Usefulness of β-hydroxy-β-methylbutyrate (HMB) supplementation in different sports: an update and practical implications

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Abstract

Introduction: although β-hydroxy-β-methylbutyrate (HMB) is generally marketed as a supplement for increasing muscle mass and strength, it is still not fully understood how and in which particular sports and conditions HMB can be more effective.

Aims: the primary purpose of this review is to update and summarize the current knowledge about the usefulness of HMB and to organize this information by different sports with specific reference to sports with high wear and tear phenomena such as soccer, rugby or football.

Methods: a search was performed in PubMed database. This review presents the results about HMB use in sport.

Results: the articles identified in this review support the notion that HMB could help to attenuate tissue catabolism and initiate muscle anabolism particularly in untrained individuals exposed to strenuous exercise or when trained individual are exposed to periods of high physical stress. HMB could therefore be applied in some specific periods of athlete’s season where there are high-intensity training periods, high density of competitions and little recovery time between them, starting recovery phases from an injury period and/or any other different situation where performance or recovery could be affected by a great catabolic environment.

Conclusion: this update contributes to clarify and define possible mechanisms and/or effectiveness of HMB supplementation related to endurance sports (i.e. cycling and athletics), strength-power sports (i.e. resistance training, football, rugby, soccer, judo, waterpolo and rowing) and recreational activities.

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Key words: HMB. Recovery. DOMS. Signalling-molecule. mTOR.

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EFICACIA DE LA SUPLEMENTACIÓN CON β-HIDROXY-β-METILBUTIRATO (HMB) EN EL DEPORTE: ACTUALIZACIÓN E IMPLICACIÓN PRÁCTICA

Resumen

Introducción: aunque el β-hidroxi-β-metilbutirato (HMB) se ha empleado generalmente como suplemento para aumentar la masa muscular y la fuerza, es necesario un mejor entendimiento de su función y averiguar en qué deportes es más efectivo.

Objetivos: el objetivo principal de esta revisión es actualizar y resumir el conocimiento existente en torno a la utilización del HMB para clasificarla en función de cada modalidad deportiva, con especial mención a aquellas actividades con un alto grado de destrucción muscular, como pueden ser el fútbol, el rugby o el fútbol americano.

Métodos: se utilizó la base de datos PubMed para la búsqueda de artículos. Esta revisión presenta los resultados obtenidos sobre la utilización de HMB clasificados por deportes.

Resultados: la mayoría de los artículos seleccionados sugieren que cuando una persona entrenada o no entrenada se somete a un ejercicio intenso difeente al habitual, el HMB puede atenuar el catabolismo muscular producido e iniciar los procesos anabólicos necesarios para recuperar lo antes posible. De esta forma, el HMB podría aplicarse en algunos momentos concretos de la temporada deportiva en los que hubiera períodos con entrenamientos de alta intensidad, o durante un periodo con alta densidad competitiva y con poca recuperación entre competiciones, o bien durante las primeras fases de la readaptación física después de una lesión y/o durante cualquier otra situación en la que el rendimiento o la recuperación se pueden ver afectados por un entorno altamente catabólico.

Conclusión: esta revisión pretende aclarar y definir los posibles mecanismos por los que la suplementación con HMB puede ser efectiva en deportes de resistencia (ciclismo y carreras de fondo), en deportes de fuerza-potencia (fútbol, yudo, waterpolo, remo, fútbol americano y musculación) y en actividades deportivas recreacionales.

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Palabras clave: HMB. Recuperación. DOMS. Molécula de señalización. mTOR.
Abbreviations

3-MH: 3-methylhistidine.
AMPK: Adenosine monophosphate protein kinase.
BCAAs: Branched chain amino acids.
Ca-HMB: β-hydroxy-β-methylbutyrate Calcium Salt.
CD: Cool Down.
CK: Creatine Kinase.
Cr: Creatine.
CHO: Carbohydrate.
CRP: C-reactive protein.
CWI: Cold Water Immersion.
DOMS: Delayed onset muscle soreness.
F: Female.
FM: Fat Mass.
FML: Fat Mass Lost.
FFM: Fat Free Mass.
GH: Growth hormone.
H: Hamstring.
HMB: β-hydroxy-β-methylbutyrate.
HMB-FA: β-hydroxy-β-methylbutyrate-Free Acid.
HMG-CoA: β-hydroxy-methylglutaryl-CoA.
IGF-1: Insulin-like growth factor.
KIC: Ketoisocaproic Acid.
LDH: Lactate Dehydrogenase.
LBM: Lean Body Mass.
LCT: Mitogen activated protein kinase / extracellular signal regulated kinase.
MAS: Running speed during an incremental test at which VO2peak is attained.
MCV: Maximal Voluntary Contraction.
NE: No Effect.
NR: Not Reported.
Q: Quadriceps.
OBLA: Onset of Blood Lactate Accumulation.
PI3K/Akt: Phosphoinositide 3-kinase / Protein kinase B.
PRS: Perceived Recovery Scale.
RCP: Respiratory Compensation Point.
Sirt1: Silent information regulation transcripts.
Tac: Tactical exercises.
Tec: Technical exercises.
TNFa: Tumor Necrosis Factor Alpha.
TNFR1: Tumor Necrosis Factor Receptor 1.
V: Velocity.
VO2peak: Peak oxygen consumption.
VT: Ventilatory Threshold.
WU: Warm-Up.
Y: Yes.

