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ORIGINAL ARTICLE

β-Alanine supplementation slightly enhances repeated plyometric performance after high-intensity training in humans

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Abstract β-Alanine (BA) supplementation has become an ergogenic aid amongst competitive athletes to augment intramuscular carnosine content, leading to higher buffer capacity and exercise performance. We investigated 27 regularly trained young males and females who were randomly allocated either to placebo (PL) or BA ingestion for 8 weeks. Every single day, BA or PL (4.0–5.6 g day^{-1}) supplements were ingested by participants and associated with a strong plyometric high-intensity training (two sessions per week during the 8 weeks). Before and after training, maximal jump heights were recorded during squat jump (SJ) and countermovement jump (CMJ) and an index of fatigue was recorded as a mean height of 45 consecutive CMJ. Blood lactate was measured at rest, after completing the fatigue test and every 5 min thereafter up to 30 min recovery. After plyometric training, SJ and CMJ were increased, respectively, by 8.8 and 6.4 % in PL group and 9.9 and 11.0 % in BA group ($p < 0.01$, no difference between groups). Blood lactate reached a maximal value of 9.4 ± 1.6 mmol l^{-1} in PL group, and 10.3 ± 1.3 mmol l^{-1} in BA group, with a slight better performance in the fatigue test (+8.6 %, $p \leq 0.01$) for BA group as compared to PL group. To conclude, 2-month β-alanine supplementation resulted in a slight improvement of explosive force after 45 maximal consecutive jumps in young athletes. However, the practical adequacy of supplementation remains questionable in an active and healthy population.

Keywords Squat jump · Countermovement jump · Blood lactate · Exercise performance · Dietary supplement

Introduction

β-Alanine supplementation (Harris et al. 2006) has become of growing interest amongst competitive athletes participating in a range of different sports, such as rowing (Hobson et al. 2013), road cycling (Howe et al. 2013; Bex et al. 2014; Gross et al. 2014a, b; Saunders et al. 2014), kayaking, swimming (Chung et al. 2012), running (Ducker et al. 2013), resistance training (Kendric et al. 2008; Kresta et al. 2014), and sprinting (Derave et al. 2007), with or without suitable effect. β-Alanine is a non-proteinogenic amino acid synthesized within the liver from the irreversible degradation of thymine, cytosine, and uracil (McMurray and Hackney 2005), and then transported to muscle cells to be combined with L-histidine to form carnosine (Sale et al. 2013). The latter has multiple functions (Caruso et al. 2012) but its primary role in muscle fibres is to maintain an intracellular buffering capacity due to its pK (a) of 6.83 (Harris and Sale 2012).

Several reviews pointed out that oral β-alanine and/or carnosine supplementation enhances exercise performance in healthy conditions (Culbertson et al. 2010; Caruso et al. 2012; Hoffman et al. 2012; Bellinger 2014; Quesnele et al. 2014) and might have potential therapeutic role in ageing, neurological diseases, diabetes, and cancer (Sale et al. 2013). Most studies and reviews gave some evidence that supplementation with β-alanine may increase athletic performance; however, one review cautioned the use of β-alanine supplementation as an ergogenic aid until there

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is sufficient evidence confirming its safety (Quesnele et al. 2014).

Those studies used classical investigations to appreciate the effect of β-alanine intake on exercise performance, such as muscle buffer capacity, delay in the onset of muscular fatigue, and facilitated recovery. However, Bellinger estimated that scientific confirmation is required for repeated maximal effort (Bellinger 2014). Therefore, we decided to investigate this specificity using squat jump (SJ) and countermovement jump (CMJ) measurements (Bosco et al. 1983; Garcia-Lopez et al. 2005; Bellinger 2014) to assess the strength of extensor muscles of the lower limbs, with and without β-alanine supplementation in human subjects.

