A Review of the Importance of Amino Acids in Sports Performance

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1.0 Introduction

This ISM paper explores the unique and multifaceted nature of Aminomics nutritional supplementation in athletes, and how the stresses they encounter individually affects overall protein and multi-nutrient needs. The goal of this review paper is to establish an information base at it relates to ISM's Aminomics and the potential for custom targeting of orthomolecular compounds to elite athletes for the ultimate outcome of increasing performance.

It is the position of Dietitians of Canada, the American Dietetic Association, and the American College of Sports Medicine that physical activity, athletic performance, and recovery from exercise are enhanced by optimal nutrition. These organizations recommend appropriate selection of food and fluids, timing of intake, and supplement choices for optimal health and exercise performance. Nutrition Science & the Olympics

Aminomics is a powerful asset for athletes who want to use nutrition to their advantage. Whether an Olympic medal is won by tenths of a second in a ski race, decimal points in a figure skating competition, or goals in an ice hockey game, an athlete's nutritional status makes a critical difference in reaching peak performance. This Aminomics review explores the overall science of sports nutrition and explores how to apply Aminomics principles to benefit an athlete's training and performance.

This review looks at:

1) Sports Nutrition Overall
2) The Importance of Protein
3) The Role of Vitamins, Minerals and Other Micronutrients in Aminomics
4) Why Amino Acids are Critical to Sports Performance

Fueling & Cooling Olympic Athletes
Just as high performing race-cars require fuel and coolant, maintaining energy, fluid, and nutrient balance are essential goals for athletes. Consistency is essential -- nutrition needs to be addressed throughout months and often years of athletic training, as well as before and during competitive events. Energy and fluid needs may differ dramatically between days of physical training and days of competition. How much foods and fluids to consume? What type? When to eat and drink? Athletes deal with these questions daily. Scientific studies conducted in laboratories and on the field, the snow, and the ice rink provide answers.

Nutrition & Training are Team Players
Nutrition and physical training are connected – long-term athletic success depends on meeting day-to-day nutritional needs. Although the stress of exercise training stimulates physiological improvement, adaptations to physical stress actually occurs in the recovery period following the exercise sessions. Satisfying an athlete's needs for re-hydrating, refueling, and rest are essential components of the recovery process.

Aminomics & Sport Focus
Although sport nutrition basics are similar for all athletes, important differences exist for individual athletes in various sports. The focus of Aminomics is on the overall nutritional needs of selected endurance sports and strength/power sports with a focus on proper amino acid / protein balancing.

Until an athlete addresses and resolves the essentials regarding proper nutrition and fueling, the athlete will most likely never achieve their full potential as an athlete.

2.0 The "Big" Picture: Athletes Nutrition Requirements

2.1 General
For serious endurance athletes, proper fueling is a critical component for success that simply cannot be ignored. Knowing what fuels (carbohydrates, protein, electrolytes, etc.) and fluids to put in the body, how much to put in, and how often to consume them is essential for achieving better performance in all sports.

Athletic performance improvement depends on successive, incremental exercise sessions that stimulate muscular and cardiovascular adaptation followed by a recovery period in which the body rebuilds itself slightly more fit than before. Thus, the real gain of exercise occurs during recovery, but only in the presence of adequate rest and optimal nutritional support. Therefore, how well you recover today will greatly determine your performance tomorrow. Athletes who attend to the recovery process as much as they do to active training are way ahead of the game and will no doubt enjoy increased performance.

Exercise creates physiological stress; you become weak and depleted after a good workout. It is during recovery that your body rebuilds itself. Your body responds to the stress of training by increasing its stress adaptation, commonly called "fitness," but only when you have all recovery components in place. Repeated, incremental sessions of exercise and properly supported recovery result in increased performance ability and improved overall health. Exercise that is either overdone or under supported by a lack of proper recovery yields negative results, such as injury, chronic fatigue, soreness, overuse syndrome, poor health, and the like. An athlete must attend as much to recovery as to active exercise to reap the benefits of hard training.

Recovery includes many factors, including rest, stretching, muscle stimulation, and sleep, but <u>we will limit our present discussion to the nutritional aspects.</u>

This paper will focus on the essential nutritional areas of recovery:
- **protein;**
- **the micronutrients**, which include vitamins, minerals, and
- **other ancillaries such as antioxidants**.

It is assumed that the athlete is properly hydrating and getting adequate, high quality carbohydrates. The following discussion recognizes the interrelationship of protein and carbohydrates. It is not intended to replace specific sports advice on carbohydrate consumption.

When coupled with education on the need for well-timed carbohydrate choices, sufficient healthy fat intake and dietary variety, ISM's Aminomics protein protocols could become a critical part of a strategic sports nutrition plan.

2.2 Quick Replenishment of Carbohydrates

Now let's consider carbohydrate replenishment, the most obvious nutritional issue caused by most exercise. Let's briefly review energy use and restoration cycle.

The primary fuel for the first 90-120 or so minutes of exercise is stored carbohydrate in the form of muscle glycogen. When it's gone, the body switches over to burning fat reserves along with carbohydrates and protein consumed during exercise. Endurance training increases both muscle glycogen storage capacity and utilization efficiency. A big part of that training is the re-supply after depletion. Studies have shown that pre-exercise muscle glycogen level is the most important energy determinant for exercise performance. To have a good race or workout, the athlete needs to start with full load of muscle-stored glycogen. That's why it's important to start replenishing carbohydrates very soon after exercise, to take advantage of the highest glycogen synthase (the enzyme that controls glycogen storage) activity, which occurs immediately after exercise, when muscle glycogen is depleted.

Glycogen synthesis from carbohydrate intake takes place most rapidly the first hour after exercise and occurs at lower levels for up to 4-6 hours longer. Moreover, researchers at the University of Texas at Austin demonstrated that glycogen synthesis is highest when subjects were given carbohydrate immediately after exercise. So depletion plus dietary carbohydrate yields the maximum glycogen re-supply.

Complex carbohydrate (polysaccharides, such as maltodextrin) is the fuel of choice for glycogen replenishment. Simple sugars (mono- and disaccharides) taken immediately after exercise have the advantage of high glycemic index (GI), indicating rapid metabolism, but the disadvantage of being relatively calorie-poor per volume and therefore unlikely to provide adequate carbohydrate nutrition without inciting digestive issues. On the other hand, complex carbs offer high GI, plus ease of digestion and high caloric impact.

Dr. Michael Colgan, in his book Optimal Sports Nutrition *[Advanced Research Press, New York, 1993 - pg 102]*, suggests consuming 225 grams of complex carbohydrates within 2-4 hours post-exercise. More than that will end up as body fat stores. Other research studies suggest that on average 650 total grams of carbohydrate is about all the carbohydrate volume that the body can regenerate into muscle glycogen stores each day. The table below shows the range when body weight and length of training are specified. The carbohydrate amount (in grams) includes everything pre-, during, and post-workout. To convert to caloric amounts, remember that one gram of carbohydrate yields four calories of energy. For example, Colgan's 225-gram recommendation equals 900 calories.

Bodyweight (lbs)	Hours Training		
	2	4	6
110	300	500	700
132	400	600	800
154	500	700	900
176	600	800	1000
198	700	900	1100

For enhanced recovery, up to 100 grams of complex carbohydrates need to be consumed in the first hour and the balance in the next three hours.

For a daily total, to complete the muscle glycogen re-synthesis picture, aim for what the above chart suggests. A 154 pound athlete doing a two-hour workout will want to consume about 500 grams (2000 calories) of complex carbs that day: 100 grams in the first hour post-exercise, another 125 grams in the next three hours, and 275 grams during the remainder of the day, including during-exercise consumption. To “play the averages”, this equals a daily total of 650 grams, or about 2500-2600 calories from carbohydrates.

2.3 Carbohydrate and the Relation to Protein and Recovery

While carbohydrate intake promotes many aspects of post-exercise recovery, it can’t do the job alone. The body needs protein. We will now review some important reasons to include protein in recovery nutrition.

By taking in ample amounts of carbohydrate immediately after training and continuing for the next few hours, athletes can get a head start on refueling their muscles after workouts. Additionally, they will also tip the scales in the direction of protein synthesis instead of protein catabolism (breakdown). In other words, ample carbohydrates are essential in rebuilding muscle cells as well as restoring muscle glycogen. Studies suggest that the carbohydrate inflow gives the muscle cells the necessary fuel to begin the rebuilding process. Using the energy derived from carbohydrates, the muscles absorb amino acids from the bloodstream, helping initiate protein synthesis.

Carbohydrates also boost the production and release of insulin from the pancreas. Insulin is an anabolic (tissue-building) hormone that has a profound positive impact on protein synthesis in muscles, and it also tends to suppress protein breakdown. A University of Texas study found plasma insulin values three to eight times higher post-workout for subjects ingesting carbohydrates versus placebo. Studies show that protein, when combined with carbohydrates, almost doubles the insulin response. This alone makes it logical to include some protein along with complex carbohydrate. A ratio of 3:1 or 4:1 (carbohydrate to protein) is a good recommendation.

Obviously, the body needs protein to rebuild stressed muscles. Endurance athletes often think that protein intake is for the power-lifting crowd, but the body doesn’t agree with that! True, intense weight training places a different kind of stress on muscles than endurance exercise, but muscle breakdown occurs all the same, and endurance athletes need more protein than a standard diet provides.

3.0 The Importance of Protein to Athletes

3.1 Introduction

The requirements of a competitive season, both physical and psychological, create a unique scenario regarding dietary protein.

The protein demands of two-a-day team practices coupled with resistance training, muscle microtrauma [30,31], elevated energy needs of accidental injury during practices, stress hormone elevations (i.e. cortisol and catecholamines) [46,48,50], cytokine elevations (e.g. interleukin-6) and related immune stress [57,70], and sleep disturbances [46,71] all contribute in an inter-related fashion.

Some potential benefits of dietary protein and amino acids for athletes are below:

1. Building blocks for structural, contractile, hormonal, immune, enzymatic and other bodily proteins
2. Provision of kcal and contribution to muscle glycogen in a relatively carbohydrate- (insulin-) resistant state during eccentric recovery and sleep debt
3. Potentially maintained performance during an otherwise stale state
4. Stimulation of protein synthesis in an otherwise catabolic state (Leu)
5. Provision of oxidative fuel to skeletal muscle as well as the gut and white blood cells during immune stress
6. Elevated antioxidant capacity via glutathione
7. Improved collagen synthesis and potentially wound healing
8. Increased nasal antibodies and/or decreased incidence of infection
9. Provision of concentrated nutrients to often poorly-fed athletes
10. Defense against stress hormone exacerbations and sleep debt

From a wellness perspective, appropriately increased nutrition support for tissue growth and repair is imperative to mental health as well as resumption of training.

3.2 Protein Goals: How Much Protein Do Athletes Need?

Protein accounts for about 15% of a person's body weight and, except for water, is the largest component in human bodies. Protein performs the same functions in sedentary and physically active individuals. However, protein requirements of athletes are increased above those of sedentary people due in part to changes in amino acid metabolism induced by exercise. A small amount of protein is used as fuel during endurance exercise. Extra protein is needed by strength-trained athletes to repair injuries to muscle fibers and to remodel muscle tissue in response to strength training.

In addition, muscle and whole-body protein synthesis is suppressed during exercise. For example, running for an hour may reduce muscle protein production in the liver by 20%. Increases in exercise intensity and duration further depress protein synthesis. Catch-up occurs after exercise. Protein synthesis increases once endurance or strength exercise has ended. Also, several studies indicate that protein synthesis during recovery is enhanced when the recovery meal contains both carbohydrate and protein.

Protein needs are related to caloric intake. Consuming sufficient calories to maintain energy balance improves nitrogen balance and decreases protein requirements. When energy intake is low, protein is broken down to meet energy needs. Using protein as an energy substrate increases protein requirements. Factors associated with increased protein requirements include the following:

- Growth
- Low calories diets
- Endurance training
- Strength training
- High muscle-to-fat ratio
- Vegetarian diets
- Vegetable proteins are less digestible and their amino acid composition is somewhat different from animal proteins. Protein needs (g/kg BW) increase as the amount of vegetable protein goes above about one third of the total protein in a person's diet.

Athletes' protein needs have received considerable investigation, not only in regard to whether athletes' protein requirements are increased, but also in relation to whether individual amino acids benefit performance. Mechanisms suggested to increase athletes' protein requirements include:

- the need to repair exercise-induced micro-damage to muscle fibers,
- use of small amounts of protein as an energy source for exercise, and
- the need for additional protein to support gains in lean tissue mass *(54,55).*

If protein needs are increased, the magnitude of the increase may depend on the type of exercise performed (endurance vs. resistance), the intensity and duration of the activity, and possibly the participant's sex.

How much protein do athletes need - and how safe are high-protein diets?

It is important to understand that protein metabolism is in a constant state of flux; although muscle and other tissues contain a large amount of stored protein, this protein is not 'locked away'. When dietary amino acids are insufficient, tissue protein can rapidly be broken down back to amino acid building blocks, which are then used to replenish the 'amino acid pool', a reservoir of amino acids that can be drawn upon to support such vital functions as energy production or immune function. This explains why muscle mass is often lost during times of stress, disease and heavy training loads, or poor nutrition.

Conversely, when dietary amino acids are in plentiful supply and other demands for protein are low, tissue protein synthesis can become the dominant process. The overall control of protein turnover – ie whether the body is in a state of anabolism (building up) or catabolism (breaking down), also known as positive or negative nitrogen balance – is governed by hormonal factors, caloric intake and availability of amino acids, particularly of the nine 'essential' amino acids that cannot be synthesised in the body and therefore have to be obtained from the diet.

For **endurance athletes**, nitrogen balance studies in men suggest a protein recommendation of 1.2 g/kg a day *(56).* Little information is available on requirements for women endurance athletes.

Resistance exercise is thought to increase protein requirements even more than endurance exercise, and it has been recommended that experienced male bodybuilders and strength athletes consume 1.6 to 1.7 g/kg of body weight a day to allow for the accumulation and maintenance of lean tissue *(55,57).* Again, data on female strength athletes are not available.

