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Effects of β-Hydroxy-β-Methylbutyrate on Aerobic-Performance Components and Body Composition in College Students

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The aim of this study was to determine the effects of oral β-hydroxy-β-methylbutyrate (HMB) supplementation (3 g/d) on selected components of aerobic performance and body composition of active college students. Subjects were randomly assigned to either an HMB (n = 8) or a placebo (PLA) group (n = 8) for a 5-wk supplementation period during which they underwent interval training 3 times a week on a treadmill. Aerobic-performance components were measured using a respiratory-gas analyzer. Body composition was determined using dual-energy X-ray absorptiometry. After the intervention, there were significant differences ($P <$ 0.05) between the 2 groups in gains in maximal oxygen consumption (+8.4% for PLA and +15.5% for HMB) and in respiratory-compensation point (+8.6% for PLA and +13.4% for HMB). Regarding body composition, there were no significant differences. The authors concluded that HMB supplementation positively affects selected components of aerobic performance in active college students.

Key Words: nutritional supplements, aerobic training, ergogenic aid

Athletes might improve performance by providing their bodies with optimal nutritional supplements (8). One nutritional supplement that has become popular in recent years is β-hydroxy-β-methylbutyrate (HMB), a metabolite generated from the breakdown of the essential branched-chain amino acid leucine.

Some studies claim that HMB can increase lean body mass, strength, and lipid oxidation when combined with a strength-training program compared with an exercising placebo group (25, 28, 33, 35). Moreover, HMB supplementation has been shown to reduce proteolysis and muscle-structure damage resulting from an acute bout of eccentric running (19), which are known to limit sport performance (1). Some studies conducted with trained subjects, however, have shown no significant changes attributable to HMB, in terms of aerobic capacity and lean body mass (26) or in biochemical markers of protein turnover and structural damage (32).

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These equivocal results regarding the effectiveness of HMB on adaptations to exercise might partly result from the participants' initial level of training. Indeed, it has been suggested that HMB would be more effective in untrained than in trained individuals (33). This difference could be explained by the anticatabolic action of HMB. In fact, it has been proposed that HMB protects the sarcoplasmic membrane during intense physical activity, thus allowing muscle cells to function at an optimal level even during stressful conditions (25). In this sense, differences concerning muscle proteolysis between the HMB and placebo groups seemed to be reduced when training levels were considered (35). Because chronic resistance training reduces the increase in protein turnover induced by an acute exercise bout (29), HMB might thus serve to facilitate the levels of cell growth only when the integrity of the membrane appears as a limiting factor, which generally occurs during the initial stage of a strength-training program (1, 2).

Although some studies have assessed the effects of HMB during a strength-training program, very few have looked at its impact on performance during an aerobic-training program (19, 26, 34). Moreover, these studies have mostly investigated the effect of HMB in highly trained athletes and have reported divergent findings. Indeed, although 1 study observed no increase in peak oxygen consumption (VO_{2peak}) but an increase in the onset of blood lactate accumulation (34), another showed no significant difference for VO_{2peak} and lactic-acid levels after HMB supplementation (26). The third study (19) showed no difference attributable to HMB in run time during a 20-km course or in VO_{2max} after training but resulted in decreased creatine-phosphokinase and lactate-dehydrogenase blood concentrations after a prolonged run. These findings of reduced markers of muscle damage and an in vitro study (7) are consistent with the hypothesis that HMB-supplemented subjects experience less muscle damage or sustain an amount of muscle damage similar to that of a placebo group but recover at a faster rate.

Whereas some studies have shown a decrease in body fat (35) and an increase in lean body mass (25) after a resistance-training program combined with HMB, just 1 study (19) evaluated the effects of HMB on body composition (7-site skinfold method) during an aerobic-training program in well-trained subjects. This last study showed no change between placebo and HMB groups in the percentage of body fat and fat-free mass. Finally, an in vitro study (7) showed that, when muscle cells are exposed to high doses of HMB, an increase in the β-oxidation of palmitate can be observed. These observations have never been corroborated in vivo, however, using clinical measures of body composition.

