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Human Nutrition and Supplements

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Abstract

Dietary supplements are isolated or bound nutrients consumed by individuals to improve their nutritional status. They are usually consumed when an individual is deficient in a particular nutrient or wants to increase his/her muscle mass. The ingredients usually used as supplement are amino acid, herbs, minerals, vitamins and enzymes. Dietary supplements are used in the form of softgels, powder, capsules, liquid, and gelcaps. There are many health benefits of dietary supplements like Iron, Zinc, Protein supplements, Vitamin D, Calcium, Omega–3 fatty acids and many more. To maintain optimal growth and development while prevent deficiency, adequate intake is advisable but excess use or high dose cause the possibility of toxicity. This chapter emphasizes various health benefits of dietary supplements and their uses.

***Keywords*:** Food supplements, sports supplements, nutrition, health

1.1 Dietary Supplements – Introduction

There is a broad variety of dietary supplements in the market. More than 56,000 distinct dietary supplements are available, according to the US Food and Drug Administration (FDA), with thousands of new products/supplements being introduced to customers each year [1].

Dietary supplements, by definition, are formula that can supplement our regular diet with nutrients and reduce the risk of deficiency diseases and health problems like Protein Energy Malnutrition (PEM) and osteoporosis. Dietary supplements can be used as remedy in case of nutrient deficiencies

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either due to any chronic disease course or lower intake of nutrients but it cannot replace a normal/regular diet and daily nutrients of a meal, which are necessary for a healthy life. Many ingredients, such as herbs/medicinal plants and hormones, are used to make dietary supplements that have not been identified as nutrients or as having any nutritional functions [2]. It was explained that, when labeled correctly, these compounds should be called supplement ingredients rather than drug ingredients.

Along with natural supplements, many synthetic supplements are also in trend. Dietary supplements [3] are presumed healthy, when taken as directed dosages, they do not pose a serious or unreasonable risk of injury or illness. The FDA now regulates the dosage limit, marketing, advertising, and most importantly the labeling of these dietary supplements.

Dietary supplements come in many forms such as pills, capsules, powders, gels and extracts, although the most popular form of consumption is in powder form. They contain many nutrients which are difficult to get from daily normal diet like amino acids, vitamins, minerals, fiber and enzymes.

1.2 Global History of Dietary Supplements

In most countries, supplements are not regulated as a whole. Instead, they are covered under a collection of already existing laws and regulations [4, 5]. That is, they are "hanging from the hook" of pre-existing law. Previously, the dilemma was whether these goods should be classified as medications or foods; however, a third alternative is to classify them as biologics under existing rules. The Dietary Supplement Health and Education Act (DSHEA) of 1994 established supplement control in the United States. In the US, the FDA regulates dietary supplements as foods rather than drugs as a result of DSHEA; however, they are treated differently from traditional foods. Even if the ingredients used in supplement preparation can have nutritional benefits or occasionally adverse consequences, they are not tested for protection or effectiveness before being released into the market, unlike drugs. When a nutritional supplement is launched/available in the market, the FDA has the duty of demonstrating that it is having adverse consequences in order to limit its use or withdraw it from the market. The FDA bases its decision on a "MedWatch" programme in which healthcare professionals have reported supplement-related complications and side effects. Consumers, on the other hand, were expected to notify the FDA of any potential supplement-related side effects. Some nutritional supplements, particularly botanical formulations, and pharmaceuticals

were regulated. In most of the countries only those supplements got permitted that met recommended criteria.

1.3 Usage of Dietary Supplements

The usage of dietary supplement is popular in all age groups to get the perfect body image or according to disease course to prevent chronic nutrient deficiencies. Usage of supplements is much more common in Western countries or developed countries in comparison to underdeveloped countries. Ethnographic studies revealed that cultural factors and family rather than individuals also have the impact on potential usage of supplements [6]. Many misconceptions exist in society about the use of iron tablets. Honduran women believe that using iron tablets will result in larger infants, and they are also concerned about gaining too much weight and creating deformities in their children. Due to the low cost of iron tablets, it has little social standing. Tiredness, fatigue, and dizziness were considered common symptoms of pregnancy in India, so women did not seek treatment [7].

There are several research studies that show that various forms of perceiving or responding to public health messages or initiatives may have a substantial effect on their success or failure.

