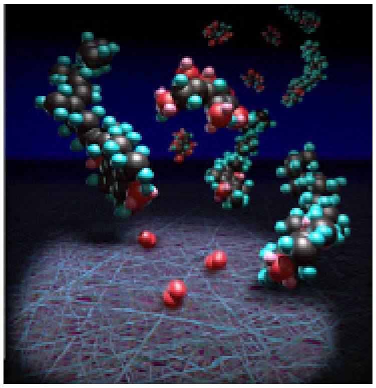
Vitamin B complex



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Abstract

You would not be able to even type ABC into your browser without ATP. In fact, within a few seconds death would wrought its ugly head had this source of energy ceased to be produced. Think logically for a moment; if this complex molecule is of such importance, then its optimization must be of prime significance if one is to train at full capacity--enter the B-Complex. It is integral to almost every step of cellular respiration (energy production). Can you afford a deficiency in this area? The answer is a clear no. I must warn you, however, the body’s ability to form energy is indeed complex beyond the readers wildest imaginations. It will therefore be no easy task to understand all the mechanisms capable of enhancing it. Today, however, you will take one giant Leap forward--that is a guarantee.

Vitamins

Vitamins can be defined as essential organic compounds required in minuscule amounts (referred to as micronutrients). Vitamins mainly function as catalysts for reactions within the body. They contain no useful energy, but as catalysts, they serve as essential links and regulators in metabolic reactions that release energy from food. Vitamins also control the processes of tissue synthesis and aid in protecting the integrity of the cells' plasma membrane; they also assist growth, maintenance of health, metabolism and much more. To refresh your memory, a catalyst is a substance that allows a chemical reaction to occur using less energy and less time than it would take under normal conditions. If these catalysts are missing, as in a vitamin deficiency, normal bodily functions can break down hindering athletic performance, and rendering a person susceptible to disease [7].

In the early part of the twentieth century, vitamins--then known as "accessory growth factors,"--were discovered. The word 'vitamin' is derived from the combination of words ‘vital amine’ and was conceived by Polish chemist Casimir Funk in 1912. Funk isolated vitamin B1 (thiamine) from rice [63].

However, vitamins achieved importance centuries before scientists isolated and classified them. The Greek physician Hippocrates (discussed in President Wilson’s suburb article, Hippocrates - Was He Hardcore?) advocated ingesting liver to cure night blindness. While he did not know the reason for the cure, we now know that vitamin A, which helps to prevent night blindness, occurs plentifully in this meat. In 1897, a Dutch physician in Java observed that a regular diet of polished rice caused beriberi in fowl, while adding rice polishings (thiamine-rich) to table scraps cured the disease. A most famous discovery was found in the early 19th century, when it was observed that adding oranges and lemons to the diet of British sailors paved the way for eradicating the dreaded disease scurvy, because of the protective effects of the vitamin C contained in the fruits. Not until 1932, however, did ascorbic acid (vitamin C) become isolated from lemon juice [63].

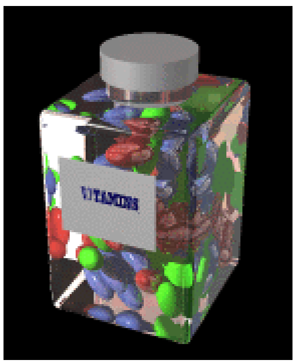
The formal discovery of vitamins revealed that these organic substances were needed by the body in minute amounts. Vitamins, their amine role having been discredited, have no particular chemical structure in common, and are often considered accessory nutrients because they neither supply energy, nor contribute substantially to body mass. Finally, with the exception of vitamin D, which is formed with the help of ultraviolet radiation, or sunshine, and some K and B vitamins, which are produced by bacteria within our intestines, the body cannot manufacture vitamins; hence, diet and or supplementation must supply them [37,28].

Vitamin classification

Vitamins are classified as either fat-soluble or water-soluble. The fat-soluble vitamins (vitamins that can mix with fat, but usually not with water) are vitamins A, D, E, and K; the water-soluble vitamins (can be dissolved/mixed in water) are vitamin C and the ***B-complex vitamins*** (based on their common source distribution and common functional relationships)[38]. Today we will narrow in on the later group.

Water-soluble vitamins, with the exception of vitamin C, are members of the B complex. Most of the B-complex group can be further divided according to general function: energy releasing, hematopoietic (refers to an agent or process that affects or promotes the formation of blood cells) and others. Other vitamins cannot be classified this narrowly because of their wide range of functions [14].

The water-soluble vitamins act largely as coenzymes, with small molecules combing with a larger protein compound (apoenzyme) to form an active enzyme that accelerates the interconversion of chemical compounds. Coenzymes participate directly in chemical reactions; when the reaction runs its course, coenzymes remain intact and participate in additional reactions. Water-soluble vitamins, similar to their fat-soluble counterparts, consist of carbon, hydrogen, and oxygen atoms. They also contain nitrogen and metal ions including iron, molybdenum, copper, sulfur, and cobalt. Because of their solubility in water, water-soluble vitamins disperse in the body fluids without being stored to any appreciable extent. If the diet regularly contains less than 50% of the recommended values for water-soluble vitamins, marginal deficiencies may develop within 4 weeks [89,88,90,12,13].



Water-soluble vitamins are absorbed into portal blood; furthermore, with the exception of cyanocobalamin (vitamin B12), they cannot be retained for long periods by the body. Any storage occurring results from their binding to enzymes and transport proteins. Generally, an excess intake of water-soluble vitamins becomes voided in the urine. Water-soluble vitamins exert their influence for 8 to 14 hours after ingestion; thereafter, their potency begins to decrease. For maximum benefit of, for example, vitamin C supplements, they should be consumed at least every 12 hours. Sweating during extreme physical activity can produce negligible losses of the water-soluble vitamins as well [3,5].

Finally, let us venture into today's subject, the water-soluble substances known collectively as, 'Vitamin B complex.'