The present study extends these findings by testing the hypothesis that the anticatabolic effect of HMB could help active individuals during an intense interval-training program by protecting the cell membranes through an accelerated recovery from exercise-induced cell damage, enhancing the effectiveness of exercise. Therefore, the aim of this study was to measure the effect of an oral HMB supplementation (3 g/d) coupled with a 5-week interval-training program, in active college students unaccustomed to this kind of training, on selected components of aerobic performance and body composition. We hypothesized that at the end of the interval-training program, HMB supplementation would be associated with greater improvements in VO_{2max}, ventilatory threshold (VT), respiratory compensation point (RCP), and muscle mass and decreases in body fat than in the placebo group.

Methodology

Subjects

Eight men and eight women ($N = 16$) were recruited on the campus of the University of Sherbrooke and volunteered to take part in this study. Characteristics of the subjects are presented in Table 1. All participants had to meet the following inclusion criteria: 1) nonsmoker, 2) medical examination stating that they were able to participate in a training program, 3) be familiarized with running on a treadmill, 4) no participation in an aerobic-training program in the preceding 6 months, 5) no involvement during the course of this study in any other type of physical training, and 6) no use of medications or supplements (i.e., caffeine, ephedrine, amphetamine, creatine, protein supplement) that could influence the results of this study. All subjects were informed of the procedures of the study, and informed written consent was obtained. The study was approved by the Ethics Committee of the Faculty of Physical Education and Sport of the University of Sherbrooke.

Experimental Protocol

All subjects were randomly assigned, except for the gender, to one of 2 groups, the experimental group (HMB; $n = 8$, 4 men and 4 women) or the placebo group (PLA; $n = 8$, 4 men and 4 women). Subjects were instructed to maintain their usual diet and lifestyle during the course of the study. The randomized control trial was conducted in a double-blind fashion. During the week before (pretest) and during the week after (posttest) the 5-week training and supplementation period all subjects were submitted to a body-composition and aerobic-performance assessment. During this pretest and posttest scheduling food intake was controlled by an investigator by means of an interview. Subjects were instructed to undergo a 3-h fast before the aerobic-performance and body-composition tests. It was not logistically possible, however, to test the same subject at the same time of day for the pre- and posttests.

Measurements

Body Composition. Body composition was measured by a dual-energy X-ray absorptiometry test (Lunar Prodigy, G.E. Medicals Corp., Madison, WI), which

Table 1 Pretraining Characteristics of All Subjects ($N = 16$)

Variable	Placebo group ($n = 8$: 4 men and 4 women)	HMB group ($n = 8$: 4 men and 4 women)	*F*	*P*
Age (y)	23.43 (0.78)	23.40 (1.25)	0.000	0.99
Height (m)	1.72 (0.04)	1.68 (0.02)	0.642	0.44
Body mass (kg)	71.31 (5.67)	64.23 (2.78)	1.275	0.28
Body-mass index (kg/m^2)	24.03 (1.22)	22.76 (0.77)	0.790	0.39

Values are presented as mean (SEM). HMB indicates β-hydroxy-β-methylbutyrate.

took place at the Research Center on Ageing of the Geriatric University Institute of Sherbrooke. Measurements included total body mass, as well as body fat and lean body mass, for each subject. In this laboratory, in a previous study (data not published), percentage coefficients of variation obtained from 2 measures obtained 1 wk apart in 10 adults were found to be 4.7% and 1.1% for body fat and lean body mass, respectively.

Maximal Oxygen Consumption, Ventilatory Threshold, and Respiratory Compensation Point. An incremental continuous test to exhaustion on a treadmill (37) (JAS Trackmaster, Model TMX22, Newton, KS) was performed using a breath-by-breath gas analyzer (Oxycon pro, Jaeger, Germany). Respiratory gases were collected to measure maximal oxygen consumption (VO_{2max}), as well as ventilatory threshold (VT) and respiratory-compensation point (RCP). Tests began with a 5-min warm-up at 8 km/h. After this initial period, the grade on the treadmill was fixed to 1% throughout the test, and the running velocity was increased by 2 km/h every 3 min until complete exhaustion. VO_{2max} was considered the mean value of the plateau on the VO_2 plot. The plateau was determined as an increase of VO_2 of less than 2.1 $mL \cdot kg^{-1} \cdot min^{-1}$ between the last 2 stages of the test (31). If a subject did not reach a plateau, other criteria as described by Shephard (31) were used to ensure that VO_{2max} had been achieved, and VO_{2max} was calculated as the mean value of the last 2 min of the test before exhaustion. VT and RCP were determined by combining 3 common methods of identifying gas-exchange thresholds (13): the ventilatory equivalents for oxygen and carbon dioxide method of Wassermann et al. (36), excess CO_2, and the V-slope method of Beaver et al. (2). The ventilatory equivalent for oxygen is defined as the ratio of minute ventilation to oxygen consumption (V_E:VO_2). The ventilatory equivalent for carbon dioxide is defined as the ratio of minute ventilation to carbon-dioxide production (V_E:VCO_2). Thus, VT was detected as the intensity corresponding to an increase in V_E:VO_2 without a simultaneous increase of V_E:VCO_2, the first sustained rise in excess CO_2, and the first increase in the slope of VCO_2 versus VO_2. RCP was determined as the intensity corresponding to an increase in both V_E:VO_2 and V_E:VCO_2, the second sustained rise in excess CO_2, and the second increase in the slope of VCO_2 versus VO_2. The combination of these 3 methods of detecting gas-exchange threshold has been shown to improve the accuracy and reliability of identifying VT (13). Both VT and RCP reflect endurance capacity, and they can well detect training-induced changes (for a review see 23).

