Branched-Chain Amino Acid Supplementation:

A Critical Analysis of its Effect on Skeletal Muscle

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Classification & Usage
Amino acids are organic compounds that combine to form proteins. When proteins are digested, amino acids are left. Amino acids leucine, valine, and isoleucine, are known as Branched-chain amino acids (BCAAs), the name referring to the unique branching structure of their residual side chain. BCAAs play a crucial role in many biochemical processes essential to human life. They represent three of nine amino acids that cannot be synthesized in the human body. For this reason BCAAs are categorized as essential amino acids because their requirements must be met exogenously. The combination of their significance to health and function, as well as their inability to be synthesized in the human body, has made BCAA an important factor when determining dietary intake.

BCAAs are naturally occurring in dietary protein sources such as lean meats, eggs, dairy, nuts, and whole grains, or in protein supplements. Dietary Reference Intakes for BCAA are based on the recommended intake of dietary protein. For Athletes 1.2-1.8g of protein per kg of body weight is recommended per day (Powers & Howley, 2009). The DRI intake for BCAAs are as follows (in mg/g of protein): isoleucine, 25; leucine, 55; valine, 32. For example a 70kg male athlete with a dietary protein requirement of 1.2 g/kg would expect to intake 2.1g of isoleucine, 4.6 g of leucine, and 2.69 g of valine.

BCAAs are primarily oxidized in skeletal muscle, and are the only amino acids not oxidized in the liver; as a result their concentrations in the diet have a direct impact on cellular amino acid concentrations (Bronsnan & Brosnan, 2006). The impact dietary intake of BCAAs can have on these amino acid concentrations is the basis for BCAA supplementation.

BCAA supplementation became popular in the early 1980s and is still a common practice (Burke, 2001). Today BCAA supplementation is popular among athletes as well
as active individuals (Burke, 2001). BCAA supplements can be purchased in pill, powder, or liquid form. According to price comparison on Bodybuilding.com, the average cost is approximately $0.15/serving (average serving size; 5g). The rationale behind supplementing with free form amino acids vs. traditional dietary sources is it allows for better control over intake, and proportions due to concise measurement; its purported increased digestion, and absorption rates which allow for amino acids to reach targeted tissues sooner (Negro, Giardina, Marzani, & Marzatico, 2008). For this reason BCAA supplements are most commonly ingested in concurrence with exercise in hopes to benefit from their positive influence on protein metabolism.

**Performance Factor**

As a result from its popular use over the years, BCAA supplementation has received a lot of attention from researchers. The majority of current research seems to be focused on BCAAs and their effects on protein metabolism. Proposed benefits to supplementing with BCAAs have included improved post exercise recovery (Negro, Giardina, Marzani, & Marzatico, 2008), promotion of increase skeletal muscle hypertrophy (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009), and improved body composition (Jitomir & Willoughby, 2008). All three factors are dependent on the state of protein metabolism in skeletal muscle. Efficacy for supplementation methods and appropriate dosages necessary to attenuate these claims require further examination of current research. In the following review of current research, we will examine the mechanisms understood to facilitate these claims, as well as the efficacy of BCAA supplementation in supporting these claims.

**Critical analysis**
The basis for these claims lies in the understanding of nitrogen balance. Nitrogen balance, also termed protein balance, is the balance between muscle protein synthesis and breakdown. This can be understood as the difference between nitrogen intake and the amount excreted in urine, feces, skin, and miscellaneous losses. It is assumed that when needs are met or exceeded an individual is in positive nitrogen balance; when intakes are inadequate, negative nitrogen balance results. The balance between muscle protein synthesis and breakdown is the metabolic basis for changes in muscle proteins (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009), which effect post exercise recovery, and ultimately result in adaptations to exercise training, including muscle hypertrophy or retention.