Vitamin B complex

B-complex consists of eight different vitamins, which include thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), piroxidine (B6), folic acid (B9), cyanocobalamin (B12), and biotin. All of the above are water soluble, and play a key role in several bodily functions, such as protein, fat, carbohydrate, and mitochondrial energy metabolism; maintenance of the liver, skin, hair, mouth, and eyes; plus so much more, which will be covered thoroughly within the following paragraphs. As mentioned above, vitamin b complex can be further broken down in to 3 general categories; that is, energy releasing, hematopoietic, or other. And some fit in both categories. Here is a list [7,12]:

Energy releasing- Thiamine (B1), Riboflavin (B2), Niacin (B3), Pantothenic acid (B5), Piroxidine (B6), and Biotin.

Hematopoietic- Folic acid (B9), Cyanocobalamin (B12), Pantothenic acid (B5), and Piroxidine (B6).

Other- Thiamine (B1), Niacin (B3), Piroxidine (B6), Folic acid (B9), and Cyanocobalamin (B12).

All of these factors will be understood, after this article.

Before we begin, here is an outline of what will be covered on each of these 8 powerhouses.

- Description- the chemical makeup and structure of each vitamin
- Digestion- how these micronutrients are digested in the human body.
- Function- A complete dissection of the process by which they benefit the body
- Deficiency- the problems caused by a deficit in any of the B-complexes
- Recommendation- within I will list food sources that contain them, recommended doses, toxicity levels, and much more.

For full comprehension of this article, I would highly recommend you read last month's issue of hyperplasia, as many of the terms and physiological occurrences are discussed therein.

Thiamine (B1)

The first aspect of the B-complex we will cover is Vitamin B1. The first to publish a correct formula and synthesis for this vitamin was Dr. Robert R. Williams in 1936. Synonyms for it are thiamine, thiamin and aneurin. Chemically, Thiamine consists of a pyrimidine ring and a thiazole moiety (or one of two parts) linked by a methylene (CH2) bridge. As stated above, it is water-soluble [63,44].

Digestion

Thiamin can travel by both active (through plasma membrane, requires metabolic energy to “power” the exchange of materials) and passive (through plasma membrane, requires no energy) transport, depending on the amount of the vitamin presented in the intestine for absorption. At low physiological concentrations, thiamin absorption is active and sodium-dependent (type of active transport). Absorption occurs primarily in the upper jejunum but can occur in the duodenum and ileum (portions of the small intestine). When intakes of thiamin are high, absorption is predominantly passive [101, 88, 83].

Transport of thiamin into red blood cells is thought to occur by facilitated diffusion (diffusion that is assisted by protein transporters). Only free thiamin or thiamin-monophosphate (TMP) is thought to be able to cross cell membranes. In red blood cells, most thiamin exists as thiamin-diphosphate (TDP) with smaller amounts of free thiamin and TMP.

The human body contains approximately 30 mg of thiamin, with relatively high but still small concentrators found in the skeletal muscles, heart, liver, kidney, and brain. In fact, skeletal muscles are thought to contain about half of the body's thiamin [107].

Following absorption, most free thiamin is taken up by the liver and converted to its coenzyme form, thiamin-diphosphate (TDP). Conversion of thiamin to TDP requires adenosine triphosphate (ATP) and thiamin pyropbospbokinase, an enzyme found in the liver, brain, as well as other tissues. About 80% of total thiamin in the body exists as TDP, 10% as TTP (thiamin triphospate), and the rest is TMP, which is inactive [88, 83, 2].

To understand transport systems, as well as more information on the digestion track, it would behoove the reader to study the following articles: Sodium - A comprehensive Analysis & Fiber Dynamics Part I**.**

Next, we will show how Vitamin b1 functions in the body, and its many beneficial traits.

Function

Vitamin b1 is absolutely essential to several bodily functions. We will break them down into 2 categories consisting of:

- Energy metabolism
- Nervous system

Energy metabolism

The Krebs cycle (also called the citric acid cycle and the tricarboxylic acid cycle) is extremely important in extracting energy from fuel molecules. Consequently, the process is thiamin dependent. TDP functions as a coenzyme (binds with certain protein molecules to form active enzymes) necessary for the oxidative decarboxylation of both pyruvate and a-ketoglutarate. These reactions are instrumental in generating energy (ATP). Inhibition of these decarboxylation reactions prevents synthesis of ATP, and of acetyl CoA needed for the synthesis of, for example, fatty acids, cholesterol, and other important compounds, and results in the accumulation of pyruvate, lactate, and a-ketoglutarate in the blood [35,26,25].

Failure to oxidize the molecules listed above (and several others), results in the accumulation of both the branched-chain amino acids and their a-keto acids in blood and other body fluids. This is characteristic of maple syrup urine disease (MSUD). MSUD results from a genetic (in-born error of metabolism) absence or insufficient activity of the branched-chain a-keto acid dehydrogenase enzyme complex. People with MSUD must avoid meat, poultry, fish, and dairy products to limit intakes. But in short, thiamin is vital for energy conversions, and if lacking in your diet and supplementation, can induce serious health problems, and inefficiencies in the iron jungle.

Concerning this topic, Sanz Paris A et. al states, "In thiamine deficiency, the Krebs cycle slows large quantities of pyruvate are diverted to lactate production and anaerobic metabolism begins [99]." Timm DE et. al states, "Thiamine is essential for central metabolic processes, including the formation of acetyl CoA from glucose and the Krebs cycle. Deficiencies in human thiamin metabolism result in beriberi and Wernicke encephalopathy[26]."

Thiamin assists many other bodily functions, such as synthesis of pentose, NADPH, and additional molecules. All of which are essential for fatty acid synthesis, cell replication and much more. Here is an additional quote form La Selva M et. al [100], "Thiamine restores cell replication, decreases the glycolytic flux and prevents fluorescent AGE formation in endothelial cells cultured in high glucose"

Nervous system

It is apparent from several neurological disorder studies concerning thiamine deficiency, and taking into account where thiamine is found (in both the nerves and brain), that this vitamin plays a vital role in nerve function. Ke ZJ et al. states [19], “results indicate that TD [thiamine deficiency] induces alterations in neurons, endothelial cells, and microglia contemporaneously. This model provides a unique paradigm for elucidating the molecular mechanisms involved in neuronal commitment to neuronal death cascades and contributory microglial activity.”

