

Nutrition and Evidence-Based Foods for Enhancement of Athletic Performance

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ABSTRACT

Adequate Energy intake has been linked to enhanced athletic performance. Apart from energy, protein is a vital nutrient in athletics for its role in repairing worn out tissues and maintenance of positive Nitrogen balance which is essential for good health of the athletes. On the other hand, optimal muscular function requires adequate supply of calcium which also helps in maintenance of healthy, strong bones and prevention of fractures during competition. Sports' anemia is a major challenge in athletics due to increased loss of iron through sweat. Therefore, athletes need adequate intake of iron to facilitate synthesis of new erythrocytes, maintenance of normal hemoglobin levels and prevention of sports' anemia. We have aimed at having a comprehensive study on role of nutrition in enhancement of athletic performance. The objectives focused on role of Nutritional supplements, Carbohydrate, Protein, Calcium and Iron in enhancement of athletic performance.

Key words: Sports' nutrition, Athlete's nutrition, Athlete's diet, Sports' diet, Athlete's performance.

INTRODUCTION

Sports nutrition is a key aspect of sports performance and several studies have indicated that adequate nourishment is vital for enhanced athletic performance. Regardless of the age of an athlete, many

studies have stated with evidence the importance of nutrition in athletic performance. Correct dietary and nutritional information should be given to the athletes in order to enable them make right decisions¹. Special nutritional needs for athletes include; enough energy intake for the sport, sufficient hydration and meal timing for optimal performance; however, they lack proper information regarding these requirements².

It is important for those who are in constant routine contact with the athletes for example parents, coaches and counselors to have updated information regarding athletes' dietary and nutritional needs. It is recommended that all those who support and guide athletes on dietary and nutritional matters need to be adequately equipped with up-to-date information on their specific requirements³. The present review looks into Nutrition for enhancement of Athletic performance as well as Established Foods for improved physical endurance and sports performance.

Nutrition for Enhancement of Athletic Performance

All the nutrients that either directly or indirectly have a role in energy metabolism will also have a role in enhancement of physical performance. Research findings have shown that oxygen intake, work output

and other variables used to measure physical performance especially by athletes are negatively affected by inadequate intake of specific minerals like Iron and calcium or vitamins that are essential for good nutrition^{4/}

One of the studies in this area has emphasized the importance of nutrition in enhancement of athletic performance, as well as physical activity and routine exercise for maintenance of good health. It further stated that adequate energy intake is essential to enable an athlete to complete a race or even enjoy a certain sporting event. The study reiterated that an athlete may more likely become exhausted or end up performing poorly during the race if he/she does not get enough energy, protein, iron, fluids, carbohydrates, vitamins and other minerals. It reported that however, athlete's ideal diet is not very different from regular diet recommended for healthy persons.⁵

The enormous stress which athletes experience during training lowers their immunity and accelerates production of reactive oxygen species. The antioxidant mechanism and immunity may be also affected by habit of taking lesser energy than recommended (RDA) and avoidance of fats. Exercise intensity and duration is determined by the athlete's maximal capacity and produces proportional oxidative stress. Poor physical performance and oxidative stress are both as a result of depletion of muscle glycogen. Increase in fat oxidation spares glycogen and so protects glycogen stores. Athletes should consume balanced diets so as to provide adequate calories to meet the increased need and to ensure replenishment of fats and carbohydrate used in sporting activities⁶.

Most of the athletes however, do not meet nutrient and calorie requirements and therefore have low fat and glycogen stores, inadequate essential fatty acids and micronutrients which results in compromised physical performance, immunity and protection against cellular oxidative damage. Undernutrition and excessive training increase the risk of

infections. Apart from acting as a source of energy to power physical performance, oxidation of fats, glycolysis, protein degradation and break down of glutamine support metabolism and immune proteins' synthesis. Reduction or excessive use of any of the proteins may cause suppression of immunity⁷.

