β-Hydroxy-β-Methylbutyrate (HMB) Supplementation Does Not Affect Changes in Strength or Body Composition During Resistance Training in Trained Men

Gary Slater, David Jenkins, Peter Logan, Hamilton Lee, Matthew Vukovich, John A. Rathmacher, and Allan G. Hahn

This investigation evaluated the effects of oral β-Hydroxy-β-Methylbutyrate (HMB) supplementation on training responses in resistance-trained male athletes who were randomly administered HMB in standard encapsulation (SH), HMB in time release capsule (TRH), or placebo (P) in a double-blind fashion. Subjects ingested 3 g · day⁻¹ of HMB or placebo for 6 weeks. Tests were conducted pre-supplementation and following 3 and 6 weeks of supplementation. The testing battery assessed body mass, body composition (using dual energy x-ray absorptiometry), and 3-repetition maximum isoinertial strength, plus biochemical parameters, including markers of muscle damage and muscle protein turnover. While the training and dietary intervention of the investigation resulted in significant strength gains ($p < .001$) and an increase in total lean mass ($p = .01$), HMB administration had no influence on these variables. Likewise, biochemical markers of muscle protein turnover and muscle damage were also unaffected by HMB supplementation. The data indicate that 6 weeks of HMB supplementation in either SH or TRH form does not influence changes in strength and body composition in response to resistance training in strength-trained athletes.

_key Words:_ strength training, ergogenic aid, HMB supplementation

Introduction

Elite athletes readily experiment with nutritional ergogenic aids in an attempt to enhance training adaptations and, in turn, performance. β-hydroxy β-methylbutyrate (HMB), a metabolite of the essential branch chain amino acid leucine is a relatively

G. Slater is with the Sports Medicine Sports Science Division of the Singapore Sports Council, National Stadium, Singapore 397718. D. Jenkins is with the School of Human Movement Studies at The University of Queensland, Brisbane, Australia 4072. P. Logan, H. Lee, and A.G. Hahn are with the Department of Physiology at the Sports Science Sports Medicine Centre, Australian Institute of Sport, Canberra, Australia 2616. M. Vukovich is with the Human Performance Laboratory at South Dakota State University, Brookings, SD 57007. J.A. Rathmacher is with the Department of Animal Science at Iowa State University, Ames, IA 50011-3150.
new dietary supplement to become commercially available; it is already popular among strength athletes (24). Unlike anabolic hormones that induce muscle hypertrophy by increasing muscle protein synthesis (8), HMB is claimed to influence strength and lean body mass by acting as an anti-catabolic agent, thereby minimizing protein breakdown and damage to cells that may occur with intense exercise (5, 17, 18). As tissue protein content is the net result of the rates at which protein synthesis and degradation occurs, muscle hypertrophy reflects either an increase in the rate of synthesis, a decrease in the rate of degradation, or a combination of both (1, 3, 6, 12). Thus, HMB may influence lean body mass accretion and strength development associated with resistance training if it is able to reduce muscle protein degradation.

Dose-responsive reductions in serum concentrations of muscle specific enzymes and urinary excretion of 3-methylhistidine (3-MH) have led researchers to conclude that HMB supplementation (1.5–3.0 g · d⁻¹ for 3–8 weeks) reduces skeletal muscle damage and proteolysis associated with the initiation of resistance training programs in previously untrained subjects (5, 18). Significantly greater gains in isoinertial strength with HMB supplementation (1.5–3.0 g · d⁻¹ as the calcium salt for 3–8 weeks) have also been reported in male (18, 20) and female (20) subjects initiating resistance training compared to those on placebo. Concomitantly significantly greater gains in lean body mass in previously untrained subjects have also been observed with HMB administration (5), adding support to the ergogenic claims made regarding HMB.

