
REVIEW OF LITERATURE

A Journey of a Thousand miles begins with a small step

The review of literature is essential for a well-designed research study because it gives a clear picture about the foot prints of previous researchers. It can contribute valuable information to the research study. By undertaking a literature review the researcher is able to critically summarize the current knowledge in the area of investigation, identifying strengths and weaknesses in previous work in relation to the present problem. It also helps to eliminate the potential weaknesses, while bringing forth the potential strengths. In addition, a good and full literature search will provide the context within which the study is to be enclosed. It brings clarity and focus to the individual's research problem by throwing light upon the path and progress of the research methodology. Reviewing as a whole helps in broadening the researcher's knowledge and contextualizing researcher's findings (Neeraja *et al.*, 2015).

The literature reviewed pertaining to the present research are discussed under the following headings:

- A. *Sports and games in India* - *The Development***
- B. *Performance capabilities of athletes* - *Some insights***
- C. *Food consumption pattern of athletes* - *Today's scenario***
- D. *Health concerns of the female athletes* - *Need of the hour***
- E. *Ergogenic aids for athletes* - *Achieving competitive edge***

A. Sports and games in India-The Development

The term sports comes from the French word "Depot" meaning leisure Indian sports dates back to the Vedic era. The ancient scriptures of India referred as "Atharva Veda" defines an oath for the sportsmen, "Duty in right hand and the fruits of victory in left". Since ancient times, sports like horse riding, wrestling,

archery and athletics have been very popular. Games like polo; chess and hockey are set to have their origin in India (www.mapsofindia.com/who-is-who/sports).

After independence on May 7, 1961, the National Institute of Sports (NIS) was set up for the development of sports at the Motibagh palace grounds in Patiala, India. On January 23, 1973, it was renamed as Netaji Subhash National Institute of Sports (NSNIS). The Sports Authority of India (SAI) originated with the committee formed to host the 1982 Asian Games in New Delhi. In 1984 the Sports Authority of India was established by the Department of Sports, Ministry of Youth Affairs and Sports, Government of India for broad basing and bringing excellence in sports across India. It has nine regional centres which are located at Bengaluru, Gandhinagar, Chandigarh, Kolkata, Imphal, Guwahati, Bhopal, Lucknow and Sonapat and two Academic institutions namely Netaji Subhash National Institute of Sports (NSNIS) , Patiala and Laxmibai National College of Physical Education (LNCPE) Thiruvananthapuram (Kerala). Through NSNIS, Patiala and some of the regional centres at Bengaluru, Kolkata and Thiruvananthapuram Sports Authority of India offers a variety of courses in sports coaching and sports medicine and SAI LNCPE, Thiruvananthapuram conducts graduate and post-graduate courses in physical education. Sports Authority of India conducts various activities and schemes to promote sports in India. (Jump up– [http://sports authority of india.nic.in/](http://sportsauthorityofindia.nic.in/)).

1. Main Schemes of Sports of Authority of India, (SAI)

The main programmes and activities of SAI consist of schemes drawn up and approved within the SAI and schemes of the Department implemented through the SAI on an agency basis. The main schemes of the SAI are given below:

- a. National Sports Talent Contest (NSTC)
- b. Special Area Games
- c. Sports Projects Development Area (SPDA)
- d. Sports Hostel Scheme

e.Boys Sports Companies in the Army

f.National Coaching Scheme

g.Sports Science Research Fellowship Scheme

(a) National Sports Talent Contest(NSTC)

Started in 1985, this scheme attempts to identify talented school children in the age group of 9 to 12 years. Children are selected in 10 Olympic disciplines, namely Athletics, Basketball, Badminton, Boxing, Football, Gymnastics, Hockey, Table Tennis, Volleyball and Wrestling through a series of tests and contests held at various levels.

Following selection, these children are admitted in SAI adopted schools (of which there are 58 at present) where their board and lodging and tuition fee are met by SAI. SAI also provides coaches and special infrastructure facilities to these schools, along with recurring grants for maintenance and equipment.

(b) Special Area Games (SAG)

This scheme, started in 1985, aims at identifying population groups and regions where natural talent and aptitude for a particular sport exists. The scheme involves a process of identification and survey of areas and regions, conduct special competitions to assess and select promising young boys and girls and give intensive training at SAG centers, where educational and vocational training facilities are also provided.

(c) Sports Projects Development Area (SPDA)

This Scheme, started in 1988, aims at providing basic sports facilities at 78 locations throughout the country, where a comprehensive and integrated system of coaching and training are provided to talented young sportspersons in the age group of 9 to 14 years. This aimed at providing in-house facilities to the talented youth in their own states. A maximum of three Olympic disciplines, in addition to one indigenous game, are offered for training. Three Olympic disciplines should

generally include at least one of the three mother disciplines, i.e. athletics, gymnastics, swimming in each Centre. Thirty out of 34 Sports project development centers have started functioning, with a total strength of 679 sportspersons. An amount of Rs. 1.00 crore is budgeted for the construction of these Centers (met equally by the Centre and the concerned State), and all running costs are met by SAI.

(d) Sports Hostel Scheme

This Scheme was introduced to provide basic facilities in each State and National level Championships. All running costs, including equipment, training, etc. are provided by SAI. Each hostel has a sanctioned strength of 50 boys and 30 girls. Eighteen hostels have so far been established with 895 children.

(e) Boys Sports Companies in the Army

This scheme is an extension of the National Sport Talent Contest Scheme and was approved for implementation from the year 1991-92. SAI and Army authorities have jointly launched this Scheme to scout talented boys' upto the age of 14 years from rural, semi urban and tribal areas and train them in sports.

Seventeen Boys Sports Companies for 2000 boys were setup during the VIII Plan at selected Regimental Centers. The boys will be put into Regimental Schools which will be affiliated to the CBSE. On attaining the age of 17 years and on completion of 10th standard, the boys will be absorbed in the Army, if they so wish. Thereby, a job is guaranteed to them. The running costs are borne by SAI. It also provides a one-time grant to the Army for creation and development of sports infrastructure, purchase of essential sports equipment upto Rs. 3.00 lakh and for training kit/aid upto Rs.1.00 lakh. Thereafter, an annual grant of Rs. 50,000/ is provided. Seventeen Boys Sports Companies have become functional with a total strength of 859 sportspersons.

(f) National Coaching Scheme

The National Coaching Scheme, which was first introduced in 1955, is meant to encourage people to take up coaching. The Scheme, over the years has undergone numerous changes and is now a major source for meeting the

requirement of coaches by various user agencies.

Under the Scheme, coaches are made available to States/Union Territories for State coaching centers, district coaching, university field stations and national sports federations/associations. Coaches are also deployed in SAI regional centers, academic wings and in house training centers. At present, the total strength of coaches under the scheme is 1677.

(g) Sports Science Research Fellowship Scheme

The Sports Authority of India awards Sports Science Fellowships to research workers for carrying out research in sports science related areas such as sports physiology, sports injuries, sports big mechanics and training methods. Under the Scheme, 5-10 fellowships are awarded every year. The value of each fellowship grant is Rs. 20,000/ per annum with an additional contingency grants of Rs. 10,000/ per annum for Academic Wings.

(http://sports.indiapress.org/main_schemes.php)

1. Academics in the field of sports

The Sports Authority of India has two functional wings relating to academics which are in the fields of sports and physical education. These are:

- i. Netaji Subhash National Institute of Sports, Patiala (NSNIS)
- ii. Laxmibai National College of Physical Education, Trivandrum

(i) Netaji Subhash National Institute of Sports, Patiala (NSNIS)

The Institute conducts academic courses for training of coaches and looks after research and development in sports related subjects. It conducts 24 months' diploma courses in fifteen sports disciplines and also offers 22 months' specialized post diploma master's course and 1 year post graduate diploma course in sports medicine. NSNIS is the only institute of its kind in the country and has so far trained 11,751 coaches at Patiala and at its centers at Bangalore (established in 1975), Calcutta (1983) and Gandhinagar (1987). In addition, under the Mass

Sports Participation Programme, certificate courses of six weeks duration were held at these centres and 15,601 sports instructors have so far been trained. NSNIS is also conducting one year post MBBS Diploma course in sports medicine and 28 doctors have so far qualified. The period of this course has been raised to two year from the academic session 1993- 94.

(ii) Laxmibai National College of Physical Education, Thiruvananthapuram

This college was inaugurated in 1984 and had developed in terms of infrastructural facilities, academic programmes and other essential requirements. This college offers a 3 year Bachelor of Physical Education (BPE) and 2 years M.PE degree courses. One hundred and forty six students (67 boys and 59 girls) are at present studying in the college. Upto the academic year 1995-96, 270 students have passed out from the college.