Nutritional Supplements use in Athletics

Due to lack of regulation for dietary supplements, there are many supplements in the world market currently, and some are of poor quality and value. Some of these supplements unfortunately contain prohibited substances especially precursors of anabolic steroids and certain stimulants⁹. Most of the supplements still have substances for example ephedrine which have been linked with serious mortality and morbidity. All stakeholders in sports share in the responsibility of ensuring that this issue is addressed. Sports' managers need to ensure that athletes receive correct nutritional counseling and support and that they are educated on the negative effects and consequences of supplements use, more so the ones that contain the banned substances. There should also be proper regulation of dietary, nutritional and all other forms of supplements¹⁰.

Use of nutritional and dietary supplements that are effective and safe, has been found to immensely enhance adequate energy intake, but use of such supplements alone is not helpful in enhancement of caloric intake in relation to one's energy needs due to increased expenditure in absence of a balanced diet¹³.

Abuse of banned substances and supplements should be condemned worldly. Therefore, effort should be focused on research studies that will provide or discover safer and more effective nutritional supplements¹⁴.

Another research study showed that composition of protein in the diet had enormous effect on muscular performance following lengthy endurance physical activity. Soluble milk protein was reported

to greatly lower muscle fatigue that is induced by strenuous physical endurance as compared with those on placebo or casein²⁰. In another study done with carbohydrate supplementation for endurance athletes, it was found that endurance was further enhanced after supplementation, whereas no improvement was witnessed among those in control group.²¹

Nutritional supplementation may be very effective in boosting performance for both recreational and competitive athletes. Metabolic processes of protein synthesis and storage of energy are optimized by combined supplementation of both protein and carbohydrate during periods of competition. In one study conducted on use of commercially available maltodextrin-fructose beverage in sports nutrition, it was found to improve exogenous carbohydrate oxidation and delivery of fluid, hence offering the much needed energy to power physical activity²³.

A related study conducted to investigate difference between consumption of commercial versus natural carbohydrate on performance in strenuous running reported that supplementation with solid carbohydrate to athletes running for a period of 1 hour and 40 min, resulted in well maintained level of blood glucose as well as enhanced performance compared to consumption of water only. The findings show that supplementation with either natural (raisins) or commercial carbohydrate source as per the recommended levels maintained the level of blood glucose, improved performance of running and were well tolerated²⁴.

Athletic performance demands a high energy input and output and muscle glycogen (carbohydrate) is the excellent fuel needed to power the exercise. Endurance physical activity has been known to deplete muscle glycogen rapidly leaving insignificant amounts and therefore inducing fatigue due to low glycogen levels in the muscles. Moreover, endurance physical activity may also lead to

exhaustion of the hepatic glycogen leading to fatigue due to low glucose in the blood²⁵

Carbohydrate requirement for athletes

The body gets energy from the three macronutrients i.e., carbohydrate, fat and protein and the highest proportion of an athlete's energy intake (at least 50%) should be provided by carbohydrates. Another study emphasized the importance of adequate intake of carbohydrates in order to meet the high calorie needs, for maintenance of normal blood glucose level and restoration of muscle glycogen stores²². A different study on relationship between physical activity and Body Mass Index (BMI) established that Physical Activity level had a significant inverse association with BMI¹⁰.

A number of studies have shown that adequate carbohydrate intake helps to delay fatigue, and it is recommended that those athletes who are in long/heavy training should have a carbohydrate intake of 6-10g/Kg bwt/day. One study established that a Low fat-high carbohydrate diet is suitable for sports because high body fat reduces synthesis of glycogen in muscles and increases the individual's risk of suffering from cardiovascular diseases²⁸.

Athlete's diet regimen should comprise of 60-70% of calorie from carbohydrates, 10-15% from protein and 20-30% from fat. Intake of high carbohydrate is important as it helps in replenishing glycogen stores in the muscles. A study on 40% and 70% carbohydrate diets revealed that after several days of exercise on the diets, participants on 40% carbohydrates had low muscle glycogen stores and could not exercise even at moderate intensity, while participants on 70% carbohydrate had muscle glycogen values that remained above 100mmol/kg and were able to continue with heavy training²⁸. Therefore, the recommendation is that a heavy training athlete should have a carbohydrate consumption of 6-10g/Kgbwt/day to provide adequate carbohydrate and replenish glycogen stores.