Time to Exhaustion at Maximal Oxygen Consumption. Three days after completing the VO_{2max} test, subjects were tested on the treadmill (Magnum by Trackmaster, JAS Fitness Systems) to measure the time to exhaustion (T_{max}) at the maximal aerobic speed (MAS) (5). This test is used to determine the maximal duration a subject can run at an intensity matching VO_{2max}. MAS was determined during the previous test and can be defined as the lowest speed that elicits VO_{2max} in an incremental test to exhaustion on treadmill. Throughout the test the grade on the treadmill was fixed to 1%. The tests began with a 15-min warm-up at 50% of MAS. Subjects then continued to run as the treadmill speed was increased in ramp fashion over a 30- to 45-s period up to MAS. When the treadmill speed equaled MAS, the timing was started. Subjects were verbally encouraged to continue for as long as possible until complete exhaustion. A test was terminated when the

subject grasped the handrails for support. This test provides useful information to select the duration of an interval-training session. T_{max} is positively correlated with aerobic capacity (4) and the ability to run in anaerobic conditions (11), so MAS and T_{max} seem to be valuable predictors of performance during races over 1500 m to a marathon (3).

Training Design

All subjects underwent a 5-wk training program consisting of interval training on a treadmill 3 times a week. Interval training was preferred because it is recognized to produce greater improvements in aerobic power (12) and induce delayed-onset muscle soreness (DOMS) (6), and the training sessions are shorter than those in continuous aerobic training. All the training sessions took place at the Sports Centre of University of Sherbrooke, and sessions were held at least 24 h apart. An investigator was present to supervise and monitor each training session.

Interval-training sessions were individualized in terms of duration and intensity to provide a similar level of physiological stress for each subject. Duration and intensity of interval-training sessions were calculated for each subject according to a T_{max} test and an incremental continuous test to exhaustion, respectively. Indeed, as described by Billat (4), it is possible to repeat in sequence 5 interval-training cycles of running if the duration of each cycle equals half of the time to exhaustion (T_{max}) at the velocity at which VO_{2max} is achieved (MAS) (4). MAS is defined as the running speed during an incremental test at which VO_{2max} is attained (3). Moreover, MAS might be the lowest velocity at which VO_{2max} is elicited and is an appropriate exercise intensity to use in interval training (21). An interval-training cycle of a run that lasted 100% of T_{max} can be defined as a slow run at an intensity equivalent to 60% of MAS followed by a fast run at an intensity equivalent to 100% of MAS. The slow run and fast run of each interval-training cycle had the same duration: 50% T_{max}. Figure 1 shows the overview of each training session. The first 5 min were devoted to a warm-up at a speed of 50% of MAS. Next, subjects performed an interval-training workout with the grade on the treadmill fixed to 1%. Then, the training session ended with the subject running at 50% of MAS for 5 min, in order to allow for recovery.

Supplementation Protocol

The HMB group received, during the entire duration of the training program, 3 g/d of calcium salt of HMB (Ca-HMB; Metabolic Technologies Inc., Ames, IA), and the PLA group was given 3 g/d of a placebo (rice flour, Metabolic Technologies). Both the HMB and the placebo were administered as 250-mg capsules, so subjects were requested to ingest during meals 12 capsules each day, equally divided between breakfast, lunch, and dinner.