Skeletal muscle hypertrophy is an increase in muscle fiber size. This is a result of protein gains due to positive net muscle protein balance over a given time period. Positive net muscle protein balance may result from an increase in muscle protein synthesis and/or a decrease in muscle protein breakdown (Blomstrand, Eliasson, Karlsson, & Kohnke, 2006). Exercise and nutrition greatly influence net muscle protein balance. Resistance exercise increases muscle protein synthesis and breakdown. However, positive net muscle protein balance does not occur in the absence of ingestion of a source of amino acids (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009). Supplementation with BCAAs will increase the supply of substrate for synthetic processes, but also may activate signaling pathways controlling protein synthesis in human muscle (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009). According to Jitomir & Willoughby, (2008), of the essential amino acids, leucine has been identified as
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the most potent for stimulation of intracellular signaling and has been the subject of investigation.

The purpose of a study done by Kevin D. Tipton, et al (2009), was to examine the effects of additional leucine supplementation to enhance muscle anabolism in association with resistance exercise and protein ingestion (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009).

**Methods**

Untrained subjects were randomly assigned to two different groups. A placebo group was given a drink comprised of flavored water (pl); and a test group was given a drink containing 16.6g of whey protein + 3.4 g of leucine (w+L) (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009) Both groups ingested their drinks immediately before performing a heavy resistance leg workout. Arteriovenous amino acid balance across the leg was measured to assess the anabolic response of muscle in each group. Assessments began immediately prior to ingestion of the solution, and continued for the following 5.5 hours (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009).

**Results**

Arterial amino acid concentrations increased immediately in response to ingestion of W+L. No increase in net balance of leucine or other amino acids were recorded for the placebo group. The net balance of leucine did increase for the test group, and remained elevated above baseline for 90-120 minutes following W+L ingestion. These results did indicate that the whey protein plus leucine in healthy young individuals results in an anabolic response in muscle. However when compared to a previous study by Tipton et
al. 2007 conducted with whey supplementation alone showed no increased response (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009).

These results support the understanding that amino acids have a positive effect on protein metabolism in skeletal muscle. However, they do not support the reasoning for additional supplementation of BCAAs, specifically Leucine, which is believed have an increased stimulatory effect on protein synthesis (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009).

Recovery is represented by a positive muscle protein balance that occurs when protein synthesis exceeds muscle protein breakdown (Negro, Giardina, Marzani, & Marzatico, 2008). Adequate recovery post exercise is necessary for skeletal muscle maintenance as well as hypertrophy. In a review by M. Negro, et al, (2008) of studies examining BCAA supplementation as it affects exercise-induced muscle protein breakdown, reported results showing a significant change favoring a positive nitrogen balance during post exercise recovery in comparison to control trials not receiving BCAA supplementation.

Delayed onset muscle soreness (DOMS) is common for most athletes, particularly those engaged in intensive training or competition. DOMS can be described by symptoms including stiffness, tenderness, and pain during movement (Shimomura, et al., 2006). These symptoms develop due to tissue damage as a result of exercise excessive in duration and/or intensity. These symptoms occur approximately 24-48 hours post exercise (Blomstrand, Eliasson, Karlsson, & Kohnke, 2006). DOMS may inhibit peak athletic performance for the next exercise bout and can delay the post exercise recovery phase (Negro, Giardina, Marzani, & Marzatico, 2008). Another study reviewed by M.
Negro, et al, 2008 looks into the possibility of reducing the effects of DOMS via BCAA supplementation.

Methods

Two groups were formed. In both groups adequate protein intake was controlled (1.6 g/kg/day). 12 g doses of BCAAs were administered orally to each participant in the test group for two weeks. Additionally, the test group also consumed 20 g of BCAA prior to the exercise test. The control group received no BCAA supplementation. Both the test and control groups participated in a cycling test 120 min in duration. Blood levels were tested for enzymes involved in oxidation of specific energy substrates associated with intense or prolonged exercise Creatine kinase (CK) and lactate dehydrogenase (LDH) as a way quantify the severity of tissue damage (Negro, Giardina, Marzani, & Marzatico, 2008).