One study established that increases in muscle glycogen were significantly greater during the first 6 hours after exercise with simple rather than complex carbohydrates and that plasma insulin levels were greater after the intake of simple carbohydrates²⁹. Therefore, according to the findings of the study carbohydrates of high glycemic index replenish muscle glycogen more rapidly and effectively. Another separate study reported that within the first day of recovery following endurance physical event, consumption of carbohydrate foods with high glycemic index resulted in higher glycogen stores than intake of similar amount of carbohydrate foods of low glycemic index³⁰. Therefore, it is beneficial to consume carbohydrate foods of high glycemic index after an exercise. Consumption of about 100g of carbohydrate within 30 minutes after exercise is recommended to maximize muscle glycogen synthesis²⁴.

Intake of carbohydrate delays fatigue rather than preventing it. Athletes can help maintain supply of energy by consuming 26-30g of carbohydrates every ½ hour during exercise. Since most 8-12 oz servings of sports drinks provide about 15-20g of carbohydrates, drinking 8-12 oz every 15min should help fight off the fatigue that occur when the muscles and liver run out of glycogen³¹.

During physical activity if one is using sports drink as a source of carbohydrate, it is recommended that carbohydrate intake rate should be between 26-30g per 30 minutes, whose amount is equal to one cup with 6-8% carbohydrate solution ingested every 15 to 20 minutes. That will ensure delivery of 1gram of carbohydrate to the body tissues per minute at the onset of fatigue³².

Only 5% of muscle glycogen is resynthesized per hour and following an endurance physical activity maximum restoration of glycogen will at least require 20 hrs as long as carbohydrate consumption amounts to 600 grams. With immediate consumption of carbohydrate at between 1.5

to 2g/Kg bwt after an exercise, 15mmol/Kg bwt of glycogen synthesis in the muscles is achieved, whereas if carbohydrate intake is delayed by 2 hrs after the physical activity, glycogen synthesis in the muscles reduce by 66 percent to 5mmol/Kg bwt. With the delayed carbohydrate intake, glycogen synthesis in the muscles 4 hours later was reported to be 45 percent slower than in individuals who were immediately fed with carbohydrate after the exercise. Therefore delayed carbohydrate feeding, reduce muscle glycogen resynthesis³³.

In a separate study to investigate effects of supplementation with carbohydrate-electrolyte drink on physical performance, the findings showed that blood glucose, cardiovascular responses, and lactate removal were significantly enhanced following recovery and supplementation with 12g percent of carbohydrate-electrolyte drink. Conclusion of the study was that carbohydrate-electrolyte drink may enhance physical performance and improve removal of lactate consequently delaying fatigue³⁶.

Protein requirement for athletes

In the body protein is utilized to repair worn out tissues and facilitate recovery after endurance physical activity, enzyme and hormone synthesis, transport of nutrients in the blood and support of connective tissues. Studies have established that athletes' protein requirement is slightly higher compared to the general population. Recommended daily protein intake (RDA) for athletes is between 1.2-2.0g/kg bwt/ day³⁸. Another study done to investigate effect of supplementation with protein and carbohydrate on after sports' nutritional status, reported higher levels of blood glucose as compared with unsupplemented participants²⁷.

The Athletes' regime of training and routine intake of nutrients determines their protein needs. A number of studies have reported that some athletes are able to get adequate protein intake from their regular diet. Present research findings consider it simplistic to depend on particular

recommendations on amounts of protein to ingest. Some studies have reported that metabolic response for ingestion of any amount of protein depends on many factors including; other nutrients in the diet, timing of eating in regard to the physical activity, composition of amino acids ingested and protein type⁴¹.

A study done on protein requirements by athletes, established that the athletes engaged in strength training have higher protein requirement of between 1.6-1.7g/Kg bwt/day whereas those involved in endurance training have relatively lower requirement of between 1.2 – 1.6g/Kg bwt/day. A related study reported that oxidation of amino acids is increased by low carbohydrate and/or energy intake and consequently increases overall requirement of protein. The study also found that low or moderately intense physical endurance activities have insignificant effect on requirement of dietary protein as long as there is sufficient intake of carbohydrate and energy and so intake of 1g/Kg bwt/day is adequate. It is only in elite athletes where requirement for dietary protein is more than that of sedentary individuals but this also goes to a maximum of 1.6g/Kg bwt/day⁴².