If HMB does reduce muscle protein catabolism associated with exercise, resistance trained subjects may not respond to HMB supplementation in the same manner as untrained individuals due to training induced suppression of protein breakdown (21). Indeed, the effect of HMB administration on resistance-trained subjects is more variable. While greater gains in strength and/or lean body mass have been reported with HMB administration (1.5–3 g · d⁻¹ as the calcium salt) in resistance-trained subjects (18, 20), this effect has not been observed by all researchers (14). Kreider and colleagues (14) recently reported that HMB administration (3–6 g · d⁻¹ as the calcium salt) for 4 weeks had no discernable effect on protein catabolism or training induced changes in body composition or strength in experienced resistance trained males. Considering that strength trained athletes have less potential for gains in strength when compared to their untrained counterparts (10), 4 weeks of HMB supplementation may be an inadequate period of time for adaptations unique to HMB supplementation to occur. The hypothesis of the present investigation was that administration of HMB for 6 weeks would be a sufficient period of time for strength training induced adaptations unique to HMB administration to be identified. Additionally, we proposed that administration of HMB (3 g · d⁻¹ as the calcium salt) in a time-release formulation would increase percentage retention and further enhance the potential of identifying adaptations unique to HMB administration.

**Methods**

**Subjects**

Seventeen members of the Australian Institute of Sport National Men’s Water Polo squad and 10 national-level male rowers volunteered to participate in this study.
Subjects had a minimum of 2 years resistance training history. Prior to the investigation, each subject was informed of the full requirements of the 6-week investigation and completed medical examinations before giving their informed consent. Participation was voluntary. The study was approved by the Australian Sports Commission Human Ethics Committee and The University of Queensland’s Medical Research Ethics Committee.

**Study Design**

Strength, biochemical, and body composition profiles of all subjects were obtained prior to this longitudinal, double-blind, parallel-design supplementation trial. As volunteers were athletes vying for selection on the Australian national team for the Sydney Olympics, relatively non-invasive and time-efficient techniques were employed. Therefore, the pursuit of highly trained volunteers was prioritized over scientific rigor in the selection of monitoring techniques.

Baseline assessment included: a 3-day food diary, a fasting venous blood sample, 24-hour total urinary collection, measurement of body mass and body composition, plus performance of three-repetition maximal (3RM) effort isoinertial strength tests. All testing undertaken at baseline was repeated following 3 and 6 weeks of supplementation. Training was standardized for the 48 hours prior to each testing period. A schematic diagram summarizing the 6-week trial is presented in Figure 1.

**Supplementation**

Following baseline assessment, subjects were matched according to total strength combined across the three lifts and in a randomized, double-blind manner, allocated to one of three groups for the duration of the 6-week trial. One group (SH) of athletes \((n = 9; 5\text{ water polo, 4 rowing})\) received standard HMB supplementation (Experimental and Applied Science, Golden, CO) at a dosage of \(3 \text{ g} \cdot \text{d}^{-1}\) throughout a 6-week resistance training cycle. The second group (TRH) of subjects \((n = 9; 6 \text{ water polo, 3 rowing})\) adopted a modified HMB supplementation regimen \((3 \text{ g} \cdot \text{d}^{-1})\) with the supplement provided in a time-release capsule, prepared by Experimental and

![Figure 1](image-url)  

**Figure 1** — An overview of the 6-week experimental period. Subjects \((n = 22)\) were tested at baseline, at week 3, and again at week 6.
Applied Science (Golden, CO). A third and final group (P) of athletes (n = 9; 6 water polo, 3 rowing) was administered a placebo (rice flour) throughout the same cycle. All athletes (SH, TRH, and P) were advised they were taking a dietary supplement that could potentially enhance adaptations in strength, power, and lean body mass associated with resistance training. The supplement was provided in labeled, sealed, plastic bottles, containing exactly 10 days dosage. Bottles were replaced upon consumption of all capsules at the end of each 10-day period. Instructions for the designated dosage regimen were provided to each subject at the start of the trial. Subject compliance in taking the supplement was verified by the use of food diaries, identifying empty supplement containers, assessing blood and urine samples for HMB concentrations, and a post-study questionnaire. Treatment codes for the 6-week trial were maintained by an independent third party who did not reveal the code until final analysis had been completed.

For SH and TRH groups, each capsule contained 250 mg of HMB. All subjects were required to consume 12 capsules daily, divided over three even doses to be taken with main meals. The intention was to maintain high circulating plasma HMB levels throughout the day. Previous work by Nissen et al. (18) has shown that two divided doses of 1.5 g each daily resulted in the loss of almost half of the supplemented HMB via renal excretion, with urinary losses proportional to blood levels. Plasma levels of HMB have been shown to peak 60–120 min after ingestion, with a half-life of approximately 6 hours (unpublished observations).