What the exact role is has yet to be determined. But there are many viable theories currently being investigated. One theory is that thiamine triphosphate helps regulate nerve impulses, via the Na+ and K+ gradient. And other important channels, helping to regulate functions through many reactions. Also, it is thought to act as a coenzyme in the production of neurotransmitters (chemical messengers between nerve fibers). Either way, results have consistently revealed that being deficient in this vitamin is highly detrimental to the function of your nervous system, making this a vital supplement [55,46,17,16,].

Deficiency

Deficiency of aneurin can cause serious ailments. One of the first symptoms of thiamin deficiency is a loss of appetite (anorexia) and thus weight. As deficiency worsens, cardiovascular system involvement (such as hypertrophy and altered heart rate) and neurological symptoms appear.

One major symptom of B1 deficiency is an ailment called, ‘beriberi’. There are three types of beriberi classified today:

- Dry beriberi- found predominantly in older adults; it is thought to result from a chronic low thiamin intake especially if coupled with a high carbohydrate intake. Dry beriberi is characterized by muscle weakness and wasting, especially in the lower extremities
- Wet beriberi- results in more extensive cardiovascular system involvement than dry beriberi; right-side heart failure leads to respiratory involvement with edema.
- Acute beriberi- seen mostly in infants has been documented in countries such as Japan.

In the United States and in Western countries, thiamin deficiency associated with alcoholism is common and is referred to as 'Wernicke's encephalopathy' or 'Wernicke-Korsakoffa syndrome'. Individuals with dependency on alcohol are particularly prone to thiamin deficiency because of:

- Decreased intake of the vitamin due to decreased food consumption.

- An increased requirement in the case of liver damage (decreased liver function impairs mp formation and, consequently, vitamin use); and
- Decreased thiamin absorption

Wernicke's encephalopathy, often manifested in those with a history of alcohol abuse, is characterized by ophthalmoplegia (paralysis of eye muscles), nystagmus (involuntary, rapid, rhythmic movement of eyeball), ataxia (Failure of muscular coordination, irregularity of muscular action), loss of recent memory, and confusion. Treatment consists of therapeutic doses (at least 100 mg) of thiamin [112,101,100].

Recommendations

Because of thiamin’s importance in energy metabolism, needed intake varies according to energy (caloric) intake. The RDA for adults is 0.5 mg/ 1000 kcal; however, an intake of no less than 1 mg/day is advised. The 1998 Dietary Reference Intakes RDA for individual intake for thiamin for adult men aged 19 years and older is 1.2 mg/day and for adult women aged 19 years and older 1.1 mg daily. Thiamin in-takes with pregnancy and lactation (secreting milk) are increased to 1.4 and 1.5 mg/day, respectively [113,47].

As far as over consumption is concerned, there appears to be little danger of thiamin toxicity associated with oral intake of large amounts (500 mg daily for 1 month) of thiamin.

Pharmacological levels of thiamin are used in the treatment of certain inborn errors of metabolism. One variant form of MSUD has been shown to respond to oral thiamin supplements (up to 500 mg daily). Other metabolic diseases that may respond to large doses of the vitamin are thiamin-responsive megaloblastic anemia id and thiamin-responsive lactic acidosis. In the latter condition, large doses of thiamin can increase the activity of pyruvate dehydrogenase in the liver, thereby decreasing the level of lactic acid, as more pyruvate is decarboxylated for entry into the Krebs cycle [4].

Finally, thiamin is widely distributed in foods, including meat (especially pork), legumes, and whole or enriched grain products. Yeast and wheat germ also contain significant amounts of this vitamin [110,98].

Riboflavin (B2)

B2, known as Riboflavin, is constructed of flavine (a ring, acts as a covalent link), which is attached to a sugar alcohol, formed by the reduction of ribose called ribitol. And once again, it is a water-soluble vitamin.

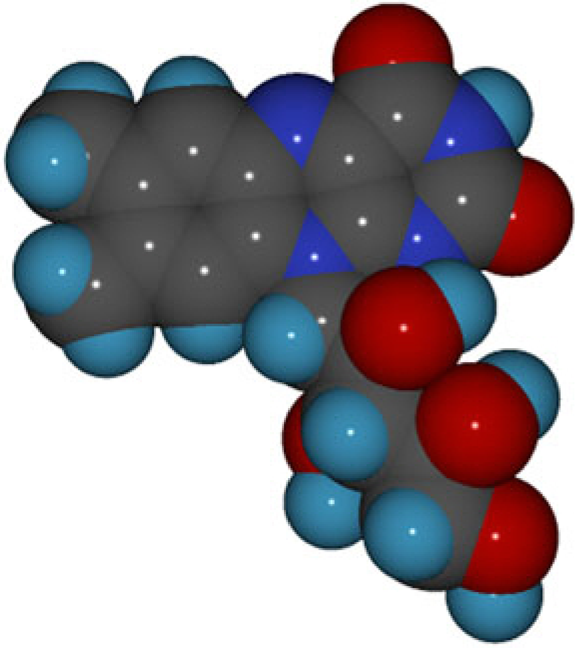
Digestion

Riboflavin is primarily absorbed in the proximal small intestine by a sodium dependent carrier. Within cells, b2 is converted to its coenzyme forms, regulated by hormones, such as the thyroid hormone. These coenzymes, than bind to apoenzymes (an enzyme, which needs a co-enzyme to be activated) forming what is called a *flavoprotein (discussed below) [62,61,60,59]*.