The Sports Development Authority of Tamilnadu (SDAT)

It is an organization registered under the Tamilnadu societies Registration Act 1975. It is headed by the Honourable Chief Minister of Tamilnadu as chairman. The management of the Authority is entrusted with an Executive Committee chaired by the Honourable Minister for Sports and Youth welfare as its chairman.

Scholarships, Awards and Incentives

The Government of Tamil Nadu has instituted scholarships, awards and incentives for outstanding sports persons. Under Sports scholarship scheme, (Minimum eligibility : National Medal Winner) in 27 disciplines are given a one-time scholarship of Rs. 5000/- for a student of High School / Higher Secondary School and Rs.6500/- for a student of college/ University. Pension scheme to sports persons of yesteryears who have crossed 58 years, whose monthly income does not exceed Rs. 2000/- are provided with a financial assistance of Rs.500/- per month during their life-time. A sports person's welfare fund has been created for providing financial help to those who are injured during their participation in National and International level competitions. Ten percent reservation in

recruitment for outstanding sportspersons in police, prisons, forest, fire and rescue service. Chief Minister's state Sports Award for outstanding sports persons consists of a citation, a replica and an award of Rs.1 Lakh.

Chief Minister's award for coaches and physical education teachers will be given to two coaches and two physical education teachers with proven excellence for having produced excellent sportspersons is given every year. This is entitled for Rs.1 Lakh cash award and a citation.

The Government of Tamil Nadu has announced a cash incentive in lieu of house/ flat /plot to the sportspersons of Tamil Nadu who win medals in Olympics, Asian Games and common wealth Games which are conducted once in 4 years and for South Asian Federation Games and National Games which are being conducted once in 2 years (vide G.O Ms. No.5, youth welfare and sports Development, dated: 24.01.2002).

Special development centres (SDCs) have been established in places that show promise in specific sports disciplines. They identify such sports, tap the talent pool and work to nurture support sports persons who have the potential. Currently there are SDCs in Tamilnadu that deal with weight lifting, hockey and basketball.

Joint Development centres were established by the Government in colleges by utilizing the available infrastructure facilities in 7 colleges for men and 5 colleges for women. The Government also prescribed the minimum eligibility and permitted college authorities' to select 230 students (men and women) for the scheme. Three sports schools, four sport hostels were established by the Government in the state. Financial assistance is provided for the inmates for their dietary allowances and kit allowances per year.

B. Performance capabilities of athletes-Some insights

Physical inactivity is the fourth leading risk factor for global mortality accounting six percent of deaths globally. Participation in regular physical activity reduces the risk of coronary heart disease and stroke, diabetes, hypertension,

colon cancer, breast cancer and depression. Additionally, physical activity is a key determinant of energy expenditure, and thus is fundamental to energy balance and weight control (WHO,2011).

Physical activity interventions were associated with improvements in health indicators. The documented health benefits include increased physical fitness (both cardiorespiratory fitness and muscular strength), reduced body fatness, favourable cardiovascular and metabolic disease risk profiles, enhanced bone health and reduced symptoms of depression.Hence physical activity is positively related to cardiorespiratory and metabolic health in children and youth(Chanda and Mathur,2015).

Higher participation of habitual physical activity and organized sports activities have significantly increased bone mass accretion (Pey Sze Teo *et al.*, 2011).Organised physical activity was beneficial in improving somatic and aerobic capacity indices (Mazureket *al.*,2015)

To achieve and maintain a high quality of life, adequate fitness is needed. Physical fitness is defined as a set of abilities individuals possess to perform specific types of physical activity (Birch *et al*, 2007).

Contractor (2011) points out that the key concept of physical fitness assessment is that physical activity should be enjoyable and that physical activity contributes to good health, optimal functioning, learning and wellbeing and is important throughout a person's life time

American Alliance For Health, Physical Education, Recreation and Dance (AAHPERD) has categorized fitness components into two categories as health related fitness and sport related fitness. Both types of fitness may be influenced by nutrition and exercise (Williams, 2005).

The components of physical fitness consist of certain specific attributes that are measurable and therefore easy to monitor.

1. Health related fitness

Cardiovascular endurance: It is the ability to sustain a series of repetitions of an activity without unduly taxing the physiological systems that furnish the fuel and oxygen to the muscles. A fit person can persist in physical activity for relatively long periods without undue stress (Charles, 2009). It can be measured by one and one half mile run test, 12 minutes running/walking, Harvard step test, Tuttle pulse ratio test, Queens college step test, Harvard step test for college women and girls (Yobu, 2010).

Muscular endurance: It is the ability of the muscle or a group of muscles to continue to function under a heavy work load without undue fatigue, over a period of time. It is of two types namely static endurance (the ability to sustain effort in fixed position) and dynamic endurance (the ability to sustain effort in movement). Muscular endurance can be measured by sit-ups, chin ups, YMCA Bench press test, Canadian standard test of fitness-push ups, YMCA 1-minute timed sit-ups test, flexed-arm hang test for girls, half squat jump tests, endurance dips and Burpee(Yobu, 2010).

Koukah Azeem and Seemah Azeem (2012) had compared the fitness variables among team games and individual games between 18 to 22 years of sports persons. They concluded that participants of individual games had significantly higher muscular endurance, muscular strength, power and cardiovascular endurance compared to the participants of team games.

Muscle strength: This relates to the amount of external force that a muscle can exert and it can be measured by assessing either the static contraction of muscles (isotonic metric method) or the dynamic contraction of muscle (isotonic method). Royer's strength test is the commonly used muscle strength test.

Flexibility: It is the range of movements in a joint. It limits the degree to which some parts of the body can bend, twist or move by means of flexion and extension of muscles. It also depends upon the ligaments that surround the joints. It varies

from one joint to another. Adequate flexibility of a joint can contribute to increased resistance to muscle injury and soreness and general state of good health. There are two types of flexibility tests namely absolute flexibility test and relative flexibility test. In absolute flexibility test only the movements are measured. In relative flexibility test, the length and width of the influencing body part is also measured in addition to the movement. Slide splits test, modified sit and reach tests, shoulder rotation tests are some of the flexibility tests in use (Birch *et al.*, 2007).

2. Skill or sports related fitness

It concerns athletes and related personnel who train towards maximal performance in a particular event or sport. The components of this type of fitness are

Agility: It is the ability to change the entire position of the body in space. In other words, the ability of the body or parts of the body to change direction rapidly and accurately. In this aspect the big muscle of the body are involved and they must be coordinated smoothly rapidly and precisely (Goswami, 2011).

Measuring agility reveals the innate and inherent qualities of the individuals. Some of the tests are side stepping, squat thrust, shuttle run, quadrant jump, semi agility test right- Boomerang run and LSU agility obstacle course (Yobu, 2010).

Balance: Balance is the ability to stay upright or stay in control of body movement. It is the ability to maintain equilibrium when stationary or moving through the coordinated actions of our sensory functions. There are two types of balance: static and dynamic. Static balance is maintaining equilibrium when stationary, while dynamic balance is maintaining equilibrium when moving. Dynamic balance is an important component of agility (Goswami, 2011).

Some of the tests which are used to measure balance test are star excursion balance test, balance backward, stork stand, bass stick, (cross wise and length wise), modified bass test of dynamic balance, dynamic test of positional balance, modified sideward leap test, the Nelson balance test (Yobu, 2010).

Co-ordination: The ability to use the senses with the body parts to perform motor tasks smoothly and accurately. It is the capacity to move through a complex set of movements. Co-ordination depends on the interaction of multiple body organs and systems including the eyes, ears, brain and nervous system, cardiovascular system and muscles. Examination of any or all these organs or systems may be necessary to determine the causes for loss of balance, dizziness or the inability to co-ordinate movement or activities (Charles, 2009; Subhangini 2008).

Some of the co-ordination tests are alternate hand wall toss test, basketball throw for distance, obstacle race, the fisher motor performance test and perpetual motor obstacle course (Yobu, 2010).

Speed: Speed is the least trainable motor ability. Speed is defined as the capacity to move a limb or the body or any other part with greatest possible velocity. Maximum speed is always achieved when no weight is attached with the body or body parts. Two types of speed quality are generally assessed for sports persons: basic speed (indicator of inherited component) and speed maintenance. Speed depends on a number of factors as muscle fibre composition, neuro-muscular coordination, elasticity of muscles and strength. Results of the speed test depends on accuracy of measurement since the distance run for such tests are short and take less time (Goswami, 2011). Some of the tests used to measure speed are 50 meter dash, 60 meter dash, 100 meter dash, 30 meters acceleration test, 30 meter flying and start test.