Athletes should be aware that increasing protein intake beyond the recommended level is unlikely to result in additional increases in lean tissue because there is a limit to the rate at which protein tissue can be accrued *(54),* although some sources have suggested an intake of 1.2 to 1.4 g/kg a day *(55).* Energy intake must be adequate; otherwise, protein will be used as an energy source, which falsely elevates estimates of the requirements under conditions of energy balance. It is worth noting that the customary diets of most athletes provide sufficient protein to cover even the increased amounts that may be needed *(7).*

Position of Dietitians of Canada, the American Dietetic Association, and the American College of Sports Medicine: endorsed by the Coaching Association of Canada

Protein Recommendations

Given that athletic training is known to increase the demands on the amino acid pool, many athletes, particularly bodybuilders and strength athletes, adopt high-protein diets to maintain a positive nitrogen balance, or at least prevent catabolism and loss of muscle tissue. However, even today there remains much debate about how much protein athletes really need to optimise and maintain performance.

Despite elevated energy requirements of frequent training and increased lean mass, research indicates that the majority of athletes fail to eat enough calories to maintain energy balance [6,10,11]. Initiating large energy expenditure by athletes does not necessarily induce a compensatory increase in food consumption [12]. Possible reasons for poor intakes could include ignorance, lack of appetite, lax dietary habits or conversely, misguided dietary discipline. An important consideration in counseling athletes is their mindset towards nutrition compared to non-athletes.

Beyond merely focusing on a small number of food items that are perceived as “healthy”, some athletes also suffer true eating disorders. Disordered eating has been reported by 21-48% of NCAA programs with cross country, track and gymnastics teams [13]. When combined with the additional muscle mass that is characteristic of athletes and higher intensity volume mesocycles, purposefully restricted intake can become problematic.

Who?	**How Much?**
RDA for sedentary adult	0.8 g/kg BW/day
Physically active adult	1.0 g/kg BW/day
Endurance athlete	**1.2 - 1.4 g/kg BW/day**
Strength athlete	**1.4 - 1.8 g/kg BW/day**
Adolescent athlete	**1.0 - 2.0 g/kg BW/day**
Maximum for adult athletes	**up to 2.0 g/kg BW/day**

Protein intake equal to 10-20% of total calories will meet the protein requirements of most athletes. The type of sport and total calorie intakes influence protein requirements. For example, cross-country skiing and ice hockey both require a high level of energy intake to meet energy expenditures.

Based on available research, the American College of Sports Medicine, the American Dietetic Association, and the Dietitians of Canada, in their recent joint position stand on nutrition and athletic performance, concluded that protein requirements are higher in very active individuals and suggested that:

- resistance athletes need: 1.6-1.7 g protein/kg body weight while
- endurance athletes need approximately 1.2-1.4 g protein/kg,

values that are about 150-200 percent of the current United States Recommended Dietary Allowances (RDA). No serious side effects have been noted in otherwise healthy persons with normal kidney function taking excess protein.

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Ingesting more protein than necessary to maintain protein balance during training (e.g., > 1.8 g/kg/d) does not promote greater gains in strength or fat-free mass *(Lemon et al., 1992; Tarnopolsky et al., 1992).*

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3.3 Protein Timing And Total Daily Protein Intake

Data clearly indicate that dietary protein or essential amino acid mixtures enhance net protein balance pre and post-resistance exercise [3,21,22]. Properly timed protein intake can enhance protein balance more than carbohydrate alone[22].

When it comes to recovery from athletic endeavors, the notion that 'it's not just what you eat but when you eat it' seems intuitively correct. For example, numerous studies have demonstrated that muscles are hungrier for refueling after exercise than they are before, giving rise to the concept of the 'post-exercise window of opportunity'.

One of the problems with making definitive recommendations about the timing of nutrition to enhance post-exercise recovery is the multifaceted nature of the components required for recovery. In broad-brush terms, there are four major nutritional requirements during post-exercise recovery:

1. Water – to replace fluid lost as sweat and to aid the process of 'glycogen fixation';
2. Electrolytes – to replenish minerals lost in sweat (eg sodium, chloride, calcium, magnesium);

3. Carbohydrate – to replenish muscle glycogen, the body's premium grade fuel for strenuous exercise, and also to top up liver glycogen stores, which serve as a reserve to maintain correct blood sugar levels;
4. Protein – to repair and regenerate muscle fibres damaged during exercise, to promote muscle growth and adaptation, and to replenish the amino acid pool within the body.

Although even a small degree of **water loss** can impair performance, the process of rehydration to replace lost water and electrolytes is relatively straightforward. Our bodies always strive to maintain optimum water and electrolyte balance, so as long as we consume plenty of fluids after training and eat a reasonably balanced diet (which will contain electrolyte minerals), full rehydration will occur as a matter of course. Moreover, it's quite easy to tell when we're fully hydrated – a pale straw-colored urine and frequent urination being the most obvious signs.

Refueling muscles with **carbohydrate** is less straightforward. Studies show that, to maximize the rate of glycogen repletion, carbohydrate consumption should be a priority after exercise. In fact, a recent literature review concluded that the highest muscle glycogen synthesis rates occur when large amounts of carbohydrate (1-1.85g per kg of body weight per hour) are consumed immediately after exercise and at 15- to 60-minute intervals thereafter, for up to five hours [(2)]. Conversely, delaying carbohydrate ingestion by several hours may slow down muscle glycogen synthesis.

Contrast this with **protein metabolism**: unlike with carbs, there's no 'protein store' in the body, other than muscle tissue, and observing changes in muscle fibres in response to protein ingestion is difficult for two main reasons:

(1) It can take many days to detect an increase in muscle fibre mass as the result of protein incorporation into muscle tissue, which makes it very difficult to deduce a link between timing of protein intake and the body's response;

(2) Proteins in the body are in a constant state of flux; if protein demand suddenly rises, muscle fibres can be broken down to provide the body with extra amino acids for the amino acid pool and then regenerated from recycled amino acids once this demand has subsided. This explains why many studies on protein intake and muscle growth/ recovery are conducted over weeks, not days.

Studies show that the presence of amino acids in the bloodstream and their availability to muscle cells is vital for protein synthesis after exercise. [(5)]. Amino acids produced an increase in protein synthesis even at rest. However, after the resistance training there was a further substantial increase in muscle protein synthesis of 30-100%! In other words, amino acid supplementation not only enhanced protein balance and synthesis at rest but also led to an interactive post-exercise effect, which resulted in around a two-fold increase in protein synthesis after exercise.[(6)].

Other studies support the notion that exercised muscles need protein very rapidly. A 12-week study on elderly males on a progressive resistance exercise program found that a post-training meal immediately after training produced bigger gains in muscle fibre thickness than when given two hours later [(7)].

The consumption of a relatively small amount of amino acids (combined with carbohydrate) immediately before exercise is a very potent stimulator of muscle protein synthesis.

In summary, there is good evidence for carbohydrate feeding as soon as possible after training; not only does it facilitate the short-term mechanism of glycogen synthesis, but it also allows for additional glycogen replenishment before the next training session (more often than not the following day). If you're taking a break from training for a few days, however, immediate carbohydrate feeding may not be necessary.

Evidence also suggests that boosting blood levels of amino acids by consuming quick-releasing proteins (or free amino acids) as soon as possible after training is a good idea; indeed, if maximizing muscle growth is the goal, it is useful to raise blood amino acid levels before training.

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3.4 Athletic Injury and Protein

Athletes experience a variety of injuries such as muscle microtrauma (principally due to eccentric contractions), soft tissue and skeletal insults, and surgery. Athletic injuries are common, occur among groups of stale athletes, and are not always met with adequate time away from the exercise regime [28,29]. Galambos, et al. [29] recently reported that 67% of athletes at the Queensland Academy of Sport are injured annually, while 18% were injured at the time of their investigation. Among NCAA Division I football players, approximately one in 20 "exposures" (practices and games) result in injuries [28]. And fully 77.5% of these injuries are the "non-time-loss" type [28], meaning that the athletes could experience higher energy and protein needs from the injury (-ies) in addition to training demands.

The least severe form of exercise-induced injury is muscle microtrauma with delayed onset muscle soreness. Albeit purposeful, microtrauma exhibits metabolic characteristics similar to clinical trauma but presents a briefer alteration.

Beyond microtrauma, athletes endure soft tissue injuries and skeletal injuries, which increase energy and protein needs further. As general examples, minor surgeries increase basal metabolic rate (BMR) by 24% while skeletal trauma has been reported to increase BMR 32% [33]. Protein-specific needs have been long-known to increase during injury, as evidenced by urinary nitrogen loss [33]. Such nitrogen catabolism is of particular concern due to the increased contribution of muscle tissue to whole body protein breakdown seen in skeletal trauma [34]. While not all recovering athletes resume full-time training status, it is common knowledge that many resume exercise by means of altered exercise regimes. Hence, a combination of elevated metabolic rate, aberrations in skeletal muscle metabolism, and resumed exercise sessions could create a negative energy balance that leads to higher protein needs.

3.5 Athletic Performance and Protein

Another example in which athletic discipline could "backfire" is training load. This is true from both the coach's and the athlete's perspective. Ongoing twice-daily (or even prolonged and intense once-daily) practices do not allow for adequate recovery.

Dietary protein and select amino acids present possible corrective measures against the effects of overtraining and underperformance. The addition of protein to a moderate-carbohydrate meal has been reported to improve glycogen synthetic rate and enhance exercise performance after an initial exercise bout, when compared to a moderate-carbohydrate meal alone [37,38].

Branched-chain amino acids have been reported to reduce visceral fat while maintaining performance among in-training athletes experiencing a moderately negative energy balance [2].

Amino acid supplementation has been shown to reduce decrements in bench press and squat performance during overreaching [39]. Further, the amino acid glutamine serves multiple roles of interest to athletes such as growth hormone secretion, collagen formation, and renal acid excretion [40-43] but also declines in serum (and muscle) during training and overtraining [44].

3.6 Endocrine and Physiological Stress and Protein
Psychological stress and sleep debt are parts of many competitive athletes' lives. Intense, frequent preseason practices and in-season practices, coupled with ongoing competitions, add an additional element of emotional and neuro-endocrine stress beyond that seen in controlled research settings.

An over-trained state can be accompanied by a reduced sex hormone:cortisol ratio and elevated catecholamines, depending on the type of overtraining [45-48]. Competing soccer players have exhibited higher cortisol concentrations during a season, simultaneously with declining glutamine concentrations [49]. Professional cyclists can exhibit relative hypercortisolemia unrelated to performance [47].

Yet concerns over increased stress hormones reach beyond performance. Cortisol is not only a catabolic hormone but elevates metabolic rate [50]. Catabolic and hyper-metabolic effects would have longer-term consequences, affecting body composition and immune status over time, rather than short-term performance. Thus, the over-trained or mid-season endocrine profile suggests catabolism and further-elevated energy and protein needs. Contrary to sedentary settings, select amino acids and proteins may actually counteract the elevation and/or catabolic effects of exercise-induced cortisol, as well as improve sleep [53-55].

3.7 Immune And Antioxidant Defenses and Protein
The immune system plays an important role in physical recovery from exercise, being a necessary part of the tissue repair process [35]. Leukocytosis and cytokine elevations are stimulated during a variety of exercise types [35,56]. However, an elevated white cell count can be severe enough to temporarily stimulate sepsis and at least some of its accompanying inflammatory catabolic cytokines (particularly interleukin-6) [56]. Routinely elevated interleukin-6 is not likely to facilitate maintained muscle mass.

Hence, repeated immune stimulation via exercise can be both helpful and detrimental to the goals of an athlete, depending on the magnitude and frequency of its response. Chronic immune system depression is detrimental and becomes apparent relatively quickly during times of overtraining [57], and during intentional weight reduction undertaken in pursuit of a weight class, such as in judo 58.

Dietary protein plays a known role in immune system maintenance. Moldawer estimated that sustained neutrophilia (neutrophils normally comprising about 60% of the white cell count) can require 30 grams of protein daily, based upon the total increase in cell number and their half-life *(American Dietetic Association annual meeting, 1995).* Although interorgan exchange of amino acids can supply this, dietary protein may play a role in supplying a portion, sparing muscle tissue. Additionally, white cells oxidize the amino acid glutamine as fuel at a time when muscle and serum concentrations of glutamine fall from exercise and ongoing training [44, 49,59].

A glutamine "tug-of-war" then results that could leave both skeletal muscle and the immune system under-supplied. According to Wilmore and Shabert [60]: "During inflammatory states, glutamine consumption may outstrip endogenous production and a relative glutamine deficiency state may exist." Wischmeyer and colleagues [61] have reported that glutamine increases heat shock protein expression and decreases inflammatory cytokines in vitro and in vivo. Recent rodent data involving exercise does suggest increased neutrophil survival and function after high-dose glutamine supplementation [62]. Glutamine has also been reported to decrease upper respiratory tact infections and increase nasal immunoglobulin-A (Ig-A) [63,64], although it does not apparently elevate salivary Ig-A or affect leukocyte subsets [11,64]. Lastly, bioactive peptides in milk proteins may also provide immune support as they have been shown to be anti-microbial, while potentially enhancing tissue growth [65].

Immune defenses are not the only defenses deserving consideration during training. Maintained antioxidant capability may also require dietary support. The multiple types of oxidative stress experienced by athletes arguably place them at greater risk than non-athletes.

Pro-oxidative processes in athletes, from mitochondrial processing, to leukocytic activity, to reperfusion "injury" are examples of elevated oxidative stress [66]. As with immune stimulation, production of free radicals in the body is beneficial but only when over-stimulation is avoided. Pederson and Hoffman [57] have suggested that pro-inflammatory cytokines increase the risk of lymphocyte damage via reactive oxygen species.

Elevated oxidative stress appears to have a dietary link; both total protein intake and the type of protein or amino acid intake matter. Recent research comparing a minimal protein intake of 0.75 g/kg·d-1 with the "habitual" intake of 1.13 g/kg·d-1 resulted in decreased erythrocyte glutathione concentrations and kinetics among non-athletes [67]. The authors suggested "increased susceptibility to oxidant stress", a situation that could be made more severe among athletes.

Regarding protein type, whey protein has been shown to mitigate a training-induced decline in monocyte and whole-blood glutathione concentrations [68].

3.8 Protein Misconceptions
The issue of protein intake requires dealing with some misconceptions.

"Only bodybuilders need high protein diets."
The truth is that endurance athletes and bodybuilders have similar protein requirements, but the way in which the body uses the protein differs. Bodybuilders need protein to increase muscle tissue; endurance athletes need protein to repair existing muscle tissue that is undergoing constant breakdown from day-to-day training.

"Endurance athletes are not trying to build muscle so therefore they need little protein."
Some studies have indicated that endurance athletes may in fact need more protein than power athletes due to their increased caloric requirements.

"Eating a high protein diet will cause unwanted weight gain and muscle growth."
Actually, the type of training you engage in determines whether you bulk up or not. High volume endurance training does not produce muscle bulk, regardless of protein intake, whereas relatively low volumes of strength training will. Either way, the muscle tissue requires protein.