All medication prescribed by physicians was permitted prior to and during the trial. However, subjects were instructed not to ingest creatine, HMB, or any other nutritional supplements or proposed ergogenic aids for a 4-week period before the start of supplementation or during the course of the study. No subject had previously ingested HMB.

**Body Composition**

Total body mass was measured on a calibrated digital scale with a precision of ±0.02 kg (A & D Co., Toyko, Japan) at a standardized time of day, 4 to 5 days before commencement of supplementation. Height was measured using a wall mounted stadiometer (Holtain Ltd., Crymych, UK), with precision to ±1 mm. Whole body body-composition measurements were determined by a Norland XR-36 series dual energy x-ray absorptiometer (DEXA) (Norland Corp., Fort Atkinson, WI), with Norland Body Composition Software (v. 2.5.0) using procedures previously described (7). Quality control calibration procedures were undertaken according to the manufacturer's specifications at the beginning of each testing session using a calibration standard provided with the scanner. All DEXA measurements were made by a qualified radiologist.

**Urine Collection and Analysis**

An animal flesh-free diet was followed for 3 days prior to and during the 24-hour urine collection in order to eliminate the effects of diet on 3-MH. Both lunch and dinner were provided in an athlete dining hall during this period to enhance compliance with the animal flesh-free diet. Subject compliance to the animal flesh-free diet was verified by maintenance of food diaries. Vegetarian meals were prepared according to directions provided by a qualified dietitian, ensuring nutrient intake was
not compromised during meat-free periods. Urine was collected in 5-L polyethylene bottles, with 2 ml of 6 N HCl as preservative. Urinary volume was quantified using a calibrated balance scale with a precision of ±0.1 g (Sartorius, Gottingen, Germany), accounting for polyethylene bottle and HCL weight. Aliquots (2 ml) of mixed 24-hour urine collection were stored at −80 °C in 5-ml cryogenic vials (Nalge Co., Rochester, NY) until analysis for 3-MH, HMB, and creatinine (CRTN).

Urinary CRTN was measured with a Boehringer Mannheim/Hitachi 911 fully automated biochemistry analyzer (Boehringer Mannheim, Mannheim, Germany) using standard photometric techniques. Urinary 3-MH and HMB were assayed using high performance gas chromatography/mass spectrometry (GC/MS) procedures previously described (19, 22).

**Blood Collection and Analysis**

On the same day as urine collection and following an overnight fast, venous blood was sampled via venipuncture from a superficial forearm vein using standard phlebotomy procedures. Venous blood was collected into an 8-ml serum separation tube (SST) and a 4-ml anticoagulant tube containing K$_2$EDTA, using the vacutainer system (Greiner Labortechnik, Kremsmünster, Austria). The EDTA tube was inverted several times to ensure mixing of anticoagulant and blood. Following coagulation of blood in the SST, both SST and EDTA tubes were centrifuged at 4,500 rev·min$^{-1}$ for 5 min using a Labofuge 400R centrifuge (Radiometer Copenhagen, Denmark). Plasma was drawn from the EDTA tubes with disposable 1-ml pasteur pipettes (Copen Italia, Brescia, Italy), transferred to 1.5-ml cryogenic vials (Nalge Co., Rochester, NY) and frozen at −80 °C for later analysis of HMB.

Serum from the SST was analyzed for CRTN, urea, creatine kinase (CK), and lactate dehydrogenase (LDH) using a Boehringer Mannheim/Hitachi 911 fully automated biochemistry analyzer (Boehringer Mannheim, Mannheim, Germany) using standard photometric techniques. Serum CRTN was assessed using a similar method as described for urine. Serum urea was measured using a kinetic UV assay, enzymatic procedure for the determination of urea using the coupled urease/glutamate dehydrogenase enzyme system (Boehringer Mannheim, Mannheim, Germany). Serum CK and LDH were assayed using an optimized standard method conforming to the recommendations of the Deutsche Gesellschaft fur Klinische Chemie (9). Remaining serum was analyzed for cortisol and testosterone using the Boehringer Mannheim ES-300 Immunoassay system (Boehringer Mannheim, Mannheim, Germany). Plasma HMB was assayed using high performance GC/MS procedures previously described (19).