Power: It is the capacity of the individual to bring into play maximum muscle contraction at the fastest rate of speed. Power may be identified as the ability to release maximum force in the fastest possible time, as is exemplified in the vertical jump, the broad jump, the shot put and other movements, against a resistance in minimum of time. Measurement of power has two types namely athletic power measurement and work power measurement. Athletic power test are quite practical. This measurement is expressed in terms of the distance through which the body or an object is propelled through space. Common athletic power measurement tests include surgent jump, broad jump and vertical arm pull test.

Work power measurement test is used for research purposes, special efforts are usually made to eliminate extraneous movements, thus placing maximum effort on the specific muscle group to be studied. Examples of this type of measurements are the vertical power jump, power lever, modified vertical power jump (work), and the vertical arm pull (work) (Yobu, 2010).

Reaction time: Reaction time is commonly estimated to know the time taken by the person to react to a stimulus. Reaction time remains a domain of psychology. Three types of reaction times are tested by psychologist's simple, complex and recognition. Simple reaction time includes the tests like 'X at a known location' 'spot the dot', and 'reaction to sound' (Goswami, 2011).

Orteg *et al.*, (2008) studied the reliability of health related physical fitness among 123 adolescents from 10 European cities by using a set of physical fitness tests such as back saver sit and reach test, handgrip, 4x10m shuttle run and 20 m shuttle run. The selected tests were found acceptable in HELENA study.

Orteg *et al.*, (2011) recorded better physical fitness in boys, except for the flexibility test and a trend towards increased physical fitness in the boys as their age increased, whereas the fitness levels in the girls were more stable across ages.

Influence of plyometric training on selected motor performances among college male students in the age group of 21 to 24 years showed significant improvement in the motor performance (Balasubramanian and Senthilkumar, 2012).

Study by Kannan *et al.*, (2012) on the influence of athletic training on selected motor variables among college students in the age group of 20 to 24 years revealed significant improvement in speed, endurance, repetitive strength and static strength.

Analysis of anthropometric and physical fitness components among inter college level male tennis players in the age group of 18 to 23 years revealed that there was significant difference on arm length, leg length, speed and agility and

insignificant difference on endurance and strength among inter collegiate tennis players (Arulmozhi and Suganthi, 2012).

Study on anthropometric measurements, body composition and somatotyping of high jump and shotput athletes revealed that high jump athletes found to have more lean body mass as compared to shotput athletes. The shotput athletes showed better anthropometric measurements and somatotyping scores (Yadav, 2015).

C. Food consumption pattern of athletes – Today’s Scenario

Athletic performance, recovery from exercise and physical activity are enhanced by optimal nutrition. Arciero *et al.*, (2015) rightly points out that the difference between winning and losing largely depends on the training and nutritional status of the athlete. Thus in order to be successful in athletic performance, proper training and nourishment must be a daily priority.

Nutritional profile of selected women athletes (19 to 24 years) in Chennai, Tamilnadu revealed that the intake of nutrients such as protein, fat, calcium and vitamin C were higher than the recommended dietary allowances. Higher consumption of dairy foods, fruit juices and snacks would have contributed to this higher intake (Jayanthi and Sowmya, 2012).

The mean calorie intake of the sports persons in the age group of 18 to 30 years at Coimbatore, Tamilnadushowed a higher intake than recommended dietary allowances. In contrast the protein intake was low (Selvanayaki and Arulmozhi, 2013).

Divyakoshi and Shiela (2012) showed that dancers and sports person of the track events consumed nutrients more than the Recommended Dietary Allowances for adolescents, while participants of team events and untrained athletes consumed less energy, carbohydrates, protein, calcium and iron. Fat intake was higher in the entire group except the participants of team events. Only 50 percent of the dancers took multivitamin supplements while all the other participants were not taking any supplements.

Analysis of mean nutrient intake of the female sports person (N=54) in the age group of 17 to 20 years revealed a deficit nutrient intake for energy, iron, carotene and sodium in comparison with the Recommended Dietary Allowances at 5 percent level of significance (Priyadharshini and Mathew, 2012).

A study done among traditional and non-traditional female athletes in Manipur, India revealed that all of them were in negative balance. Their food and nutrient intake was found to be lower than the Recommended Dietary Allowance except for fleshy foods and protein, which showed excess of 23 to 33 percent and 5.5 percent respectively in non-traditional athletes (Anel and Subapriya, 2012).

Keisingh and Annapoorni (2012) did a study among the sports persons of Gandhigram Rural Institute, Dindigul, Tamilnadu. The results showed poor dietary and hydration pattern. Their energy intake was deficit by 28 percent. Their diet also showed calcium deficit of 26 percent compared to the Recommended Dietary Allowances and 24 percent had shown lower intake of vitamin A.

Mean food intake among athletes and non-athletes in the age group of 17 to 23 years was carried out by Balaji and Subapriya (2012) at Coimbatore, Tamilnadu. The results revealed that athletes, both male and female consumed diets deficit in cereals and millets, fruits, milk and milk products, fats/oils and sugar. Mean nutrient intake among both male and female athletes showed deficit in energy, protein, fat, calcium, carotene, riboflavin and vitamin C. Male athletes consumed excess of iron. None of the athletes consumed suggested quantity of fluids per day.

Haakson *et.al*, (2014) revealed that some athletes avoided dairy products in the meal consumed before exercise due to fear about gastrointestinal discomfort. Regular exclusion of dairy foods may unnecessarily reduce the intake of high quality proteins and calcium with possible implications for body composition and bone health. They showed that the dairy based pre exercise meal does not affect gut comfort or time trial performance in female cyclists. They recommended including substantial amounts of dairy foods in meals consumed before strenuous cycling without impairing either gut comfort or performance.

According to Pameela (2009) total energy expenditure is the sum of resting energy expenditure, dietary-induced thermogenesis and physical activity. It varies with gender, age and body size. Physical activity accounts for 10 percent to 15 percent of total energy expenditure. Athletes in strenuous training programs or any person who participate in endurance sports may increase total energy expenditure by 2 to 3 fold due to physical activity. She quotes the Institute of Medicine published formulas for estimated energy requirement based on gender, age, weight, height and physical activity from Food and Nutrition Board (2003).

Males

$$\text{EER} = 662 - 9.53 \times \text{age}(\text{yr}) + \text{PA} \times [5.91 \times \text{weight}(\text{kg}) + 539.6 \times \text{height}(\text{m})]$$

Females

$$\text{EER} = 354 - 6.91 \times \text{age}(\text{yr}) + \text{PA} \times [9.36 \times \text{weight}(\text{kg}) + 726 \times \text{height}(\text{m})]$$

PA = 1.25 if “active” and 1.48 if “very active”.

**** EER – Estimated energy requirement; PA – Physical activity**

Table 1

Classification of sports and games according to energy expenditure

Category	Event
GROUP I	Power events of Higher weight category(80Kg and above), Weight lifting, Boxing, Wrestling, Judo, Throwing events, Kabbadi
GROUP II	Endurance events: Marathon, Long distance running, Walking, Road cycling, Rowing middle and long distance swimming
GROUP III	Team events, Athletics and power events of middle weight category(65Kg), Hockey, Football, Volleyball, Basketball, Tennis, Sprints, Jumpers, Boxing, Wrestling, Weight Lifting, Judo and Swimming
GROUP IV	Events of light weight category: Gymnastics, Table Tennis, Boxing, Wrestling, Weight Lifting and Judo
GROUP V	Skills games shooting and Archery

Table 2

Average body weight and energy expenditure levels assumed and allowances suggested

Event category	Body weight (kg)	Energy allowances		Calories ration		
		Kcal/kg/day	Kcal/day	Carbohydrate	Protein	Fat
Group I	85	70	6000	55	15	30
Group II	65	80	5200	60	15	25*
Group III	65	70	4500	64	15	21*
Group IV	60	60	3600	65	15	20
Group V	60	50	3000	55	15	30

* **Glycogen loading**

#Source: **Nutrition and hydration guidelines by Panandiker et al., (2007).**

Protein is the most crucial nutrient for general health and athletic performance because of its role in protein synthesis, energy metabolism, body composition, immune support and satisfaction (Arciero *et al.*, 2014; Booth and Nicholson, 2005). Research supports timed daily protein feedings throughout the day to maximize protein synthesis and thus lean muscle mass accretion (Areta *et al.*, 2013; Philips *et al.*, 2007; Arciero *et al.*, 2013).