Methods

Study population

Twenty-seven white young subjects (students of physical education) were enrolled in this study: 13 subjects in placebo group (PL) (six men and seven women, age 21.4 ± 2.1 years, mean ± SD, weight 63.7 ± 8.5 kg, height 174.7 ± 11.6 cm); 14 subjects in β-alanine group (BA) (six men and eight women, age 22.1 ± 2.1 years, weight 63.6 ± 10.0 kg, height 168.8 ± 9.4 cm). All subjects were healthy and physically active. None of them were subjected to allergy or intolerant to the placebo or β-alanine supplementation. The informed written consent of the subjects was recorded after full explanation of the whole investigation. This study was approved by the Medical Ethical Committee of the Academic Hospital and this project was conducted in accordance with the guidelines of the declaration of Helsinki of 1975 as revised in 1976.

Placebo and β-alanine double-blind supplementation was randomly distributed, and administered during 8 weeks. The total daily doses of 5.6 g were split into single doses of 800 mg ingested every 2 h, starting at 08.00 hours. Each single dose contained either microcrystalline cellulose (PL) or β-alanine (BA) enrobed in small digestible capsules. This wide daily distribution avoided the appearance of potential symptoms of paraesthesia or irritation of the skin (Sale et al. 2013).

Exercise protocol

The exercise protocol was carried out in the morning the day before the beginning of the supplementation and 3 days before the end of the 8-week supplementation.

The exercise test was based on vertical jump tests largely used to assess different forms of explosive strength in the extensor muscles of the lower limbs (Bosco et al. 1983; Sebert et al. 1990; Bobbert et al. 1996; Garcia-Lopez et al. 2005; Bobbert 2014). The subjects performed five maximal squat jumps (SJ), then five countermovement jumps (CMJ). The average of the three intermediate heights was used for statistical analyses. Then, subjects underwent a fatigue test consisting of 45 consecutive CMJ followed by 30-min rest. An "Optojump" instrument system (Microgate, Italy), consisting of two parallel bars disposed opposite to each others and connected to a computer, was used to quantify the flight time during vertical jump estimating the height of the jump. This system has been validated by Glatthorn et al. (2011) using a force plate.

Blood lactate was collected from warmed ear samples before the fatigue test, by its end and every 5 min during the recovery period (30 min), using the "Lactate Scout analyser" (Senslab, Germany), a biosensor enzymatic amperometry. This test strip uses L-lactate oxidase to catalyse the oxidation of L-lactate.

Training was carried out during 8 weeks, two sessions per week, and consisted in repeated plyometric exercises of the lower limbs performed during 30–50 s each (five exercises per session, repeated twice).

Statistics

Conventional statistical methods were used to calculate means, standard deviation and standard error of the mean.

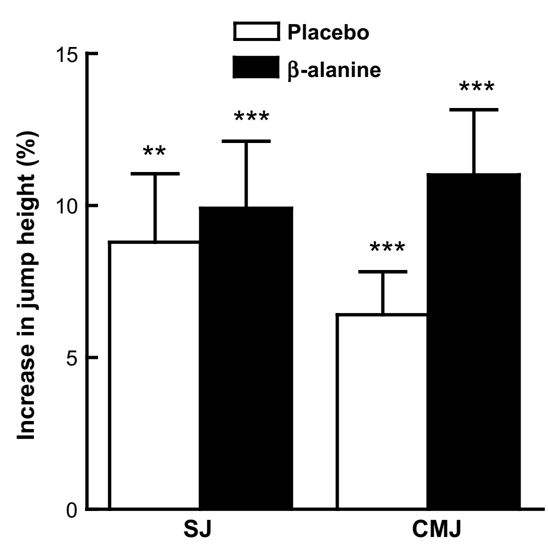

Fig. 1 Comparison in % of SJ and CMJ height after training increased. The increase was significantly different in the both group (respectively 8.8 ± 2.3 and 6.4 ± 1.4 % for SJ and CMJ in PL group and 9.9 ± 2.2 and 11.0 ± 2.1 % in BA group). No significant differences between the two groups were observed. **, ***Significant differences with the pre-training condition at, respectively, $p < 0.01$ and $p < 0.001$