Results

Following analysis, results showed decreased serum levels of CK and LDH activity for several days after exercise. Specifically, serum CK activity increased to maximum values at 24 hours post exercise by approximately 275% in the control group. In contrast, CK levels increased only 175% in the supplemented subjects. Serum LDH levels increased to maximum values at 4 hours post exercise by approximately 55% in the control group, while LDH levels increased only 40% in the test subjects. The results of this study support the idea that supplementing BCAAs to a diet containing adequate amounts of these amino acids significantly decreased markers of muscle damage following prolonged exercise (Negro, Giardina, Marzani, & Marzatico, 2008).
In order for an individual to improve body composition through fat loss, a hypo caloric diet is necessary. Often, this situation ends with a decrease in lean mass as well as body fat due to the difficulty in maintaining a positive protein balance when caloric intake is restricted (Jitomir & Willoughby, 2008). Also associated with BCAA supplementation is the claim to improve body composition by supporting retention of lean mass during prolonged periods of energy restriction. The claim is supported by the idea that BCAAs specifically leucine have a powerful anabolic signal and promote protein synthesis (Tipton, Elliott, Ferrando, Aarsland, & Wolfe, 2009). This in addition to increased number of AAs serving to replace oxidized molecules will support a positive nitrogen balance resulting in retention of skeletal muscle. Another study reviewed by Jean Jitomir and Darryn S. Willoughby (2008) tests the efficacy of these claims.

**Methods**

25 competitive wrestlers were divided into 3 experimental diet groups for 19 days. Group one fed a high-protein energy restricted diet in combination with BCAA supplementation. Group two was fed a low-protein hypo caloric diet. Group 3 was fed an isocaloric control diet. The Wingate test was used to measure anaerobic performance capacity before and after the test period (Jitomir & Willoughby, 2008).

**Results**

The high-protein, supplemented diet documented positive changes in body composition. The results yielded a significantly greater fat loss, especially in visceral adipose tissue, in comparison with the low-protein hypo caloric diet group, as well as control group. The high-protein diet, supplemented, group also was able to maintain
anaerobic performance capacity based on analysis using the Wingate test (Jitomir & Willoughby, 2008).

**Efficacy**

It has been confirmed that exogenous sources of BCAAs are beneficial, and adequate ingestion is essential to health (Shimomura, et al., 2006). Studies have also proven that BCAAs also promote a positive nitrogen balance that can result in improved post-exercise recovery, skeletal muscle hypertrophy, and retention of lean mass. However, no definitive explanations for this effect have been proven. In regards to BCAA supplements, some studies show that supplementation in addition to adequate dietary intake may improve post-exercise recovery (Shimomura, et al., 2006) as well as support lean mass retention during hypocaloric conditions (Jitomir & Willoughby, 2008). Conclusive research has yet to be done to definitely explain the mechanisms involved or to prove that specifically BCAA supplementation (vs. dietary protein containing a variety of amino acids) would be beneficial.

**Safety**

Although the efficacy has not been proven, supplementation with BCAAs is considered to be safe. Current research on adverse effects associated with BCAA supplementation is limited. Adequate dose–response data from human or animal studies on which to base an upper limit were not available, but this does not mean that there is no potential for adverse effects resulting from high intakes of amino acids from dietary supplements.

**Ethical/Legal Issues**
Supplementation with BCAAs is legal in the United States. There are no ethical issues surrounding BCAA supplementation as it pertains to health or performance. BCAAs are not on found on any band substance lists. Due to its necessity in the human diet, I do not foresee any future ethical issues unless extremely high intakes of BCAAs are proven to illicit such a response to be deemed unethical.

**Recommendation**

Preceding any recommendations for BCAA supplementation I would need to assess the individual’s current nutritional intake and training status. For a typical healthy individual with an active lifestyle able to consume recommended amounts of protein from favorable sources then I would not recommend supplementation. If a competitive athlete entering in intensive phase of training who also is able to meet their daily recommended intake from dietary sources, I may give a different recommendation. Even though BCAA supplementation has not been proven to improve recovery, there is some evidence supporting its effects. Since it is considered to be safe, I would recommend supplementation of BCAAs in addition to adequate dietary intake. Another case in which I would recommend BCAA supplementation would be in an instance were an individual is not able to ingest the recommended amounts of essential amino acids from dietary protein sources. In this case I would recommend supplementation of BCAAs to meet recommended requirements.

**References**

Blomstrand, E., & Essen-Gustavsson, B. (2009). Changes in amino acid concentration in


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