"Carbohydrates are the most important fuel for exercise."
While carbohydrates are indeed the body's preferred source of fuel, protein plays an important part in the energy and muscle preservation needs of endurance athletes. Under normal conditions, protein serves a vital role in the repair, maintenance, and growth of body tissues. However, after about 90 minutes of exercise in well-trained athletes, when muscle glycogen stores become nearly depleted, the body will synthesize glucose from the fatty and amino acids of lean muscle tissue. It's a process called gluconeogenesis, which is the body literally cannibalizing itself to provide an alternative fuel option during a state of glycogen depletion. The degree of soreness and stiffness after a long, intense workout is a good indicator of just how much muscle cannibalization you have incurred.

Research has shown *[Lemon, PWR "Protein and Exercise Update" 1987, Medicine and Science in Sports and Exercise. 1987;19 (Suppl): S 179-S 190.]* that exercise burns 10-15% of the total amount of calories from protein by extracting particular amino acids from muscle tissues. If the endurance athlete does not provide this protein as part of the fuel mixture, more lean muscle tissue will be sacrificed through gluconeogenesis to provide fuel and preserve biochemical balance.

In simple terms, you need to provide protein or the body will steal it from muscle tissue. The longer one exercises, the more muscle tissue is sacrificed and the more performance, recovery, and immune system are compromised.

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4.0 The Importance of Micronutrients: Vitamins, Minerals, Antioxidants

We've discussed carbohydrates and protein, so now we will focus on micronutrients. Unlike liters of water and hundreds of grams of carbs and up to a hundred grams or more a day of protein, these nutrients function at milligram and sometimes microgram quantities. We will discuss a few key nutrients in this group.

4.1 Vitamins And Minerals

Vitamins and minerals are team players; they work together with other nutrients.

Micronutrients play an important role in:

- energy production,
- hemoglobin synthesis,
- maintenance of bone health,
- adequate immune function, and
- the protection of body tissues from oxidative damage.

They are also required to help build and repair muscle tissue following exercise. Theoretically, exercise may increase or alter the need for vitamins and minerals in a number of ways.

Exercise stresses many of the metabolic pathways in which these micronutrients are required, and exercise training thus may result in muscle biochemical adaptations that increase micronutrient needs. Exercise may also increase the turnover of these micronutrients, thus increasing loss of micronutrients from the body.

Finally, higher intakes of micronutrients may be required to cover increased needs for the repair and maintenance of lean tissue mass in athletes.

Athletes at the greatest risk of poor micronutrient status are those who restrict energy intake or have severe weight-loss practices; who eliminate one or more of the food groups from their diet; or who consume high-carbohydrate, low micronutrient-dense diets.

The **B-complex vitamins** have two major functions directly related to exercise. Thiamin, riboflavin, vitamin B-6, niacin, pantothenic acid, and biotin are involved in energy production during exercise *(4,70- 74),* whereas folate and vitamin B-12 are required for the production of red blood cells, for protein synthesis, and in tissue repair and maintenance *(75).* Limited research has been conducted to examine whether exercise increases the need for some of the B-complex vitamins, especially vitamin B-6, riboflavin, and thiamin *(70,71,73,75,76).* The available data suggest that exercise may increase the need for these vitamins slightly, perhaps up to twice the current recommended amount *(72).*

The **antioxidant nutrients** – such as **vitamins A, E, and C; beta carotene; and selenium** – play an important role in protecting the cell membranes from oxidative damage. Because exercise can increase oxygen consumption by ten- to 15-fold, it has been hypothesized that chronic exercise produces a constant "oxidative stress" on the muscles and other cells *(77,78).* In addition, muscle-tissue damage caused by intense exercise can lead to lipid peroxidation of membranes. However, although there is some evidence that acute exercise may increase levels of lipid peroxide by-products *(79),* habitual exercise has been shown to result in an augmented antioxidant system and reduced lipid peroxidation *(77).* Thus, a well-trained athlete may have a more developed endogenous antioxidant system than a sedentary person *(80).* Athletes at greatest risk for poor antioxidant intakes are those following a low-fat diet, those who restrict energy intakes, or those with limited dietary intake of fruits and vegetables.

The **primary minerals** low in the diets of athletes – especially female athletes – are **calcium, iron, and zinc** *(11,81).* Low intakes of these minerals can usually be attributed to energy restriction or avoidance of animal products such as meat, fish, poultry, and dairy products.

Calcium is especially important for the building and repair of bone tissue and the maintenance of blood calcium levels. Inadequate dietary calcium increases the risk of low bone-mineral density and stress fractures. Female athletes are at greatest risk for low bone-mineral density if energy intakes are low, dairy products are eliminated from the diet, and menstrual dysfunction is present *(8,22).* Vitamin D is also required for adequate calcium absorption, regulation of serum calcium levels, and promotion of bone health. The two primary sources of vitamin D are fortified foods, such as milk, and ultraviolet conversion in the skin, which produces the vitamin. Athletes who live at northern latitudes or who train primarily indoors throughout the year – such as gymnasts and figure skaters – may be at risk for poor vitamin D status, especially if they do not consume foods fortified with vitamin D *(82).*

Iron plays an important role in exercise because it is required for the formation of hemoglobin and myoglobin, which bind oxygen in the body, and for enzymes involved in energy production. Iron depletion (low iron stores) is one of the most prevalent nutrient deficiencies observed in athletes, especially female athletes. The impact of iron depletion on exercise performance is limited, but if this condition progresses to iron deficiency anemia (low hemoglobin levels), exercise performance can be affected negatively *(4,81).*

Iron affects oxygen transport and aerobic metabolism as a component of hemoglobin, myoglobin, and oxidative enzymes. Immune function is dependent on iron-containing enzymes. Consuming adequate amounts of iron is essential for optimal aerobic endurance performance. Iron depletion is the first stage of iron deficiency and the most common type of iron deficiency among athletes.

The high incidence of iron depletion in athletes is usually attributed to poor energy intake due to avoidance of meat, fish, and poultry that contain iron in the readily available heme form; vegetarian diets that have poor iron bioavailability; or increased iron losses in sweat, feces, urine, or menstrual blood. Depleted iron stores are more prevalent in female athletes*(81,83).*

Chromium deserves specific mention because it plays an important role in how well insulin works. Studies suggest athletes who consume chromium (along with ample carbohydrates) within two hours of completion of exercise will experience a 300% increase in the rate of glycogen synthesis compared to no supplementation.

Zinc is essential for protein synthesis, it aids in healing and immune function, and is present in antioxidant enzymes and enzymes involved in energy metabolism. Survey data indicate that approximately 90% of men and 81% of women have zinc intakes below the 1989 RDAs (15 mg and 12 mg, respectively) *(85).* This nutritional shortfall is also seen in athletes, particularly females *(11).* Because of the role that zinc plays in growth, building, and repair of muscle tissue, and in energy production, assessing the diets of athletes for adequate zinc intake is prudent.

Athletic Benefits of Vitamins

Vitamins	Immune System Function	Muscle/Tissue Growth/Repair	Energy Production	Healthy Vision	Metabolism	Detoxifier	Nervous system Functio
Vitamin A		*		*	*		
Vitamin D		*					*
Vitamin E		*				*	*
Vitamin B1			*				
Vitamin B2		*	*	*			
Vitamin B3					*	*	*
Vitamin B6	*		*		*		*
Vitamin B12	*		*				*
Biotin		*			*		
Folic Acid	*	*	*				
Vitamin C	*	*					

Athletic Benefits of Minerals

Minerals	Bone Growth	Muscle/Tissue Strength/Repair	Energy Production	Metabolism	Nervous System function	Detoxifier	Immune System Function
Calcium	*	*			*		
Magnesium	*	*	*		*		
Potassium		*			*		
Chromium				*			
Copper		*					*
Iodine		*	*	*			
Iron			*				
Manganese		*					
Selenium		*		*		*	*
Zinc		*					*

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4.2 Antioxidants

Free radicals build up during exercise-responsible for muscle cell membrane damage and post workout soreness.

Antioxidants are another group of micronutrients desperately needed post-workout. Some vitamins (notably C & E) have antioxidant benefits, and other nutrients, described below, offer many further antioxidant benefits.

You need a wide spectrum of antioxidants because prolonged exercise produces many different types of free radicals. Each antioxidant has an affinity for different target free radicals. No one antioxidant, say vitamin E, will protect from all the ravages of free-radical production.

6.0 The Importance of Amino Acids

6.1 Background

6.1.1 Essential and non-essential amino acids

All proteins are constructed from amino acid building blocks chemically linked together. Our diets typically contain around 20 of these amino acid building blocks in the foods we eat. Once the plant or animal proteins we eat have been digested to release the amino acids, our cells reassemble them to produce human proteins such as hair, skin, muscle etc.

Of the ≈20 amino acid building blocks, some are considered absolutely **essential** because they can't be manufactured in the body from other molecules. These include:

- Arginine
- Histidine
- Isoleucine
- Leucine
- Lysine
- Methionine
- Phenylalanine
- Tyrosine
- Tryptophan
- Valine

The other amino acids are classed as **non-essential** because they can be synthesized in the body from fragments of the essential amino acids and carbon residues from glucose metabolism. More recently, scientists have identified a third category of amino acids, known as '**conditionally essential'**. Conditionally essential amino acids can be synthesized in the body when demand is low, but when demand rises (eg at times of metabolic stress) synthesis can't keep up with demand and dietary sources then become vital. The amino acid glutamine is thought to fall into this category, being non-essential at rest but becoming essential at times of severe metabolic stress.

6.1.2 Amino acids and proteins

Amino acids are the building blocks of proteins, and also play a central role as intermediates in metabolism *(20).* Amino acid molecules are linked together (through peptide linkages) to form proteins.

The kind of protein that results is dictated by the types of amino acids involved and the sequence in which the amino acids are arranged. That alone decides whether a protein will turn out to be skin, muscle, hormone, enzyme, serum or an antibody. The sequence of the amino acids within the proteins also decides how that protein will fold into a three dimensional structure and how stable that structure will be *(20).*

The twenty eight or so amino acids in the human body combine in a number of ways to account for 150 or more intermediates and more than 40,000 proteins known to us *(3).* It is estimated that the human body has around 250,000 – 300,000 proteins, much of which have not yet been characterized or catalogued *(21).*

Proteins serve the following vital functions:

1. Most cellular functions, including cellular energy production
2. Enzyme production: Formation of enzymes which regulate chemical reactions within our body

3. Immune proteins: Formation of antibodies which fight infection and also confers upon us the immunity from all internal and external insults
4. Contractile proteins: Formation of muscles
5. Structural proteins: Formation of ligaments, tendons, cartilage, bone, hair, nails etc
6. Regulatory proteins: Formation of hormones
7. Transport proteins: Formation of blood proteins and hemoglobin (responsible for oxygen delivery to every body tissue)
8. Neurotransmitter proteins: Formation of chemicals that help nerve impulse transmission

Understandably, the functions served by the proteins are functions of the amino acids themselves.

It is important to realize that each amino acid plays a different metabolic or biochemical role in the human body and that deficiency of one amino acid may also affect the functioning and/or the production of another. It is worth noting here that the requirements for specific amino acids are directly altered when the body is under stress. In other words, physical (or even psychological) disorders and plasma amino acid levels bear a direct relationship to each other.

5.2 The General Role of Amino Acids in the Body and Health:

The following is a brief account of the key amino acids (alphabetical):

1) Alanine
2) Arginine
3) Asparagine
4) Asparagine
5) Aspartic Acid
6) Glutamine And Glutamic Acid
7) Glycine
8) Histidine
9) Isoleucine
10) Leucine
11) Lysine
12) Methionine
13) Phenylalanine
14) Proline
15) Serine
16) Threonine
17) Tryptophan
18) Tyrosine
19) Valine

1) ALANINE:

Functions: Alanine is an immune system marker and indicates how effectively the immune system is killing malignant cells. Alanine is also vital for the production of protein, essential for proper function of the central nervous system and helps form neurotransmitters. Alanine is necessary for the promotion of proper blood glucose levels from dietary protein.

Dietary sources: Beans, meat, nuts, seafood, seeds, soy, whey, brewer's yeast, brown rice

2) ARGININE:

Functions: Plasma levels of Arginine are directly proportional to tumour regression. Arginine sets the pace at which immunological proteins are manufactured and this, in turn, determines the rate of immunological response. Low levels indicate a slow immunologic response.

Dietary sources: Whole wheat, nuts, seeds, peanuts, brown rice, soy, raisin

3) ASPARAGINE:

Functions: Asparagine controls protein balance and is able to burn fat to build proteins. It is one of the principal amino acids involved in the transport of nitrogen. It also mediates a variety of chemistries that stimulate the immune system.

Dietary sources: Dairy, beef, poultry, eggs

4) ASPARTIC ACID:

Functions: Aspartic Acid controls the levels of a variety of amino acids and blood gases that control pH balance and reduce anaerobic activity. Since malignant cells are anaerobic, aspartic acid helps to reduce malignant activity. Aspartic acid also serves as an excitatory neurotransmitter in the brain which provides resistance to fatigue and leads to greater endurance.

Dietary sources: Sprouting seeds, oat flakes, meat, avocado, asparagus

5) GLUTAMINE and GLUTAMIC ACID:

Functions: Glutamine is converted to Glutamic Acid (Glutamate) after it crosses the blood-brain barrier. Glutamic acid combines with the amino acid taurine to form GABA (gamma amino butyric acid). GABA regulates neuron firing and neurochemical activity in the brain.

Glutamine also serves as a source of fuel for cells lining the intestines. Without glutamine the intestinal cells would waste away. Glutamine regulates the expression of certain genes and helps regulate the biosynthesis of DNA and RNA. Construction of DNA is dependent upon adequate amounts of glutamine.

Dietary sources: Beef, fish, milk, yoghurt, cheese, spinach, cabbage, parsley

6) GLYCINE:

Functions: Glycine is essential for the synthesis of amino acids produced by various organ systems. It is vital to the production of nucleic acids, glucose, hemoglobin and bile acids. It also exerts an inhibitory influence on the central nervous system and may be important in the control of epilepsy and spastic disorders.

Dietary sources: Fish, meat, beans, dairy

7) HISTIDINE:

Functions: Histidine is used in the manufacture of histamines, which are the first line of defence in immunological response. Chronic low levels of histidine demonstrate immunological suppression, leaving the host organism open to a variety of immunological challenges, such as cancer. High levels, on the other hand, demonstrate immunological competency.