Introduction

Limiting the wear and tear process while exercising and adequate recovery afterwards is fundamental for preserving athletes’ health and their optimal performance. The two key components of recovery are rest and supply of adequate nutrients. Essential nutrients are particularly important. The branched chain amino acids (BCAAs) leucine, isoleucine and valine have been widely studied in this context. Leucine has important roles in protein metabolism, glucose homeostasis, insulin action. Leucine has anti-catabolic properties and facilitates recovery from exercise.

In 1996, it was suggested that a plausible candidate responsible for these effects could be its intracellular derived metabolite β-hydroxy-β-methylbutyrate widely known as HMB, which is endogenously produced in animals and humans. The first step in HMB production is the reversible transamination of leucine to α-ketoisocaproate (KIC) by the enzyme branched chain amino acid transferase. Then, KIC is either metabolized into isovaleryl-CoA in the mitochondria, by the enzyme α-ketoacid dehydrogenase, or into HMB in the cytosol, by the enzyme alpha-ketoisocaproate dioxygenase. KIC is mainly metabolized into isovaleryl-CoA, with only some 5% of leucine being converted into HMB. Isovaleryl-CoA is further metabolized to beta-methyl crotonyl-CoA and then to beta-methyl gluconyl-CoA and β-hydroxy-methylglutaryl-CoA (HMG-CoA). Similarly, HMB can also be converted to beta-hydroxy-methylbutyrate-CoA and then to HMG-CoA. HMG-CoA is a precursor in cholesterol synthesis or alternatively can be degraded to Acetoacetyl-CoA, acetyl CoA and acetoacetate, a ketone body.

Consequently, as precursor of cholesterol it may have structural functions by its incorporation to cell membranes and through acetyl CoA or ketone body may serve as an energy substrate.

Empirically, HMB has been classically proposed and is widely used as a nutritional supplement to limit muscle damage during exercise and to increase muscle gain after strenuous exercise or hard training. The effectiveness of HMB supplementation needs further clarification into how to optimize its administration (dosage and timing) and better specify in which particular conditions its use is recommended and effective. A dose of 3g/day of HMB produces better results on performance markers and has potential health benefits.

Since HMB is a metabolite of leucine, the question is why not simply taking proteins, BCAA or leucine instead of its metabolite. To put this into perspective, a subject would need to consume over 600 g of high quality protein to obtain the amount of leucine (60 grams) necessary to produce the typical 3 g daily dosage of HMB used in human studies. Since consumption of this amount of protein is not realistic and perhaps not even healthy either, HMB is typically administered via dietary supplementation.

In athletic context, a number of studies during the last 15 years have indicated that HMB supplementation may elicit several ergogenic benefits, including better recovery, increased strength, increased lean body mass (LBM), decreased body fat, increased power and improvements in aerobic performance.
Eficacia de la suplementación de HMB en el envejecimiento muscular, la catabolismo, la recuperación muscular y el rendimiento de los atletas deportivos

Francisco J. Albert García et al.

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La suplementación con HMB ha sido utilizada como una estrategia potencial en el tratamiento de pacientes con atrofia muscular, cachexia y sarcopenia. Mientras que algunos estudios han sugerido que la HMB puede ser efectiva en estos programas, otros estudios no han demostrado beneficios. En este estudio, se presenta una revisión sistemática de la literatura científica existente sobre la efectividad de la suplementación con HMB. Se analizarán los posibles mecanismos de acción de la HMB en diferentes deportes, con el objetivo de clarificar y definir las características específicas de cada deporte. La información se organizará en tres tablas (I a III) para cada deporte. La revisión incluirá estudios que evalúen la eficacia de la HMB en deportes específicos, en relación con diferentes variables como edad, género, nivel de entrenamiento y tipo de deporte. Se espera que esta revisión proporcione una guía práctica para entrenadores, nutricionistas y médicos deportivos que deseen entender la relación entre la suplementación con HMB y el rendimiento deportivo.
Usefulness of β-hydroxy-β-methylbutyrate (HMB) supplementation in different sports: an update and practical implications