There are also other factors which act as a barrier for usage and selection of different supplements.

1.4 Types of Dietary Supplements

Supplements can be classified in three categories according to ingredients selected for their preparation: 1. Natural Dietary Supplements, 2. Semi-Synthetic Supplements, 3. Synthetic Dietary Supplements.

1.4.1 Natural Dietary Supplements

Natural supplements are made up with original extract of the natural ingredients or botanicals (herbs, fruits, vegetables, etc). No added chemicals are used in preparation of these supplements. These supplements are more expensive in comparison to synthetic supplements.

1.4.2 Semi-Synthetic Supplements

These types of supplements contain some amount of natural ingredients but their nutrient density will depend on the synthetic chemicals also, which are easily prepared *in vitro* and easily added to natural ingredients

to increase the nutrient density of the product. These are a cheaper source of nutrients and sometimes have low bioavailability.

1.4.3 Synthetic Supplements

These types of products are prepared by using all synthetic ingredients *in vitro*. No natural ingredients are required to prepare these products. Mostly these products contain predigested or simple monomers which can easily be digested and absorbed by the human body. Many differences were reported between certain natural and synthetic vitamins in regard to physiochemical properties, proven clinical advantages of natural vitamins. Recent studies also proved the fact that natural vitamins are nutritionally better than synthetic vitamins [8].

To prove the difference between natural and synthetic supplements, many randomized control trials were conducted. Meinrad Lindschinger [9] in 2019 conducted a trail for effect of B complex vitamins on Homocysteine, Oxidative Stress, and Antioxidant Level and found no statistically noticeable difference between both the groups but some favorable tendencies like more sustainability, and less oxidative stress and homocysteine levels were observed in natural vitamins, which have more sustainability in comparison to synthetic ones.

Apart from this, supplements can also be classified in another way by number of nutrients present in one entity such as single nutrient mineral/vitamin (high protein, caloric dense, etc.) and multiple micronutrients or having multiple nutrients in single tablet/capsules. Many supplements are available in the market which is targeting organ-specific disease such as kidney disease or liver disease.

The quality of supplement is a challenge; either it is botanical or synthetic, and many adulterants or misidentifications are related to this. Certain categories of supplements, like supplements related to sport and sexual performance, particularly use some unlabeled prohibited substances to deliver "spiking" and even sometimes the addition of active synthetic drugs.

1.5 Nutritional Adequacy and Dietary Diversity

Nutritional Adequacy is defined as a diet providing all the nutrients in balanced form, thus providing adequacy.

A diet is called a diverse diet when it includes various food groups (cereals, pulses, milk products, vegetables, fruits, meat product, etc.), which is important for attaining sufficient nutrient adequacy and sufficient development and body expansion [10, 11, 14].

Dietary diversity is defined as "the number of different foods or food groups consumed over a given reference period" [12, 14]. A diet covering all the food groups in balanced amount will provide adequate macronutrients and micronutrients, which could improve overall health especially in schoolchildren and decrease the prevalence of many chronic diseases such as cardiovascular diseases (CVDs), diabetes mellitus, metabolic syndrome and cancers, etc. [13, 14].

The best indicator used for assessing diet quality is Dietary diversity score (DDS), which is linked inversely with risk of chronic diseases [14].

Thus, it is important to focus on dietary diversity as it can help in improving the health status, especially in relation to abdominal obesity and its related diseases [15]. Generally, there is poor dietary diversity leading to poor nutritional adequacy, making it necessary to provide dietary supplements to treat some of the chronic diseases.

1.6 Calcium and Vitamin D Supplements

As the population ages, osteoporosis remains a major public health issue. Calcium and vitamin D have long been identified as essential nutrients for bone health and its maintenance. Adequate doses of calcium and vitamin D are important for patients with bone loss. Unfortunately, around 90% of women are not getting adequate calcium and more than 50% of women getting treatment for bone loss may have inadequate levels of vitamin D [16, 17].

The most important element in the body is Calcium, which is essential for many cell functions. Apart from bone health, Calcium plays an essential role in blood coagulation, neuromuscular activity and normal cardiac function apart from bone function.