Function

FMN and FAD (flavoproteins) are the principle forms of riboflavin. They are coenzymes, and used in several actions, particularly in the oxidation (reactant that accepts electrons from another reactant) of agents, vital for many process to occur. Here is a list of the many uses of vitamin b 2 [111,79,59,29]:

- Like thiamin, it acts as a coenzyme in the breakdown of fats, proteins, carbs, and other nutrients.
- Helps fatty acid reduction. CoA needs FAD to accomplish this.
- Assists choline catabolism.
- Required for neurotransmitter (such as dopamine, and others) oxidation.
- Necessary for catabolism of nutrients in the liver.
- Helps b6 (discusses shortly) in many reactions, as it is often FMN dependent.
- Assists eye and skin maintenance.



Deficiency

There is no exact understood mechanism for disease related to b2 deficiency; however, clinical symptoms of deficiency after almost four months of inadequate intake have shown inflammation of the tongue, loss of function on the outside of the lips and at the sides of the mouth, sore throat, a red or bloody/puffy mouth, inflammation of skin, eyes become light sensitive, and nerve dysfunction, to name a few.

Extreme lack of riboflavin may slow the synthesis of the coenzyme form of vitamin B6 and niacin synthesis (later discussed within this article). Conditions and populations associated with increased need for riboflavin intake are many. Deficiency often occurs with heart disease, some cancers, thyroid disease, and excess alcohol intake. Women on pregnancy pills are also more likely to develop deficiency than women not taking these drugs. Concerning this topic, Wacker J et. al states [80]:

> *"Riboflavin deficiency should be considered a possible risk factor for preeclampsia. Insufficient concentrations of the riboflavin-derived cofactors flavin adenine dinucleotide and flavin adenine mononucleotide could contribute to the established pathophysiologic changes including mitochondrial dysfunction, enhanced oxidative stress, and disturbances in nitric oxide release."*

Finally, have you ever noticed when taking a multi vitamin, or perhaps a vitamin b supplementation pill, your urine-changed color? This is due to riboflavin. Riboflavin is a fluorescent yellow compound. Ingestion of this will most likely induce a change in urine color, to light yellow/bright orange. Also, small amounts of vitamin b2 are secreted in the feces, causing a yellowish color. This side effect is harmless though, so you can put your mind at ease when this occurs [113,59,32].

Recommendation

The 1989 RDA for riboflavin is given in milligrams per 1,000 kcal. The recommended allowance for people of all ages is 0.6 mg/ l,000 kcal with a minimum intake of 1.2 mg for persons whose caloric intake may be more than 2,000 kcal. Through the years, the recommended allowances for riboflavin have been calculated in relation to:

- Protein requirement,
- Energy intake
- Metabolic body size.

Because of the interdependence of these three variables, allowances calculated by the various methods have not differed significantly. The 1998 DRI RDA for individual intake for riboflavin is similar to the 1989 RDA. The DRI RDA for adult men and women aged 19 years and older for individual intake for riboflavin is 1.3 and 1.1 mg/day, respectively. With pregnancy and lactation the DRI for daily riboflavin intake increases to 1.4 and 1.6 mg, respectively. Toxicity associated with large oral doses of riboflavin has not been reported. Good sources of Vitamin B2 are eggs, meat, legumes, milk, and milk products such as cheese [80,67].

Niacin (B3)

Niacin, also known as nicotinic acid nicotinamide, and vitamin b 3, is a water-soluble vitamin, and apart of the b-complex.

Digestion

In the human body, niacin is broken down to Nicotinamide adenine dinucleotide phosphate (NADP), and nicotinamide adenine dinucleotide (NAD). These are the primary forms which niacin functions within the body.

In the intestine, NAD and NADP may be hydrolyzed to release free nicotinamide. This can be absorbed in the stomach, but primarily in the small intestine. In low concentrations, free nicotinamide is absorbed by a sodium dependent carrier. In high concentrations, it uses passive diffusion.

Most of the niacin in the blood is found as nicotinamide, a small amount of the time as nicotinic acid. From here, they move through the cell via a sodium dependent carrier system [107,85,57,56,15]

Function

Almost 200 enzymes require NAD and NADP to function. To name a few B3 functions, NAD helps glycolysis, oxidation of pyruvate, acetyl CoA by the kreb cycle, and fatty acids. NADP assists with fatty acid synthesis, cholesterols and steroid synthesis, oxidation of glutamate, and DNA synthesis. Some enzymes which require NADP are glutathione reductase, dihydrofolate, and tetrahydrofolate [107,56,43,33].

For much more on NAD in relation to energy metabolism, read, Energetic Transference Occurring in the Biosphere Part II: Anaerobic Energy Pathways.

Deficiency

Deficiency of niacin often results in a condition known as pellagra. The side effects are known as four d's; dermatitis (inflammation of skin), dementia (a mental disorder characterized by a general loss of intellectual abilities involving impairment of memory, judgment and abstract thinking as well as changes in personality), diarrhea, and death. Dermatitis is much like a sunburn at first and appears on areas exposed to sun such as the face and neck and on the extremities such as the back of the hands, wrists, elbows, knees, and feet. Some neurological problems are paralysis of extremities, and dementia (the second D) or delirium. Several gastrointestinal problems may occur such as nausea, vomiting, and diarrhea (the third D). Ultimately, if this problem is not treated, death occurs. A poor diet, and excess alcohol leads to increased niacin needs; as does stress, trauma, and prolonged fevers [64,30,3]. Concerning this topic, Spronck JC and Kirkland JB, said this [27]:

> *"These data show that niacin is required for the maintenance of chromosomal stability and may facilitate DNA repair in vivo, in a tissue that is sensitive to niacin depletion and impaired pADPr metabolism. Pharmacological intakes of niacin do not appear to be further protective compared to adequate intakes. Niacin supplementation may help to protect the bone marrow cells of cancer patients with compromised nutritional status from the side effects of genotoxic chemotherapy drugs."*

Recommendation

The 1989 RDA for adults is 6.6 mg of niacin per 1,000 cals consumed. The DRI RDA recommends at least 16 mg per day. For pregnancy and lactation, the DRI RDA recommends 18 mg a day. Up to 35 mg a day has been suggested. For high cholesterol, up to 3 g of nicotinic acid per day has been applied. The mechanism of action for lowered cholesterol is not clearly understood; it is proposed that nicotinic acid decreases the levels of camp in the adipocytes, thereby decreasing lipase activity. Decreased lipase activity results in a decreased mobilization of fatty acids from the adipocytes and, therefore, a decreased substrate for synthesis of very low-density lipoproteins (VLDLs) in the liver. Decreased production of VLDLs lowers triacylglycerollevels, because VLDLs contain relatively high amounts of triacylglycerols. Furthermore, with decreased VLDLs there is less synthesis of LDL (bad cholesterol) and thus lower serum cholesterol levels. An increase in the HDL (good cholesterol) appears to be due to a decrease in their breakdown within the liver [113,107,70].