Practical implications and use of HMB in specific sports

The scientific literature on the effects of HMB on different physiological components evidences that it is population specific and that it depends on the subjects’ physical training status, age, and health status (see figure 2 for a summary of HMB reviews in athletic context). The data show that HMB supplementation could assist in increasing strength and decreasing body fat in untrained healthy individuals as well as in elderly individuals. Several studies have failed to find statistically significant changes in strength and body composition among those subjects who were already on a physical training regimen. The lack of significant changes in such articles has been related to the lack of an adequate exercise stimulus. When high exercise intensity (>80% 1 repetition maximum [1RM]) or progressive loading periodization programs are used in trained individuals, HMB supplementation has shown similar results to untrained or recreational populations. New evidence has shown that HMB supplementation could increase strength, hypertrophy, and power after a 12-week periodized program. Therefore, HMB seems to be more effective during periods of enhanced proteolysis.

Consequently, HMB, at the recommended dose, appears to interact with the training protocol utilized as well as with the experience of the athlete. It is likely that HMB will work ideally if consumed at a dosage of 3g/day for 2 weeks prior to periods of high intensity training.
Table I

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Age</th>
<th>N (Sex)</th>
<th>Doseage</th>
<th>Form</th>
<th>Training Experience</th>
<th>Body Composition</th>
<th>Biochemistry</th>
<th>Sport Performance</th>
<th>Training Load</th>
<th>Duration</th>
<th>Training Modality</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallagher et al.⁶⁵</td>
<td>USA</td>
<td>NR 37M</td>
<td>Placebo, 38 or 76 mg/kg</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>Greater LBM</td>
<td>CK, no effect on lipid profile, immune system or renal function</td>
<td>Greater isokinetic and isotonic torque (independent of dose)</td>
<td>Isometric and isotonic testing protocol</td>
<td>8 weeks</td>
<td>Progressive resistance training</td>
<td>Y</td>
<td></td>
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<tr>
<td>Panton et al.⁶⁶</td>
<td>USA</td>
<td>20-40</td>
<td>39M 36F</td>
<td>3 g/day or Placebo</td>
<td>CaHMB</td>
<td>Trained and Untrained</td>
<td>Decreased in Body Fat %</td>
<td>Decreased CK</td>
<td>Greater increase upper body strength</td>
<td>3 days/week</td>
<td>11 exercises 3x3-6 reps 90% 1RM</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Wilson et al.⁶⁷</td>
<td>USA</td>
<td>23±2 16M 3 g/day or Placebo</td>
<td>HMB</td>
<td>Untrained</td>
<td>NE</td>
<td>Decreased LDH (before exercise)</td>
<td>NE</td>
<td>3xMVC H&amp;Q 55 Maximal Eccentric unilateral knee extension/FLexion</td>
<td>Acute (1 day)</td>
<td>Strength Test</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>Muller⁶⁸</td>
<td>South Africa</td>
<td>19-24</td>
<td>40M 3 g/day or Placebo</td>
<td>HMB</td>
<td>Trained</td>
<td>Decreased Total Body Mass Increased LBM</td>
<td>Decreased CK</td>
<td>Increased power output</td>
<td>1h Upper Body Exercises and Lower Body Exercises 3 times/week</td>
<td>8 weeks</td>
<td>Resistance training</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Nunan et al.⁶⁹</td>
<td>Great Britain</td>
<td>30±5.5 14M</td>
<td>3 g/day HMB and KIC or Placebo</td>
<td>HMB and KIC</td>
<td>Recreational</td>
<td>NR</td>
<td>Decreased CK</td>
<td>Rapid Recovery 1RM</td>
<td>Downhill running protocol</td>
<td>14 days</td>
<td>Downhill Running Protocol</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Faramarzi et al.⁷⁰</td>
<td>Iran</td>
<td>NR 24M</td>
<td>3 g/day or Placebo</td>
<td>HMB</td>
<td>Untrained</td>
<td>Increased LBM</td>
<td>Decreased blood urea nitrogen in urine</td>
<td>Improved strength 1RM</td>
<td>NR</td>
<td>8 weeks</td>
<td>Resistance training</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Xing⁷¹</td>
<td>USA</td>
<td>24,3±2,2 17M 3 g/day HMB-FA or Ca-HMB</td>
<td>HMB-FA</td>
<td>Untrained</td>
<td>NE</td>
<td>NE</td>
<td>NE</td>
<td>Single bout eccentric exercise</td>
<td>4 days</td>
<td>Eccentric protocol</td>
<td>N</td>
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</table>