**Strength Testing**

On the same day that blood and urine samples were collected, subjects performed 3RM isoinertial strength tests for three exercises: bench press, 45° leg press, and chin-ups, in that order. These are the three isoinertial strength tests routinely used by volunteers in this investigation to monitor resistance training adaptations. Each athlete performed a standardized warm-up for each exercise based on previously measured 3RM results (8 reps @ 40% previous 3RM, 5 reps @ 60% 3RM, 3 reps @ 80% 3RM, 3 reps @ 3RM). This was followed by attempts at progressively heavier weights (2.5-kg increments for bench press and chin-ups; 5-kg increments for 45°
leg press) to obtain the athlete's new 3RM. Subjects were required to maintain good lifting form in all exercises. A 3RM strength test was chosen, as all athletes had previous experience in the use of this repetition range to monitor strength training adaptations. Furthermore, this repetition range more closely approximated the repetitions prescribed during the investigation. All 3RM tests were performed under the supervision of a certified strength and conditioning specialist using standardized lifting criteria (16).

**Training**

Resistance training programs, designed to maximize strength development, were prepared and monitored at each training session by Australian Institute of Sport strength and conditioning coaches. All athletes undertook 2–3 resistance training sessions weekly and were in a pre-competition phase of training. Each session emphasized compound exercises including bench press, chin-ups, leg press, shoulder press, and seated rowing, with all major muscle groups trained at each session. Each exercise used a repetition range of 4–6 for 3–5 sets, with a total of 24 to 32 sets per session. Other sport specific training was under the direct guidance of each athlete's respective coach.

**Dietary Intervention**

All subjects completed training logs throughout the entire investigation and also maintained regular dietary logs. In addition to advice on maintaining dietary logs, all subjects received advice from a qualified dietitian on the most appropriate nutritional intervention to maximize muscle hypertrophy, optimizing conditions under which HMB supplementation may work. To support an increase in energy density, all subjects were required to supplement their diet with a vitamin/mineral fortified carbohydrate/protein powder (Myoplex Plus™, Experimental & Applied Sciences, Golden, CO) providing an additional 1170 kJ, 24 g carbohydrate, 42 g protein, and 2 g fat per day. Subject compliance in taking this supplement was verified by the use of food diaries. Food diaries were evaluated and analyzed by a qualified dietitian using Foodworks dietary analysis program (Zyris Software, Brisbane, Australia). Results of data from food diaries during the period of supplementation (weeks 2, 4, and 6) were averaged and compared to baseline to assess the effectiveness of dietary intervention in increasing energy density.

**Statistical Analysis**

For subjects with missing data from a specific test at week 3, a mean substitution method was employed to account for the missing value. For all other missing data, subjects test results were removed from analysis for that specific test only. When HMB formulations were assessed separately, all dependent variables were analyzed using a $3 \times 3$ repeated measures factorial analysis of variance (ANOVA). When HMB formulations were assessed together, all dependent variables were analyzed using a $2 \times 3$ repeated measures factorial ANOVA. Furthermore, for the combined data, delta scores (week 6-baseline) were calculated for key performance parameters (body composition, 3RM strength). Strength of changes from baseline was evaluated by calculating proportion of variance accounted for ($R^2$), an indicator of
effect size in ANOVA (2). Operationally defined, $R^2 = 0.01$ is a small effect size, $R^2 = 0.06$ is a medium effect size, and $R^2 = 0.14$ is a large effect size. It was considered important to obtain information relating to effect size so that any medium to large effects were not missed due to the relatively small subject pool.

All statistical analysis was undertaken using Stata software (v. 5, StatSoft, Tulsa, OK). Significance was accepted at $p < .05$. When a significant Group × Time interaction or significant main effect was observed, a Newman-Keuls post hoc test was used to locate significant differences between means. All data are presented as the mean ± SEM.

Results

Subjects

While all subjects completed the 6-week trial, 5 subjects (2 P, 2 SH, 1 TRH) were not included in the analysis due to injuries incurred during the study period that prevented them from participating in one or more testing periods. Characteristics of the remaining subjects (7 P, 7 SH, 8 TRH) are presented in Table 1. Three of these subjects (1 P, 2 SH) were removed from analysis of urinary parameters due to incomplete 24-hour urine collection during one of the testing periods.