Another study also found out that improvement in protein status was similar with intake of whole protein sources as compared with ingestion of free amino acid supplements. It was reported that seeking of additional nutritional interventions including use of nutritional supplements was common among endurance athletes in the effort to optimize their competitiveness. However, for supplementation to be effective it must be aligned to a good training dietary and training regime, as well as nutritional and dietary needs for one's training⁴³.

Another study was carried out to find out the efficacy of protein supplementation in enhancement of recovery parameters following endurance exercise in strength athletes. The study involved 15 males who are engaged in strength athletics. The participants were selected randomly and

divided into 2 groups i.e., supplementation and placebo groups. The supplementation group participants were each given 42g of protein supplement which was ingested at pre and post exercise and its' effect on recovery from an endurance physical exercise was examined. All participants had their maximal strength testing performed during trial 1. The research findings indicated that appropriate protein supplementation administered at pre- and post-endurance training session enhances recovery from exercise significantly at 24 and 48 hours post exercise⁴⁵.

Requirement of calcium in Athletics

Calcium together with iron, phosphorus and magnesium are essential in a number of functions in the body, which include; maintenance of oxygen transport especially iron, bone mineralization, acting as cofactors of many enzymes and muscular sustenance and excitation of nerves. A study done on female athletes reported that most of them ingest lesser calcium than the Recommended Dietary Allowance (RDA)⁴⁶.

It is vital to strive for achievement of optimal bone mass in adolescence as there is significant relationship between fractures due to sports stress and inadequate intake of calcium. In another separate study, Calcium supplements were found to improve bone health to a significant extent. Apart from the females who experienced amenorrhea, calcium status of all other athletes improved after their bone mineral density was assessed⁴⁷.

A different study found out that however much prevention of osteoporosis and bone health demand sufficient intake of calcium, increase in only physical activity doesn't automatically lead to increase in requirement for calcium and other micronutrients. Increased intake of dietary calcium or calcium supplements by athletes is advocated for in order to replenish calcium losses through sweat. In order to meet increased requirements and replenish nutrient losses due to endurance physical

activities, it is recommended that athletes should always consume a diet rich in protein, energy, fat, minerals, fluid and vitamins⁴⁸.

Before one takes any drugs there should be doctor's prescription in order to avoid unfavorable drug-nutrient interactions which may interfere with absorption of certain nutrients especially critical for athletes. For example, absorption of calcium is greatly curtailed by intake of the antibiotic tetracycline. Athletes may suffer osteoporosis if calcium intake is insufficient more so since there is also increased loss due to sweating. Women are the most at risk of developing osteoporosis as they develop the female athlete triad (Amenorrhea, disordered eating and osteoporosis⁴⁹).

Iron requirement in athletics

One of the studies done in this area found out that when compared to healthy sedentary persons, iron deficiency anemia is likely to be more prevalent in athletes. Apart from reducing performance in athletics, iron deficiency greatly impairs immunity and therefore causes other physiologic and metabolic dysfunctions⁵⁰. Research has shown that other than low iron intake due to wrong dietary choices, there is also high rate of iron turnover which is also a cause for negative balance of iron. Other factors responsible for this includes; high sweating rate, urinary losses and reduced absorption. Iron supplementation at a low dose is considered beneficial especially to young women in athletics under dietary and clinical supervision to ensure maintenance of iron status during and following exercise⁵¹

Whereas depletion of iron among female athletes is a common phenomenon, this is the same case for the entire population. Though supplementation with iron has known health benefits, it has questionable benefit in regard to those who are non-anemic.⁵² It is advised that athletes should ensure intake of a balanced diet which should include rich sources of heme iron

and dairy products, in order to maintain good status of the minerals⁵³.

In another study on iron status of athletes, low levels of ferritin, haematocrit, and hemoglobin was a very common phenomenon among trained athletes.⁵⁴ "Sports anemia" is defined by these three parameters. Therefore, low levels of iron could be as a result of intestinal bleeding, sweating, impaired absorption, low intake of iron and haemolysis. Consumption of iron rich diet/food and iron supplementation are the two key strategies of replenishing depleted iron stores and treating anemia⁵⁵.