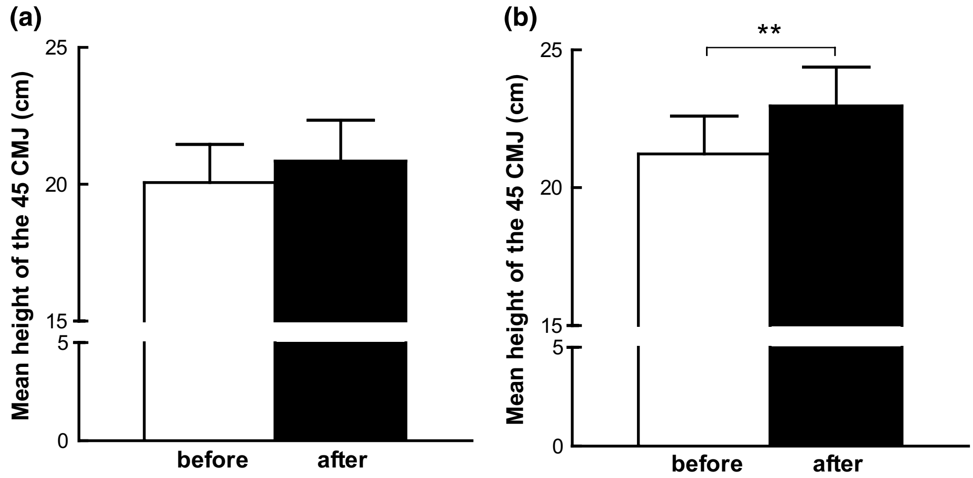

Fig. 2 Mean heights of the 45 CMJ after training in both group (**a** PL group, **b** BA group). A significant increase was observed only in BA group (+8.6 ± 2.0 %, $**p < 0.01$)

Prior comparing each independent variable, the normality of the data was confirmed with the Kolmogorov–Smirnov test. Covariance analyses (ANCOVA) were used to calculate regression and angular coefficient. Jump heights (in cm), the mean height of the 45 consecutive CMJ (in cm), and the evolution of post-exercise values over 30 min were recorded before and after exercise training in PL and BA groups. Gains between pre- and post-tests (in %) were investigated in PL and BA groups. A repeated measures ANOVA was used to compare the variations amongst the means of blood lactate followed by Dunnett's multiple comparisons for post hoc analyses with the pre-exercise value as a control when the value was less than 0.05. A probability of $p \leq 0.05$ was considered significant for all conditions.

Results

Squat jump (SJ) and countermovement jump (CMJ) values, recorded in placebo (PL) and β-alanine (BA) groups, before and after supplementation are reported in Fig. 1. After training, an increase in jump height (in cm) was observed not only for SJ in both PL group (+8.8 ± 2.3 %; $p < 0.01$) and BA group (+9.9 ± 2.2 %; $p < 0.001$) but also for CMJ (6.4 ± 1.4 and 11.0 ± 2.1 %, respectively, for PL and BA groups; $p < 0.001$), without any statistical differences between the two groups.

The fatigue test (mean height of the consecutive 45 CMJ) did not show any statistical differences in pre-test values between PL and BA groups. The BA group showed an improved average performance (+8.6 ± 2.0 %, $p < 0.01$) after supplementation (Fig. 2). Moreover, the decline in jump heights during the fatigue test was reduced in a lesser extent in the BA group (3.9 %; $p \leq 0.05$; Fig. 3).

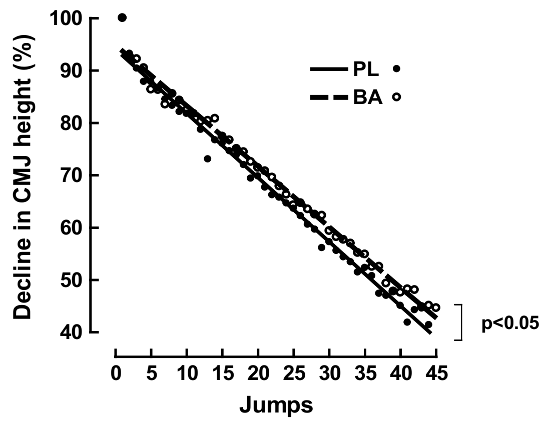

Fig. 3 Comparison of the negative linear regression in CMJ heights over time after training in both groups. The equations were, respectively, for PL and BA groups: $y = -1.226 + 94.04$; $r^2 = 0.79$; $p < 0.001$ and $y = -1.158 + 94.83$; $r^2 = 0.80$; $p < 0.001$. The slope of the regression obtained after training was significantly reduced for the BA group in comparison to PL group ($p < 0.05$)

Blood lactate increased by the end of the 45 CMJ in both groups (PL 9.4 ± 1.6 mmol L^{-1}, BA 10.3 ± 1.3 mm L^{-1}, NS between groups) and decreased progressively during the 30 min post-exercise with no differences in pre- and post-test values (Fig. 4).