It is an important part of the architecture of bone and is required for bone mineral deposition for the entire life. The majority of the calcium (99%) is in the bones and teeth plasma and extracellular fluid (ECF) also contains some amount of calcium. High or low levels of plasma calcium indicate positive or negative calcium balance. Bone resorption increases to restore plasma levels, if the plasma level decreases. Sufficient calcium intake is important to maintain the balance. With the help of vitamin D, calcium is adequately absorbed in small intestines [18, 19].

At around the age of 30, the peak bone mass is adequately achieved; therefore, sufficient physical activity and taking the recommended doses of vitamin D and calcium in adolescence and young adulthood helps in ensuring adequate bone mass development [19]. Therefore, to ensure

adequate intake of calcium, a lot of calcium supplements are readily available for all age groups.

The Calcium Carbonate and Calcium Citrate are the two most popular calcium supplements. These supplements have been observed to be adequately utilized when taken with any food [19, 20].

Among the calcium salts, Calcium carbonate supplements provide maximum percentage of elemental calcium. Calcium carbonate has composition of 40% of elemental calcium in comparison to 21% of elemental calcium present in calcium citrate. Around 13% of it is found in calcium lactate, and around 9% is found in calcium gluconate [19, 21].

Vitamin D is another necessary nutrient required for maintaining bone health. The most important function of vitamin D is intestinal calcium absorption regulation along with the stimulation of bone resorption leading to the serum calcium concentration maintenance [19, 22]. The main sources of vitamin D are sunlight, diet, and supplements. Some studies have shown that around 90% of people between the ages of 50 to 70 years do not receive adequate vitamin D from the diet they consume [19, 23].

Calcium intake influences optimal intake of vitamin D. High intake of dietary calcium along with vitamin D is required for optimum bone health [19, 24]. Patients can be counseled regarding intake of calcium supplements, which also contain vitamin D, and through this adequate supplementation can be achieved.

Therefore, proper nutrition education about healthy lifestyle, with intake of adequate vitamin D and calcium along with proper physical activity can prevent bone loss and osteoporosis. This nutrition education can be given from time to time to all age groups since bone loss increases as the age progresses [19].

Proper bone health is not maintained by many people as they do not receive an adequate amount of nutrition, although there are a variety of dietary sources of the two nutrients. Also, a very limited amount of vitamin D is synthesized from the skin since people have been made more aware of the damaging effects of sunlight. Therefore, people have to depend on the supplements to meet the amounts necessary for bone health [19].

1.7 Omega-3 Fatty Acid and Health Benefits

Since the 1900s, cardiovascular diseases (CVDs) are the main reason behind morbidity along with mortality worldwide.

The most used dietary supplements are probiotics, which are the fastest-growing supplements along with fish oil (Omega-3 fatty acids), multivitamins, Vitamin D, and coenzyme Q10 (CoQ10), in that order.

Providing multi-vitamin supplementation helps in reducing cardiovascular events; occurrence of coronary artery disease, a trial fibrillation and heart failure is directly linked with Vitamin D levels; CoQ10 deficiency is linked to myocardial dysfunction and with statin myopathy. It is recommended to take probiotics for lowering blood pressure and circulating lipids. However, studies done on the effects of dietary supplementations are not adequately quoted, as people believe that dietary supplements have a beneficial effect in maintaining a healthier diet and lifestyle, but rare randomized studies performed could not prove this [25].

Consumption of two fatty acids per week, i.e., 0.3-0.5 grams of eicosapentaenoic acid and docosahexaenoic acid per day is recommended since omega-3 fatty acids intake is found beneficial in decreasing the levels of triglyceride, blood pressure, platelet aggregation, arrhythmia, and atherogenesis [26].

Recent studies have shown that increased intake of LCn3 can slightly reduce the risk of coronary heart disease mortality, and reduce serum triglycerides. Increasing ALA reduces the risk of cardiovascular events and arrhythmia slightly [27].

1.8 Zinc Supplementation and Health Benefits

The biological growth of the human body, immune function, cell proliferation, enzyme functioning, gene expressions, genome stability, reproductive functions, and stabilization of DNA are some of the vital functions of a trace element called Zinc. Zinc plays a very important role in maintaining the homeostasis of the human being. In categorical pattern, the role of this trace element is grouped into three major functions – Zinc acts like a catalyst, it has structural functions and regulatory functions [28]. The effective absorption is less of the Zinc present in solid food and varies depending on the diet composition; therefore Zinc supplement administered is done in aqueous solutions and has great absorption of around 60-70% [29].