The supplement's purity was not directly analyzed for this investigation, but the purity of the supplement from the supplier as evaluated by another study (25) by high-performance liquid chromatography was >99% HMB.

In order to guarantee that the study was conducted in a double-blind fashion, all supplements were prepared and coded by the supplier, and the placebo and supplement capsules were not visually different. At each training session, the

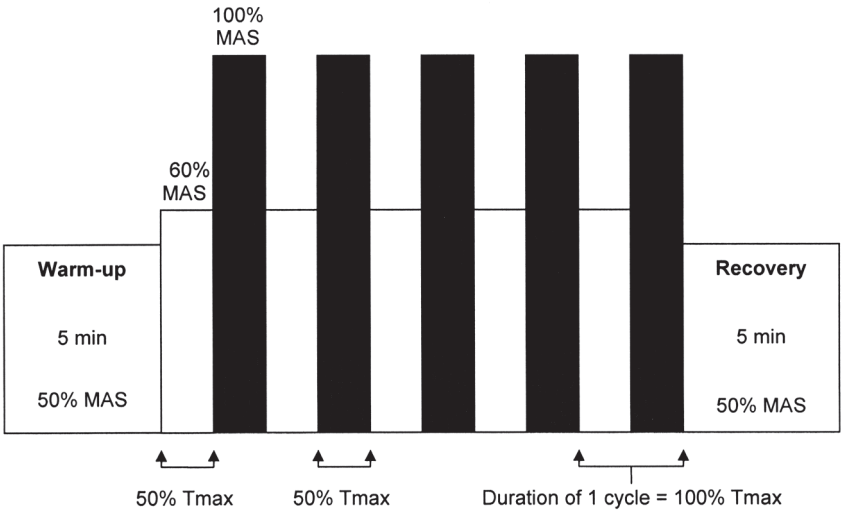

Figure 1 — Overview of 1 interval-training session adapted from Billat (4). MAS indicates minimum running speed during an incremental test at which maximal oxygen uptake is attained, and T_{max}, time to exhaustion at maximal oxygen consumption.

investigator reminded each subject to carefully comply with the supplement-ingestion protocol.

Statistical Analysis

A univariate analysis of variances (ANOVA) was first used to verify the similarities between the 2 groups at baseline (pretest). Then a 1-way ANOVA was conducted to examine significant changes between pre- and posttests in each group. Finally, a repeated-measures ANOVA was used to assess possible time × treatment effects for each dependent variable. Statistical significance was set at an alpha level of $P < 0.05$. The statistical analyses were performed using SPSS 11.0 software (Chicago). Data are expressed as mean ± SEM.

Results

Based on discussions with the subjects after each training session, their compliance was very good (>95%) regarding the supplementation and strict adherence to a normal daily diet. Indeed, 2 subjects in the experimental group forgot to take supplementation during just 1 meal each. Furthermore, adherence to the training program was perfect (100%) according to an investigator who was present to supervise and monitor each training session. The supplements were well tolerated, and no side effects were reported. Based on criteria described by Shephard (31), all subjects attained VO_{2max} during the pre- and postincremental continuous test

to exhaustion. Finally, the pretest results showed no difference between groups in terms of subject characteristics (Table 1) or for any of the dependent variables studied (Tables 2 and 3; $P > 0.05$).

Components of Aerobic Performance

Aerobic-performance data are presented in Table 2 but given only as percentages in the text to simplify the results. For both groups, VO_{2max} significantly increased after the treatment. Regarding VO_{2max}, however, a treatment × time effect indicated that VO_{2max} increased significantly more in the HMB group (when expressed in percentage of increase) than in the PLA group (+8.4% ± 0.9% and +15.5% ± 1.8% for the PLA and HMB groups, respectively).

Analyses of data indicate that the T_{max} significantly decreased for both groups as a result of the training program. Regarding T_{max}, however, a treatment × time effect indicates that T_{max} decreased more in the HMB group than in the PLA group (–27.1% ± 9.1% and –42.4% ± 6% for the PLA and HMB groups, respectively).