Abbreviations used in the table. HMB: β-hydroxy-β-methylbutyrate; HMB-FA: β-hydroxy-β-methylbutyrate-Free Acid; Ca-HMB: β-hydroxy-β-methylbutyrate Calcium Salt; NR: Not Reported; OBLA: Onset of Blood Lactate Accumulation; RCP: Respiratory Compensation Point; NE: No Effect; LDH: Lactate Dehydrogenase; CK: Creatine Kinase; TNFa: Tumor Necrosis Factor Alpha; TNFR1: Tumor Necrosis Factor Receptor 1; CRP: C-reactive protein; 3-MH: 3-methylhistidine; VT: Ventilatory Threshold; LBM: Lean Body Mass; FFM: Fat Free Mass; FM: Fat Mass; Cr: Creatine; PRS: Perceived Recovery Scale; KIC: Ketoisocaproic Acid; CHO: Carbohydrate; CWI: Cold Water Immersion; M: Male; F: Female; Y: Yes; N: No; MAS: Running speed during an incremental test at which VO2max is attained; MCV: Maximal Voluntary Contraction; H: Hamstring; Q: Quadriceps; WU: Warm-Up; Tec: Technical exercises; Tac: Tactical exercises; CD: Cool Down; V: Velocity.
exercise able to induce muscle damage. Supplements should be taken at a dose of 1-2 g, 30-60 minutes prior to exercise if consuming HMB-FA and 60-120 minutes prior to exercise if consuming HMB-Ca. Many of the earlier studies used HMB formulated as a calcium salt (HMB-Ca); however, a new free acid form of HMB (HMB-FA) has been shown to yield higher plasma concentrations in shorter amount of time compared to the calcium salt form44. These results offer the theoretical advantages of achieving a greater bioavailability of HMB and providing potential benefits to improve training adaptations44,55.

Effects of HMB in Endurance Sports

Cardiorespiratory endurance refers to the ability of performing activity for prolonged periods of time56. Previous studies have demonstrated the potential benefits of HMB for aerobic athletes. This information is shown in table II. Vukovich and Dreifort investigated the effects of HMB supplementation on peak oxygen consumption (VO2peak) and the onset of blood lactate accumulation (OBLA) in eight endurance-trained master-level competitive cyclist with an average training volume of 300 miles per week. Participants performed a graded cycle ergometer test until exhaustion. Results from the graded exercise test indicated that HMB supplementation increased by 8% the time to reach (VO2peak) while leucine and the placebo did not have any effect. The VO2 at 2 mM blood lactate (OBLA) increased with HMB (9.1%) and leucine (2.1%) supplementation, but did not change with placebo supplementation. The discrepancy with other endurance training studies could be due to training experience of the participants in the investigation. It has been suggested that active men and women not used to high intensity interval training may benefit more from HMB-Ca supplementation than trained athletes who are used to high intensity interval training. Individualized high intensity interval training (HIIT) programs were applied based on each participant’s baseline fitness level and monitored throughout the 28 days of training. It should be take into account that the training stimulus to stimulate physiological adaptation can be insufficient in some studies.

The results obtained from high intensity interval training studies shows that a four-week HIIT program in combination with HMB-FA is an effective training stimulus for improving aerobic performance. In addition, the use of HMB-FA supplementation, in combination with HIIT, resulted in greater changes in VO2peak, power output at ventilatory threshold (FVT) and ventilatory threshold (VT) than HIIT alone. These results are in accordance with other studies that used HMB supplementation with aerobic training methods for augmenting the beneficial effects on aerobic performance by increasing fatigue threshold measures that reflect the physiological response to moderate and/or severe intensity exercise.

The mechanism for these benefits of HMB on aerobic performance and fat loss are poorly understood. However, recent evidence demonstrated that HMB supplementation could improve fatty acid oxidation as has been previously described in HMB’s mechanisms of action.

Effects of HMB on Strength and Power Sports

Strength and power are two of the most critical attributes of success in sport. Strength training increases muscle fiber size and maximal tension output. These adaptations are attained by positive muscle protein balance and satellite cell addition to pre-existing fibers. Also, the activation of mTOR signalling pathway appears to be very important for contraction induced increases in muscle protein synthesis.

Several research groups in this area investigated conflicting results when men and women where supplemented with HMB during a resistance training programme. Among the outcome variables analyzed in these studies were 1RM bench press, 1RM deadlifts, 1RM rowing, 1RM shoulder press, 1 RM chin up, 1RM leg extension, 1RM squats, and 1RM biceps curl. In addition, other physiological variables, such as body composition, power production, creatine kinase levels, and lactate dehydrogenase, were also evaluated. This information is presented in table III together with studies that showed strength and power benefits in sport-specific movements, i.e. squat, bench press and vertical jump. In contrast, researchers have found small treatment effect when using non-specific, isolated movements. Furthermore, as previously mentioned, the lack of significant changes in performance could be attributed to the absence of periodized and progressive exercise programs. Finally, benefits of HMB supplementation are more marked when exercise involves multi-joint movement that stresses a greater total amount of the skeletal muscle system.