In another study to investigate anemia in sports⁵⁶, it was found that over one third of the participants presented depletion of iron stores in the body (serum ferritin <12µg/L).

Dietary supplementation for a period of 6 wks yielded a significant iron intake of 18.5mg/day, improved tissue iron status but did not increase iron Stores. Elevation of dietary iron intake, lengthy period of intervention and low iron status affected improvement in hematological indices⁵⁷.

Reduction in oxygen transport and activity of muscle enzyme in iron deficiency is what interferes with physical performance. To avoid negative drug interactions, overdose risk and intolerance, over the counter medications need to be discouraged.⁵⁴ A recent study done on nutritional supplementation for sporting females has confirmed that interventions involving use of rich dietary sources of iron e.g. products of staple foods provide another way by which to improve intake of iron and consequently increasing iron stores in exercising female athletes.⁵⁸

According to recent study findings, maximal and submaximal physical exercise performance is significantly enhanced by daily supplementation with iron, confirming the importance of iron supplementation in prevention and treatment of iron deficiency in athletes⁵⁵.

In yet another similar study both maximal and submaximal physical performance were found to be greatly improved by supplementation with iron on daily basis in

all women studied in their reproductive age⁵⁹. In an earlier study on iron status of endurance athletes, it was suggested that iron deficiency experienced by endurance athletes may be attributed to loss of iron through sweat⁶⁰.

In another study done to investigate blood volume and total hemoglobin for athletes, total hemoglobin (tHb) and blood volume in endurance athletes were higher by between 35 to 40% as compared to other groups of athletes⁵³. This shows that with optimal provision of iron rich food sources, it is possible to avoid sports' anemia in athletes. One study done on sports' anemia has established that apart from iron deficiency, high deficiency of vitamin B₁₂ and folic acid causes anemia and lowers physical endurance performance⁵⁴.

A study done to investigate hemoglobin and serum iron levels of athletes, it was reported that levels of serum iron and hemoglobin were reduced following a lengthy physical activity⁶¹. In another similar study involving older women who were engaged in moderate exercises, insignificant changes in status of iron was reported⁶². Prolonged physical exercises were found to raise the requirement for compounds that contain iron such as myoglobin and cytochrome. This increased requirement may lower tissue stores of iron and athletes may benefit from iron rich supplements⁶³.

Due to negative balance between increased iron losses resulting from exercises and dietary iron absorption, all athletes engaged in endurance physical activities are at high risk of developing iron deficiency. Most research findings have reported insignificant performance improvement due to iron supplementation to athletes whose iron deficiency is prelatent, although importance of iron supplementation to athletes suffering from iron deficiency is well documented, studies have found this to be untrue for athletes without anemia but with depleted iron stores only (prelatent iron deficiency)⁸. In one study on iron supplementation for athletes, it was observed that optimal athletes' performance requires adequate iron

intake since it is utilized for energy production and oxygen transport and most athletes develop iron deficiency. Gut bleeding, sweating, hemolysis and hematuria all are mechanisms that can cause iron losses and anemia⁶⁴.

A total of 18 research studies involving 620 participants reported relative VO₂ max of women in athletics. Both women with iron deficiency and those with undetermined iron status were reported to have significant improvement in physical endurance following iron supplementation. Only the female athletes on training showed the improvement and not those who were not in training⁶⁵.

In yet another study on iron supplementation for female athletes and control participants, assessment was done to determine their immunologic patterns, nutritional status and biochemical parameters that are related to iron deficiency⁶⁶. In a separate research study, it was shown that reduction in hemoglobin and hematocrit led to impaired tissue oxygen delivery and caused lowered VO₂ max. the importance of the two on improvement of VO₂ max was confirmed by supplementation with hematocrit to normal levels²⁹. It is however not clear what effects do supplementation with iron have on performance in athletics, for athletes with low levels of serum ferritin although evidence has been documented showing significant improvement of physical endurance performance and reduced dependency on glucose to provide energy⁴⁶

Established Nutrient rich Foods with potential to enhance sports' performance Millet

Health and Nutritional Value of Millet

Several research findings have reported that millet is high in energy and nutrients key for enhancement of sports performance, especially protein, calcium and Iron⁶⁷. Millet contains the highest percentage of protein (11.5%) compared to other cereals and tuber staple foods. Similarly, it has the highest percentage of available carbohydrates (64.6

g per 100g). It is equally high in energy (395 Kcal per 100g) as compared to other cereals and tuber staple foods⁶⁸.