Training and Diet

There were no differences between groups in total lifting volume during the 6-week trial. Total energy and protein intake was not different between groups at baseline or during the period of supplementation. However, dietary advice and supplementation significantly increased mean protein intake (pre $1.7 ± 0.1 \text{ g} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$, post $2.4 ± 0.1 \text{ g} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$; $p = .05$) and tended to increase mean energy intake (pre $202.6 ± 7.7 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$, post $224.1 ± 9.5 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$; $p = .06$) in all groups combined during the trial.

Table 1 Characteristics of the 22 Subjects Included in the Final Analysis of Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>P</th>
<th>SH</th>
<th>TRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>24.0 ± 1.4</td>
<td>24.9 ± 2.0</td>
<td>25.3 ± 1.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>191.4 ± 2.1</td>
<td>192.2 ± 1.7</td>
<td>190.1 ± 2.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>89.0 ± 1.1</td>
<td>89.7 ± 1.8</td>
<td>90.7 ± 3.9</td>
</tr>
<tr>
<td>Resistance training history (years)</td>
<td>7.1 ± 1.7</td>
<td>7.4 ± 2.0</td>
<td>6.9 ± 0.8</td>
</tr>
</tbody>
</table>

Note. P = placebo group; SH = standard HMB group; TRH = time-release HMB group.
Body Composition

Body mass increased significantly \((p < .01)\) during the 6 weeks of training and supplementation, but no significant differences were observed between groups at any time point in absolute body mass (Table 2). While a significant \((p = .01)\) increase in total lean mass (excluding bone mineral content) was also identified during the course of the trial, no Group \(\times\) Time interaction \((p = .25)\) was evident (Table 2). Subjects tended \((p = .06)\) to decrease fat mass during the 6 weeks of training. However, no Group \(\times\) Time interaction \((p = .45)\) was reported (Table 2).

Strength

While significant \((p < .001)\) increases in total strength were observed, no Group \(\times\) Time interactions were evident between groups in 3RM strength at any time point for any of the three strength tests, either separately or when results from lifts were combined (Table 3). However, there was a trend \((p = .09)\) towards an interaction for 3RM chin-up strength. Upon completion of the trial, 3RM chin-up strength scores appeared greater for both P and TRH compared to SH. All subjects increased chin-up 3RM results during the investigation except one. When this outlying subject’s results were removed from analysis, any effect on chin-up 3RM strength was lost \((p = .20)\).

Table 2  Body Composition Measurements Before (Baseline) and After 3 and 6 Weeks of Either Placebo (P), Standard HMB (SH), or Time-Release HMB (TRH) Administration

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Week 3</th>
<th>Week 6</th>
<th>Variable</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total lean mass (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>69.2 (1.2)</td>
<td>69.9 (1.0)</td>
<td>70.1 (1.0)</td>
<td>Group</td>
<td>.87</td>
</tr>
<tr>
<td>SH group</td>
<td>68.7 (2.1)</td>
<td>70.6 (1.2)</td>
<td>69.9 (1.1)</td>
<td>Time</td>
<td>.01</td>
</tr>
<tr>
<td>TRH group</td>
<td>69.2 (2.6)</td>
<td>70.5 (2.1)</td>
<td>72.7 (1.8)</td>
<td>Group (\times) Time</td>
<td>.25</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>14.2 (0.8)</td>
<td>14.9 (1.1)</td>
<td>13.8 (1.1)</td>
<td>Group</td>
<td>.90</td>
</tr>
<tr>
<td>SH group</td>
<td>15.7 (1.9)</td>
<td>14.7 (1.5)</td>
<td>14.7 (1.6)</td>
<td>Time</td>
<td>.06</td>
</tr>
<tr>
<td>TRH group</td>
<td>16.6 (2.8)</td>
<td>15.9 (2.5)</td>
<td>14.1 (2.7)</td>
<td>Group (\times) Time</td>
<td>.45</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>89.0 (1.2)</td>
<td>89.80 (1.4)</td>
<td>89.7 (1.4)</td>
<td>Group</td>
<td>.85</td>
</tr>
<tr>
<td>SH group</td>
<td>89.7 (1.9)</td>
<td>90.0 (2.1)</td>
<td>89.9 (1.8)</td>
<td>Time</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>TRH group</td>
<td>90.7 (3.9)</td>
<td>91.6 (3.7)</td>
<td>92.2 (3.8)</td>
<td>Group (\times) Time</td>
<td>.23</td>
</tr>
</tbody>
</table>