For both groups, VT was improved when expressed in $mL \cdot kg^{-1} \cdot min^{-1}$ ($P < 0.05$). No significant difference was found, however, for either group when the results were expressed as a percentage of VO_{2max} relative to each group. On the other hand, analyses of the data did not indicate a significant difference regarding the improvement of VT between the groups (+9% ± 1.9% and +11.1% ± 3.6% for the PLA and HMB groups, respectively). The results of the evolution of RCP for both groups are almost similar to those of VT. Indeed, regardless of the group investigated, there was a significant increase in RCP when expressed in $mL \cdot kg^{-1} \cdot min^{-1}$, whereas this was not the case when expressed in percentage of VO_{2max}. Unlike VT, however, RCP significantly improved more for the HMB group than for the PLA group (time × treatment effect) after the 5 wk of training (+8.6% ± 1.2% and +13.4% ± 2% for the PLA and HMB groups, respectively).

Body Composition

Body-composition data are presented in Table 3. They do not indicate significant changes between the pre- and posttest for either studied group. Furthermore, there was no significant difference (no time × treatment effect) between the 2 groups for all body-composition variables after the training and supplementation period.

Discussion

To our knowledge, this is the first study to investigate the effects of HMB supplementation on different components of aerobic performance, as well as on body composition, in active college students unaccustomed to high-intensity interval training.

The results of this 5-wk study indicate that a high-intensity interval-training program significantly increased VO_{2max}. Furthermore, the addition of HMB supplementation of 3 g/d increased this improvement twofold. The present results are in contrast with those of 3 other studies in which there were no increases in VO_{2max} after a supplementation period in previously trained subjects (19, 34, 26). Although speculative, it thus appears that HMB improves VO_{2max} in active subjects unaccustomed to interval training but remains ineffective in previously trained athletes. It

Table 2 Aerobic-Performance Components for Placebo and HMB Groups Pre- and Postsupplementation

Aerobic-performance component	Placebo Group (n = 8)			HMB Group (n = 8)		
	Pretest	Posttest	Change (% of pretest)	Pretest	Posttest	Change (% of pretest)
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	51.74 (2.73)	56.11 (3.10)[a]	+8.38 (0.90)	50.63 (2.56)	58.34 (2.73)[a]	+15.47 (1.78)[b]
T_{max} (min)	4.15 (0.39)	2.99 (0.41)[c]	–27.06 (9.11)	6.35 (1.16)	3.49 (0.71)[a]	–42.44 (5.99)[b]
VT ($mL \cdot kg^{-1} \cdot min^{-1}$)	32.88 (1.57)	35.78 (1.63)[c]	+9.03 (1.88)	33.81 (1.60)	37.61 (2.23)[c]	+11.08 (3.55)
VT (% of VO_{2max})	63.89 (2.19)	64.21 (2.19)	+0.59 (1.57)	66.93 (1.39)	64.40 (2.27)	–3.77 (2.92)
RCP ($mL \cdot kg^{-1} \cdot min^{-1}$)	41.43 (2.37)	44.88 (2.40)[c]	+8.55 (1.24)	42.59 (1.89)	48.30 (2.34)[c]	+13.41 (2.01)[b]
RCP (% of VO_{2max})	80.21 (2.47)	80.31 (2.45)	+0.17 (0.96)	84.35 (1.26)	82.89 (1.68)	1.73 (1.36)

[a]Significantly different than presupplementation values for the same group ($P < 0.01$).

[b]Time × treatment effect. Significantly different change between the 2 groups because of supplementation ($P < 0.05$).

[c]Significantly different than presupplementation values for the same group ($P < 0.05$).

Values are means (SEM). HMB indicates β-hydroxy-β-methylbutyrate; VO_{2max}, maximal oxygen uptake; T_{max}, time to exhaustion at maximal oxygen consumption, determine the maximal duration a subject can run at an intensity matching VO_{2max}; VT, ventilatory threshold; and RCP, respiratory-compensation point.