Besides, histidine is also needed for the growth and repair body tissues, and to maintain the myelin sheaths that protect nerve cells. It also helps in the manufacture of red and white blood cells, and protects the body from heavy metal toxicity. The stomach uses histidine to produce gastric juices.

Dietary sources: Dairy, meat, fish, wheat, rye

8) ISOLEUCINE:

Function: Low levels of Isoleucine can lead to sugar imbalances. Sugars are necessary in the production of immunoglobulins which stimulate immunological response and momentum. Low levels indicate a responsively slow immune system. In conjunction with valine and leucine it promotes muscle recovery. It is also needed for the formation of hemoglobin.

Dietary sources: Almonds, cashews, chicken, eggs, fish, lentils, liver, meat

9) LEUCINE:

Function: Plasma levels of Leucine similarly manage sugars. However, optimal levels in both Isoleucine and Leucine demonstrate the ability to build sugars and branched amino acids that act as immunological stimulants and nutrients to various glands in the brain and endocrine system. This manages the overall competency of the immune system. Low levels indicate low immunological response.

Dietary sources: Brown rice, beans, nuts, whole wheat

10) LYSINE:

Functions: Lysine is one of the two most critical amino acids. Plasma levels indicate the degree and extent of overall immunological competency. Lysine is a branched amino acid. This means it is used in the production of every immunological protein, antibody, antigen, hormone, growth factor and cytokine (protein). Low levels indicate deficiencies in overall immunological functioning. It also helps to absorb calcium and supports bone development in children.

Dietary sources: Milk, cheese, eggs, lima beans, meat, brewers yeast

11) METHIONINE:

Functions: Methionine assists in the breakdown and absorption of fats. Approximately 20% of amino acids are derived from consumption of protein which is broken down by fats. Fats are also requisite to the absorption of nutrients. Low levels of Methionine affect levels of essential amino acids. Methionine is also critical in the absorption of sulphur and sulphur based chemistry which is critical in the formation of nucleic acid. Methionine is used in the manufacture of Choline which stimulates the neurological components of the immune system. Level of methionine will rise only when all amino acids are effective. It shows whether the body is taking in and utilizing amino acids efficiently.

Dietary sources: Meat, fish, eggs, yoghurt, beans, lentil, garlic, onion

12) PHENYLALANINE:

Functions: Phenylalanine plays an important role as an immune system marker and as an indicator of expression of various brain chemicals that stimulate the immune system. As an immune system marker, levels of Phenylalanine increase with the killing, fragmenting and recycling of the constituent materials of malignant cells. In other words, it indicates the burden of damaged cells. Phenylalanine also inhibits enzymes that break down stimulatory brain chemistry, thus keeping immuno-excitory chemistry at optimal levels.

Dietary sources: Dairy, almond, lima beans, peanuts, avocadoes

13) PROLINE:

Functions: Proline is a marker of anaerobic activity. A low level of proline is indicative of a contained bacterial infection. Proline is the precursor for hydroxyproline, which the body incorporates into collagen, tendons, ligaments, and the heart muscle. Proline helps strengthen cardiac muscle.

Dietary sources: Dairy products, eggs, beef, poultry

14) SERINE:

Functions: Serine is needed for the metabolism of fats and fatty acids. It aids in the production of immunoglobulins and antibodies, and is a constituent of brain proteins and nerve sheaths. It is important in the production of cell membranes, and in the synthesis of muscle tissue.

Dietary sources: Meat, dairy, wheat, peanuts, soy

15) THREONINE:

Functions: Threonine metabolizes into neuro-electrolytes and ensures continual and optimal messaging for immune response. It is found in high concentration in the central nervous system, the muscles and the heart.

Dietary sources: Meat, dairy, eggs

16) TRYPTOPHAN:

Functions: Tryptophan plays a key neurological and physiological role by ensuring metabolic stimulation of various chemistry and processes that regulate circadian cycles (wake/sleep states) and all of the attendant circadian activities relative to these cycles. Low levels are usually present with poor wake and sleep states, underwritten by poor chemical and metabolic activities consistent to each state. Tryptophan levels also give insight into how iron is bound to various resource chemistries and transported to various sites for manufacture and remanufacture into immunological cells and chemistry.

Dietary source: Oats, bananas, milk, cottage cheese, meat, fish, turkey, peanuts

17) TYROSINE:

Functions: Tyrosine is critical in the production of dopa and dopamine (which regulates brain function), and epinephrine and norepinephrine (which regulates heart function). Tyrosine is also reported to have an antioxidant effect, which may help to protect from cancer and coronary heart disease, and reduce aging.

Dietary sources: Meat, fish, dairy, eggs, almonds, avocado, bananas

18) VALINE:

Functions: Valine is a neuro-excitory amino acid. Optimal levels are usually present with stable psychology and physiology. Low levels indicate psychological and physiological depression. Valine is a stimulant of the thymus gland, and the thymus produces the T-lymphocytes of the immune system.

Dietary sources: Dairy, meat, grains, mushrooms, soy, peanuts

5.3 The Critical Role of Amino Acids in Sports Training and Performance

There are numerous benefits of amino acids at the professional sport level. The functions of amino acids can be divided into three categories:

1. Muscle building
2. Increase of stamina
3. Recovery from fatigue

The following discussion highlights research regarding the **ergogenic** (enhancing physical performance) effects of individual amino acids and various combinations of amino acids:

1) Alanine
2) Arginine
3) Asparagine
4) Aspartic Acid
5) Branched Chain Amino Acids:
    a. Isoleucine
    b. Leucine
    c. Valine
6) Cysteine
7) Glutamine And Glutamic Acid
8) Glycine
9) Histidine
10) Lysine
11) Methionine
12) Phenylalanine
13) Proline
14) Serine
15) Taurine
16) Threonine
17) Tryptophan
18) Tyrosine
19) Other
    a. Creatine
    b. Hydroxymethylbutyrate (HMB)
    c. Carnitine

1) Alanine

Beta Alanine is a non-essential amino acid. Alanine has one of the simplest chemical structures of all the amino acids. The structure of Alanine is such that it is quite simple for Alanine to be converted into glucose which, as we all know, is the fuel that muscles need to keep working.

Anecdotal evidence suggests that it may help reduce muscle fatigue. Additionally, recent research has indicated that Alanine supplementation may allow the body to produce higher concentrations of Carnosine, a chemical compound that is known to buffer the buildup of acids that occur in fatigued muscles. The most effective way to increase Carnosine concentrations in the muscles is to supplement with Carnosine precursors, Alanine and Histidine.

Some scientists have suggested that taking Alanine supplements may help keep muscles working longer during extended exercise because it can be released from muscle tissue and converted into glucose when the body has run through its stored glucose supplies. This is only conjecture at this point, as no studies have directly tied Alanine levels to a reduction in muscle fatigue.

Note: When you ingest carnosine intact, most of it is broken down in the gastrointestinal (GI) tract into its constituent amino acids, beta-alanine and histidine. Some intact carnosine does escape the GI tract freely but even that amount is quickly broken down in our blood by the enzyme carnosinase. In a very short time, all the carnosine you just ingested is either eliminated or broken down into beta-alanine and histidine. These two amino acids are then taken into the muscle, where they are converted back into carnosine with the help of the enzyme carnosine synthetase.

2) L-Arginine
Arginine supplementation may be ergogenic because it is a substrate for nitric oxide (NO) synthesis, a potent endogenous vasodilator that benefits blood flow and endurance capacity.[25.]

- Overall stimulant of the immune system
- Low levels associated in poor repair and maintenance
- Proper levels reduce time of recovery from injury
- It elevates the secretion of insulin and growth hormone which are known for their of muscle building properties. Arginine is closely related to the secretion of growth hormone. Growth hormones are important both for muscle building and for muscle repair. Replenishment of arginine is considered to promote the synthesis of myoproteins.
- One of the most important benefits of L-Arginine is that it increases blood flow so your heart can pump more blood to your muscles. It is the precursor to nitric oxide (NO2), which keeps your blood vessels dilated (vasodilator), allowing the heart to obtain sufficient oxygen and provide that “rock hard pump”.

ISM Observations:
- Athletes tend to be low (40 – 55)
- Normal ≈ 70 – 90

3) Asparagine
- Acts as a marker. All protein stores (as measured by asparagines) were sub-optimal.
- Should see Asparagine go up after protein balancing
- Research with aspartate and asparagine has suggested that the duo may in some way slow down glycogen depletion in the muscles and liver, thus prolonging an athlete’s ability to exercise.
- It is also believed that aspartate and asparagine may somehow help keep blood levels of tryptophan under control during prolonged exercise, possibly reducing the risk of mental fatigue during lengthy exertion
- Aspartate and asparagine supplementation produced longer endurance times, inducing more temperate blood lactate levels and promoting better conservation of precious glycogen.
- Aspartate and asparagines increased the ability of muscles to spare glycogen – and heightened the capacity of muscles to break down fats for energy. In addition, time to exhaustion was about 40% longer with supplementation
  Source:
    - *Biochemistry of Exercise IX, International Biochemistry of Exercise Conference. Champaign, Illinois: Human Kinetics Publishers, pp261-275, 1996*
    - *Physiology and Behavior, vol.57, pp367-371, 1995*
    - *International Journal of Sport Nutrition and Exercise Metabolism, vol 13, pp65-75, 2003*

ISM Observations
- Athletes are at 42-47
- Optimal ≈ 50-60

- Building too much cortisol and adrenaline because Tyrosine is below 60

4) Aspartates.
Potassium and magnesium aspartates are salts of aspartic acid, an amino acid. They have been used as ergogenics, by enhancing fatty acid metabolism and sparing muscle glycogen utilization or by mitigating the accumulation of ammonia during exercise.

The effect of aspartate supplementation on physical performance is equivocal, but about 50 percent of the available studies have indicated enhanced performance in exercise tests of aerobic endurance *6*.

5) Branched-chain amino acids "BCAA": Valine, Leucine and Isoleucine:
Generally, the three branched chain amino acids, leucine, isoleucine and valine, boost energy while helping to counteract muscle protein breakdown during exercise. In addition, they promote the biosynthesis of other amino acids, nucleotides, and biological amines. Branched chain amino acids are unique in that they are not metabolized by the liver.

BCAAs comprise 1/3 of muscle tissue and are the first amino acids to be catabolized due to intense exercise. Therefore, dietary BCAA supplementation is particularly important for hard-training individuals looking to maximize their muscle gains. The body requires higher amounts of branched chain amino acids during and following exercise as they are taken up directly by the skeletal muscles versus first being metabolized through the liver, like other amino acids. Low BCAA levels contribute to fatigue and they should be replaced in one-hour or less following exercise or participation in a competitive event. *(Bassit RA, Nutrition 2002 May;18(5):376-9.)*

There are two primary mechanisms regarding the ergogenic value of supplementation with BCAAs:

1) BCAA supplementation during intense training may help minimize protein degradation and thereby lead to greater gains in fat-free mass. *(Carli et al., 1992; Coombes and McNaughton, 1995). (Kreider, 1998).*

2) Lack of availability of BCAA during exercise contributes to central fatigue *(Newsholme et al., 1991).* BCAA supplementation reduces Perceived Exertion and mental fatigue during prolonged exercise and improves cognitive performance after exercise, and may improve physical performance, such as during exercise in the heat or in actual competitive races where central fatigue may be more pronounced *12.*

> *Mechanism:* During endurance exercise, BCAAs are taken up by the muscles rather than the liver in order to contribute to oxidative metabolism. The source of BCAAs for muscular oxidative metabolism during exercise is the plasma BCAA pool, which is replenished through the catabolism of whole body proteins during endurance exercise *(Davis, 1995; Kreider, 1998; Newsholme et al., 1991).* However, the oxidation of BCAAs in the muscle during prolonged exercise may exceed the catabolic capacity to increase BCAA availability, so plasma BCAA concentration may decline during prolonged endurance exercise *(Blomstrand et al., 1988; Blomstrand et al., 1991).* The decline in plasma BCAAs during endurance exercise can result in an increase in the ratio of free tryptophan to BCAAs. Free tryptophan and BCAAs compete for entry into the brain via the same amino-acid carrier *(Newsholme et al., 1991).* Therefore, a decrease in BCAAs in the blood facilitates entry of tryptophan into the brain. Moreover, most tryptophan in the blood is bound to albumin, and the proportion of tryptophan bound to albumin is influenced by the availability of long-chained fatty acids *(Davis et al., 1992; Newsholme et al., 1991).* In endurance exercise free fatty-acid concentration rises, so the amount of tryptophan bound to albumin falls, increasing the concentration of free tryptophan in the *blood (Davis, 1995).*

Collectively, the decline in plasma BCAAs and increase in free tryptophan during prolonged endurance exercise alters the ratio of free tryptophan to BCAAs and increases the entry of tryptophan into the brain *(Newsholme et al., 1991).* An increased concentration of tryptophan in the brain promotes the formation of the neurotransmitter 5-hydroxytryptamine (5-HT). 5-HT has been shown to induce sleep, depress motor neuron excitability, influence autonomic and endocrine function, and suppress appetite in animal and human studies. An exercise-induced imbalance in the ratio of free tryptophan to BCAAs has been implicated as a possible cause of acute physiological and psychological fatigue (central fatigue). It has also been hypothesized that chronic elevations in 5-HT concentration, which may occur in athletes maintaining high-volume training, explains some of the reported signs and symptoms of the overtraining syndrome: postural hypotension, anemia, amenorrhea, immunosuppression, appetite suppression, weight loss, depression, and decreased performance *(Newsholme et al., 1991; Gastmann and Lehmann, 1998; Kreider, 1998).*

Studies have confirmed that BCAA administration with or without carbohydrate prior to and during exercise can affect physiological and psychological responses to exercise *(Coombes and McNaughton, 1995; Hefler et al., 1993; Kreider et al., 1992; Kreider and Jackson, 1994).*

<u>BCAA Highlights:</u>

- BCAAs are crucial for the formation of new muscle and the retention of existing muscle tissue. A deficiency of any one of these amino acids can lead to severe metabolic imbalances that could negatively impact the ability to build new muscle, and could also have far reaching health consequences.
- BCAA are unique among amino acids in that they are not metabolized in the liver. Rather, they are stored directly in muscle tissue and serve to help grow new muscle and increase strength, resist the breakdown of muscle tissue, and can provide extra energy to the muscle if it is under heavy exertion by quickly converting to glucose.
- Research has shown that muscles break down BCAA during exercise, suggesting that supplementation might provide extra muscular fuel.
- BCAA is helpful during extended exercise at intensities below the lactate threshold. The explanation goes like this: as blood concentrations of the BCAA decline during exercise (a result, presumably, of their increased breakdown by muscles), levels of another amino acid – tryptophan – can increase by as much as 100%. Since tryptophan ‘competes’ with the branched-chain amino acids to squeeze through capillaries in the brain and gain access to neural tissue, this may well mean that athletes’ brains become relatively full of tryptophan and relatively devoid of branched-chain amino acids during extended exercise. That is not a lethal scenario, but it is worthwhile noting that tryptophan is easily converted inside the brain to a chemical called serotonin, which has sometimes been called the brain’s ‘sandman’, since it can induce feelings of extreme fatigue and sleepiness. (*Acta Physiologica Scandinavica, vol 133, pp115-121, 1988)*
- As a result, supplementation with branched-chain amino acids might limit perceptions of fatigue during prolonged physical efforts, and thus enhance performance. Indeed, in one US study triathletes who took in BCAA were able to run considerably faster during the run portion of a triathlon than non-supplemented ‘controls’. (*Running Research News, vol 7(3), pp1, 5-7, 1991)*
- There is also increasing evidence that BCAA supplementation is very important immediately after exercise. *(Am J Physiol Endocrinol Metab, vol 281(2), ppE365-E374, 2001)*. Supplements had little effect on protein metabolism during the training session, but seemed to produce a smaller release of amino acids from the leg muscles during the post-workout recovery. Ingested branched-chain amino acids may have a protein-sparing effect during recovery from exercise, which could have the knock-on effects of enhancing the quality of recovery, reducing the risk of injury to muscle tissue and making it easier for athletes to conduct high-quality workouts on subsequent days. Research seems to indicate that

leucine may be the key BCAA associated with amplified protein synthesis following training. *(Canadian Journal of Applied Physiology, vol 27(6), pp646-663, 2002)*

BCAA Summary

(1) BCAA contribute to muscle building

- Muscle tissues are comprised of two proteins, actin and myosin. The main components of the two proteins are leucine, isoleucine, and valine. BCAAs account for about 35% of the essential amino acids contained in myoproteins. Replenishment of BCAAs increases the raw materials for muscle tissues, contributing to muscle building.