Concerning mega doses, consuming 1g and above may induce [67,54]:

- Release of histamine, which causes flushing and is bad for people with asthma. Sometimes this may occur with as little as 10 mg.
- Raises acidic levels in body.
- Induces itching.
- Raises glucose levels
- May injure liver by obstructing flow of nutrients to the small intestine.

Up to 500 mg of niacin appears to give relatively no adverse effects. Niacin may be found in dairy products, poultry, fish, lean meats, nuts, and eggs. Legumes and enriched breads and cereals as well [64].

Pantothenic acid (B5)

Pantothenic acid is derived from the Greek word "pántothen", meaning "from all quarters," and as its name depicts, it is found present in virtually all plants and animal foods, hence, deficiency is not likely. It is part of the chemical makeup of Coenzyme A. It is also known in other forms -Calcium Pantothenate, Pantothenate, and Panthenol [74,63].

Digestion

This vitamin occurs mainly as coenzyme A. It is primarily absorbed in the small intestine via passive diffusion. Transportation in the heart, muscles, and liver cells is done by a sodium active transport. Within the central nervous system, adipose, and renal uptake, facilitative diffusion is used [74,42,12].

Function

Synthesis of CoA is dependant on Pantothenic acid. As discussed throughout this article, CoA is used in many reactions, such as the kreb cycle, and production of energy from carbohydrates, proteins, and lipids. It also assists metabolism of certain drugs, skin, and steroids. Studies have show than Vitamin b5 may accelerate the normal healing process after surgery [78,76,75]. Here is one study by Taherzadeh MJ [73] “Physiological effects of deficiency of pantothenate, a necessary precursor in the synthesis of coenzyme A, were studied… the time required for complete conversion of the glucose decreased by 40%. Acetate addition affected the acetate and glycerol yields in a similar way in pantothenate-rich medium”

Deficiency

Deficiency usually occurs with people who are severally malnutritioned, along with alcoholics, diabetics, and certain bowel diseases. Side effects are vomiting, fatigue, weakness, and a burning feet syndrome, characterized by abnormal skin sensations [33,7,6,69].

Recommendation

The DRI recommends 5 mg a day for adults. For certain conditions such as pregnancy, 7 mg's a day is recommended. Concerning side effects, intakes of 100 mg a day for Vitamin b 5 may increase niacin excretion. 10 g a day (besides niacin excretion) has exhibited no side effects. 20 g a day may cause some intestinal distress, and diarrhea. Pantothenic acid can be found in egg yokes, legumes, whole grains, mushrooms, broccoli, avocados, and several plants and meats [113,77,69,7,6].

Pyridoxine (B6)

The b-complex Pyridoxine, is a water-soluble vitamin. It was discovered in 1934 by P. Gyorgy. Its composition is complex; made of several vitamers (one of two or more similar compounds capable of fulfilling a specific vitamin function in the body) its 3 major forms are pyridoxine (PN), pyridoxal (PL), and pyridoxamine (PM). These vitamers are comparable in function, and quite often interchangeable within a given reaction [63].

Digestion

For digestion to occur, vitamin b must be broken down, and separated into its 3 main components pyridoxine, pyridoxal, and pyridoxamine. This occurs in the intestinal brush border, via enzymatic reactions. Absorption occurs primarily in the jejunum (middle portion of small intestine, connects with the duodenum (first portion) and the ileum (last portion) of the small intestine) by passive diffusion. In the intestine, PN is converted to pyridoxine phosphate (PNP), PL is converted to pyridoxal phosphate (PLP), and PNP is often converted to PLP, while PM remains the same, and composes about 15% of the vitamers in the blood. 60% of vitamin b 6 found in the blood is PLP. In order for PLP to cross the cell membrane it must be broken down to PL. The liver stores approximately 10% of vitamin b 6, while muscles store the most at 80%. Other storage houses are the kidneys, brain, and red blood cells [7].

Function

B6 acts as a coenzyme for approximately 100 essential chemical reactions. These include protein and glycogen metabolism, proper action of steroid hormones, pyruvate production, production of red blood cells and much more. It assists in many decarboxylation reactions (removal of carboxyl group) for the production of several compounds such as glutamate (major neurotransmitter of the central nervous system). It also is of great use to the immune system in that it helps hemoglobin production and increases the amount of O2 carried by it. Also, it assists white blood cell production, all of which is vital for your health. Ortiz A et. al reports that [1], "Vitamin B6 is essential for cellular functions and growth due to its involvement in important metabolic reactions."

Pyridoxine is additionally responsible for the synthesis of many compounds. For example, niacin depends on a PLP dependant reaction to be broken down. Others required by Pyridoxine for synthesis are amino acid histidine, carnitine, nitrogen containing compounds, CoA and glycine taurine, dopamine, and helps regulate neurotransmitters, playing a major role in the nervous system.

Finally, it appears PLP helps glycogen degradation. This theory is in its infancy, but studies show that it acts as a protein buffer to help maintain the compound, and promote covalent bonds to form glucose [102,97,7].

Deficiency

Signs of deficiency are fatigue, glossitis (sore tongue) sleepiness, dermatitis (skin inflammation), neurological problems, eye problems, seizers, kidney and heart diseases, and convulsions in infants. Tryptophan and niacin synthesis will be slowed as well.

People more likely to be deficient in this are infants, old people, excessive alcohol consumption, those on a variety of drugs, and certain medical conditions. High protein intake and stress may inhibit this as well.