Table 3 Body-Composition Components for the Placebo and HMB Groups Pre- and Postsupplementation

	Placebo Group (n = 8)			HMB Group (n = 8)		
Body-composition component	Pretest	Posttest	Change (% of pretest)	Pretest	Posttest	Change (% of pretest)
TBM (kg)	71.31 (5.63)	70.86 (5.37)	–0.43 (0.69)	64.23 (2.78)	63.98 (2.68)	–0.34 (0.58)
Total BF (kg)	15.48 (2.91)	14.89 (2.68)	–0.98 (3.07)	12.49 (1.57)	12.03 (1.66)	–4.78 (2.58)
Total LBM (kg)	52.88 (3.64)	53.01 (3.53)	+0.35 (0.12)	49.10 (2.92)	49.27 (2.70)	+0.53 (0.74)
Total BF (% of total tissue mass)	21.83 (3.16)	21.29 (2.93)	–0.39 (2.66)	20.41 (2.52)	19.64 (2.56)	–4.53 (2.39)
Total LBM (% of total tissue mass)	78.18 (3.16)	78.71 (2.93)	+0.78 (0.51)	79.59 (2.52)	80.36 (2.56)	+0.98 (0.50)

Values are presented as mean (SEM). HMB indicates β-hydroxy-β-methylbutyrate; TBM, total body mass; BF, body fat; and LBM, lean body mass.

is therefore important to take into account the initial level of training and the type of training (high-intensity intermittent vs. continuous aerobic) when one examines HMB's effectiveness. Some investigators have addressed this issue when assessing the effect of HMB on strength and muscle mass after a strength-resistance-training program (20, 32). As mentioned in another study (25) these results suggest that HMB is effective at enhancing physical performance at the beginning of an unaccustomed training program and that this effectiveness decreases with training. More studies are needed, however, with the same kind of training that include previously trained and previously untrained subjects to postulate about this. On the other hand, the effectiveness of HMB might simply result from the types of training programs that the subjects underwent. Indeed, VO_{2max} in the present study was similar to that of the subjects that were currently training in the study by Knitter et al. (19). In the latter study, however, the authors did not provide any information about the training the subjects underwent, so presently it is not possible to speculate about the effectiveness of HMB and the type of training program.

The present study also found an increase in VT and RCP after the 5 wk of training in both groups when expressed in $mL \cdot kg^{-1} \cdot min^{-1}$. For RCP, the increase was significantly greater in the HMB group than in the PLA group. For VT, the increases were not significantly different in the 2 groups. These results suggest that HMB supplementation can reduce the metabolic acidosis resulting from insufficient buffering of lactic acid during intense exercise (for a review see 24). Some researchers have suggested that the VT response was produced by a stimulus other than the onset of blood lactate accumulation (17). Evidence supporting the dissociation of lactate and ventilatory thresholds has emerged from studies examining patients with McArdle's disease who cannot produce lactic acid but displayed a thresholdlike ventilatory response similar to that of normal patients (17). This observation led to the tentative conclusion that the hyperventilation observed during intense exercise does not appear to be influenced by pH. These observations must be interpreted with caution, however, because individuals with McArdle's disease can exhibit a mechanism for ventilatory drive that compensates for their lack of blood acidosis. Although a variety of additional mechanisms have been postulated to explain the increased ventilation (core temperature, serum potassium and catecholamine, neuronal impulses, local mechanoreceptors), it is uncertain whether one or more of such mechanisms could contribute to the hyperpnea during exercise. Moreover, a recent study (23) directly demonstrated that the onset of hyperventilation starting at RCP can be attributed to a failure of buffering capacity. Those authors demonstrated that a decline in blood pH, induced by lactic acidosis, is a major stimulus for hyperventilation during intense exercise, although additional factors might also stimulate ventilation.

Both VT and RCP reflect differences in endurance capacity. High values of both thresholds, particularly that of RCP, reflect the ability to tolerate high-intensity activity over a long period of time even with high blood lactate concentration (24). Our results show that a greater increase in RCP after HMB supplementation can be explained by the proposed training. Indeed, the improvement induced by high-intensity (100% VO_{2max}) endurance training above anaerobic threshold has already been reported to be more marked for RCP than for VT (27). Therefore, our findings suggest that during intense endurance training, HMB supplementation might support the improvement in pH-buffering capacity induced by training.

Knitter et al. (19) proposed that HMB could have affected muscle-buffering capacity by acting on the cellular proteins' content by preventing their catabolism or by stimulating their synthesis, as indicated by a reduced blood plasma creatine-kinase concentration after a 20-km run. Furthermore, some findings indicate that HMB might decrease protein catabolism, as indicated by a decrease in 3-methylhistidine excretion during strength training (25). The effect of HMB on buffering capacity is reinforced by Vukovich and Dreifort (34), who observed a blood lactate concentration corresponding to VO_{2peak} that increased after HMB supplementation. Muscle-buffering capacity was not measured in the present study, so it is still hypothetical that HMB can improve it.