Millet is among the healthiest grain foods, though not very popular. Millet is among the non-allergenic and most digestible grain that is rich in many nutrients and has a characteristic sweet flavor. With alkalizing effect to the blood and easy digestibility, millet is a popularly sought grain for detoxification³².

Millet is a rich source of carbohydrate and also excellent source of micronutrients like magnesium, manganese, thiamine and niacin. Having carbohydrate of higher glycemic Index, millet is good as a post exercise meal to ensure replenishment of glycogen reserves. Consumption of millet causes reduced blood C-reactive protein and triglycerides. A study done in South Korea reported that millet consumption is appropriate to prevent cardiovascular diseases. The alkalizing effect and other nutritional benefits of millet make it very suitable for sports⁶⁹.

A recent analytical study done by a team of experienced biochemists, established that all the varieties of millet had high levels of antioxidant activity. They then concluded that this property qualifies millet intake to be among the most suitable foods for sports' endurance and performance. Other important qualities of millet are that it is non allergenic and gluten free and therefore it is tolerated well by all sports men and women including those who experience certain food allergies. Being also a rich source of B complex vitamins, its' consumption increases metabolism of carbohydrates and ultimately increasing energy generation for optimal sport performance. Since it is a great source of energy and gluten free, millet is suitable for all athletes including the celiac athletes who are allergic to wheat or any other source of gluten⁷⁰.

Soy bean

Nutritional value of Soy bean and its' effect on performance

It has also been established that Soybean is superior to all other pulses in terms of nutritional value. It has the highest levels of Protein, Energy, Iron, Calcium and Zinc. In a study conducted on 30 participants put on soy-based supplement, 28 participants were able to conduct the test after the study of 6 weeks. Only slight improvement in maximum aerobic capacity and running performance was observed with bone density and bone mass showing no significant change. In one group of the participants there was significant increase in running velocity and had lower lactate levels after the supplementation⁷¹.

Moreover, the same group showed reduced differences in metabolic parameters due to exercise and insulin post exercise. The study findings revealed that soy protein supplement increases aerobic energy and metabolic rate of moderate endurance trainers even in absence of body composition, inflammatory reaction and exercise induced stress changes⁷².

A separate study finding showed that serum male sex hormones and soy protein consumption were inversely related. Another research provided evidence that revealed that lowered serum sex hormones may lead to reduced lean body mass more so after resistance training⁹.

Soy protein provide the best source of all amino acids especially essential amino acids and therefore most suitable above all plant proteins. A study on organoleptic properties showed that the greater the amount of malted ingredients in a food product, the better the taste, texture and flavor and the poorer the colour. It also showed that the higher the proportion of soybean in the product, the better the chemical values and the lesser acceptable the product was⁷³.

Skim milk powder.

A number of studies have reported milk to be a good source of calcium which vital in maintenance of bone health and optimal muscular function especially for athletes. One of the studies specifically reported skim milk powder as one of the richest sources

of calcium ⁷⁴. Another study done on nutritional composition of skim milk powder reported that the levels of Energy, Protein, Calcium and Iron were 500 Kcal, 34-37g, 1,257 mg and 0.32mg per 100g respectively affirming it's richness in energy, protein and calcium. ⁷⁵.

CONCLUSION

The studies have shown a strong link between adequate carbohydrate intake, delayed fatigue and enhanced physical endurance. Low fat-high carbohydrate diet is suitable for sports because high body fat reduces synthesis of glycogen in muscles. Protein is utilized to repair worn out tissues and facilitate recovery after endurance physical activity. Athletes need higher intake of calcium and may suffer osteoporosis if calcium intake is insufficient more so since there is also increased loss due to sweating. Hemoglobin and serum iron levels of athletes are in many cases low due to increased iron losses due to increased sweating, therefore affecting their physical performance. Millet, Soy bean and Milk products have been highlighted as good sources of nutrients that support physical endurance and performance.

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