Also, a deficiency in B6 has been shown to increase the amino acid homocysteine found in the blood. Studies have shown that an excess of this protein can inflict blood clotting, and promote heart disease/strokes [53,36,31].

Recommendation

B6 consumption is based on protein intake, the RDA recommends .0016 mg of Vitamin b6 per 1 gram of protein. The DRI RDA recommends at least 1.3 mg for young male adults, and 1.7 for those 50 and over. For female adults and those over

50, they recommend 1.3 and 1.5 g respectively [87,86]. 100 mg per day is the upper intake for adults. Many doctors suggest 100-200 mg a day of b6 to treat carpal tunnel disease (A condition where there is a disturbance of median nerve function in the wrist as the nerve passes through the carpal tunnel.). There have been innumerable studies, which show its effectiveness. Ellis JM et. al states the following from two scientific journals [105, 102],:

> *"It is concluded that patients with a severe syndrome including the carpal tunnel defect have a deficiency of vitamin B6, and that both the syndrome and the deficiency are relived by therapy with pyridoxine."*

> *" In my practice, vitamin B6 (pyridoxine) therapy (100 to 200 mg daily for 12 weeks) has proved curative for a large percentage of patients having carpal tunnel syndrome (CTS). Laboratory determination of the vitamin B6 status has been useful in diagnosing deficiency and in making decisions relative to surgery. This paper directs particular attention to prevention of CTS during pregnancy and discusses changes in symptoms during the course of treatment of CTS with vitamin B6."*

Scientist Laso Guzman FJ had this to say from his experiment [23]:

> *"Twelve patients with carpal tunnel syndrome were studied. Clinical and electrophysiological data were obtained and an estimation of vitamin B6 (pyridoxine) status by an assay of erythrocyte aspartate aminotransferase and coenzyme stimulation assay were done. None of the patients was found to have vitamin B6 deficiency. Patients were treated with 150 mg of pyridoxine daily for 3 months. Erythrocyte aspartate aminotransferase increased significantly (p less than 0.001) in all the patients. In 6 patients there were clinical and electrophysiological improvement and erythrocyte aspartate aminotransferase increased more than in the other 6 patients. The data obtained appear to indicate that although vitamin B6 deficiency is not common in carpal tunnel syndrome patients, pyridoxine supplementation can be recommended as adjuvant treatment in those patients undergoing surgery."*

Here is an excellent quote from Folkers K et. al, who makes a very bold claim [103]:

> *"Blood samples from four patients at the time of surgery to relieve the compression of the carpal tunnel syndrome, which was diagnosed by clinical and electromyographic evaluation, were differentially assayed to determine the specific activities and the % deficiencies of the erythrocyte glutamic oxaloacetic transaminase (EGOT). The data from these assays revealed that these four patients had a severe deficiency of vitamin B6. These data, in conjunction with previous biochemical and clinical results over five years, underscore the desirability, and even necessity, of testing by the EGOT analysis for the presence of a severe deficiency of vitamin B6 in all such patients before surgery. Treatment with vitamin B6 (pyridoxine) for a minimum period of 12 weeks, depending upon the duration and severity of the symptoms, has been effective without exception."*

Kasdan ML et. al came to the same conclusion [24]:

> *"We reviewed 1075 patients presenting over a 12-year period with symptoms of carpal tunnel syndrome. A total of 994 had a final diagnosis of carpal tunnel syndrome. There were 444 male and 550 female patients with a mean age of 42 years. Three-hundred and ninety-five related symptoms to their job. Surgery was performed in 27 percent of the total diagnosed cases with approximately 97 percent relief of symptoms. Satisfactory alleviation of symptoms was obtained in 14.3 percent of patients treated conservatively prior to 1980, with one or a combination of splinting anti-inflammatory agents, job or activity change, and steroid injections. In 1980, vitamin B6 (pyridoxine) was added as a method of conservative treatment. Satisfactory improvement was obtained in 68 percent of 494 patients treated with a controlled dosage (100 mg b.i.d.). While our findings were not the result of a controlled scientific study, we feel they suggest that regulated use of vitamin B6 may be helpful in treating many cases of carpal tunnel syndrome."*

In conclusion, though the exact mechanism has not yet been determined, it is clear through hundreds of experiments that pyridoxine plays a significant role in the treatment of carpal tunnel syndrome. Another, similar problem known as Tarsal Tunnel Syndrome (Compression of the posterior tibial nerve caused by thickening of the laciniate leading to symptoms of pain or paresthesia over the sole of the foot) is also often treated with B6.

Finally, due to its wide variety of functions in the nervous system, such as production of neurotransmitters dopamine, serotonin, supplementation of this vitamin is often suggested for treating abnormal nerve sensations in the legs, arms, and other bodily functions. Along with headaches, and states of depression [103,81,66,67,24,23,22,21,20].

Concerning overdoses, 200 mg a day appears to have no adverse effects. But 500 mg inflicts some neuro toxicity. And 1-6 grams daily has been shown to result in several side effects such as ensory and peripheral neuropathy (dysfunctions in nervous system) including numbness of the feet and hands, unsteady movement, abnormal sensations of the dorsal root ganglia (group of nerves) in the spinal cord, impaired tendon reflexes, and degeneration of sensory fibers.

Pyridoxine is found in poultry, fish, pork, eggs, soybeans, oats, whole-grain products, nuts, seeds and bananas [66,53,36,31].

Folic acid (B9)

Folic acid is named after the Latin word, “folium” for leaf. This vitamin was discovered by DR. Lucy Wills, while researching how to prevent anemia (loss of red blood cells) during pregnancy. Synonyms for folic acid are vitamin B9, folacin, Pteroylglutamate, Pteroylmonoglutamate, and folate. B9 is composed of 3 parts; pteridine connected to paraaminobenzoic acid (PABA), which forms Pteroic acid. Finally, Pteroic acid is connected to glutamic acid to form folic acid. These compounds must be present for activation of vitamin B9 [68,63].