United States Department of Agriculture (2010) suggests 10 to 35 percent of protein intake for proper weight control. However, recent data suggested that consuming protein at the higher acceptable range (25 to 30%) enhances energy expenditure (Bray *et al.*, 2012; Ebbeling *et al.*, 2012; Wycherley *et al.*, 2012). It also enhances the body composition and may do so independent of inducing weight loss (Arciero *et al.*, 2006; Krieger, 2006). This is important because it will have important implications for athletes attempting to improve health and performance outcomes without undergoing calorie restriction and weight reduction. Recent data also shows that the combined effects of increased dietary protein and reduced glycaemic index diets enhances weight loss maintenance and improve body composition (Larsen *et al.*, 2010; Isken *et al.*, 2010; Soenen *et al.*, 2013).

Dietary protein containing a full complement of essential amino acids with high leucine content highly stimulates muscle protein synthesis (Moore *et al.*, 2009). In addition there is speculation that a frequent intake of macronutrient protein containing meals favours an anabolic state resulting in an increase in protein synthesis and accretion. This enhances functional capacity of muscles and an increase in lean body mass, leading to improved body weight control and athletic performance (Areta *et al.*, 2013; Moore *et al.*, 2009).

Increased dietary protein intake, nutrient quality (low glycemic index and unprocessed carbohydrates) and frequency of eating (4 to 6 times per day) are more important than total energy intake to improve body composition, reduce abdominal obesity and maintain lean body mass. This also enhances post prandial thermogenesis and thus athletic performance (Arciero *et al.*, 2013).

Panandiker and Sathyanarayana *et al.*, (2007) suggested that endurance athletes and body builders should consume 1 to 1.5g protein/ kg body weight to maintain lean body mass. Athletes who follow vegetarian diets have greater protein requirements (1.3 to 1.8g/kg body weight) because of the lower quality of plant derived proteins (Pameela, 2009). While planning diets for Indian athletes protein intake may exceed 2g/ kg body weight (Panandiker *et al.*, 2007).

According to Rao (2006) fats must be adequate in the diet of athletes to provide adequate energy density. Moderate consumption of fat and a balance between saturated and unsaturated fats are desirable (Panandiker *et al.*, 2007). According to Flynn and Connaly (2006) very high fat diets are undesirable for athletes as they are stored as adipose tissue leading to acidosis during exercise and thus adversely affect the performance.

Fat oxidation is influenced more by carbohydrate intake. Fat oxidation increases as carbohydrate intake decreases; carbohydrate metabolism inhibits fat oxidation (Prentice *et al.*, 1998). Consumption of glucose during moderate exercise has been shown to inhibit expressions of fatty acid translocase, uncoupling protein 3 (UCP3) and carnitine palmyl transferase compared to the same exercise performed in a fasting state (Arkinstall *et al.*, 2004; Civiterase *et al.*, 2005).

Increase in the levels of the fat components is detrimental to health and also sports performance. On the other hand, increase in the protein component result in more muscle mass and hence are beneficial to athletes (Birch *et al.*, 2007).

Fat intake varies among athletes in different sports. Endurance athletes tend to have lower fat and higher carbohydrate intake than sprinters and short distance runners. Collegiate athletes many of whom are living away from home may consume too much dietary fat because of an over reliance on fast foods. They should focus not only on the total amount of fat in their diet but also on the type of fat consumed. Saturated and Trans fat should be kept to a minimum. These fats have been shown to be the most detrimental to cardiovascular health.

Monounsaturated and polyunsaturated fats are beneficial to health. Monounsaturated fats are found mainly in plant foods including olives, olive oil, canola oil, nuts, seeds and avocados. Polyunsaturated fats can be further broken down into omega- 3 and 6 fatty acids. Good sources of omega 3 fatty acids include fish, walnuts and flaxseeds. Corn, sunflower and safflower oils are rich sources of omega 6 fatty acids (Fink *et al.*, 2006; Kris-Etherton *et al.*,2002; Spano,2010).

Carbohydrates are the preferred source of energy for all body functions and muscular exertions. Reduced glycogen availability is commonly associated with fatigue (Ortenblad *et al.*, 2013). Carbohydrate consumption prior to or during prolonged exercise enhances performance (Ormsbee *et al.*, 2014; Tenlesiet *et al.*, 2011; Vandenbogaerde *et al.*,2011). Athletes should follow a high carbohydrate diet to replenish glycogen and maintain blood glucose (Rodviguez *et al.*, 2009; Burke *et al.* 2010). However Volek *et al.*, (2013) suggested a high fat and reduced carbohydrate diet as an effective alternative. It can be a valuable alternative for athletes who need to manage body weight or have signs of metabolic impairment. In addition, the lower glycogen levels that result from carbohydrate restriction may enhance adaptation to endurance training(Burke *et al.*, 2010; Hawley *et al.*, 2006; Baar *et al.*, 2008).

Yeo *et al.*, (2011) suggested restriction of carbohydrate intake long enough to promote fat adaptation and then increasing carbohydrate intake prior to or during a competition in order to restore glycogen levels.

Endurance athletes must maintain blood glucose and replenish glycogen stores during and following longer bouts of exercise (Burke *et al.*, 2010).

The concept of GI was cited as a potential concept in improving exercise performance and enhancement of exercise capacity (O' Reilly, Wong and Chen, 2010). Large glycemic and insulinemic responses following the ingestion of high GI foods promotes muscle glycogen re-synthesis, which is recommended during the recovery period. Conversely, low GI foods have been shown to produce lower

glycemic and insulinemic responses during rest in the postprandial period (Brown *et al.*, 2013; Stevenson *et al.*, 2005).

There have been several studies on the beneficial effects of pre-exercise ingestion of low GI carbohydrate food products that results in a decrease in postprandial hyperglycemia and hyperinsulinemia, increasing oxidation of free fatty acids and possibly a better maintenance of plasma glucose concentrations, sustaining carbohydrate availability during exercise (O' Reilly, Wong and Chen, 2010).

In a study conducted on eight endurance-trained male runners who consumed an isocaloric meal containing either low GI or high GI carbohydrate foods two hours before running and after an overnight fast, Wong *et al.* (2008) observed that there is an improved performance time following the ingestion of a low GI meal, with blood glucose and serum free fatty acids concentration higher throughout the performance run. Consumption of the high GI pre-exercise meal resulted in a greater rate of muscle glycogen degradation and higher serum insulin concentrations during the performance run.

In a similar study, Moore *et al.* (2010) tested the effects of consumption of low GI and high GI foods 45 minutes prior to a 40km time-trial on ten male cyclists to determine the effects on metabolism and subsequent endurance performance. A greater carbohydrate oxidation was observed after the consumption of low GI food, coupled with increased carbohydrates availability throughout the exercise period, sustaining energy production and improving exercise performance.

On recovery period, Stevenson *et al.*, (2005) found that the ingestion of a low GI carbohydrate recovery diet consumed within the 24 hours period following prolonged heavy exercise results in a greater endurance capacity during steady state exercise in the post absorptive state the following day, as compared to a high carbohydrate diet.

Modified starches have gained popularity because of the benefits to digestion and gastric emptying rate mostly due to the amylase amylopectin ratio. Higher the rate of amylase and amylopectin, the greater the resistance to

digestion, blunting the initial response of blood glucose and insulin. This spares glycogen stores and enhances fat oxidation (Tester *et al.*, 2004). However it should be noted that despite the amylase: amylopectin ratio the gastric emptying and absorption rates may also be manipulated by modifying the different starches consumed i.e. hydrothermal modification (Ormsbee *et al.*, 2014).

Water soluble vitamins such as vitamin C, B1, B2, B6 and niacin are involved in energy metabolism. Folic acid and Vitamin B12 are involved in cell development. Deficiency of B group vitamin can result in premature fatigue and inability to maintain heavy training program. Vitamin A, C and E have antioxidant properties (Panandiker *etal.*, 2007).

Recommended Dietary allowances of calcium for Indians suggested by ICMR (2010) for sedentary women is 600 mg/day. For an athlete there is an increased risk of stress fracture which is associated with lower calcium intake and lower bone density. Female athletes should have an adequate supply of calcium to avoid calcium loss from bones. The calcium intake of 1 to 2g per day is recommended for athletes (Srilakshmi, 2014). Extra calcium in an athlete's diet may help to reduce the risk of stress fractures in sports women with menstrual irregularities (Bean, 2002).

In regard to athletic performance phosphorous is a component of adenosine triphosphate (ATP), which provides energy for all forms of cellular function. In quick, explosive movements, phosphorous is needed for the formation of creatine phosphate, which provides an immediate form of energy for cells. During endurance activities, phosphorous buffers acidic end products of energy metabolism, allowing an athlete to sustain his or her effort and delay fatigue. Finally phosphorous plays a role in energy production by phosphorylating glucose, preparing it to proceed through glycolysis (Fink *et al.*, 2012).