Discussion

The present study shows a reduced statistical decline in performance during the 45 maximal CMJ (+8.6 %) in males and females submitted to high-intensity training during 2 months whilst consuming 5.6 g β-alanine (BA) every day, without any statistical differences between groups (Fig. 2). Previous publications already suggested possible benefits of β-alanine supplementation in high-intensity trained athletes

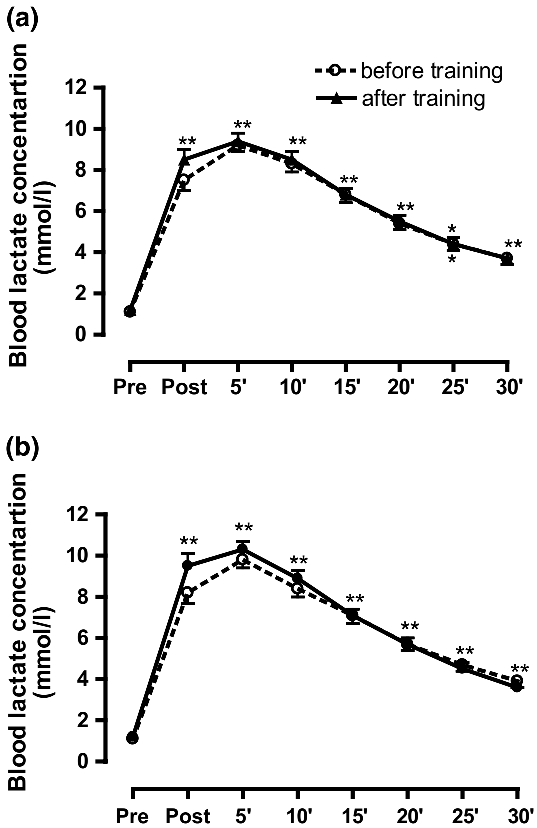

Fig. 4 The distribution of the blood lactate before and after training in Pl (**a**) and BA (**b**) groups. **Significant difference between rest and post-exercise conditions (at the end of the fatigue test and every 5 min during the recovery period) at $p < 0.01$. However, there is no significant difference between Pl and BA groups before and after training

(Howe et al. 2013; Sale et al. 2013; Painelli et al. 2014), whilst other studies were less convincing (Culbertson et al. 2010; Kresta et al. 2014; Quesnele et al. 2014). Moreover, a recent study observed an increase of 7 ± 3 % in power output after three maximal CMJ in professional alpine skiers (Gross et al. 2014a, b). Due to a wide daily distribution of the supplementation, our subjects did not experience any side effect disturbances, as often observed after BA absorption (Harris et al. 2006; Décombaz et al. 2012).

Our results showed that a 2-month training increased single jump height both in placebo and β-alanine supplementation groups, as observed recently by Gross et al. (2014a, b) on professional alpine skiers. Nevertheless, maximal blood lactate concentrations and blood lactate decline during the recovery period (30 min) did not show any statistical differences between placebo and β-alanine consumers. Thus, we could argue that during the 45-jump test anaerobic glycolysis and lactate accumulation were not connected to any major disturbance of buffering capacity, accumulation of lactate, or improved mitochondrial coupling. A possible explanation is that BA supplementation increased carnosine muscle content in subjects and that the proton-sequestering property of the carnosine molecule reduced the drop in muscle pH induced by the anaerobic glycolysis, improving performance (Harris et al. 2006).

To conclude, 2-month β-alanine supplementation resulted in a slight improvement of explosive force after 45 maximal consecutive jumps in young athletes. However, the practical adequacy of supplementation remains questionable in an active and healthy population.

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical standard Statement of human rights: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee and with the 1964 Helsinski declaration and its later amendments or comparable ethical standards. Statement on the welfare of animals: This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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