Note. Total lean mass (excluding bone mineral content) and fat mass are calculated from DXA scan results. Values are means \((SEM)\) for 7 subjects in the P and SH groups, and 8 subjects in the TRH group.
Table 3 Three Repetition Maximum Isoinertial Strength Test Results Before (Baseline) and After 3 and 6 Weeks of Either Placebo (P), Standard HMB (SH), or Time-Release HMB (TRH) Administration

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Week 3</th>
<th>Week 6</th>
<th>Variable</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>91.8 (6.5)</td>
<td>95.00 (6.4)</td>
<td>97.5 (6.3)</td>
<td>Group</td>
<td>.86</td>
</tr>
<tr>
<td>SH group</td>
<td>91.1 (5.1)</td>
<td>93.2 (4.6)</td>
<td>95.7 (4.6)</td>
<td>Time</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TRH group</td>
<td>94.7 (4.9)</td>
<td>97.2 (5.3)</td>
<td>100.3 (4.7)</td>
<td>Group × Time</td>
<td>.91</td>
</tr>
<tr>
<td>Leg press (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>325.0 (21.3)</td>
<td>370.0 (21.2)</td>
<td>397.1 (19.5)</td>
<td>Group</td>
<td>.59</td>
</tr>
<tr>
<td>SH group</td>
<td>365.7 (35.9)</td>
<td>387.9 (29.9)</td>
<td>407.9 (25.0)</td>
<td>Time</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TRH group</td>
<td>321.9 (16.3)</td>
<td>359.4 (15.0)</td>
<td>388.1 (19.2)</td>
<td>Group × Time</td>
<td>.50</td>
</tr>
<tr>
<td>Chins (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>112.5 (2.5)</td>
<td>117.9 (2.6)</td>
<td>121.1 (2.1)</td>
<td>Group</td>
<td>1.00</td>
</tr>
<tr>
<td>SH group</td>
<td>114.2 (6.0)</td>
<td>117.5 (5.5)</td>
<td>118.6 (5.4)</td>
<td>Time</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TRH group</td>
<td>113.5 (3.8)</td>
<td>117.6 (3.8)</td>
<td>120.3 (3.8)</td>
<td>Group × Time</td>
<td>.09</td>
</tr>
<tr>
<td>Combined (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P group</td>
<td>529.3 (25.2)</td>
<td>582.9 (27.1)</td>
<td>615.8 (26.5)</td>
<td>Group</td>
<td>.75</td>
</tr>
<tr>
<td>SH group</td>
<td>571.0 (39.1)</td>
<td>598.6 (33.4)</td>
<td>622.2 (28.5)</td>
<td>Time</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TRH group</td>
<td>530.1 (18.7)</td>
<td>574.2 (17.1)</td>
<td>608.7 (21.3)</td>
<td>Group × Time</td>
<td>.39</td>
</tr>
</tbody>
</table>

*Note.* Values are means (SEM) for 7 subjects in the P and SH groups, and 8 subjects in the TRH group.

**Blood and Urinary Parameters**

A significant Group × Time interaction (p < .01) was observed for plasma HMB with both SH and TRH observed to have higher plasma HMB levels than P at weeks 3 (P 2.9 ± 0.4; SH 55.4 ± 10.4; TRH 38.7 ± 8.5 nmol/ml) and 6 (P 3.2 ± 0.6; SH 32.8 ± 9.2; TRH 18.3 ± 4.5 nmol/ml). Similar results were observed for urinary HMB excretion with a significant Group × Time interaction identified (p < .01). Both SH and TRH had higher urinary HMB excretion than P at week 3 and 6. Percentage retention of HMB was not significantly different between SH and TRH at either week 3 (SH 59.5 ± 8.1, TRH 58.0 ± 8.0%; p = .90) or week 6 (SH 74.8 ± 4.5, TRH 66.7 ± 12.0%; p = .62) of the investigation.