(2) Increase of stamina and recovery from fatigue

- When an athlete undertakes strenuous exercise for a lengthy period, the body begins to decompose proteins and consume BCAAs in order to compensate for insufficient energy sources. Post-competition blood level of BCAAs may be decreased by as much as 20%, because of intramuscular BCAAs consumption during long periods of exercise. Muscle damage can be reduced and inhibit the lowering of muscular strength by replenishing BCAAs timely, before, during and/or after physical activity. Taking BCAAs preserves energy sources and helps maintain stamina. Also, by taking BCAAs immediately after physical activity or before going to bed, muscle recovery is improved and muscle soreness prevented.
- Amino acids constitute myoproteins and serve as an energy source during exercise. Therefore, athletes use amino acids for the purposes of nutrition and recovery from fatigue. Amino acids are absorbed faster than proteins, so they can easily be replenished during physical activity.

(3) Improve physical and toughness with BCAA

- BCAAs function to suppress the production of lactic acid, a substance that causes fatigue. Muscular fatigue occurs from continuous exercise when the level of lactic acid in the blood increases. This results in the pH in muscles being decreased, causing difficulty in muscle contraction. However, replenishment of BCAAs will inhibit the elevation of the lactic acid level in the blood even during strenuous exercise.

(4) Arginine and leucine with BCAAs for athletes

- In addition to BCAAs, arginine and leucine also have positive effects on the body during physical activity. Arginine is closely related to the secretion of growth hormone. Growth hormones are important both for muscle building and for muscle repair. Replenishment of arginine is considered to promote the synthesis of myoproteins. Leucine also helps the synthesis of myoproteins and inhibits their breakdown.

(5) Fat burning

- Tissues are increased by accelerating the regeneration of muscles after doing aerobic exercise. Replenishing BCAAs, the raw materials for muscle, helps this process. Muscles are the “furnace in which fat is burned”, therefore, increasing muscle mass boosts the body’s metabolism and increases the consumption of energy, meaning more fat burning.

Specific Additional BCAA Detail:

- Isoleucine:
    - Isoleucine is an important anabolic compound, which means that Isoleucine is a key component in the process of creating new proteins.

- Those with insufficient Isoleucine concentrations may find themselves burning muscle instead of fat during very intense workouts, which is highly detrimental to athletic performance. As such, Isoleucine is very useful to those athletes, such as boxers and wrestlers, who need to increase their strength while maintaining their weight.

- Leucine:
  - Helps regulate sugar levels and also participates in hormone production, wound healing as well as energy regulation. It helps prevent the breakdown of muscle proteins that sometimes occur after trauma or severe stress.
  - While all of the branched chain amino acids are important for athletes, Leucine has the most far reaching benefits for strength athletes both in terms of new muscle creation and muscle retention.

- Valine:
  - Needed for muscle growth and repair. It can be used as an energy source in the muscles and in doing so preserves the use of glucose. It has the ability to create extra energy for tired muscles in order to fight muscle fatigue.

6) Cysteine

Cysteine is a semi-essential amino acid. "Semi-essential" means that it can be created naturally by the body but not in high enough amounts to meet all of the body's needs in all circumstances.

- Associated with an increasing plaque i.e., typical of poor eating habits.
- Infers exposure to hydrogenated and transformed fats and fatty acids and deficient levels of chemistry capable of recovering plaque.
- High levels associated with atherosclerosis and heart disease, Parkinson's, Alzahaemers.
- Also associated to early onset of cardiovascular disease.
- Cysteine has a number of beneficial effects such as enhancing toxin removal, aiding in the proper functioning of the central nervous system, immune system enhancement, blood pressure regulation, visual acuity, muscle creation, and fat burning.
- To build the muscles you need to reach your peak performance level, you need to keep muscles and tissues free from the toxins that are produced as a byproduct of strenuous exercise. Cysteine helps the body clear out these toxins which allows more muscle to grow and protects against muscular degradation. Cysteine also helps in the production of insulin, which has been shown to have beneficial effects on muscle growth and retention.
- One of the most beneficial aspects of Cysteine is its ability to convert itself to glucose in an emergency. Rigorous exercise burns stored glucose in the cells. When the glucose is gone, the cell can no longer operate. If this happens to enough muscle cells, the athlete becomes weak and fatigued. Fortunately, it has a simple chemical structure that is easily converted to glucose and can provide muscles with an extra burst of energy that helps keep fatigue and weakness at bay.
- Aspirin is commonly used by athletes to treat the aches and pains that result from strenuous exercise. The problem with this is that aspirin can be very tough on the stomach and has been known to degrade the tissues lining the stomach and has even lead to ulcers. Cysteine has been shown to mitigate some of the stomach damaging effects of aspirin usage, and is helpful for digestive health in general.

ISM Observations

- Athletes – elevated levels

7) Glutamine/ Glutamic Acid
Glutamine is a non-essential amino acid, most abundant in muscle and plasma.*2,4* Glutamine is the most abundant amino acid (protein building block) in the body and is involved in more metabolic processes than any other amino acid. Glutamine is converted to glucose when more glucose is required by the body as an energy source. It serves as a source of fuel for cells lining the intestines. Without it, these cells waste away. It is also used by white blood cells and is important for immune function.

Some studies have shown improvement in high intensity resistance training effects.*11* No serious side effects have been reported with glutamine use.

Glutamine supplementation may be a strategy to promote muscle growth *(Rennie et al., 1994; Rennie, 1996).* Glutamine is also an important fuel for white blood cells, so reductions in blood glutamine concentration following intense exercise may contribute to immune suppression in over-trained athletes *(Parry-Billings et al., 1990a; Parry-Billings et al., 1990b; Parry-Billings et al., 1992; Kargotich et al., 1996; Newsholme and Calder, 1997).*

Preliminary studies indicate that supplementation with branched-chain amino acids (4 to 16 g) and/or glutamine (4 to 12 g) can prevent the decline or even increase glutamine concentration during exercise *(Kreider, 1998).* In theory, these changes in glutamine concentration could have beneficial effects on protein synthesis and immune function.

Glutamine may be theorized to be ergogenic as an important fuel for some cells of the immune system, such as lymphocytes and macrophages, which may be decreased with prolonged intense exercise, such as that related to overtraining. Glutamine may also promote muscle glycogen synthesis, and has been studied for potential enhancement of muscular strength.

Atletes who over-train may experience decreased plasma glutamine levels, which may impair functions of the immune system and predispose the athlete to various illnesses *17,18.* Illness may impair training and eventual performance.

Glutamic acid is a non essential amino acid that has a number of effects, most of which are due to its ability to convert to Glutamine, one of the most important amino acids. Of particular interest to athletes, it positively impacts energy production, wound healing, emergency energy release, immune system health, and a number of other factors.

Glutamic acid on its own works as a neurotransmitter and has some minor performance enhancing capabilities. Glutamic acid intake is important in the creation of new muscle tissue. Glutamic acid creates substances that are necessary components of muscle fiber.

Glutamic acid supplements can reduce the amount of training time lost since Glutamic acid has been shown to be instrumental in the process of wound healing and recovery. Glutamic acid also decreases the amount of time it takes to recover from burn injuries.

8) Glycine
Glycine is a nonessential amino acid and is an important component of collagen. Although much of the early research revolved around glycines ability to increase strength in athletes, more recent studies have documented that oral glycine can raise growth hormone levels in humans. Researchers have hypothesized that the reason glycine has been found to increase muscle strength in many studies, (with females experiencing a 22% increase and men a 32% increase in cycle ergometry workloads after ingestion of 5 to 12 grams of glycine daily) may be the result of its growth-hormone-boosting capabilities.*(25)*

Glycine is one of the stimulatory agents inducing the pituitary gland to secrete hGH.*(25)*

Glycine enhances growth hormone levels already produced during a whole-body resistance training program and during anaerobic or intermittent exercise. In subjects performing endurance exercise where growth hormone release is low, glycine would not show any benefit because this amino acid only enhances effects of growth hormone already produced. Acute ingestion of glycine appears to stimulate release of growth hormone and increase creatine synthesis rates. Both of these attributes are desirable for persons undergoing progressive weight training.*(28)*

Treatment with arginine and glycine increases subjects mean resistance to fatigue up to 28% over the controls during acute exhaustive high-intensity anaerobic isokinetic exercise. The subjects taking glycine and arginine also experienced an overall gain in total muscle work of 10.5% more than controls.*(29)*

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9) L-Histidine
A semi-essential amino acid, meaning external sources are needed to replenish its levels in the body.

- First line of defence immunologically and toxicologically
- Histidine (His) is elevated in plasma and brain during protein deficiency as well as in several pathological conditions, leading to the possibility of a direct effect on central nervous system (CMS) function.
- HypoHistidinemia (low histidine)
  - associated with accelerating disease such as arthritis, Parkinson’s, etc. and increased susceptibility to infection and food chain toxins
- Recent discoveries have suggested that large levels of Histidine may indeed promote muscle growth indirectly since it is a precursor to Carnosine. Carnosine, which is composed of Histidine and alanine, is extremely beneficial for athletes. It is well known that our muscles become fatigued for a number of reasons but one of the biggest culprits is the buildup of lactic acid and other acid substances that are formed during anaerobic respiration. The key to maintaining peak performance is to reduce the negative effects of acid buildup. Carnosine has been shown to be a key component of certain proteins that effectively buffer the harmful effects of acid buildup in the muscles. While Carnosine itself can be taken via supplements, studies have suggested that it is possible to achieve higher Carnosine concentrations by taking Histidine and allowing the body to create its own Carnosine.

ISM Observations

- Athletes – chronically low (57-71)
- Normal ≈ 80

10) L-Lysine
Lysine is an amino acid that is very important in the production of many essential proteins in the human body. It is considered an essential amino acid because the body cannot fabricate it out of precursor chemicals.

- An antiviral used to repair heart and helpful in maintaining healthy blood vessels.
- A significant increase in heart disease has been observed in athletes.

- Lysine is effective in helping the body combat bacterial infections by assisting in the production of natural antibiotics. Lysine is also useful for helping control viral infections, particularly those caused by the Herpes virus family. Every athlete knows that continuous training is important to stay in peak condition. Nothing throws a wrench in those plans more than losing time to an illness or injury.
- Studies have shown that Lysine, working in accord with other amino acids, enhances the production and release of growth hormone. Growth hormone is necessary to achieve the muscle building.
- It also enhances the fast metabolism response, which allows additional energy to be released when muscle cells have used up other available energy supplies. This helps muscles to keep working after they would have otherwise succumbed to fatigue.
- The repetitive motions that are common in strength training workouts can wreak havoc on ligaments, tendons and bones. Lysine has been shown to improve the uptake of calcium into bone tissue, which helps bones maintain their rigid structure. It is also important in the creation of collagen, which is a vital component of tendons and ligaments. Many sports related injuries are due to strains, sprains, and other injuries to the connective tissues. Taking Lysine supplements can help you avoid such injuries and can also enhance the body's healing in response to a broken bone, strain, sprain, or tear.
- Lysine is also helpful in that it is a precursor to chemicals that encourage the use of fatty acids for energy. This means that Lysine can protect muscles from degradation during strenuous exercise and helps reduce the fat content in the body. Lysine supplements are particularly useful in this regard for athletes who need to create new muscle but need to remove fat at the same time.

ISM Observations

- Athletes – all scored a bit low

11) L-Methionine

An essential amino acid, meaning external sources are needed to replenish its levels in the body. This amino acid contains sulfur. It breaks down fats and inhibits the buildup of fats in arteries and in the liver. It is a powerful antioxidant. Methionine is needed for the production of collagen and nucleic acids, and is vital for protein synthesis.

- A marker for how well the body is metabolizing amino acids into protein. When muscle is complete, Methionine scores should be up.
- It is an indicator that athletes have substandard protein expression and muscle structure. This may be due to incomplete protein manufacture.
- Muscles could even be weaker:
    - i.e., inadequate adipose tissue: Body fat-the cells that synthesize and store fat, releasing it for metabolism. It is found mainly under the skin but also in deposits between the muscles. It may develop anywhere, but tends to accumulate beneath the skin, where it can act as a shock-absorber and insulator.
- Methionine is also used to promote the growth of connective tissue (i.e. tendons and ligaments) and helps the body recover after injury. Of particularly importance to athletes, it is also a necessary precursor to creatine, a substance that has been proven to enhance athletic performance. Creatine is perhaps the most commonly used supplement in sports today. It is well known for its ability to enhance muscle growth and strength. It is also useful for making energy available to muscles thereby allowing them to perform longer and at higher efficiency. It has also been suggested that creatine can be used in the treatment of certain cardiovascular conditions since it enhances the strength of the cardiac muscle and is a necessary component in the creation of creatine and, as such, is of great interest to athletes of all kinds.
- Methionine helps the liver process fats and avoid the condition known as "fatty liver" that occurs when the liver cannot successfully process fat quickly enough. Many athletes take

Acetaminophen to treat the aches and pains that are a natural part of working out. Methionine helps the liver deal with the Acetaminophen, which has been shown to cause liver damage with prolonged exposure. For this reason, some medical professionals have suggested that it should be added to Acetaminophen to avoid liver complications.