The results of several studies suggest that changes in strength and power following HMB supplementation are optimized within a context of a periodized as compared to a non periodized training program. Furthermore, those findings suggest that supplementation with HMB is effective for improving strength and power. Translated into athletes and coaches’ languages, this means that when facing periods of high training frequencies (overreaching cycle of training) HMB and/or HMB/ATP supplementation may not only prevent typical declines in performance (power, strength and perceived recovery) that are characteristic of overreaching but might also result in additional gains in strength.
<table>
<thead>
<tr>
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<th>Dosage</th>
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<th>Biochemistry</th>
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<th>Training Load</th>
<th>Duration</th>
<th>Training Modality</th>
<th>Efficacy</th>
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<td><strong>Cycling</strong></td>
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<tr>
<td>Vukovich &amp; Adams(^7)</td>
<td>USA</td>
<td>NR</td>
<td>8M</td>
<td>3 g/day HMB, Leucine or Placebo</td>
<td>CaHMB</td>
<td>Trained</td>
<td>NR</td>
<td>NR</td>
<td>HMB increased time to reach VO2 peak and VO2 at OBLA</td>
<td>NR</td>
<td>2 weeks</td>
<td>Specific Endurance exercise condition</td>
<td>Y</td>
</tr>
<tr>
<td>Vukovich &amp; Dreifort(^2)</td>
<td>USA</td>
<td>NR</td>
<td>8M</td>
<td>Placebo, Leucine or 3g/day HMB</td>
<td>CaHMB</td>
<td>Trained</td>
<td>NR</td>
<td>NR</td>
<td>HMB increased time to reach VO2 peak and VO2 at OBLA</td>
<td>NR</td>
<td>2 weeks</td>
<td>Specific endurance exercise condition</td>
<td>Y</td>
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<tr>
<td><strong>Athletics</strong></td>
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<tr>
<td>Knitter et al.(^1)</td>
<td>USA</td>
<td>20-50</td>
<td>16F 16M</td>
<td>Placebo or 3 g/day</td>
<td>CaHMB</td>
<td>Trained</td>
<td>NR</td>
<td>Lowered LDH and CK</td>
<td>NR</td>
<td>Prolonged run</td>
<td>1 week</td>
<td>Specific exercise condition</td>
<td>Y</td>
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<tr>
<td>Byrd et al.(^1)</td>
<td>USA</td>
<td>NR</td>
<td>28M</td>
<td>3 g/day HMB, Creatine or Placebo</td>
<td>CaHMB</td>
<td>Trained</td>
<td>NR</td>
<td>NR</td>
<td>HMB lowered soreness</td>
<td>Downhill running protocol</td>
<td>1 week</td>
<td>Specific exercise condition</td>
<td>Y</td>
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<tr>
<td>Robinson et al.(^1)</td>
<td>USA</td>
<td>21±2.4</td>
<td>21M 21F</td>
<td>Placebo</td>
<td>HMB-FA</td>
<td>Trained</td>
<td>NE</td>
<td>NR</td>
<td>Greater increase in VO2max and Power VT and VT</td>
<td>3 times/week 5x2min (1minRec) %VO2max</td>
<td>4 weeks</td>
<td>HIIT</td>
<td>Y</td>
</tr>
<tr>
<td>Lamboley et al.(^1)</td>
<td>Canada</td>
<td>23±1</td>
<td>16F 16M</td>
<td>Placebo</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>No effect on LBM or FM</td>
<td>NR</td>
<td>Greater increase in VO2max and RCP</td>
<td>5x100% MAS</td>
<td>5 weeks</td>
<td>Interval training</td>
<td>Y</td>
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</table>
## Table III

Studies examining the effect of HMB on performance stratified by strength and power sports