On the other hand, the data also indicate no significant changes for VT and RCP between the groups after the training program when the 2 thresholds are expressed in percentage of VO_{2max}. This can be attributed to the fact that the ratios VT:VO_{2max} and RCP:VO_{2max} stayed constant after the training, which means that VT and RCP improvements induced by training do not exceed VO_{2max} increase.

The T_{max} values for the pretest are in accordance with those found in the existing literature (22). Even if the T_{max} has a large aerobic component, it also reflects the ability of athletes to run in anaerobic conditions (11). Our results indicate that the T_{max} significantly decreased for both groups. Furthermore, this decrease was significantly larger for the HMB group. Two main factors can explain this. First, the T_{max} is negatively correlated with VO_{2max} (11). This explains why the HMB group has the greatest increase in VO_{2max} while recording the greatest decrease in T_{max}. Second, an intense training program using intensities close to VO_{2max} was not suitable to produce an increase in T_{max} (18). Thus, the larger decrease of T_{max} in the experimental group can be explained by the intense interval training coupled with HMB supplementation that together are well adapted to improve VO_{2max}. The more VO_{2max} is increased the harder it is for subjects to maintain the higher running speeds for extended periods of time.

Although the mechanisms whereby HMB influences some components of sport performance are unknown, it is suggested that HMB might have affected cell-membrane protection as demonstrated by an in vitro study (7). Nissen et al. (25) have suggested that HMB might provide a protecting and anticatabolic effect that could decrease free-radical-induced protein breakdown. HMB can be converted to HMG-CoA, which can provide carbon for cholesterol synthesis and thus support cell-membrane integrity. Muscle-cell-membrane stability was not measured in the present study so it is not possible to assert that HMB improves some components of aerobic performance by protecting the sarcolemma. Nevertheless, Billat et al. (6) demonstrated that 4 wk of the same interval training used in the present study induced a significant increase of subjective ratings of DOMS in endurance-trained athletes (for a review about DOMS, see 10). From this finding we can assume that the stress induced by this type of training could induce DOMS in subjects unaccustomed to high-intensity interval training similar to the subjects in the present study. Exercising while experiencing DOMS can decrease performance while performing typical endurance-type activities (15, 16). Therefore, HMB could help maintain cell integrity during intense exercise and prevent muscle damage and associated protein breakdown. For this reason, HMB might have a greater effect during the initial phase of a training program. After that, muscle cells become more resistant to exercise-induced cell damage (9, 14) and the effectiveness of HMB is reduced.

The second aim of this study was to examine the capacity of HMB supplementation to enhance the effects of a high-intensity endurance-training program on body composition. There was no time × treatment effect concerning any body-composition variables after the training period. This indicates no significant differences in body-composition changes between groups. The lack of significance between the 2 studied groups could be explained by a high variance of change in body-composition results. Indeed, body-composition measures from dual-energy X-ray absorptiometry can be influenced by state of hydration and food intake. Scanning all subjects in the morning before breakfast was not logistically possible; the subjects were scanned between 8 AM and 2 PM. Longer studies are needed to postulate about the effect of HMB on body composition in active individuals after high-intensity aerobic training. Nonetheless, the fact that in other studies (20, 30, 32, 35) HMB was associated with a greater body-fat reduction remains largely unexplained, even if it seems that the subjects' initial level of training remains a critical factor regarding the effect of HMB on body composition.

The present study suffers from 3 major limitations. 1) We assume that the training induced DOMS, but this or other indicators of membrane damage were not measured. Therefore, from the present findings the concept that HMB might preserve cell-membrane stability remains just a speculation, although there is good evidence that it occurs (19, 25). 2) Lactate-buffering capacity was not directly measured during the present study. Indeed, we used ventilatory results VT and RCP to assess it. 3) Subjects were not scanned with dual-energy X-ray absorptiometry in the same order and at the same time of day between the pre- and posttests, so body-composition results might have been influenced by the subjects' state of hydration.

In conclusion, this study found that compared with a placebo condition, supplementation with HMB coupled with a high-intensity interval-training program induced a greater increase in VO_{2max} and in RCP in active subjects. Our results support the hypothesis that HMB represents an effective supplement to improve some components of aerobic performance. In this sense, HMB seems to support the normal response of training in subjects unaccustomed to high-intensity interval training.

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