- Strains, sprains, tears, pull--no matter what you call them they can stop your work out cold. They can also keep you from training while the injury heals. Methionine is a necessary component of collagen, which is a protein that is necessary in the production and maintenance of ligaments and tendons. Methionine can help protect against sprains and strains and also aids in quick recovery should these injuries occur.
- Another common problem that athletes endure is inflammation due to joint overuse or injury. Methionine helps to bring down inflammation by destroying the agents in the body that cause inflammation, allowing the athlete to get back to training as quickly as possible. Methionine can also reduce inflammation that is caused by certain health conditions such as rheumatoid arthritis.

ISM Observations

- Athletes – scored 14-25 none were optimal, many are as low as chronically ill people
- Normal ≈ 30

12) Phenylalanine

Phenylalanine is an essential amino acid that cannot be produced by the human body. It has been shown to reduce pain from some typical athletic injuries, to help in the reduction of fat, to stimulate alertness, and to increase metabolic rate.

Phenylalanine has been shown to have effects that enhance the body's ability to fight aches and pains of this sort. Phenylalanine also helps fight muscle spasms and inflammation that can occur from vigorous exercise.

Phenylalanine is necessary for the production of other amino acids that enhance the production of adrenalin. Adrenalin is the hormone that is responsible for the human "fight or flight" response, or the state of hyper stimulation that occurs in moments of physical stress. Athletes can benefit from having increased adrenaline because it encourages the release of energy supplies and enhances the use of sugars and fats.

Phenylalanine is one of the few amino acids that can enter the brain directly from the bloodstream. In the brain, Phenylalanine is used to create certain neurotransmitters (chemicals that relay messages between adjacent neurons, or nerve cells) that are responsible for controlling mood and alertness. For this reason, it has been suggested that athletes can benefit from Phenylalanine supplementation via an increased level of awareness.

13) Proline

Proline is a nonessential amino acid. The body makes proline from glutamic acid, and deficiency is rare in healthy individuals with a healthy diet.

Proline is an amino acid needed for the production of collagen and cartilage. It keeps muscles and joints flexible and helps reduce sagging and wrinkling that accompany UV exposure and normal aging of the skin.

Proline helps the body break down proteins for use in creating healthy cells in the body. It is absolutely essential to the development and maintenance of healthy skin and connective tissues, especially at the site of traumatic tissue injury. Proline and lysine (another one of the amino acids that is important to protein synthesis) are both needed to make hydroxyproline and hydroxylysine, two amino acids that form collagen. Collagen helps to heal cartilage and to cushion the joints and vertebrae. For this reason, proline supplementation may prove beneficial for treatment of conditions such as osteoarthritis, persistent soft tissue strains, and chronic back pain.

The body needs proline to maintain muscle tissue as well. Decreases in proline levels have been noted in prolonged endurance runners and others following prolonged exercise. Athletes that subject their body to routine, rigorous workouts benefit from Proline supplementation by avoiding loosing muscle mass—the body begins to cannibalize its muscle for energy when glucose supplies run low.

14) Serine

Serine is a non-essential amino acid derived from the amino acid glycine. It is important to overall good health, both physical and mental.

- Serine helps form the phospholipids needed to make every cell in the body. It is also involved in the function of RNA and DNA, fat and fatty acid metabolism, muscle formation, and the maintenance of a healthy immune system.
- Low scores are indicative of managing an inordinate burden of damage.
- Serine is used to make B-Cells. B-cells circulate to find damage and tell the immune system how to react.
- Intensity of response in the use of Serine is directly related to the damage. Protein needed to repair the damage is diverted from performance stores.

ISM Observations

- Athletes – all scored a bit low

15) L-Taurine

Taurine is a non-essential sulfur-containing amino acid, but it lacks a genetic codon to be incorporated into proteins or enzymes. Nevertheless, it plays a role in several metabolic processes, such as heart contraction and antioxidant activity. Taurine is an ingredient in several so-called energy drinks, such as Red Bull. Red Bull, which contains taurine and caffeine favorably influence cardiac parameters, mainly an increased stroke volume, during recovery after exercise. *(Baum and Weiss 31)*. Others reported that 7 days of taurine supplementation induced significant increases in V02max and cycle ergometer exercise time to exhaustion; the ergogenic effects were attributed to taurine's antioxidant activity and protection of cellular properties. *(Zhang 32)*

- A fundamental building block of muscle
- Chronically low is associated with all disease states and substandard muscle.
- taurine is found in the heart muscle, white blood cells, central nervous system, and skeletal muscle. It plays an important role in metabolism. Adults bodies can make Taurine, however, when not enough is made, the deficiency must be corrected by supplementation. Taurine is a building block of all other amino acids. It functions in the brain and heart to help stabilize cell membranes. It comprises of over 50% of the total free amino acid pool of the heart.
- Taurine plays an important role in nitric oxide production, where lowered taurine levels leads to the reduction of nitric oxide production. Nitric oxide is a gas that's present for an instant each time a muscle contracts and blood vessel dilates. This is important in that this widens the blood channels leading to greater blood flow, which results in greater oxygen and nutrient delivery. Athletes need the increase in blood flow for oxygen and nutrient delivery, and without adequate nitric oxide, this isn't possible, and when deficient in L Taurine, there is less nitric oxide production.
- Taurine is found in high concentrations in skeletal muscles and plays an important role in modulating contractile function. Taurine increases force generation by enhancing Sarcoplasmic Reticulum's Ca^{2+} accumulation and release. Increasing taurine levels also augments the mean rate of increase in the force response. It is suggested that balancing the endogenous taurine concentrations is crucial for maintaining the appropriate force

output during muscle contraction. Muscle fibers possibly modulate their contractility by increasing or decreasing the intracellular taurine levels in response to neuronal inputs *(J Physiol. 2002 Jan;538:185-94).*

- Several studies5,6 have shown a loss of taurine into plasma with exercise with the greater loss coming from higher intensity work. *(Ward RJ, Amino Acids 16 (1): 71-77) and (Cuisinier C, Eur J Appl Physiol 87 (6): 489-495)*

- Taurine feeding after exercise induced muscle damage has a cytoprotective role. *(Dawson R, Amino Acids 22(4): 309 -324, 2002)*
- Muscle cells bathed in taurine create much greater force production in the individual fibres. Taurine modulates the accumulation of Ca+2 in the sarcoplasmic reticulum (a sac within the muscle where calcium is stored) allowing a greater supply when needed or decreased contents when not during the process of contraction and muscle movement. *(Bakker AJ, J Physiol 1538:185 -194, 2002)*

ISM Observations

- Athletes – only one athlete was normal-average
    - several were extremely low ("HypoTaurinemia")
- Normal ≈ 140

16) L-Threonine

An essential amino acid, meaning the body cannot manufacture it on its own and must receive it from an outside source.

- Normally enhances alertness.
- The nervous system is the main source of strength, power and focus for an athlete yet few athletes pay attention to emotional state when it comes to training for an event. Stress has been noted to release cortisol having a catabolic effect leading to decreased immunity, mental function and performance. Dopamine, norepinephrine, GABA and acetylcholine are neurotransmitters that manipulate brain chemistry for performance.
- Threonine is required to help maintain the proper protein balance in the body, as well as assist in the formation of collagen and elastin in the skin.
- Vital for protein utilization in one's diet, as well as maintaining the appropriate protein balance.
- The proper function of connective tissue (ligaments and tendons) is crucial in all forms of athletics. Strains and sprains are among the most common sports injuries and are likely responsible for more missed training time than any other type of injury or illness. Sprains and strains are much more common in people who do not have enough Threonine in their diet. Threonine is a necessary precursor for chemicals that are instrumental in the growth and maintenance of tendon and ligament tissue. Any athlete who is concerned with connective tissue health should consider using a Threonine supplement.
- Training can also be impacted by illness. Athletes who continuously push their bodies to the limits may find that they get sick more than other people do because their intensive exercise activities use up many of the resources that are used to fuel the immune system. Studies have shown that it is one of the amino acids that are crucial to proper immune system functioning. Threonine is central to the production of natural antibiotics that help the body resist bacterial infection. This amino acid is also important in the creation of chemicals that help ward off viral infections.

ISM Observations

- Athletes – all scored a bit low

17) Tryptophan.
Tryptophan (TRYP), is a precursor for serotonin, a brain neurotransmitter theorized to suppress pain. Free tryptophan (fTRYP) enters the brain cells to form serotonin. Thus, tryptophan supplementation has been used to increase serotonin production in attempts to increase tolerance to pain during intense exercise.

Studies have not been able to confirm the use of Tryptophan as an effective ergogenic *10.*

18) Tyrosine
L-Tyrosine is a non-essential amino acid produced in the body from the metabolism of L-Phenylalanine.

Tyrosine is a precursor for the catecholamine hormones and neurotransmitters, specifically epinephrine, norepinephrine, and dopamine. An inadequate production of these hormones or transmitters can compromise optimal physical performance. Thus, as a precursor for the formation of these hormones and neurotransmitters, tyrosine is likely an ergogenic.

- Cortisol and adrenaline strips 1,2,5 hydroxy D3 out of muscle. Tyrosine is the "glue" of nutrients in muscle.
    - In the absence of D3 – rapidly diminishing muscle viability/ protein storage affecting overall system profile of protein and ultimately all aspects of performance.
- Optimally, Tyrosine is used to stimulate the thyroid to express epinephrine and norepinephrine, dopa and dopamine. The "epis" ehnhance physical performance and durability. The "Dopis" enhance mental and neurological performance and durability.
- Tyrosine takes one of two pathways:
    1. Stimulates adrenals – cortisol and adrenaline
    2. Stimulate thyroid – "dopis" and "epis" – improved performance
- Summary: Tyrosine and phenylalanine lead to alertness and mental arousal. Tyrosine is an amino acid that has an effect of waking a person up, it is an important precursor for the synthesis of dopamine and norepinephrine. Tyrosine supplementation before a workout or sporting event increases strength, decreases fatigue, and decreases anxiety. Hard training athletes will benefit from supplementing with L-tyrosine as it helps to offset fatigue and stress associated with intense training.

ISM Observations

- Athletes – all had low levels of Tyrosine… andd therefore likely low levels of dopamine and epinephrine, likely resulting in lower performance and durability.
- The athletes tend to have infections and chronic inflammation which is forcing Tyrosine to channel #1 above, instead of channel #2 for better performance.

Summary Chart of Key Athletic Benefits of Amino Acids

Amino Acids	Immune System Function	Detoxifier	Energy Production	Pain Threshold	Mental Alertness	Muscle/Tissue Growth/Damage
Arginine	*	*				
Histidine	*			*		*
Leucine					*	*
Isoleucine	*				*	*
Lysine	*		*			*
Methionine			*			
Phenylalanine				*	*	
Threonine	*					*
Tryptophan			*	*	*	*
Valine			*		*	*
Carnatine		*				*
cysteine		*				*
Glutamine		*			*	*
Taurine						*
Tyrosine		*			*	*

OTHER

19 (a) Creatine

Creatine is a naturally occurring amino acid derived from the amino acids glycine, arginine, and methionine *(Balsom et al., 1994; Williams et al., 1999).* Most creatine is stored in skeletal muscle, primarily as phosphocreatine; the rest is found in the heart, brain, and testes *(Balsom et al., 1994; Kreider, 1998).* The daily requirement of creatine is approximately 2 to 3 g; half is obtained from the diet, primarily from meat and fish, while the remainder is synthesized *(Williams et al., 1999).* Creatine supplementation has been proposed as a means to "load" muscle with creatine and phosphocreatine (PCr). In theory, an increased store of creatine or phosphocreatine would improve the ability to produce energy during high intensity exercise as well as improve the speed of recovery from high-intensity exercise.

The use of creatine has become very popular, not only among elite athletes, but also average athlete circles. Creatine is produced in the body by the liver, kidneys and pancreas. It also occurs in our diet in meat and fish. It may aid the production of energy in the muscle, particularly during high intensity exercise. It also has been shown to increase muscle mass. Creatine seems to work better in some individuals, especially when the initial creatine concentration is low. Creatine is often lower in vegetarian athletes for instance. The safety and efficacy of creatine have not been determined exclusively.

A number of studies have been conducted to determine the effects of creatine supplementation on muscle concentrations and performance.

- Creatine supplementation (20 g per day or 0.3 g per kg body mass per day for 4 to 7 days) has been reported to increase intramuscular creatine and phosphocreatine content by 10 to 30% *(Casey et al., 1996; Febbraio et al, 1995; Green et al., 1996a; Green et al., 1996b; Greenhaff et al., 1993a; Hultman et al., 1996; Smith et al., 1998b, Vandenberghe et al., 1997).*
- There is also evidence that creatine supplementation enhances the rate of PCr resynthesis following intense exercise *(Greenhaff et al., 1993b; Greenhaff et al., 1994a; Greenhaff et al., 1994b).*
- Most studies indicate that short-term creatine supplementation increases:
    - total body mass *(Hultman et al., 1996; Williams et al., 1999)*,
    - work performed during multiple sets of maximal effort muscle contractions *(Greenhaff et al., 1993a; Volek et al., 1997),* and
    - single and/or repetitive sprint capacity *(Birch et al., 1994; Grindstaff et al., 1997; Prevost et al., 1997)*.
- Long-term creatine supplementation during training has been reported to promote greater gains in:
    - strength *(Earnest et al., 1995; Peeters et al., 1999; Stone et al., 1999; Vandenberghe et al., 1997),*
    - fat-free mass *(Kreider et al., 1998; Stone et al., 1999; Stout et al., 1999; Vandenberghe et al., 1997),* and
    - sprint performance *(Kreider et al., 1998; Peyreburne et al., 1998; Stout et al., 1999)*.