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Age</th>
<th>N (Sex)</th>
<th>Dosage</th>
<th>Form</th>
<th>Training Experience</th>
<th>Body Composition</th>
<th>Biochemistry</th>
<th>Sport Performance</th>
<th>Training Load</th>
<th>Duration</th>
<th>Training Modality</th>
<th>Efficacy</th>
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<tr>
<td><strong>Resistance Training</strong></td>
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<tr>
<td>Nissen et al.¹⁰</td>
<td>USA</td>
<td>19-29</td>
<td>41M</td>
<td>0, 1.5 or 3 g/day</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>Decreased LBM</td>
<td>Decrease CK and 3-MH</td>
<td>Increased Total weight lift (Dose dependent) Increased 1RM biceps curl and ROM Decreased DOMS</td>
<td>3 times/week during 3 weeks 3x5 reps 90% 1RM</td>
<td>7 Weeks</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Nissen et al.⁷⁴</td>
<td>USA</td>
<td>19-22</td>
<td>32M</td>
<td>0, 1.5 or 3 g/day</td>
<td>CaHMB and Nutrient Powder</td>
<td>Trained</td>
<td>Increased FFM</td>
<td>NR</td>
<td>Increased 1RM Bench and Squat lift</td>
<td>6 times/week during 3 weeks 3x4 reps 90% 1RM</td>
<td>7 weeks</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Panton et al.⁶⁶</td>
<td>USA</td>
<td>20-40</td>
<td>36F 39M</td>
<td>Placebo or 3 g/day</td>
<td>CaHMB</td>
<td>Trained and Untrained</td>
<td>Greater LBM and FML</td>
<td>NR</td>
<td>Greater upper body strength (3-15%)</td>
<td>Monitored High Intensity progressive resistance training</td>
<td>4 weeks</td>
<td>High Intensity resistance training</td>
<td>Y</td>
</tr>
<tr>
<td>Jowko et al.⁷⁵</td>
<td>USA</td>
<td>19-23</td>
<td>40M</td>
<td>Placebo, 3 g HMB, HMB and Creatine or Creatine</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>Positive effect on LBM (additive effect HMB and Cr)</td>
<td>Only HMB lowered CK, urine urea nitrogen, and plasma urea</td>
<td>HMB and Creatine additive effect on weight lifted</td>
<td>1-4 set x 5-8 reps 45-75% 1RM</td>
<td>3 weeks</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Paddon-Jones et al.³⁰</td>
<td>Australia</td>
<td>21-22</td>
<td>17M</td>
<td>0 or 3 g/day</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>NR</td>
<td>NR</td>
<td>No effect on strength</td>
<td>NR</td>
<td>6 days</td>
<td>Test Eccentric Exercise</td>
<td>N</td>
</tr>
<tr>
<td>Van Someren et al.⁷⁶</td>
<td>Great Britain</td>
<td>20-24</td>
<td>8M</td>
<td>3 g/day HMB 3 g/day KIC</td>
<td>CaHMB</td>
<td>Untrained</td>
<td>Decreased CK biceps curl and ROM Lower DOMS</td>
<td>Greater 1RM biceps curl and ROM Decreased DOMS</td>
<td>3x10 reps 70% 1RM</td>
<td>2 weeks</td>
<td>Weight training Eccentric Exercise</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Thomson⁷⁷</td>
<td>New Zealand</td>
<td>24±4</td>
<td>34M</td>
<td>Placebo or 3 g/day</td>
<td>CaHMB</td>
<td>Trained</td>
<td>NR</td>
<td>NR</td>
<td>Greater leg extension strength</td>
<td>3 times/week 9 exercises/session 2-3 set 5-15 reps 30-90s recovery</td>
<td>9 weeks</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Reference</td>
<td>Country</td>
<td>Age</td>
<td>N (Sex)</td>
<td>Dosage Form</td>
<td>Training Experience</td>
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<td>Biochemistry</td>
<td>Sport Performance</td>
<td>Training Load</td>
<td>Duration</td>
<td>Training Modality</td>
<td>Efficacy</td>
<td></td>
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<tr>
<td>Van Someren et al.</td>
<td>Great Britain</td>
<td>23±4</td>
<td>8M</td>
<td>3 g/day HMB, 3 g/day KIC</td>
<td>CaHMB</td>
<td>NR</td>
<td>Decreased CK</td>
<td>Greater 1 RM biceps curl, ROM, lower DOMS</td>
<td>Single bout of eccentric resistance exercise</td>
<td>2 weeks</td>
<td>Eccentric Exercise</td>
<td>Y</td>
<td></td>
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<tr>
<td>Thomson et al.</td>
<td>New Zealand</td>
<td>24±4</td>
<td>34M</td>
<td>3 g/day or Placebo</td>
<td>HMB</td>
<td>Increased FM</td>
<td>NR</td>
<td>Increased Strength lower body</td>
<td>3 times/week 9 exercises/session 2-3 set 5-15 reps 30-90s recovery</td>
<td>9 weeks</td>
<td>Weight training</td>
<td>Y</td>
<td></td>
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<tr>
<td>Kruszewski</td>
<td>Poland</td>
<td>NR</td>
<td>182M</td>
<td>2 g/day HMB, 900mg L-Carnitine, 20mg Creatine or Placebo</td>
<td>HMB</td>
<td>Increased LBM</td>
<td>Decreased water content</td>
<td>NR</td>
<td>Improve muscle tone</td>
<td>Weightlifting: 5 days/week 60-100%RM 3 exercises Bodybuilding: 3 times/week 3x12 reps 50%RM Isometric: 5 times/week 3 exercises 3x3 reps or 3x4 reps 80%RM</td>
<td>4 weeks</td>
<td>Weight training</td>
<td>Y</td>
</tr>
<tr>
<td>Townsend et al.</td>
<td>USA</td>
<td>22±2,4</td>
<td>40M</td>
<td>3 g/day HMB-FA or Placebo</td>
<td>HMB-FA</td>
<td>NR</td>
<td>Attenuated TNFa and TNFR1</td>
<td>NR</td>
<td>4 sets 10 reps 70-80% 1RM 3 exercises</td>
<td>4 days</td>
<td>Resistance training</td>
<td>Y</td>
<td></td>
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<tr>
<td>Gonzalez et al.</td>
<td>USA</td>
<td>23±3</td>
<td>40M</td>
<td>3 g/day HMB-FA or Placebo</td>
<td>HMB-FA</td>
<td>Attenuated CRP (HMB-FA+CWI)</td>
<td>Maintained average power/repetition</td>
<td>NR</td>
<td>4 sets 10 reps 70-80% 1RM 3 exercises</td>
<td>4 days</td>
<td>Resistance training</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
Table III (cont.)

