increases in the sums of the static muscle torques of the athletes receiving HMB.

CONCLUSIONS

In summary, among the legally approved supplements examined in the present study, HMB appears to provide the most effective support for the development of maximal strength and improvement of the composition of the body. All the three supplements examined seem to beneficially affect maximal strength, but their effects on body mass and composition are controversial. This refers especially to L-carnitine, which is widely advertised as a substance supporting the reduction of fat.

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