Digestion

To be absorbed, B9 must be broken down to monoglutamate. This occurs in the small intestine by the enzyme conjugase. This process is zinc dependent--a deficiency in zinc will inhibit this process. Absorption primarily occurs in the jejunum of the small intestine, and is sodium dependent. In the blood, folate is primarily found as monoglutamate. Throughout the body, B9 is reduced to several forms such as THF, N^5/N^{10} Methyl THF, among others. The liver stores the majority of folic acid [108,91,52,18,9,].

Function

Health News stated [45], "Folate delivers head-to-toe health advantages." Lets see what exactly these are. Folate helps in the metabolism of several amino acids such as histidine, glycine, serine, and methionine. These processes will be discussed subsequently [92,71,8,7].

Histidine

Histidine (an amino acid) can be broken down to uronic acid; this can further be reduced to formiminoglutamate (FIGLU). This with the help of THF can further be broken down to glutamic acid. When deficient in Pteroylglutamate, FIGLU accumulates, instead of being converted, and used as glutamate (as stated early, this is vital for nervous function).

Glycine and Serine

Folate in the form of N5 and N10 (discussed above) is necessary for both glycine, and serine synthesis (valuable amino acids used in the metabolism of fats, carbs, muscular growth, immune system, and much more) and degradation. It also helps activate enzymes such as pyridoxal phosphate (PLP) to complete the reactions.

Methionine

THF is required for breakdown of homocysteine to methionine. Tying the article together, folate, vitamin B 12 (discussed next), and B6, all show to play a role in this process. Research shows that high homocysteine concentrations promotes heart disease. An experiment revealed supplementing with these 3 vitamins reduced homocysteine concentrations by 50%!

Other

Folic acid is essential for cell division, production of DNA and RNA, and assists the prevention of changes in DNA, which may lead to cancer.

Deficiency

Deficiency of folic results in anemia, depression, dementia, increased rate of heart disease and cancer, loss of appetite, weight loss, to name a few. People with increased folate needs are the elderly, alcoholics, bowel diseases, pregnant and lactating (secretion of milk) women, and the ingestion of certain drugs [68-70]. Additionally, Rami;rez T et. al states [82], “Deficiencies of folic acid and methionine, two of the major components of the methyl metabolism, correlate with an increment of chromosome breaks and micronuclei.”

Recommendation

The DRI RDA recommends 400 ug for adults. With an additional 200 and 100 ug for pregnancy lactation respectively.

Concerning side effects, studies suggest no side effects of consuming 400 mg of folate per day. However, some studies are contradictory to this, showing 15 mg of folate daily induce insomnia, irritability, diminished zinc status, and gastrointestinal distress. Toxicity for oral supplementation has not been reported. 5,000 ug of folate a day can mask B12 deficiency. Alleviating anemia, but at the same time, masking neurological inflictions that are due to B12 deficiency. It is recommended that if you are 50 years old, to ask a doctor to monitor your B12 level. But in short, make sure you are consuming proper amounts of B12, and these problems will not exist. Sources of folic acid include mushrooms, green vegetables such as broccoli, spinach and asparagus, as well as fruits grains, and legumes (particularly lima beans) [68,34].

Cyanocobalamin (B12)

Vitamin B12, also called cobalamin, and cyanocobalamin, is an active coenzyme, vital for many reactions, discussed shortly.

Digestion

First, B12 is acted upon by a salivary enzyme in the stomach. It then proceeds to combine with a protein known as ‘R-protein’ called intrinsic factor before entering the small intestine. After this, a pancreatic enzyme called trypsin separates it from the protein. Then, it is combined with another protein, and from there the ileum absorbs 70% of it, mainly by passive diffusion. After absorption, B12 is binded to one of 3 R proteins called TCI, TCII, or TCIII in the blood. About 90% of cyanocobalamin found in the body is bound to TCI.

Contrary to other water-soluble vitamins, B12 can be stored in the body for extended amounts of time, even for years. It is primarily stored in the liver; other places are the heart, spleen, brain, kidneys, bones, and muscles [94,93 ,49].

Function

As discussed previously, B12 plays a large part in the conversion of homocysteine to methionine, which helps protect the heart from disease. It assists conversion of THF into any of its coenzyme forms, when deficient in B12, folate is trapped in its methyl form. Cobalamin helps oxidation of several compounds. CoA and the kreb cycle are also dependent on B12. It helps nerve cells, red blood cells, and the manufacturing/repair of DNA. It is vital for processing carbohydrates, proteins and fats, which help make all of the blood cells in our bodies. It also assists memory [7,66,41].

Deficiency

Lack of B12 results in anemia, constipation, heart disease, depression, weakness, neurological failures, permanent nerve damage, nausea, flatulence (gas), loss of appetite, confusion, weight loss, numbness/tingling in hands and feat, difficulty in maintaining balance, memory loss, and soreness of the mouth or tongue. Here is another interesting study by Petchkrua W [39]:

> *"Vitamin B12 (or cobalamin) deficiency is well known in geriatric patients, but not in those with spinal cord injury (SCI). This retrospective study describes vitamin B12 deficiency in SCI… CONCLUSION It is recommended that physicians consider vitamin B12 deficiency in their patients with SCI, particularly in those with neurologic and/or psychiatric symptoms. These symptoms often are reversible if treatment is initiated early."*

Recommendation

The DRI RDA recommends 2.4 ug of vitamin B12 per day for adults age 19 and up. With an increase of .2 and .4ug for pregnancy and lactation accordingly.

No toxicity has been reported for massive doses of vitamin B12. Those with greater needs of Cobalamin are elderly people, those with gastrointestinal disorders, vegetarians, and those with pernicious anemia, which causes the absence of intrinsic factor, inhibiting cyanocobalamin absorption. Great sources are meats such as fish, shellfish, poultry, eggs (especially the yoke) and dairy products. They are rarely contained in plants [49-52,66].