To estimate the average physiological requirement of Zinc, a factorial method was used, keeping in mind the absorption of zinc and losses through both intestinal and non-intestinal pathways as represented in Table 1.1.

The "Zinc deficiency" is more prevalent in young children, as required for their growth and development, in adolescents for pubertal growth

Table 1.1 Zinc physiological requirement in regard to age group and gender.

	Who			FNB		IZINCG	
Variables age	**Reference wt. (kg)**	**Requirement (mg/day)**	**Variables age**	**Reference wt. (kg)**	**Requirement (mg/day)**	**Reference wt. (kg)**	**Requirement (mg/day)**
6-12 mo	9	0.84	6-12 mo	9	0.84	9	0.84
1-3 year	12	0.83	1-3 year	13	0.74	12	0.53
3-6 year	17	0.97	4-8 year	22	1.20	21	0.83
6-10 year	25	1.12					
10-12 year	35	1.40	8-13 year	40	2.12	38	1.53
12-15 year	48	1.82					
15-18 year M	64	1.97	14-18 year M	64	3.37	64	2.52
15-18 year F	55	1.54	14-18 year F	57	3.02	56	1.98
Pregnancy	-	2.27	Pregnancy*	-	4.1-5.0	-	2.68
Lactation	-	2.89	Lactation*	-	3.8-4.5	-	2.98

*Different stages of pregnancy/lactation. WHO=World Health Organization; FNB=Food and Nutrition Board; IZiNCG=International Zinc Nutrition Consultative Group
International Zinc Nutrition Consultative Group (IZiNCG) [30].

spurt, and during pregnancy and lactation period, as Zinc is essential for infant growth. The elderly population also take insufficient amount of Zinc required by the body. The statistics states that 13% of mortality and 4% of global child morbidity is prevalent because of the deficiency of Zinc.

Ota E. *et al.* (2015) conducted a review that includes data from 21 randomized controlled trials (RCTs) with a sample size of 17,000 women and their infants. The data revealed that the supplementation of Zinc during pregnancy leads to a relative reduction of 14% in birth of preterm infants with placebo, but no other beneficial evidence was discovered regarding intake of zinc supplementation during pregnancy [31].

The deficiency of Zinc can lead to growth retardation, hypo-gonadism, hepato-megaly, spleno-megaly, wrinkled and dried skin, and severe iron deficiency anemia [32]. Severe immune deficiency can also develop and can cause many fatal infections before 25 years of age [33]. Recent studies also indicated that a decrease in cell–mediated and humoral immune response and increased susceptibility to infections like diarrheic diseases is observed in Zinc deficient patients. Administration of zinc in acute diarrhea conditions was found to be a beneficial therapeutic remedy in children [34, 35]. A recent research [36] stated a positive impact of Zinc supplementation in conditions like pneumonia and acute diarrhea. The mortality rate in children due to diarrhea has been reduced by supplementation of Zinc in developing countries over a period of less than five years. Zinc supplementation also has a beneficial effect on conditions like "enteropathicacrodermatitis, Wilson's, chronic hepatitis C, shigellosis, leprosy, leishmaniasis" and the common cold [37, 38].

Recent studies indicated the increased risk of neuro-degenerative disorders, affecting "neurogenesis" and increasing "neuronal apoptosis" due to the deficiency of Zinc, which further can lead to difficulty in understanding and increasing forgetfulness. This further links zinc deficiency with cerebral-aging, depression, anxiety, Alzheimer's disease and Parkinson's disease [39–41].

1.9 Iron Supplementation and Health Benefits

As compared to zinc, an abundance of iron is present on earth [42, 43], and every living organism requires iron biologically for proper development, growth and functioning of the human body [44, 45]. Even if it is present in abundant amounts, Iron in the environment act like a growth-limiting [43]. Iron in the presence of oxygen forms oxides, becomes insoluble in nature, and is thus unavailable for uptake by living organisms [42]. In the

human body, Hemoglobin contains iron, and is present in bound form. Iron is bound to a protein called hemoprotein as heme compounds [46]. Iron is essential for formation of hemo-globin and myo-globin, which carries oxygen and transport throughout the human body. Almost 2/3rds of the human body's Iron is used for circulating erythrocytes in the living organism and 15% of iron is bound to myoglobin in muscle tissue. The presence of Iron is required even for the synthesis of heme-enzymes and many other iron containing enzymes [46, 47]. Around 25% of Iron is present in mobilizable iron store [48].