With regard to sports, magnesium plays an important role in bioenergetics. It serves to stabilize the structure of ATP and improves the effectiveness with which the enzyme adenosine triphosphatase acts on ATP and thus releases

energy. Magnesium is also involved in glucose and lipid metabolism. It serves as a cofactor for seven key glycolytic enzymes and thus impacts both anaerobic and aerobic carbohydrate metabolism. It also plays a role in lipid and protein metabolism. Inside the mitochondria, magnesium is essential for the aerobic production of ATP via the electron transport chain. Finally during activity, muscles rely on magnesium for proper contraction and relaxation(Golf *et al.*, 1994).

Study on magnesium supplementation and the physical performance of the volley ball players by Setaro *et al.*, (2014) concluded that magnesium supplementation improved alactic anaerobic metabolism.

The important role that magnesium plays in muscle function and bioenergetics is the driving force behind the development and marketing of sports related supplements containing magnesium (Fink *et al.*, 2012).

In the athletic world, especially for endurance sports, sodium is heralded as a life saver. Moderation is the key allowing for flexibility in recommendation based on individual needs. Replacing sodium and potassium may be beneficial during continuous activity longer than two hours especially in a hot environment (Chandrasekar and Jain, 2005).

Sims *et al.*, (2007) points out that pre exercise ingestion of a high sodium beverage increased plasma volume before exercise and perceived strain during exercise and increased exercise capacity in warm conditions.

Athletes need to make an effort to choose potassium rich foods while keeping sodium intake under control (Berardi *etal.*, 2009).It is a nutrient that athletes should consume on a daily basis for proper body functioning. It is associated with growth and development of tissues (Fink *et al.*, 2012).

In regard to athlete's performance, chloride is one of the extracellular electrolytes that are critical for maintaining fluid balance throughout the body (Fink *et al.*, 2006).

The minerals required by the body in quantities less than 100mg per day or trace minerals which includes iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum and selenium (Fink *et al.*, 2012).

Iron is critical for proper health as well as optimal performance. It is best known for aiding in the formation of compounds essential for transporting and utilizing oxygen, thus it is critical for aerobic activities and endurance training. Iron also plays a role in healthy immune function and brain development as well as energy production through its inclusion in various enzymes (Bean, 2002). Recommended Dietary Allowances for Indian women is 21mg/day (ICMR 2010).

Red meat, liver, fortified breakfast cereals, shellfish, whole grain bread, pasta, cereal, pulses, and green leafy vegetables are the good sources of iron. Extra iron in the diet improves the oxygen carrying capacity of the red blood cells and therefore improves aerobic performance (Srilakshmi, 2016).

Zinc is important for enhancing health and athletic performance. It is a component of many enzymes involved in the metabolism of protein, carbohydrates and fats. It helps to heal wounds, assist the immune system and it is needed for building cells. Food sources of Zinc include meat, egg, wholegrain cereal, milk and dairy products (Bean, 2002).

ICMR (2010) recommends an intake of 10 g/day of zinc for an adult women. Zinc is a crucial nutrient for exercise recovery due to its role in protein synthesis and repair of tissues. Zinc also interacts with insulin and increases the affinity of haemoglobin for oxygen (Fink *et al.*, 2012). It strengthens the resistance of interosseous ligaments or muscle tendons during dislocation and sprain and prevents tendonitis in athletes (Speich *et al.*, 2001).

Other trace minerals such as chromium, copper, manganese, iodine, molybdenum and selenium play a role in athletic performance (Fink *et al.*, 2012).

Athletes lose fluid through sweat and insensible losses very rapidly especially in hot and humid climates. This can cause a substantial decrease in

performance in the very next bout of exercise and pose a risk of heat injuries among athletes (Fink *et al.*, 2006).

Vallier *et al.*, (2007) points out that dehydration not only reduces athletic performance but also places athletes at risk of health problems and even death. Devlin *et al.*, (2006) emphasises that fluid losses during vigorous activity may account for upto four litres/hour. A body water loss of as little as one percent of body mass impairs exercise capacity by as much as 30 percent. Heat exhaustion can occur at around five percent body mass loss. Circulatory collapse and heat stroke can occur at around ten percent body mass loss (Birch *et al.*, 2007).

Godek *et al.*, (2005) observed that the American football players with high sweat rate and consuming hypotonic fluids to promote sodium dilution and maintain safe hydration.

Bardis *et al.*, (2013) revealed that mild dehydration decreases cycling performance during a 5 km outdoor hill course, probably due to greater heat strain and greater perceived intensity. Water is an important nutrient for athletes therefore athletes should replace the lost fluid by possibly drinking chilled liquids at frequent intervals during the event. Chilled water is absorbed faster and helps to lower body temperature (www.timetorun.com, 2006).

Study done by Lafata *et al.*, (2012) on the effect of a cold beverage during an exercise session combining both strength and energy systems revealed that drinking cold water can significantly mediate and delay the increase in core body temperature during an exercise session in a moderate climate with euhydrated subjects. The ingestion of cold water improved performance for 49 percent of the participants in the road jump.

Female players drank approximately 6.3 ± 1.09 to 8.7 ± 0.5 glasses of water daily whereas male players drank approximately 9.4 ± 1.6 to 12.7 ± 1.8 glasses of water daily (Nande *et al.*, 2009).

Tests of strength and power are largely unaffected by dehydration of up to about 2 to 4 percent of body mass. However, decrease in the performance of

endurance tests may occur at these levels especially in warm environments. Severe body water deficits, can have adverse effects on measures of mood and cognitive function (Ronald *et al.*, 2015).

Institute of Medicine (IOM), Washington (2004) recommended to include fluids 0.5 litres/day from foods and 2.2 litres/day from beverages resulting in a total of 2.7 litres/day for women above 19 years of age.

Milk is the only food which has got the power to sustain life in all the stages of development and is considered as an important part of a balanced diet. Besides being a source of quality proteins and energy rich fat, it contains important micronutrient like calcium, potassium, sodium, magnesium and vitamins which are vital for overall development and physical activity (Singh and Srivastava, 2011; Srivastava and Singh, 2012). Milk protein is the best source of protein for athletes because of its whey protein and casein content (Christine, 2015).

Animal proteins such as eggs, dairy products, meat and fish contain all the essential amino acids in high amounts and therefore considered as complete proteins. In order to gain the performance edge athletes can meet protein needs by consuming a variety of protein rich foods from both plant and animal sources (Fink *et al.*, 2012).

Vegetables and fruits are essential for good health. They are a valuable source of dietary fibre, vitamins, minerals, and phytochemicals, which have a beneficial effect on health. Increased consumption of fruits and vegetables are needed to stabilize health and avoid oxidative stress. A diet deficient in micronutrients with antioxidant functions can result in an imbalance in the athlete's redox biology in favor of accumulation of Reactive Oxygen and Nitrogen Species (RONS) and disturb redox signaling and control. This situation is called oxidative stress, resulting in molecular cell and tissue damage (Peterneli *et al.*, 2011; Petibios *et al.*, 2005).

In athletes, an overwhelming production of RONS can induce increased inflammatory process, decreased immunity, increased susceptibility to injury and prolonged recovery (Casagrande *et al.*, 2010).

D.Health concerns of female athletes – Need of the hour

Anaemia

Iron deficiency anaemia (IDA) is a public health concern among adolescents. Park (2011) quotes that as per district level health survey 2002-04, the prevalence of anaemia in adolescent girls was very high (72.6%) in India, with prevalence of severe anaemia at a rate of 21 percent. Scholl (2011) points out the probable reasons for iron deficiency anaemia as heavy menstrual loss, iron deficient diet, vegetarian eating styles, frequent dieting or restricted eating and altered absorption. The consequences of anaemia are impaired cognitive function, decreased work capacity and compromised immune functioning (Chanda and Mathur, 2015 and Georgilef, 2008).

Beard and Toin (2000) have reviewed more than two decades of research on iron status and exercise. Their report states that female athletes, distance runners and vegetarian athletes are at the greatest risk of developing altered body iron. As many as 26 to 60 percent of female athletes are affected by iron deficiency (Constantini *et al.*, 2000; Malczewska *et al.*, 2001, Cowelet *et al.*, 2003).

Loss of iron through sweat may have a greater impact on the iron status of males since they tend to sweat more than women. Short term sports anaemia can occur in athletes beginning an exercise program or starting a period of intense training leading to sudden increase in blood volume. This rapid change dilutes the blood concentration resulting in low level of haemoglobin. After one to two months of consistent training, blood concentration returns to normal and the sports anaemia is remedial (Fink *et al.*, 2012).