- caffeine has been reported to counteract the potential ergogenic value of creatine supplementation *(Vanakoski et al., 1998; Vandenburghe et al., 1996).*

19 (b) Hydroxymethylbutyrate (HMB)

The **leucine** metabolite hydroxymethylbutyrate has become a popular dietary supplement to promote gains in fat-free mass and strength during resistance training *(Kreider, 1999).* The rationale is that leucine and its metabolite α -ketoisocaproate (KIC) appear to inhibit protein degradation *(Nair et al., 1992; Nissen et al., 1996),* and this anti-proteolytic effect may be mediated by HMB.

Animal studies indicate that approximately 5% of oxidized leucine is converted to HMB via KIC *(Nissen et al., 1994; Van Koevering et al., 1994).* Supplementing with leucine and/or HMB may therefore inhibit protein degradation during periods associated with increased proteolysis, such as resistance training.

Although much of the available literature on HMB supplementation in humans is preliminary in nature, several recently published articles and abstracts support this hypothesis.

- Leucine infusion appears to decrease protein degradation in humans *(Nair et al., 1992).*
- HMB supplementation during 3 to 8 weeks of training has been reported to promote significantly greater gains of fat-free mass and strength in untrained men and women initiating resistance training *(Nissen et al., 1996; Nissen et al., 1997; Vukovich et al., 1997).* In some instances these gains were associated with signs of significantly less muscle damage (efflux of muscle enzymes and urinary 3-methylhistidine excretion) *(Nissen et al., 1996).*
- Although these findings suggest that HMB supplementation during training may enhance training adaptations in untrained individuals initiating training, it is less clear whether HMB supplementation reduces markers of catabolism or promotes greater gains in fat-free mass and strength during resistance training in well-trained athletes. Indeed, there are several reports of no significant effects of HMB supplementation (3 to 6 g per day) in well-trained athletes *(Almada et al., 1997; Kreider et al., 1997; Kreider et al., 1999).*

19 (c): L-Carnitine

Carnitine is sometimes called an amino acid, but it is not. It is similar in structure to B vitamins, especially choline. However, carnitine is not a true vitamin because the body makes it in small amounts. Carnitine is also found in animal products, especially red meat. L-Carnitine is found in most cells of the body.

L-carnitine is made in the body from the amino acids lysine and methionine, and is needed to release energy from fat. The body also needs vitamin C, iron, niacin, and vitamin B6 to produce carnitine. It transports fatty acids into mitochondria, the powerhouses of cells. In infancy, and in situations of high energy needs, such as pregnancy and breast-feeding, the need for L-carnitine can exceed production by the body. Therefore, L-carnitine is considered a "conditionally essential" nutrient.1

Because carnitine plays a critical role in fat burning, carnitine is an aid in promoting sports endurance. Fat is the #1 fuel our body uses in endurance sports, and research shows carnitine enhances aerobic performance, allowing athletes to exercise longer without fatigue. Carnitine also increases the peak running speed in athletes by 6%.7 Chronic Fatigue Carnitine is an effective treatment for the fatigue seen in a number of chronic neurologic diseases. Chronic fatigue patients given 3,000 mg of carnitine saw statistically significant clinical improvement in 12 of the 18 studied parameters after 8 weeks of treatment. Increases in energy, well-being, and other parameters occurred more markedly the longer patients took the carnitine.

The available research on L-carnitine supplementation does not appear to support claims of enhanced aerobic or anaerobic exercise performance. While it is true that carnitine plays a vital role in energy metabolism, additional carnitine from exogenous sources does not appear to yield any benefit above and beyond the necessary physiological dose. While benefit not clearly demonstrated, data to date can not be interpreted as excluding any benefit either.

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6.0 The Implications of Aminomics for Athletes

6.1 Introduction

The main goal of any athlete is to improve performance, endurance and decrease recovery time. This section of this review offers potential guidelines of how to apply Aminomics, when to use it, and how much to use.

Aminomics© is the correction of amino acid deficiency through the application of targeted amino acid profiles and supported by all necessary micro-nutrients to optimize performance.

We have discussed that amino acids are the essential medium through which the human gene translates into proteins. And protein is the mainstay of human structure and chemistry.

From this standpoint Aminomics© is closely related to genomics (the study of the genes in an individual) in that the genes carry the instructions of exactly how the amino acids (the building blocks of proteins) are to be metabolized into proteins.

It is the genes that decide how the amino acids molecules are to be sequenced and linked to each other which, in turn, determine the structure and nature of proteins. And proteins are an integral and vital part of human function, structure and chemistry.

The study of the structure and function of proteins is known as proteomics.

In can be said therefore that amino acids are a vehicle that the genes utilize to be able to express the all-important proteins.

Genes ---→ Amino acids ---→ Proteins
(Genomics) (Aminomics) (Proteomics)

Aminomics© is based on the analysis of deficient amino acids in an individual's plasma and the administration of targeted amino acid supplementation while ensuring that all key micronutrients needed for protein assimilation are available.

6.2 The Aminomics Protocol

Amino acids, vitamins and minerals – An inter-relation:
Besides being the building blocks for all kinds of proteins, amino acids also play a vital role in the proper utilization of vitamins and minerals in the human body. Even after they have been absorbed and assimilated, vitamins and minerals will not be as effective unless the proper amino acids are present (3). Minerals too, will not work unless vitamins are present in the right proportions *(21).*

It is obvious therefore, that amino acids, vitamins and minerals are integrally inter-related. **Moreover, all the necessary amino acids have to be supplied to the body within a 2-3 hour period; otherwise proper protein assimilation will not take place** *(22).* **And even after all the amino acids are present, their assimilation will be restricted to that level which corresponds to the lowest available amino acid.** For example, if the lowest level of any one of the available amino acid is at 60%, the assimilation of all the amino acids will remain restricted to only 60% *(22).*

Amino acid deficiency:
Either an excessive or an inadequate intake of a single essential amino acid is reflected as an increase or a decrease in the plasma concentration of that amino acid *(23).* Moreover, for some essential amino acids such changes may be associated with an even greater change in their concentration in the free amino acid pool of body tissues, mainly in skeletal muscle *(24).*

An individual may be deficient in amino acids for a variety of reasons. These include *(25, 26):*

- An unbalanced, low protein diet
- Impaired absorption
- Disease (particularly infection and malignancy)
- Physical and psychological stress
- Drug use (including chemotherapy for cancer)
- Excessive excretion (impaired kidney function)
- Imbalance of vitamins and minerals
- Trauma
- Genetic factors
- Developmental age

Deficiency of amino acids would obviously compromise all the vital functions of the human body that are served by the proteins.

Amino acid deficiency is also likely to lead to reduced energy levels, defects in metabolism, sleeping disorders, chronic fatigue, digestive problems, hair loss and skin ailments, nervous reactions, emotional upset, stress and general poor health *(3).* Other symptoms of amino acids deficiency include obesity, malnutrition, and buildup of wastes in the bloodstream *(3).*

The Aminomics© compounds manufactured by ISM are in a high-grade/pharmaceutical (i.e., pure), balanced and bio-available format. Additional pure free-form (unbonded) amino acids are also used. No digestion is required to release these amino acids, which means they can cross from the gut into the bloodstream within minutes rather than hours.

Additional to the amino acid supplementation, the Aminomics formulation contains collateral nutrients such as appropriate anti-oxidants, vitamins, enzymes, minerals and lipotropic factors. All these combine to facilitate proper and timely absorption, metabolism and immediate protein construction.

6.3 Whey as a Base Source of Protein
There are four commonly used proteins; whey, casein, egg and soy. Of these, whey is digested most rapidly, taking only about two hours to release its amino acids. Soy and egg release their amino acids at a gentler rate – around five hours – while casein is a slow-releasing protein, taking up to seven hours to release its amino acids. All these figures are approximate, as there is a large degree of individual variability in digestion rates.

Protein Quality Comparison Chart

Protein Type	Protein Digestibility Corrected Amino Acid Score (PDCAAS) [1]	Amino Acid Score	Protein Efficiency Ratio (PER) [2]	Biological Value (BV)	Protein Digestibility % (PD)
Whey Protein	1.00	1.14	3.2	100	99
Whole Egg	1.00	1.21	3.8	88-100	98
Casein	1.00	1.00	2.5	80	99
Soy Protein Concentrate	1.00	.99	2.2	74	95
Beef Protein	0.92	.94	2.9	80	98
Wheat Gluten	0.25	.47	NA	54	91

Source:
[1] Protein Quality Evaluation, Report of the Joint FAO/WHO Consultation
[2] Reference Manual for U.S. Whey Products, 2nd Edition, U.S. Dairy Export Council

6.3.1 Fast and slow proteins

There is a big difference between amino acids and protein; although amino acid solutions don't reach the muscles instantly, they are absorbed very rapidly by comparison with protein. That's because the process of digesting proteins (consisting of long chains of chemically linked amino acids) to release the constituent amino acid building blocks is quite time consuming – even for rapidly digested proteins like whey. A post-workout high-protein drink or meal could take several hours to produce maximum amino acid concentrations around muscle cells, yet we know it is the presence and availability of high levels of amino acids that seems to stimulate growth, especially after exercise.

Research suggests that the key to stimulating maximal protein synthesis in exercised muscles is to raise the level of circulating blood amino acids as rapidly as possible after exercise – or, even better, beforehand. Whichever strategy is employed, it is clear that proteins that digest and release their amino acid building blocks rapidly are best suited to raising blood amino acid levels quickly.

Whey is a protein complex derived from milk. The biological components of whey, including lactoferrin, beta-lactoglobulin, alpha-lactalbumin, glycomacropeptide, and immunoglobulins, demonstrate a range of immune-enhancing properties. In addition, whey has the ability to act as an antioxidant, antihypertensive, antitumor, hypolipidemic, antiviral, antibacterial, and chelating agent.

6.3.2 Aminomics Whey

ISM believes that whey protein is the premier protein for recovery and enhanced immune system function:

- Whey protein has the highest biological value (BV) of any protein source. BV rates the availability of the protein once ingested, and whey is arguably the most rapidly absorbed protein, exactly what you want post-workout.
- Relative to other protein sources, whey has a high concentration of branched-chain amino acids (BCAAs)--leucine, isoleucine, and valine. BCAAs, particularly leucine, are important factors in tissue growth and repair. Leucine has been identified as a key amino acid in protein metabolism during the translation-initiation pathway of protein synthesis.
- Whey is also a rich source of two other important amino acids, methionine and cysteine, which stimulate the natural production of glutathione, one of the body's most powerful antioxidants and a major player in maintaining a strong immune system. Glutathione also supports healthy liver function.

- Short four-amino acid chains known as quadripeptides constitute another key component of whey protein. Quadripeptides have a pain-killing (analgesic) effect that can help alleviate the soreness after an intense workout or all-out race effort.

Whey's amino acid profile makes it ideal for body composition and to support protein synthesis and muscle growth. Other bioactive components found in whey might benefit additional aspects of health in active people and trained athletes by improving immune function and gastrointestinal health and exhibiting anti-inflammatory activity. Whey components, such as IgA, glutamine, and lactoferrin, can beneficially impact common complaints among athletes, including repeated infections and gastrointestinal disturbances.

Scientists studied the effects of a fast-digesting protein (whey) and a slow-digesting protein (casein) in two groups of volunteers:

- Nine elderly subjects (average age 72);
- Six young subjects (average age 24).

They found that, irrespective of age, whey protein led to a faster rise in blood amino acids than casein, thereby producing a higher rate of muscle protein synthesis. While there was no exercise component in this study, these results mirror suggest that consuming protein or amino acids as soon as possible after exercise is beneficial for muscle protein synthesis.

Lower levels of sIgA and glutamine [103,104] have been found after intensive exercise and in over-trained individuals, and have been correlated with increased frequency of infection. [105] Free radical damage is thought to delay muscle recovery and impair performance. [107] Whey prevents free radical damage through supporting intracellular glutathione levels and supplying lactoferrin for additional antioxidant activity.

Each scoop of **Aminomics Whey** contains 10 grams of micro-filtered **whey protein isolate**, with no added fillers, sugar, and artificial sweeteners or flavoring. The key word here is isolate. Manufacturers supply two forms of whey, isolate and concentrate. Whey protein concentrate contains anywhere from 70% to 80% actual protein, the remainder being fat and lactose. Isolate, on the other hand contains 90% - 97% protein, with little, if any lactose or fat, making it the purest form of whey protein available. Because isolate contains almost no lactose, even those with lactose intolerance find it an easily digestible protein source. We use only isolate in all our whey containing products.

In addition, each scoop of Aminomics Whey contains additional amino acids essential for athletes in supporting enhanced recovery and immune system function.

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6.4 When to Take Ergogenic Supplements

6.4.1 Timing for a Superior Recovery

Often after a really hard workout the tendency is to want to relax. The problem with this scenario is that you're not giving the body a fighting chance to recover quickly and efficiently. We've all heard about that "window of opportunity" that's present immediately after a workout, the time the athlete needs to take advantage of to help the body in "refilling the tank."

The body will adapt to the training by storing more and more glycogen, its premium fuel, in the muscles.

Another area that is necessary to remember is in regards to immunity. One of the benefits, perhaps the primary benefit, of exercise is that it aids in building a strong immune system. However, in order to take advantage of this benefit, the athlete needs to provide nutrient support to the body right after a workout, when the immune system is vulnerable. It makes sense to replenish essential, immune system enhancing nutrients shortly after a workout, when the body's supplies have been depleted or exhausted.

Unfortunately, far too many athletes don't and wonder why they continue to have poor performances or, even worse, continue to get sick.

6.4.2 When to Take Protein

Whey protein ingestion results in a rapid, though transient (1-2 h) peak in serum amino acid. Studies have shown that timing of protein ingestion in relation to exercise activity influences its overall utilization and effectiveness.[8,43]

A rapid influx of amino acids into the muscle cells immediately after training will theoretically reduce muscle catabolism by providing an alternative source of amino acids for utilisation, thus protecting the muscle itself. A RAPIDLY ABSORBED (I.e., Whey) supplement of amino acids, taken immediately after training, is essential.

It is recommended that for optimal effectiveness, protein consumption occur immediately before and soon after resistance training as well as soon after aerobic activity.

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6.4.3 When to Take Multi-Nutrients

This is worth emphasizing, because it's somewhat counter-intuitive.

Some athletes might think: "I'm setting out on a workout that will involve several hours of intense energy output. It makes sense that I have enough vitamins on board <u>before</u> I start, lest I become depleted and crash, so I'll take my vitamin supplement before I train."