Breast milk contains very little amount of Iron, which is sufficient in early infancy. 0.7 – 0.9 mg/day iron is required by the infant from 4-6 months after birth till the remaining part of the first year as represented in the Table 1.2. A double amount of Iron is required between the age of 1 and 6 years. During the period of growth spurts in adolescents, there is an increase in demand for Iron by the human body [49].

1 to 3 gms of iron is stored in the body of an average adult. The intake by diet and loss of iron needs to be balanced by the human body. The shedding of cells from the mucosal surface and skin leads to a loss of about 1 mg of iron [50]. Among premenopausal female adults, an average loss of 2 mg per day of Iron takes place due to menstruation [51]. The enhancement of human body mass during the neonatal stage and for growth and development in the childhood stage transiently boosts iron requirements [52].

When the supply of Iron is compromised, including the erythron, the medical condition is defined as Iron deficiency. Iron deficiency also takes place due to no mobilizable iron stores [53]. Iron deficiency can be present in human beings with or without anemia. The development of Anemia can cause many functional defects which include cerebral development, immune system, and work capacity [42, 54–56]. Deficiency of Iron during the different stages of pregnancy is correlated with negative outcomes for both maternal health and neonatal health, including high risk of infection, maternal-mortality, low birth weight infants and peri-natal mortality [57].

The depletion of Iron stores, and the body not being able to supply enough iron as compared to the metabolic demands to replenish the iron loss and to sustain development of the human being, become the major cause of iron deficiency [42]. Lack of consumption of bio-available iron and impaired absorption of Iron are also considered to be one of the primary causes of Iron deficiency [58, 59].

Iron supplementation is one of the major strategies which is used to treat Iron deficiency among populations with different age groups. "Ferrous

Table 1.2 Iron requirement by World Health Organization.

Age/sex	mg/day[b]
4-12 months	0.96
12-24 months	0.61
2-5 years	0.70
6-11 years	1.17
12-16 years (girls)	2.02
12-16 years (boys)	1.82
Adult males	
Pregnant women[c]	1.14
First trimester	0.8
Second and third trimester	6.3
Lactating women	1.31
Menstruating women	2.38
Postmenopausal women	0.96

Iron requirements of 97.5% of individuals in terms of absorbed iron[a], by age group and sex (World Health Organization, 1989).
[a]Absorbed iron is the fraction that passes from the gastrointestinal tract into the body for further use. [b]Calculated on the basis of median weight for age. [c]Requirements during pregnancy depend on the woman's iron status prior to pregnancy [49].

iron salts (ferrous sulfate and ferrous gluconate)" are used for oral iron supplementation, due to their high bioavailability and low cost [60]. The best way to take an iron supplement is to take it on an empty stomach as the iron absorption is higher during that stage but can cause nausea and epi-gastric pain due to the high iron dosage (usually 60 mg Fe/day) [61]. In developing countries, during pregnancy, Iron supplementation is advisable due to the low iron stores in the human body [62].

1.10 Dietary Supplements and Sports

Dietary supplements are isolated or bound nutrients consumed by the individuals to improve their nutritional status. They are usually consumed when an individual is deficient in a particular nutrient or wants to increase his/her muscle mass. The ingredients usually used as supplement are amino acid, herbs, minerals, vitamins and enzymes. Dietary supplements are used in the form of "softgels, powder, capsules, liquid, and gelcaps".

In today's era of sports competition and zeal, it is a common false belief of athletes that supplement consumption will magically improve their performance. But experts on sports nutrition still emphasize a well-balanced diet. The human body's requirement for vitamins and minerals can be met easily by consumption of fruits and vegetables (yellow orange, red, deep green, and blue). Moreover, they contribute to the body's antioxidant pool and reduce oxidative stress. Scientific studies have revealed that taking extra vitamins and minerals supplements has no role in increase of muscle mass, strength or VO_2 max. An athlete should consume five to nine servings of fruit and vegetables in a day. Egg, meat, milk and milk products are wholesome foods containing both vitamins and minerals in good amount. It is good nutrition and sound training techniques that yield improvements and better performance rather than supplements. Intense training and balanced nutrition and diet should be the first priority in an athlete's nutrition program.