Davidson (2007) points out that the iron deficiency anaemia occurs when iron losses or physiological requirements exceed absorption. Bean (2002) pinpoints that female athletes are more prone than non-athletes to iron deficiency anaemia, due to increased losses associated with training or a low dietary intake.

Micro dietary analysis of iron deficiency anaemia and adolescent sports girls by Rajalakshmi *et al.*, (2012) revealed that the selected sports girls from Trichy had suffered from mild to moderate anaemia. They had the habit of skipping of meals and ate a suboptimal diet. Poor intake of iron rich food and iron absorption enhancing foods were recorded.

Anaemia affects the growth as well as physical work capacity of rural adolescent girls in Vellore district of Tamilnadu which was recorded by modified Harvard's step test and six minute walk test (Gayathridevi and Mageshwari, 2015).

Female athletic triad

Arora (2011) points out that the desire for athletic success combined with the pressure to achieve a prescribed body weight may lead to the development of medical disorders including disordered eating, menstrual dysfunction and low mineral density collectively known as the female athletic triad. Alone or in combination the disorders of the triad can have a negative impact on health and impair athletic performance. An athlete who engages in severe energy restriction or who has been bingeing and purging for a long time is likely to experience a greater decrease in performance.

Bean (2002) says that athletes competing in weight categories sports such as Judo and light weight rowing are also more likely to develop eating disorders due to pressures of meeting the weight criteria. A study conducted by Agarwal (2007) revealed that disordered eating like bulimia and anorexia nervosa are prevalent among female athletes (52%).

Female athletic triad has recently been expanded to recognize that Relative Energy Deficiency in sports (RED-s) has a broader range of negative effects on body systems with functional impairments in both male (0-28%) and female (18 to 45%) from aquatic sports (Melin *et al.*, 2015).

Anorexia athletica(AA)

A subclinical condition in which individuals practice inappropriate eating behaviors and weight control methods to prevent weight gain and/or fat increases.

Anorexia athletica does not meet the criteria for a clinically defined eating disorder, but the behaviours exhibited are on a continuum that could lead to the more severe clinically recognised eating disorders (Fink *et al.*, 2012).

Menstrual disorders and stress fractures

Study done by Kavithamaheswari (2012) in Madurai district of Tamil Nadu on the prevalence of menstrual disorders in female athletes in the age group of 16 to 21 years revealed that out of 300 athletes studied 252 of them had menstrual problems such as dysmenorrhea (37%), Oligomenorrhea (14%), dysmenorrhea and premenstrual syndrome (14%) and amenorrhea (7%).

Nutritional profile of 100 women athletes in Chennai, the State Capital of Tamil Nadu revealed 25 percent of them as underweight (Jeyanthi *et al.*, 2012). Amenorrhea is common among anorexics. The combination of low body fat levels, restricted calorie intake, low calcium intake, intense training and stress can result in bone thinning, stress fractures and other injuries and ultimately premature osteoporosis. Gastro intestinal problems, electrolyte imbalances, kidney and bowel disorders and depression are also common (Bean, 2002).

Calcium deficiency

Calcium is needed for adequate skeletal development. Pameela (2015) highlights the existence of linear relationship between dietary calcium intake and calcium retention among the adolescents. Their diet lacks in milk and milk products and green leafy vegetables. Deficiency of calcium at this stage may affect bone mineralization, leading to a risk of osteoporotic fractures later in life. Female athletes who menstruate irregularly have higher risk for the development of stress fractures, lowered bone mineral density and potentially osteoporosis. (Bean, 2002).

Vitamin D deficiency

Vitamin D deficiency can exist among young, active and healthy people by putting them at increased risk of injury and prolonged recovery. There is strong correlation between vitamin D sufficiency and optimal muscle function. Increased

levels of vitamin D reduce inflammation, pain and myopathy while increasing muscle protein synthesis, ATP concentration, strength, jump height, jump power, exercise capacity and physical performance (Shuler *et al.*,2013).

Zinc deficiency

Zinc is needed for growth, fertility and proper immune functioning. Athletes on calorie restricted diets or poorly planned vegetarian diets may be at increased risk for zinc deficiency due to low zinc intake. Increased needs such as during growth and development, malabsorption caused by chronic iron supplementation or high dietary phytate and fibre, and increased losses by means of chronic diarrhoea, diabetes and or sweat losses also contribute to low zinc levels(Chanda and Mathur, 2015).

It is evidenced from the studies conducted among athletes that sufferers of eating disorders have a disturbed body chemistry as well as a psychological predisposition to an eating disorder more than half of those suffering from anorexia have a severe zinc deficiency and that recovery is more successful if zinc supplements are given (Bean, 2002).

Upper respiratory tract infections (URTI)

Prolonged and high intensity exercise affects immune function and leads to an increased risk of upper respiratory infections (URTI) in endurance athletes. The increased incidence of upper respiratory symptoms may negatively affect athletic performance (Majtan, 2012).

Bovine colostrum supplementation has been investigated as a possible nutritional counter measure to enhance (or maintain) immune function and reduce upper respiratory symptoms risk, following strenuous or prolonged exercise and during intensive training periods(Davidson, 2012).

Athletes exposed to high-intensity exercise show an increased occurrence of gastrointestinal symptoms like cramps, diarrhoea, bloating, nausea and bleeding. These problems have been associated with alterations in intestinal

permeability and decreased gut barrier function. The increased gastro intestinal permeability, a so called 'leaky gut' leads to endotoxaemia and results in increased susceptibility to infections and auto immune diseases, due to absorption of pathogens / toxins into tissue and the blood stream (West *et al.*, 2009; Fasano 2012; Deoliveria *et al.*, 2011).

Lamprecht *et al.*, (2012) concluded that an adequate probiotics supplementation can improve intestinal barrier integrity in sports people. It is evidenced the probiotics have the potential to reduce the incidence and severity of respiratory infections and shorten the duration of gastro intestinal symptoms in trained athletes (Glesson *et al.*, 2011; Cox *et al.*, 2010 and Kekkonen *et al.*, 2007).

Other studies report attenuation of exercise – induced increase in pro and anti-inflammatory cytokines after 11 weeks (West *et al.*, 2011) and increased plasma antioxidant levels after 4 weeks of probiotic supplementation (Martarelli *et al.*, 2011).

In a double blind, placebo-controlled study, 200 mg/day of pleuran for 3 months compared to a placebo supplementation decreased the incidence of symptoms associated to upper respiratory infections suppressed the changes in the phagocytosis process and increased the number of natural killer cells in regularly training athletes (Majtan, 2012).

Dilutional hyponatremia and dehydration

Excessive sweating, combined with consumption of plain water in copious amounts (e.g. 10L in 4 hours), results in a sodium deficit referred to as dilutional hyponatremia. The symptoms of hyponatremia are disorientation confusion, seizure and coma. This condition is quite rare and most often occurs in marathon and ultra marathon type events lasting longer than 3 hours and in individuals who ingest large volumes of fluid without electrolytes (Fink *et al.*, 2012).

Tan and Lee (2015) points out that exercising in the heat often results in an excessive increase in body core temperature, which can be detrimental to health and endurance power. Ingesting slurry is an effective and practical strategy to

prevent excessive rise of body core temperature and improve endurance performance.

Benton et al.,(2015) points out that when dehydration reduces body mass by more than two per cent, it influences mood, increases fatigue and decreases alertness (2015).

According to Pierce (2005), the primary reasons for consuming a sports drink is to prevent dehydration, this is done by replacing the fluid and electrolytes that are lost through sweat as quickly as possible.

A study conducted by Khanna and Manna (2005) revealed that carbohydrate electrolyte drink had a significant role on energy balance during exercise as there in no significant change in blood glucose and lactate levels thereby decreasing the event of fatigue. Crosswell *et al.*, (2007) in their study showed that carbohydrate electrolyte drink prevents a decline in aerobic performance when compared to water and the carbohydrate electrolyte drink was more effective in maintaining plasma volume than water during recovery from aerobic exercise.

E. Ergogenic aids for athletes

An ergogenic aid is a food or food component which purports to improve the capability of an athlete to improve their performance (Birch *et al.*, 2007) Ergo, which is derived from the Greek word *ergon*, refers to work; genic is derived from *genman*, which means to generate or produce. An ergogenic aid is anything that enhances a person's ability to perform work or, in the case of athletics, to perform better. The ultimate goal of using ergogenic aids is to gain a competitive edge over the opponent. Ergogenic aids can take many different forms nutritional physiological, bio mechanical, psychological and pharmacological (Fink *et al.*, 2012).