Studies examining the effect of HMB on performance stratified by strength and power sports

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Age</th>
<th>N (Sex)</th>
<th>Dosage Form</th>
<th>Training Experience</th>
<th>Body Composition</th>
<th>Biochemistry</th>
<th>Sport Performance</th>
<th>Training Load</th>
<th>Duration</th>
<th>Training Modality</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowery et al.²²</td>
<td>USA</td>
<td>21,7±0,4</td>
<td>17M</td>
<td>3 g/day HMB-FA and ATP or Placebo</td>
<td>Trained</td>
<td>Increased LBM</td>
<td>Attenuated CK and Cortisol</td>
<td>Increased strength + power Improved Recovery (PRS)</td>
<td>Phase 1: Undulation Periodization 3x8-12RM 5x5maxV 3x3-5RM Phase 2: Overreaching 3x8-12RM Phase 3: 5x5maxV 1x3-5RM</td>
<td>12 weeks</td>
<td>Resistance training</td>
<td>Y</td>
</tr>
<tr>
<td>Wilson et al.⁴⁹</td>
<td>USA</td>
<td>21,6±0,5</td>
<td>20M</td>
<td>3 g/day HMB-FA or Placebo</td>
<td>Trained</td>
<td>Increased LBM</td>
<td>Attenuated CK and LDH Decreased Body Fat</td>
<td>Increased total strength and power (vertical jump and Wingate) Improved Recovery (PRS)</td>
<td>Phase 1: Undulation Periodization 3x8-12RM 5x5maxV 3x3-5RM Phase 2: Overreaching 3x8-12RM Phase 3: 5x5maxV 1x3-5RM</td>
<td>12 weeks</td>
<td>Resistance training</td>
<td>Y</td>
</tr>
<tr>
<td>Football</td>
<td></td>
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</tr>
<tr>
<td>Kreider et al.⁸¹</td>
<td>USA</td>
<td>20-22</td>
<td>40M</td>
<td>0, 3 or 6 g/day CaHMB</td>
<td>Trained</td>
<td>No effect on LBM or FM</td>
<td>No effect markers of muscle damage No effect on strength</td>
<td>NR</td>
<td>4 weeks</td>
<td>Weight training</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Kreider et al.⁸²</td>
<td>USA</td>
<td>20-22</td>
<td>18M</td>
<td>0, 3 g/day CaHMB</td>
<td>Trained</td>
<td>No effect on LBM or FM</td>
<td>No effect markers of muscle damage</td>
<td>No effect on strength or Intermittent High Intensity exercise performance 5 hours/week 1-3 sets x 2-8 reps - 60-95% 1RM</td>
<td>4 weeks</td>
<td>Off-Season Weight training and Agility training</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>
Table III (cont.)