That reasoning is not valid because of the way the body processes nutrients. True, you do need an ample supply of vitamins and minerals to undertake endurance athletics. However, except for electrolytes and vitamin B-6, there's not much you can add of any useful nature just before a workout. <u>The time to supply the body is actually right after workout, not just before</u>.

The body is most receptive to micro-nutrients when it's depleted. Then it runs on the stored nutrients. This is a generality, but it's very true for most vitamins and minerals. **The time to take vitamins is after, not before, a workout or race.** You need to re-supply, and you also need many micronutrients for the recovery process.

The body loses many vitamins and minerals not only through the process of energy production, but also in sweat. Aminomics multinutrient supplements contain ample amounts of all the key nutrients in readily bioavailable form.

More is NOT Better

Many of ISM's Aminomics recommendations discussed above are to consume less of a given substance. Bottom line is that if you're not using the correct amounts, you're not getting the best benefits possible.

7.0 Protein: When is Enough, Enough?

7.1 The Protein Puzzle

The all-pervading folklore in sports is that you need to pack in the protein. Up to 4g of protein per kg of body weight per day (contrast this with the standard Recommended Daily Allowance of 0.8g/kg) has often been recommended. There is evidence that athletes involved in resistance training have a heightened protein requirement. But 4g/kg seems to be way over the top.

Peter Lemon, a researcher based at Kent State University, Ohio, has been investigating athletes' protein needs for a number of years. He concludes that strength training athletes need to consume more protein than the RDA, recommending levels of 1.5-2.0g/kg. He emphasizes that although increasing protein intakes above the RDA (in tandem with resistance exercise) may enhance muscle gain, this increase is not a continuing linear relationship - the effect appears to plateau out at relatively modest increases

This was borne out by a study which compared a group of experienced strength-trained athletes with a group of sedentary controls. Both groups were tested at three protein intake levels - low, moderate and high (0.86, 1.4 and 2.4 g/kg body weight respectively). The protein intake required to maintain body protein levels was 1.4g/kg for strength athletes and 0.69 for sedentary subjects. An increase in protein intake from low to moderate increased the rate of protein synthesis in strength athletes, but increasing to the high level did not have any further effect. *('Evaluation of protein requirements for strength trained athletes', Tarnopolsky et al, J App Physiol, Vol 73, pp1986-95)*

There isn't enough information currently to be able to draw out hard and fast rules on protein requirements. In a review, it was concluded, 'it is prudent for the resistance trainer to consume at least 1.2g protein per kg body weight per day, but not more than 2g/kg' *('A review of Nutritional Practices and Needs of Bodybuilders', Journal of Strength and Conditioning Research, Vol 9 pp116-124)*

7.2 Do Some Athletes Eat Too Little Protein?

Inadequate protein intake can occur in athletes, particularly among athletes whose energy demands are low or those who overemphasize carbohydrate in daily eating patterns. Athletes who do not consume enough protein to meet their requirements risk being unable to maintain muscle tissue and to repair muscle damage that occurs during exercise.

A protein requirement that is higher than the RDA does not mean that exercisers need to consume just protein supplements. Athletes in training need to be eating more food overall than their sedentary colleagues - this will automatically increase protein intake. Additional protein can be obtained when a variety of foods are eaten and the total energy intake is high enough.

Protein foods should be chosen with other nutritional goals in mind, too. A mistake some athletes make when focusing exclusively on protein is to end up eating lots of high-fat foods. For the sake of general health as well as stamina, it's best to go for lower-fat protein foods that also provide a range of other nutrients. The following table gives a list of some recommended protein foods and their protein content

Protein content of selected foods

All foods below have low to moderate fat content, and provide 10g of protein:

- grilled fish 50g
- tuna/salmon 50g
- lean beef or lamb 35g
- veal 35g
- turkey or chicken 40g
- game meat 35g

- eggs 2 small
- cottage cheese 70g
- non-fat fruit yoghurt 200g carton
- skimmed milk 300ml
- wholemeal bread 4 slices
- muesli 1 cup (100g)
- cooked pasta 2 cups
- cooked brown rice 3 cups
- cooked lentils .75 cup
- red kidney beans .75 cup

Generally, protein value….

- Meat, poultry and fish 7 grams per ounce
- Beans, dried peas, lentils 7 grams per 1/2 cup cooked
- One large egg 7 grams
- Milk 8 grams per cup
- Bread 4 grams per slice
- Cereal 4 grams per 1/2 cup
- Vegetables 2 grams per 1/2 cup

7.3 Dangers of Too Much Protein

Unlike carbohydrate or fat, amino acids are not stored. Most amino acids function as part of protein structures, enzymes, or are used as precursors to form hormones, neurotransmitters, or nucleic acids. A pool of free amino acids accounts for no more than 1.0% of all amino acids in the body.

Free amino acids that are not used for protein synthesis can be broken down and their carbon skeleton used to make glucose, oxidized for energy or stored as fat. The amino portion ends up as urea that is excreted in urine or sweat. Research on strength athletes indicates that at a daily protein consumption of 2.4 g/kg BW, amino acid oxidation increases and no further protein synthesis occurs. **Consuming more protein than is needed promotes protein oxidation, urea formation, diuresis, and can increase risk for dehydration.**

> **"Dietary supplementation of protein beyond that necessary to maintain nitrogen balance does not provide additional benefits for athletes."**
>
> *Review of the literature on dietary protein supplements, Dr. Richard B Kreider PhD (Department of Human Movement Sciences & Education, The University of Memphis, Memphis, Tennessee)*

Dietary supplementation of protein beyond that necessary to maintain nitrogen balance does not provide additional benefits for athletes. Ingesting carbohydrate with protein prior to or following exercise may reduce catabolism, promote glycogen re-synthesis, or promote a more anabolic hormonal environment. Whether employing these strategies during training enhances performance is not yet clear.

Potential risks of excessive dietary protein include:

- Skimping on the carbohydrates needed for muscle glycogen repletion (risking the development of chronic fatigue)
- Dehydration
- Potential kidney damage over time: Impairs Kidney function/ kidney stones
- Excessive bone loss (as protein increases urinary calcium loss) For every 10 g of excess protein intake, we lose 16 mg calcium (doubling protein intake increases calcium loss by 50%)

- Increases risk for heart attack, strokes, cognitive impairment, mental diseases (dementia, Alzheimer's)

7.4 THE BOTTOM LINE

Protein is necessary for the active athlete, but more is not necessarily better.

Take home points

- Protein needs for endurance athletes: 1.2-1.4 g/ kg body weight;
- Protein needs for body building athletes: 1.6-1.7 g/kg body weight
- The average athlete gets more than enough protein to adequately train (for both endurance and body building competitions)
- Excess protein only adds excess calories (since the primary fuel of our bodies during activity is glucose and then fat) which adds FAT, hindering athletic performance

How Much to take?

To find out how much protein one requires:

- Multiply your weight in kilograms by 1.4 to 1.7, depending on your exercise intensity.
- This gives you the amount of protein (in grams) you should consume on a daily basis. (To convert from pounds to kilograms, divide by 2.2)

**To calculate your body weight in kilograms: divide your body weight in pounds by 2.2

Thus, a 165-pound (75kg) athlete in high training mode should consume about 128 grams of protein daily. In real-life amounts, to obtain 128 grams of protein you would need to consume:

- a quart of skim milk (32 grams),
- 3 oz. of tuna (15 grams),
- 7 oz. lean chicken breast (62 grams),
- 4 slices of whole wheat bread (16 grams), and
- a few bananas (one gram each).

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8.0 SAFETY, LEGALITY

8.1 Drug testing and amino acids

Since amino acids are originally contained in the body, they pose no problems in a dope test.

8.2 WADA & CCES Background

All athletes are responsible for ensuring that they comply with the rules and regulations of competition, which include any sport federation restrictions and the WADA Prohibited List.

The Canadian Centre for Ethics in Sport (CCES) promotes ethical conduct in all aspects of sport in Canada. The CCES is committed to promoting a fair and doping-free sport environment for all Canadian athletes. CCES does not “clear” or “endorse” consumer products for consumption by Canadian athletes.

WADA / CCES on Protein & Amino Acids & Vitamins/ Minerals

Use of amino acid supplements is not prohibited by the World Anti-Doping Agency (WADA).

ADDENDUM

SPORT SPECIFIC INFORMATION

Focus on Hockey
Hockey is primarily an anaerobic sport, consisting of intense, short (30-45 second) shifts. Training programs focus on building power in muscles and explosive movements.
Yet, a good aerobic base is needed for better efficiency in carrying oxygen, storing glycogen in muscles, and clearing the anaerobic system of waste.

Overview:

- High intensity, intermittent activity that incorporates strength training in the exercise program.
- Resistance exercise provides the stimulus for gains in muscle size and strength.
- Strength training relies on anaerobic metabolism for energy production. The primary fuel for resistance exercise is muscle glycogen. Amino acids are not used as energy substrates for either strength training or ice hockey competition activity.
- Building muscle is energy intensive. The primary nutritional need is to meet total energy requirements. For each day of strength training, an athlete may need more than 40 kcal/kg BW just to maintain muscle mass. Combined with appropriate resistance training, additional calories are required to build muscle.
- Protein turnover (synthesis and degradation) is elevated in strength athletes. Protein requirements are increased to supply amino acids to maintain nitrogen balance and to support enhanced rates of protein synthesis.

- Amino acids are used to repair muscle trauma that results from repeated muscle contractions and eccentric contractions in particular.

- Protein intakes above 2.0 g/kg BW do not improve strength gains compared to intakes of 1.4-1.8 g/kg BW. Consuming more protein than 2.0g/kg BW results in increased protein oxidation and urea formation.
- Protein requirements of novice strength athletes to maintain nitrogen balance appear to be at the higher end of the range (1.7 g/kg BW) compared to that of elite strength athletes.
- Muscle is about 75% water and 22% protein by weight. Muscle building requires adequate hydration.

Overall Daily Values For Hockey Players
http://btc.montana.edu/olympics/nutrition/profile04.html

Sources of Calories should be:

- Fat- 30% (Avoid saturated fats)
- Protein- 10-15%
- Carbohydrates- 55-60%

Post-game Nutrition the “Recovery Window”

- First thirty-sixty minutes after intense exercise known as “muscle recovery window” or “glycogen window”.
- Muscles can rebuild and reenergize 2-3 times faster in this time period.
- Leads to much less muscle soreness and higher energy the next day (important in back-to-back game situations)

Appropriate recovery divided into three areas:

- replenishing fluids (and electrolytes) to prevent future cramping and dehydration.

- replenishing muscle glycogen stores through eating carbs and drinking sports drinks
- fixing muscle tissue damage by eating protein

Protein for Hockey Players
Recent research has found that a 4:1 (g) ratio of carbs:protein have beneficial effects in terms of glucose absorption. Protein, in this ratio with carbs, stimulates insulin to uptake glucose into cells beyond the level it normally would when consuming carbohydrates alone. Too much protein can slow re-hydration and glycogen replenishment.

Protein is also needed to repair muscle tissue tears in third phase of recovery process.
1.5g protein/kg body weight is the normal overall requirement for professional hockey players (this is .68g/lb).

Average player in NHL: 198lbs x .68g/lb= 135 g protein/day

US Olympic Athlete Profiles
Male Ice Hockey Player

Age: 27 years
Height: 6'2"
Weight: 198 lb (90 kg)
Body composition:
13% body fat
Muscle fiber type: Vastus lateralis muscle: approximately 50% Type I (slow twitch), 38% Type IIa (fast twitch), and 12% Type IIb (fast twitch, glycolytic)

VO2max: 62 mL/kg/min

Energy expenditure:
Resting energy expenditure: 2,100 kcal/day
Total daily energy expenditure for an exercise training day: 5,000 kcal/day

Exercise training (representative day):

Description: Short warm-up, repeat bouts of high-intensity skating, instruction, special plays and controlled scrimmages
Intensity: Variable; interval type training (repeat bouts of high-intensity skating)
Duration:1.5-2 hour/session, 2 sessions per day
Frequency: 5-6 days/week (nongame days)
Energy expenditure during exercise training: 500-700 kcal/hr

Sport nutrition guidance: (for a 198 lb (90 kg) male ice hockey player):

Energy expenditure (includes skills training on ice: two 1.5-2 hour sessions) = 5,000 kcal/day
Energy intake = 5,000 kcal/day

Calorie distribution: 60% Carbohydrate, 13% Protein, 27% Fat

Nutrient	g/kg BW	Grams/Calories	% of Total Calories
Carbohydrate	8.3	750/3,000	60
Protein	1.8	162/650	13
Fat	1.7	150/1,350	27
Total		5,000	100

Sample menu:
Note: The menu meets this athlete's needs for total energy, carbohydrate, protein, and fat and exceeds his Recommended Dietary Allowance (RDA) for vitamins and minerals.

Breakfast
- 1/2 grapefruit
- 4 medium pancakes
- 2-1/2 tsp margarine
- 1/4 cup margarine
- 1 scrambled egg
- 12 oz 1% milk

Morning Snack (during exercise practice)
12 oz sports drink(6% carbohydrate)

Lunch
- 1 meatball sub sandwich
- 16 oz non-cola soda
- 1 oz potato chips
- 1 apple

Afternoon Snack (during exercise practice)
12 oz sports drink (6% carbohydrate)

Afternoon Snack (after exercise session)
- 16 oz orange juice
- 1 banana
- 2 fruit newtons

Dinner
- 12 oz non-alcoholic beer
- 2 oz tortilla chips
- 1/4 cup salsa
- 1 cup black bean soup
- 2 beef burritos
- 1 cup Spanish rice
- 1 slice Mississippi Mud pie

Evening Snack
- 1 sandwich: 2 slices bread, 3 oz boiled ham, 2 tsp mustard

- 1 cup 1% milk
- 3 sugar cookies

Nutrition analysis: 5,075 calories

Nutrient	% of Total Calories
760g Carbohydrate	60%
160g Protein	13%
155g Fat	27%

Cross Country Skiing

- Prolonged, continuous, moderate to intense activity.
- 5-10% of the energy needs for endurance exercise (>90 minutes) may come from protein, primarily from branched chain amino acids (leucine, isoleucine, valine) within skeletal muscles.
- Protein synthesis is suppressed during exercise and stimulated when physical activity ends.
- Protein degradation increases during prolonged exercise.
- Endurance exercise appears to improve the efficiency of the body to utilize nitrogen.
- Amino acids are used to repair muscle trauma that results from repeated muscle contractions and eccentric contractions in particular.
- Protein use as an energy substrate increases during high intensity, long duration endurance activity.
- Protein makes a greater contribution to total energy production during endurance exercise when muscle glycogen levels are low.