Nutritional aids are nutrients designed to influence physiological or psychological processes to increase physical power, mental strength or mechanical edge (Williams, 2005; Christine, 2015).

Williams (2005) points out that supplements for the competitive athlete constitute approximately 10 percent of total dietary supplement sales and are popular worldwide. Proceedings of conference on performance enhancing supplements organized by the office of dietary supplements reported that about 99 percent of American athlete in the 2000 Olympic Games used dietary supplements a percentage similar to supplement use by elite Australian swimmers.

Bean (2002) focuses on popular ergogenics namely

1. Antioxidant supplements

Substances that quench free radicals which includes enzymes, vitamins, minerals and phytochemicals. They help to reduce the symptom and risks associated with high levels of free radicals generated during exercise.

2. Protein supplements

Powders that mix with milk or water to make a 'shake' or protein bars. Most popular brands are based on whey protein. Other protein ingredients include another type of milk protein called casein or soy protein. Whey proteins may stimulate immune system; high glutamine content spares muscle and prevents immune suppression during heavy training. It is more beneficial to strength and power athletes.

3. Branched chain amino acid (BCAA) supplements

Three IAAs (Intermediate amino acids) that have a branched molecular configuration valine, leucine and isoleucine. They decrease protein break down during intense exercise but may not offer any advantage over carbohydrate supplementation.

4. Meal replacement products (MRPS)

They are designed to provide near perfect balance of nutrients and possibly other ergogenic aids in a drink. It is highly convenient, good way of combining nutrients and supplements. Best used as snacks rather than meal substitutes. Athletes with high nutritional needs and busy schedule can benefit by this

5. Creatine

It is made naturally from three amino acids in the body. It is stored mostly as phosphocreatine (PC) in muscles. Phosphocreatine generates energy during high intensity activity. It prolongs maximal power output, speeds recovery, regenerates lean and total body mass and buffers accumulated lactic acid in muscles. Athletes involved in high intensity and anaerobic based sports, interval training and possibly aerobic bouts can utilise this.

6. Glutamine

It is a dispensable amino acid (DAA) found in muscle cells, the major fuel of the immune system. It helps to prevent muscle breakdown and suppresses exercise- induced immune depression. Any athlete during periods of intense training or immediately after prolonged intense exercise can benefit from this.

7. HMB (Beta-Hydroxy beta-methylbutarate)

It is a metabolite of the amino acid leucine. It reduces muscle damage, repairs and builds muscles after exercise, increases muscle strength and reduces body fat. Strength and power athletes, athletes wishing to gain lean mass can benefit from this.

8. Caffeine

It is a stimulant. It increases concentration, alertness and endurance. Athletes involved in both high intensity short term activities and endurance activities may benefit.

Pregame meal eaten within thirty minutes is very beneficial regardless of age, gender and sports. The meal should be high in starch and a mixed proportion of carbohydrates, protein and fat (Clark, 2006).

Dun ford and Smith (2006) says that supplements can be in the form of capsule, powders, shakes, liquid food and candy like bars, which includes protein shakes, carbohydrate bar and amino acid capsules.

Carbohydrate feeding before and during endurance exercise has been shown to improve exercise performance. When the exercise is longer it helps to increase oxidation of blood glucose and spares liver glycogen (Konig and Delbert

2006). Carbohydrate rich drink consumed 2 to 3 hours prior to an exercise ensures filling the labile glycogen store (Anita, 2005).

Hargreaves *et al.*, (2005) revealed that fatigue is delayed during prolonged exercise if muscle glycogen is spared. Supplementation of glucose and fructose resulted in an eight percent quicker time of completion during the time trial compared with only glucose and 19 percent improvement compared with only water.

Meti (2006) opined that supplementation of carbohydrate laddu and Kokum peels electrolyte sports drink to foot ball players had a significant improvement in strength, agility and endurance performance.

Vann Essen *et al.*, (2006), concluded that athletes who consumed carbohydrate and protein drinks were able to complete their time trial of 4.4 percent faster than the athletes who were given a placebo. Carbohydrate feedings resulted in faster sprint, increase in endurance power and higher average jump (Winnicket *al.*, 2005).

According to Thomas *et al.*, (2007) a low glycemic index (GI) pregame meal may prolong endurance during strenuous exercise by inducing less post prandial hyperglycemia and hyper insulinemia, lower levels of plasma lactate before and during exercise and by maintaining plasma glucose and free fatty acid at high level during critical periods of exercise.

The concept of GI was cited as a potential concept in improving exercise performance and enhancement of exercise capacity (O'Reily, Wong and Chan, 2010). Large glycemic and insulinemic response following the ingestion of high GI foods promotes muscle glycogen re synthesis, which is recommended during the recovery period. Conversely, low GI foods has been shown to produce lower glycemic and insulinemic responses during rest in the post prandial period (Brown *et al.*, 2013; Stevenson *et al.*, 2005).

There have been several studies on the beneficial effects of pre-exercise

ingestion of low GI carbohydrate food products that results in a decrease in postprandial hyperglycemia and hyperinsulinemia, increasing oxidation of free fatty acids and possibly a better performance of plasma glucose concentration, sustaining carbohydrate availability during exercise (O'Reilly, Wong and Chen, 2010).

Carbohydrate electrolyte supplementation improved the moderate intensity endurance capacity of active females during the follicular phase of the menstrual cycle (Sun and Wong, 2015).

Carbohydrate ingestion before and during a game seem to have the greatest impact on intermittent sports performance towards the end of the game (Baker *et al.*, 2015).

Dicocum pasta product supplemented to long distance runners had significant improvement in the endurance capacity when compared to the normal diet (Kavitha, 2006).

Hespe *et al.*, (2006) studied the impact of soy protein supplementation on college athletes and recorded an increase in stamina. Adelardi (2008) revealed that bovine colostrum supplementation helped 35 elite field hockey players to improve running performance particularly in terms of speed and endurance.

Whey proteins are superior in quality and have high concentration of branched chain amino acids (BCAA) making it an ideal supplement for sports men. It helps to elevate the glutathione level thereby strengthening the immune system (Kamala and Uthara, 2006).

Beta-alanine supplementation in high intensity exercise by Harris and Sale (2012) revealed that an increase in the intracellular buffering capacity which in turn increased high intensity exercise capacity and performance.

Jones and Bailey *et al.*, (2012) investigated the endurance enhancing nitric oxide bioavailability through supplementation of the diet with nitrite salts or nitrate rich beet root juice. The beetroot juice reduced the oxygen cost of exercise and improved the exercise performance. Studies among competitive cyclists had

shown a one to two percent reduction in the time to complete time trial distances between 4 and 16 km.

Powerset *et al.*, (2012) recorded an increased amount of growth hormone both at rest and after resistance exercise by three gram of oral GABA supplementation.

Cruzat *et al.*, (2014) had done a study on amino acid supplementation and its impact on immune function in the context of exercise. They revealed that although exercise training stimulated the production of reactive oxygen species (ROS), their overall intracellular concentration may not reach damaging levels due to enhancement of antioxidant responses. However, inadequate exercise training may result in oxidative stress, muscle fatigue, and muscle injury.

Trenellet *et al.*, (2008) founded that four weeks of creatine pyruvate intake significantly improved the performance during intermittent hand grip exercise of maximal intensity. Creatine pyruvate enhanced the endurance due to increased activity of the aerobic metabolism.

Bemben and Lamout (2005) studied the impact of creatine supplementation on athletes and noted that it increased athlete's endurance capacity by delaying fatigue.

A study by Slowineka-Lisowska *et al.*, (2015) on the influence of carnosine on pro-oxidant status in elite kayakers and canoeists revealed that carnosine which is a dipeptide formed from the amino acids B-alanine and histidine and found in large amounts in the brain and fast twitch muscle has an antioxidant role and accounts for about 11 percent of the muscles ability to buffer the H⁺ ions produced by high intensity exercise.

The effect of two-week L-carnitine supplementation on exercise induced oxidative stress and muscle damage among active healthy young men suggested that two weeks daily oral supplementation of L-carnitine has alleviating effects on lipid peroxidation and muscle damage markers following an acute bout of exercise

(Parandak *et al.*, 2015).