Biotin

Biotin is also known as vitamin H and coenzyme R. It was isolated in 1936 when researchers showed consumption of raw eggs caused a deficiency. Uncooked egg whites contain a protein called avidin, which strongly binds to biotin in the intestinal tract and inhibits absorption. Thankfully, cooking eggs effectively destroys this protein. It is water soluble, and considered to be apart of the B-complex. It is made of two rings, an ureido ring, connected to a thiophene ring, with an additional valeric acid side chain [63].

Digestion

Biotin connected to proteins must be digested by enzymes prior to absorption. It is broken down to free biotin, biotoinyl peptides, or biocytin. There is still little information concerning the absorption of biotin in the human body. But it is believed to occur in the upper one-third to one-half of the small intestine. Absorption within the duodenum is thought to be higher than in the jejunum, and that is thought to be higher than the ileum. This may occur via a sodium dependent mechanism, or by passive diffusion. Little biotin is absorbed in the colon. Biotin is stored in minute quantities of the muscles, liver, and brain. Lastly, intestinal bacteria can manufacture small amounts of biotin, making this vitamin unique to most other vitamins, which cannot be made from natural process [40,7].

Function

Biotin acts when covalently bound to biotin dependent enzymes (biotin also assists cell growth and replication). These include B-methylcrotonyl CoA carboxylase, Propionyl CoA carboxylase, Pyruvate carboxylase, and Acetyl CoA carboxylase. We will discuss these 4 reactions next [58,65].

B-methylcrotonyl CoA carboxylase

This enzyme is vital for the catabolism of the amino acid leucine (the most abundant amino acid found in proteins). B-methylcrotonyl CoA carboxylase is formed during leucine catabolism. This is a biotin dependent reaction, and further changed to B-methyl*gluta*conyl CoA carboxylase, which is broken down to form acetoacetate and acetyl CoA.

Propionyl CoA carboxylase

Propionyl CoA carboxylase is important for the breakdown of isoleucine, threonine, and methoinine, all of which help make propionyl CoA. Propionyl CoA carboxylase assists other catabolization reactions. Tests show a biotin deficiency decreases the activity of this enzyme.

Pyruvate carboxylase

A lack of biotin shows to inhibit pyruvate activity. Pyruvate carboxylase is necessary for gluconeogenesis (synthesis of glucose, from non-carbohydrate), and helps replenish oxalocetate for the Krebs cycle.

Acetyl CoA carboxylase

For malonyl CoA to form Acetyl CoA carboxylase needs biotin. This reaction provides a mechanics for digestion of several amino acids, and chained fatty acids. Succinate formed, enters the kreb cycle.

Jitrapakdee S and Wallace JC elaborate further on this discussion [73]:

> "*The biotin carboxylase family is comprised of a group of enzymes that utilize a covalently bound prosthetic group, biotin, as a cofactor. These enzymes, which include acetyl-CoA carboxylase, pyruvate carboxylase, propionyl-CoA carboxylase, methylcrotonyl-CoA carboxylase, geranoyl-CoA carboxylase, oxaloacetate decarboxylase, methylmalonyl-CoA decarboxylase, transcarboxylase and urea amidolyase, are found in diverse biosynthetic pathways in both pro-karyotes and eukaryotes…Further comparisons of biotin-dependent carboxylases with other groups of enzymes in the protein data bank reveal that this family of biotin enzymes has strong similarities in specific domains to a number of ATP-utilizing enzymes and to the lipoyl-containing enzymes.*"

Deficiency

Lack of this vitamin may induce hair loss, rashes around the openings of the eyes, nose, mouth ect., central nervous system abnormalities such as depression, lethargy, hallucinations, and paresthesias (tingling, numbness, ect.). dermatitis, muscle pain, loss of appetite, slight anemia, an inflamed tongue, and weakness. Excess alcohol intake, bowel diseases, ingestion of raw eggs, and certain drugs, will induce greater biotin needs [114,109,66]. Furthermore, Bender DA. States [10], “Biotin deficiency leads to impaired glucose tolerance”

Recommendation

Because of the uncertain use of biotin in the intestine, It is hard to conclude an exact consumption rate. The 1989 RDA recommended 30-100 mg of biotin per day for children of 11 years of age, to adults. Another suggests is 30 ug a day for adults, and 35 ug for women. Toxicity of biotin has not been reported. Sources for biotin are liver, brewer's yeast, egg yolk, soybeans, peanuts, cauliflower, mushrooms, and legumes [71,72,11].

Final Recommendations

As clearly displayed, Vitamin B-complex is absolutely essential for the bodybuilding life style. So the question is, what do you do from here? Obtaining B-Vitamins from food is possible, but can be very difficult, especially if you are on restricted calories. As such, I would highly recommend you purchase a B-Complex supplement. Furthermore, taking into account that it is virtually impossible to consume too much of these water-soluble beasts, and that as athletes, we are more susceptible to losing vitamins through loss of water from animalistic training sessions, there is no reason why you wouldn’t. But be sure to study this article thoroughly, consume the proper servings as recommended, and avoid harmful products such as alcohol, which promote deficiencies, and contribute nothing but harm to your body. Finally, results show that consuming vitamin b with a meal enhances absorption, and avoids gastrointestinal distress, which is often induced if consumed on an empty stomach. From there, enjoy your gains [67,29,28,7,9].

Conclusion

20 Wisdom crieth without; she uttereth her voice in the streets: 21 She crieth in the chief place of concourse, in the openings of the gates: in the city she uttereth her words, saying, 22 How long, ye simple ones, will ye love simplicity? and the scorners delight in their scorning, and fools hate knowledge? 23 Turn you at my reproof: behold, I will pour out my spirit unto you, I will make known my words unto you. Proverbs 1:20-23 [48]

These are exciting times my friends. The Lord Jesus has blessed Abcbodybuilding with an abundance of innovation. My final suggestion to our fellow hyperplasia viewers is to take advantage of this opportunity. Knowledge is literally knocking at your door--all you have to do is open up.

Call unto me, and I will answer thee, and show thee great and mighty things, which thou knowest not. - Jeremiah 33:3 [48]

Keep it Hardcore

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