Studies examining the effect of HMB on performance stratified by strength and power sports

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Age</th>
<th>N (Sex)</th>
<th>Dosage Form</th>
<th>Training Experience</th>
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<th>Biochemistry</th>
<th>Sport Performance</th>
<th>Training Load</th>
<th>Duration</th>
<th>Training Modality</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ransone et al.83</td>
<td>USA</td>
<td>20-22</td>
<td>35M</td>
<td>Placebo or 3 g/day CaHMB</td>
<td>Trained</td>
<td>No effect on body composition</td>
<td>NR</td>
<td>No effect on weight lifting strength</td>
<td>4 days/week</td>
<td>4 hours/day</td>
<td>Strength: 10 exercises/session 8-12 sets x 2-10 reps 70-90% 1RM Endurance exercises (V) Endurance exercises (tempo):</td>
<td>N</td>
</tr>
<tr>
<td>Jay Hoffman et al.84</td>
<td>USA</td>
<td>20-22</td>
<td>26M</td>
<td>0 or 3 g/day CaHMB</td>
<td>Trained</td>
<td>No effect on body composition</td>
<td>NR</td>
<td>No effect on performance</td>
<td>Pre-Season specific training</td>
<td>4 weeks</td>
<td>Football camp specific training</td>
<td>N</td>
</tr>
<tr>
<td>Faramarzi et al.9</td>
<td>Iran</td>
<td>20±0.7</td>
<td>24M</td>
<td>3 g/day, P or HMB and Creatine (HMBCr)</td>
<td>Trained</td>
<td>NR</td>
<td>Decreased LDH and CK</td>
<td>Increased peak power Increased mean power Increased anaerobic performance</td>
<td>Team training program (10'WU + 15' Tec + 30'Tac + 25'Game + 10'CD)</td>
<td>6 days</td>
<td>Specific training</td>
<td>Y</td>
</tr>
<tr>
<td>O’Connor &amp; Crowe85</td>
<td>Australia</td>
<td>25±1</td>
<td>27M</td>
<td>3 g/day HMB or HMB and Creatine</td>
<td>Trained</td>
<td>NR</td>
<td>NR</td>
<td>No effect on soreness, ROM, or elbow flexor strength</td>
<td>NR</td>
<td>6 weeks</td>
<td>Weight training</td>
<td>N</td>
</tr>
<tr>
<td>O’Connor &amp; Crowe85</td>
<td>Australia</td>
<td>25±1</td>
<td>30M</td>
<td>3g HMB 3g Creatine 6g CHO</td>
<td>Trained</td>
<td>NE</td>
<td>NR</td>
<td>NE</td>
<td>NR</td>
<td>6 weeks</td>
<td>Weight training</td>
<td>N</td>
</tr>
<tr>
<td>Hung et al.96</td>
<td>Taiwan</td>
<td>21.8±1,1</td>
<td>8F</td>
<td>3 g/day or Placebo HMB</td>
<td>Trained</td>
<td>No effect on LBM Increased Fat Loss;</td>
<td>NR</td>
<td>Attenuates decreases in power</td>
<td>Regular Judo Training</td>
<td>3 days</td>
<td>Specific Training</td>
<td>Y</td>
</tr>
<tr>
<td>Waterpolo and Rowing</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Weight training</td>
<td>N</td>
</tr>
<tr>
<td>Slater et al.91</td>
<td>Australia</td>
<td>24-26</td>
<td>27M</td>
<td>0 or 3 g/day CaHMB</td>
<td>Trained</td>
<td>No effect on LBM No effect markers of muscle damage</td>
<td>No effect on strength</td>
<td>2-3 days/week 3-5sets x 4-6 reps</td>
<td>6 weeks</td>
<td>Weight training</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>
When a long-term (12 weeks) periodized training program is used in trained individuals, HMB has been found to increase strength, power, and muscle mass in major upper and lower muscle groups. Moreover, when similar outcome variables were evaluated in healthy untrained individuals after a supervised resistance-training program 3 times per week for 8 weeks, torque generation, creatine phosphokinase and body composition significantly improved among those supplemented with HMB, as compared with those not supplemented.

Collectively, these studies provide evidence supporting the usefulness of HMB supplementation specifically in conditions of high proteolysis, which is frequent in phases of the competition with high intensity exercise done at a high frequency rate. Therefore, it seems appropriate to hypothesize that HMB could help in increasing cardiorespiratory fitness, strength, power and physical function in those experiencing the effects of negative protein turnover in specific catabolic environments.

Conclusions

Within the sports context, the evidence shows that HMB could have positive effects on several catabolic conditions such as attenuation of the characteristic rise in catabolic biomarkers, limitation of rise in stress hormone response (overreaching) and decreases in power in athletes facing periods of high-density competitions, high-intensity training, first stages of injury recovery and/or any other different situations in which muscle adaptations could be affected by the catabolic environment.

Therefore, since adequate balance between the training stimulus and the subsequent recovery is a great challenge for exercise physiology, HMB supplementation could be of interest as a signalling molecule that may convey specific information to optimize recovery. Future research will additionally contribute to elucidate the underlying mechanisms by which HMB acts improving high-intensity training adaptations.

Acknowledgements

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Usefulness of β-hydroxy-β-methylbutyrate (HMB) supplementation in different sports: an update and practical implications

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