Sahlin (2015) studied the muscle energetic during explosive activities and potential effects of nutrition and training. The results revealed that dietary supplementation with creatine increases muscle creatine and phospho creatine (PCR) and enhances performance, especially during repeated short periods of high intensity exercise. The ergogenic effect of creatine is related to an increase in temporal and spatial buffering of ATP and to increased muscle buffer capacity. Bicarbonate loading increases extracellular buffering and can improve performance during high intensity exercise by facilitating lactic acid removal from the contracting muscle. Supplementation with beta-alanine increases the content of muscle carnosine, which is an intracellular buffer. It is clear that performance during high intensity exercise can be improved by interventions that can increase the capacity of anaerobic ATP production, suggesting that energetic constraints set a limit for performance during high intensity exercise.

Ingestion of caffeine supplements among recreational cyclists improved both cycling power output and auditory response time following two hours of moderate and high intensity interval cycling, compared to caffeine taurine niacin based supplement (Seigert and Conner, 2015).

Chmiei *et al.*, (2015) found in their study that 52 percent of professional athletes consumed energy drinks and 63 percent of athletes who practiced sport competitively used energy drinks.

Bayat-Chandegani *et al.*, (2015) studied the effect of pomegranate juice supplementation on muscle damage, oxidative stress and inflammation induced by exercise in healthy young men. The findings of the study suggested potential beneficial effects of pomegranate juice in strengthening the antioxidant defense system and reducing oxidative stress.

Capsules containing 3.6 g/day of eicosapentanoic acid rich fish oil supplementation improved exercise economy in humans (Kavabata *et al.*, 2015)

During a short term recovery both lemon tea and carbohydrate electrolyte solution showed beneficial effects in maintaining cognitive performance. However carbohydrate electrolyte solution appears to be more effective than lemon tea and distilled water in rehydrating female participants (Wong *et al.*, 2015).

Karakilicik *et al.*, (2015) studied the effect of vitamin C and exercise on lipid profile, platelet and erythrocyte indices in young soccer players. The players were in the age of 23.50 ± 0.59 years, 67.66 ± 1.52 kg body weights and 1.74 ± 0.03 m height. The results indicated that the high density lipoprotein cholesterol (HDL-C) levels were significantly increased ($P < 0.05$) with only exercise, the cholesterol and low density lipoprotein cholesterol (LDL-C) were decreased ($P < 0.05$ to $P < 0.01$) with exercise and exercise plus vitamin C treatment. The TBARS levels increased ($P < 0.05$) with exercise training, it was decreased ($P < 0.05$) with exercise plus vitamin C treatment. The platelet count (PLT), mean platelet volume (MPV), platelet cut (PCT) and red blood cell distribution width (RDW) were significantly decreased ($P < 0.05$) with exercise plus vitamin 'C' supplementation.

Pleuran, a unique insoluble β -glucan isolated from edible mushroom *pleuroteus ostreatus* significantly reduced the incidence of upper respiratory tract infection symptoms in athletes since it is a immunomodulator (Majtan, 2012; 2009; Boboveak *et al.*, 2010 and Bergendiova *et al.*, 2011).

Daily supplementation with bovine colostrum normally for periods between one and twelve weeks has a beneficial effect on immune function in athletes or individual subjected to strenuous physical activity or intensive training regimens (Davidson, 2012).

Crooks *et al.*, (2006) demonstrated that a 12 week period of daily supplementation with a commercial chocolate drink powder (26g/day) containing bovine colostrum (equivalent to 12g/day) in a group of distance runners, resulted in 79percent increase in resting saliva S-I gA concentration. It is beneficial and confers protection in athletes.

Kuehl(2012) points out that tart cherry consumption appears to possess effectiveness in tracting the inflammatory reaction seen in both acute inflammation injury pain syndrome encountered among athletes.

Epigallocatechin-3-gallate (EGCG) is a flavonoid constituent of many plants with high levels found in green tea. EGCG has anti-inflammatory and anti –oxidant properties and is known to cross the blood brain barrier where it can affect brain chemistry and physiology (Bhattacharya *et al.*, 2015).

Pregame meal made of dried roasted banana powder, soy isolate, chocolate powder, jaggery, green gram dhal and cashew nut given to female foot ball players (17-20 years) showed a significant improvement in their performance level at one per cent level of significance (Priyadarshini and Mathew, 2012).

Sugarcane juice ingestion is equally effective as sports drink and plain water during exercise in a comfortable environment, it is a more effective rehydration drink than sports drink and plain water in post exercise as it enhances muscle glycogen synthesis (Kalpana *et al.*, 2013).

Karami *et al.*, (2015) identified protective effect of glutamine by the expression of HSP70 and reduction of cortisol on exercise induced stress. Thus athletes who wish to compete or have intense exercise, glutamine consumption is recommended. Sodium phosphate supplementation on repeated high intensity cycling efforts revealed that sodium phosphate supplementation improved repeated-sprint and time-trial cycling efforts both 1 and 4 days post-loading in trained athletes (Brewer *et al.*, 2015).

Carbohydrate electrolyte solutions enhanced moderate intensity endurance capacity in active females during the follicular phases of the menstrual cycle (Sun and Wong, 2015). Systemic review by Fontan *et al.*, 2015 revealed that use of carbohydrate before physical activity with the appropriate composition and administration proved effective in increasing physical performance.

Caffeine is an ergogenic aid widely used before and during prolonged exercise Cruz *et al.*, 2015 found out that caffeine spares the endogenous

carbohydrate stores during submaximal performance around one hour and maintains maximal lactate steady state among cyclists.

Fluid

Exercising in the heat often results in an excessive increase in body core temperature, which can be detrimental to health and endurance performance. The ingestion of cold drinks can reduce body core temperature before exercise but less so during exercise (Tan and Lee, 2015).

Ergogenic foods

Supplementation of Carbohydrate and protein mixture has helped in improving the athletic performance (Amirdhaveni and Shoba, 2012). Effect of glucose ingestion on endurance performance was studied by Sugumar (2012) among ten male sports persons in the age 18 to 25 years. Each subject was given glucose mixed water or plain water and made to remain seated for 15 minutes. After that they were made to run in treadmill at 4km/h/minute, at 60 percent of target heart rate for 30 minutes and 90 percent of heart rate until they exhausted. The results revealed that there was a significant improvement on endurance performance due to the effect of glucose ingestion. Ingesting carbohydrate during prolonged exercise influences neurotransmitter production in the brain in a way that delays the onset of 'central fatigue' in addition to the positive metabolic effects on the working muscle.

Hemaprabha and Sreelakshmi (2012) had developed an egg protein enriched ready to eat cookies to enhance sports performance. Organoleptic analysis revealed that incorporation of spray dried whole egg at 5 per cent levels in cookies with best overall acceptability scores.

Assessment of physical fitness and impact of spinach extract (Octacosanol) intake on the antioxidative status of athletes revealed that the TBARS, glutathione concentration and SOD levels had increased. Since Octacosanol has shown beneficial effects it can be recommended as a supplement for athletes to enhance their performance (Lalitha *et al.*, 2012).

Efficacy of multinutrient supplementation on nutritional status and physical endurance of sports persons by Sairam *et al.*, (2012) showed a positive effect of a multinutrient supplement on physical endurance namely cardio-respiratory endurance (treadmill) muscular endurance (push-ups) and nutritional status of sports persons.

Specific training with creatine supplementation among women athletes found to be better than specific training group without supplement and control group in improving body mass, total body water level and decreasing total body fat level due to specific training (Malathi *et al.*, 2012).

Magnesium supplementation (250mg/day) in oxidative stress showed improvements in cardio respiratory function (Prakash, 2012).

Cereals like rice flakes, samai, bajra along with other ingredients like soyabean, gingelly seed and jaggery were combined to formulate an iron rich supplement to enhance the performance of college athletes (Sangeetha *et al.*, 2012).

Calcium rich pre exercise breakfast meal containing 1350 mg of calcium consumed 90 minutes before a prolonged and high intensity bout of stationary cycling, attenuates the exercise induced rise in markers of bone resorption (Haakonssen, 2015).

Supplementation with purple grape juice showed an ergogenic effect in runners by promoting increased time-to-exhaustion, accompanied by increased antioxidant activity and a possible reduction in inflammatory markers (Toscano *et al.*, 2015).

Avocados are the rich source of disease fighting antioxidants such as A,C and E that help in clearing dangerous free radicals. Avacados milkshake supplementation to sports persons during training and before endurance events helped in the resistance of fatigue,thus maintaining fitness (Selvanayaki and Arulmozhi, 2011).

Supplementation of sports food made of sorghum, soyflour, skimmed milk powder and sugar powder enhanced the endurance capacity significantly in terms of calories burnt, distance covered and the time of exhaustion in treadmill test (Asha *et al.*, 2009).

Capsules containing 3.6 g/day of eicosapentanoic acid rich fish oil supplementation improved exercise economy in humans(Kavabata *et al.*,2015).