As per the DSHEA, dietary supplements should be well labelled as per the guidelines and should be identified as "Dietary supplement and not drug". Among the various forms of supplements, proteins are the commonest choice for athletes. Here are three common forms of protein supplements:

1.10.1 Protein Concentrates

They are the product of protein extraction by heat and acid or enzymes. They have 60-80% protein; the other 20-40% is fats and carbohydrates.

1.10.2 Protein Isolates

Further filtration of concentrates separates large amount of fats and carbohydrates, and concentrates the amount of protein. Protein-isolate powders have around 90–95% protein.

1.10.3 Protein Hydrolysates

Further by the use of acid or enzyme and by heating of isolates detached the amino acids bonding which produces hydrolysates. They are absorbed more quickly by the body [63].

Protein supplements can also be classified on the basis of their source. Some of most available in the market are given in Table 1.3 below.

Table 1.3 Types of sports supplements.

Type of supplements	Benefits	Limitations
Milk Protein	• Contains both slow and fast proteins • Has 80% casein (slow) and 20% whey (fast) protein • Less expensive • Other nutrients are also there	• Contain fats and cholesterol • Shelf life is less • Not suitable for lactose intolerant person
Whey protein	• Contains fast proteins • They are rapidly digested • Highest amount of BCAA, increase muscle growth and repair • Less muscle fatigue and wasting	• Protein powder needs to be mixed with water
Soy Protein	• Comparable to animal protein • Also a fast protein • Some forms may contain isoflavones	• May not build muscles as that of whey and casein • Taste may be unfamiliar to athlete
Egg protein	• Perfect protein due to essential amino acid profile • Contains all 13 essential nutrients • Cholestrol and fat is not present in egg whites	• Half of the protein is present in egg yolk but its also high in cholesterol. Salmonella bacteria can develop easily in raw eggs. • May be allergic for some

1.11 Dietary Supplements and FDA

The formulation and regulation of dietary supplements is taken care of by FDA. The regulations are applied by FDA in different sets, covering "conventional" foods and "drug products". Under the Dietary Supplement Health and Education Act (DSHEA) of 1994:

1.11.1 Manufacturers and distributors of adulterated or misbranded dietary supplements and dietary ingredients – market products are prohibited. This means that the responsibility of a particular company for evaluating and testing the product for safety and correct product labelling has to be done before marketing to make sure that the product satisfies all the requirements of DSHEA and FDA regulations.

1.11.2 Any adulterated or misbranded dietary supplement product that reaches the market is the responsibility of the FDA to take action on it.

Dietary supplements includes both liquid and solid external substances. So before jumping to supplement types, it is important for sports nutrition students to understand fluid and its importance.

1.12 Dietary Supplements and Toxicity

In today's scenario, it has been observed that there is a growing trend of increased intake of multi-vitamin/multi-mineral supplements in developed countries [64, 65]. As reported by the study, 33% of US adults consume multi-vitamin and multi-mineral supplements [66] and intake is high among "male military personnel" (32–47%) and among "military women" 32–47%) [67]. About 64-81% of "long-term cancer survivors", consume large amounts of multi-vitamin and mineral supplements [66]. To maintain optimal growth and development and prevent deficiency, adequate intake is advisable but excess use or high dose cause the possibility of toxicity [68]. The dosage of pyridoxine (vitamin B6) higher than 500 mg/d reported the conditions of Photo-sensitivity and neuro-toxicity. Vitamin E doses of 800–1200 mg/d can cause bleeding which is further associated with anti-platelet action, and dosage more than 1200 mg/d give the symptoms of acute diarrhea, muscle cramping, cloudy vision, and gonadal dysfunction [69]. Excess intake of vitamin A is also linked with toxicity. In two large clinical trials, the "Retinol Efficacy Trial" [70]

and the "ATBC study" [71], the increased risk of lung cancer is associated with male smokers consuming β-carotene supplements. The ABTC study reported the increased mortality and incidence of prostate cancer in male alcohol users consuming the β-carotene supplement. The consumption of "fish liver oils" having vitamin A and multi-vitamin supplements in them can cause hypervitaminosis A [72, 73].

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