A trend (p = .07) towards a Group × Time interaction emerged for plasma CK. While CK levels did not significantly change throughout the trial in the SH and TRH groups, levels in the P group peaked after week 3 (P 411.3 ± 118.8; SH 310.3 ± 63.1; TRH 206.9 ± 38.0 u/L). No significant Group × Time interactions (p = .39) were observed among groups for LDH. Furthermore, no significant interactions were observed among groups for testosterone, cortisol, serum urea, CRTN, or urea nitrogen-to-CRTN ratio. Both urea and CRTN values fell within normal reference ranges. The urea nitrogen to CRTN ratio (baseline: 26.6 ± 0.9; week 3: 29.6 ± 1.5; week 6: 30.8 ± 1.5 kg) increased from baseline to week 3 (p = .05) and remained elevated for
the remainder of supplementation. No significant interactions were observed among
groups in 3-MH to creatinine ratio ($p = .38$).

**HMB Data Combined**

As percent retention of HMB was not significantly different between SH and TRH,
results were combined (CHMB) and compared to P. A trend ($p = .07$) towards a
Group $\times$ Time interaction emerged again for CK but not LDH ($p = .62$). No signifi-
cant interaction was observed for any other biochemical, strength, or body composi-
tion parameter. Apart from 3RM chin-up strength ($R^2 = 0.14$), no moderate to large
effects sizes were observed for rates of change in total lean mass ($R^2 = 0.046$), fat
mass ($R^2 = 0.041$), bench press ($R^2 = 0.007$), leg press ($R^2 = 0.035$), or combined
strength ($R^2 = 0.045$).

**Tolerance**

Analysis of mid and post intervention questionnaires revealed that all subjects who
were administered HMB tolerated the product with no reports of gastrointestinal or
other side effects.

**Discussion**

While the training and dietary intervention of the current investigation resulted in
significant strength gains and favorable changes in body composition, HMB adminis-
tration had no discernable influence on these parameters. Our results are in agree-
ment with other research that has assessed the effect of HMB administration (3–6
g $\cdot$ day$^{-1}$) on strength training responses in resistance-trained athletes during four
weeks of intervention (14).

The present data contrast to those previously reported from a number of trials
on untrained (5, 18, 20) and trained (18, 20) individuals. Studies assessing the
influence of HMB administration on resistance training adaptations in previously
untrained subjects have reported improved isoinertial repetition maximum strength
(20) and increases in lean body mass (5) compared to subjects administered placebo.
The reported increases in lean body mass in as little as 4 weeks are surprising given
that increases in maximal strength of untrained volunteers during the initial weeks
of training have been generally ascribed to neural adaptations only (11, 23).

As has been previously proposed (5, 14, 25), resistance-trained individuals
could be less responsive to HMB administration than untrained subjects. This would
most likely be due to training-induced adaptations such as the suppression in skel-
etal muscle protein breakdown observed in resistance trained individuals (21). In
contrast to this hypothesis, however, enhanced resistance training adaptations have
been shown to occur with HMB administration (3 g $\cdot$ day$^{-1}$ as calcium salt in divided
doses) in resistance trained individuals in as little as 4 weeks (18, 20). Nissen et al.
(18) attributed these to an enhancement in muscle function with HMB supplemen-
tation due to significantly greater 1RM bench press (placebo 2.45 kg, HMB 6.82 kg; $p
< .01$) and fat-free mass gains (placebo $\approx$ 0.5 kg, HMB $\approx$ 2.7 kg; $p < .05$ at week 4),
the latter at least during the initial 39 days of intervention. However, results may have
been confounded by the co-ingestion of additional protein (37 g), vitamins, miner-
als, glutamine, and chromium picolinate in HMB administered subjects only (25).
In an effort to clarify the impact of training status on response to HMB, Panton et al. (20) administered HMB (3 g · day⁻¹) to a large group of trained and untrained males and females undertaking 4 weeks of resistance training. Identifying no significant differences in responses, trained and untrained subjects’ results were pooled. Results indicated that individuals administered HMB experienced greater increases in both 1RM bench press strength and fat-free mass. Furthermore, percentage body fat tended to be lower, and plasma CK levels tended to be suppressed, with HMB administration compared to the placebo group. The authors concluded that HMB favorably influenced resistance training responses irrespective of training status.

There may be several reasons why the body composition and strength data of Panton et al. (20) contrast those of the current investigation. First, the training status of their subjects was not clearly reported. Baseline strength data reported by Panton et al. (20) indicate that their “trained” subjects were relatively weaker, and thus less trained, than those who participated in the current investigation. Furthermore, it is reasonable to question why the data of Panton et al. (20) was pooled when the mechanisms and potential for adaptations to the resistance-training stimulus are known to differ between untrained and trained individuals (4, 10, 21). Moreover, the investigation by Panton et al. (20) was only over 4 weeks; Nissen et al. (18) also observed greater gains in lean body mass only during the initial 4 weeks of their investigation. Thus, it could be argued that HMB is only beneficial during the initial period of administration. However, results from the current investigation at week 3 do not support this.

It could be argued that the small sample size and thus relatively low statistical power of the current investigation limited our potential for identifying small differences in resistance training responses. The small effect size for delta scores in body composition and combined strength do not support a limitation due to sample size. However, it should be noted that relative gains in lean body mass for subjects administered HMB were similar to those reported in larger investigations (18, 20), identifying favorable responses with HMB supplementation in resistance trained individuals.

The impact of other sport specific training on results cannot be discounted. While analysis of training diaries confirmed no significant differences in total training volume between sports, training intensity was described subjectively, making a comparison between sports difficult. However, every effort was made to evenly distribute rowing and water polo athletes between the three administration groups (P, SH, TRH), reducing any impact of variation in training load. Furthermore, training was standardized for each athlete in the 48 hours prior to each testing period.

While the marker of muscle protein turnover was not affected by HMB administration, supplementation did appear to suppress increases in plasma CK levels. This response has been observed previously with HMB administration following both running (13) and resistance exercise in untrained (5, 18) and trained (14) males. While a mechanism for this effect is yet to be identified, it has been postulated that HMB is metabolized to β-hydroxy-β-methylglutaryl CoA (HMG-CoA), serving as a key carbon source for cholesterol synthesis (17). Nissen and Abumrad (17) propose that greater intracellular cholesterol availability could maintain membrane integrity and reduce muscle damage in response to resistance exercise. It is not possible to support or refute this proposed mechanism based on results of the current investigation. However, if HMB did enhance membrane integrity, a reduction in LDH levels would also be expected; this was not observed.
Although plasma CK has been used routinely in HMB-related research, its value as an indicator of skeletal muscle damage has been questioned (15, 26, 27). Direct assessment of muscle function via measurement of maximal voluntary isometric contraction torque has been suggested as the best method for quantifying muscle injury (27). Subsequently, Gallagher et al. (5) reported a greater increase in peak isometric torque and concomitantly lower CK levels with HMB administration (3 g·day⁻¹ for 8 weeks), although the former may simply be related to lower baseline values and thus greater potential for improvement among individuals administered this dosage of HMB. This is supported by data from the same investigation indicating that peak isometric torque was not affected by higher doses (6 g·day⁻¹) of HMB. If HMB does reduce skeletal muscle damage, this may allow more frequent and intense training sessions to be undertaken and improve the rate of recovery between sessions. However, this was not evident from performance assessment tests utilized in the current investigation.

To date, all evidence of a reduction in protein catabolism following HMB administration has come from a decrease in 3-MH excretion, specifically during the first 2 weeks of a 3-week investigation on previously untrained individuals (18). This effect was not evident upon completion of that study and has not been observed in any other HMB related investigation. While monitoring 3-MH excretion is a relatively simple and non-invasive method, there is a need to undertake further investigations using more precise techniques like amino acid tracer research to clearly define the effect of HMB administration on protein synthesis and degradation.

In summary, our results show that 6 weeks of HMB administration (3 g·day⁻¹ as either standard or time-release encapsulation) does not influence adaptations to resistance training in athletes with a strong resistance training history. Longer duration investigations on a larger sample of resistance trained individuals, using precise methods of monitoring skeletal muscle damage in addition to protein synthesis and degradation, will be necessary before conclusions can be drawn on the ergogenic value of HMB administration in this population.

References


**Acknowledgments**

This investigation was supported by grants from Experimental and Applied Sciences, Inc., Golden, CO, and the Olympic Athlete Program, Australian Sports Commission. The authors would like to thank coaching staff and athletes from the men’s water polo and rowing programs at the Australian Institute of Sport. Special thanks also to Nicole Horvath, Simone Ransley, Tanya Boston, and Sally Clark from the Department of Physiology and Stuart Cormack from the Strength and Conditioning Unit, Australian Institute of Sport. All experiments comply with current Australian law.