Dr. Siddhartha Debnath Memorial Oration: 2015

PHYSIOLOGY OF SOCCER IN INDIAN CONTEXT

INDRANIL MANNA*

Department of Physiology, Midnapore College (Autonomous), Midnapore, West Bengal, India; ***E-mail****: indranil_manna@yahoo.com*

Soccer is the world's most popular sport. A common aspect of this sport is the necessity of teamwork to complement individual skills. In order to adapt to technical evolution within the game, players have to meet the physical demands required. Soccer talent may be identified among the children at their early childhood. Furthermore, growth and development phase of life has impact on training. Anthropometric, physical and physiological variables contribute to selection procedures. Besides, success is based on the synthesis of anthropometric characteristics and motor abilities as well as optimal technique. To achieve the best possible performance, training has to be formulated according to the principles of periodization. Long term training and participating in competitions brought the changes within the soccer players, which can be monitored through various anthropometric, physical and physiological variables. This would enable the coaches to assess the current status of the soccer players and the degree of training adaptability and provide an opportunity to modify the training schedule accordingly to achieve the desired performance. However, the present status of the Indian soccer team is not satisfactory at international level. Therefore, extensive research work is needed in this arena to improve the status of the Indian Soccer team.

Soccer (football) is unarguably the world's most popular sport. A common aspect of this sport is the necessity of teamwork to complement individual skills. Soccer is characterised as a high intensity intermittent sport (Hoff, 2005; Reilly *et al.*, 2000a). The game is played for 90 minutes, during which players run at different speeds and execute technical skills randomly. A high number of accelerations and decelerations, associated with the large number of changes in direction of play create an additional load to the muscles involved as in soccer, those players better suited to cope with the demands of the game reach the elite level (Hoff, 2005; Reilly and Secher, 1990). The game of soccer underwent a tactical change. The intermittent high intensity pattern of activity during the match requires a high function of both the aerobic and anaerobic energy delivery pathways (Impellizzeri *et al.*, 2006). It has been reported that the anthropometric, physiological and biochemical characteristics of soccer players have a role as part of a holistic monitoring of players (Miller *et al.*, 2007; Nedeljkovic *et al.*, 2007).

Body composition has an important role in playing soccer (Gil *et al.*, 2007). Since in soccer lots of physical contacts occur and many movements and skills are involved a high level of physical demand is required which involves kicking, short sprinting, throwing, catching, trapping, etc (Hoff, 2005; Reilly, 2005). Since soccer players have to cover a big area in the ground during attacks and defenses, the game demands for aerobic fitness as

***Corresponding author.** : **Indranil Manna**, Department of Physiology, Midnapore College (Autonomous), Midnapore, West Bengal, India; **E-mail**: indranil_manna@yahoo.com

well as anaerobic one (Reilly, 2005; Miller *et al*., 2007). A high number of accelerations and decelerations associated with a large number of changes in direction of play create an additional load to the muscles involved. So, just those players who are suited to cope with these demands reach elite levels (Reilly, 2005; Miller *et al*., 2007). The intermittent high intensity pattern of activity during matches requires a high function of both aerobic and anaerobic energy delivery pathways (Impellizzeri *et al*., 2006; Reilly and Secher, 1990). Moreover, power and strength have great impacts over the game which is required during sprinting and in execution of various skills with the ball (Hoff, 2005; Reilly, 2005).

Soccer talent has several properties that are genetically transmitted. Nevertheless, talent is not always evident at an early age but trained people may be able to identify its existence by using certain markers (Impellizzeri *et al*., 2006; Reilly *et al*., 2000a). These early indications of talent may provide a basis for predicting those individuals who have a reasonable chance of succeeding at a later stage. To identify athletic potentiality, norms of the anthropometric, physical and physiological profiles have an importance because they represent the health, metabolic and cardiovascular status of the athletes, which relates with the achievement level of a particular group (Impellizzeri *et al*., 2006). Various factors like socio-economic condition, diet, physical activity may reflect on these variables. Upon selection athletes underwent a long term training programme. The yearly training plan is formulated according to the age groups. Training helps to develop the Physique, strength, endurance as well as skills (Bompa, 1999). To achieve the best possible performance, training has to be formulated according to the principles of periodization (Bompa,1999). Furthermore, growth and development phase of life has impact on training (Impellizzeri *et al*., 2006; Reilly *et al.*, 2000b). The training-induced changes observed in various anthropometric and physiological parameters can be attributed to appropriate load dynamics.

The present review is focused on the three basic areas of Soccer: (a) Talent Identification and (b) Soccer Training and (c) Monitoring Soccer Performance.

2. TALENT IDENTIFICATION

Identifying and selecting talented soccer players are not straightforward operations. Detection and identification of talent are more difficult in team games than in individual sports such as running, cycling or rowing, where predictors of performance are more easily scientifically prescribed (Reilly *et al.*, 2000b). Sports talent may be identified from children at their early age when they show interest in different sports (Impellizzeri *et al.*, 2006; Reilly, 2005). Anthropometric, physical and physiological profiles contribute to selection procedures (Impellizzeri *et al.*, 2006; Reilly *et al.*, 2000b).

2.1. Anthropometric predictors of talent

Players' anthropometric characteristics [e.g. stature (height), body mass (weight), body composition, limb girth] are related to performance is important (Impellizzeri *et al.*, 2006; Reilly, 2000b). The implication is that such measurements may assist in the identification of talent (Reilly *et al*., 2000b). Successful young soccer players, for instance, appear to have similar somatotypes/physiques to older successful performers (Malina *et al.*, 2000). In particular, adult stature, which is commonly used for prediction, is strongly influenced by genetic factors (Impellizzeri *et al*., 2006), whilst other physical attributes (e.g. muscle mass, body fat) are seen as being more amenable to training, and dietary influences (Reilly *et al.*, 2000b).

Research evidence indicates that elite youth soccer players have greater biological age (i.e. more physically mature) than their less proficient counterparts and coaches appear to favour players advanced in morphological growth during the selection process (Malina *et al*., 2000). This trend in favour of children born early in the selection year (e.g. September–December) is apparent in several countries (e.g. Sweden, Belgium and United Kingdom) and persists into adult elite squads (Helsen *et al*., 2000). Over 50% of players who attended the English Football Association's National School when it was based at Lilleshall were born between September and December (Reilly *et al*., 2000b). A similar percentage of players selected for the England national team during the 1986, 1990, 1994 and 1998 World Cup qualifying campaigns were born early in the selection year (Reilly *et al*., 2000b). This latter finding suggests a 'residual bias' as a result of selection policies at youth level that favour individuals born in the early part of the academic year (Impellizzeri *et al*., 2006). The discrimination bias was particularly evident with goalkeepers and defenders, who tended to be the tallest and heaviest players at adult level (Reilly *et al.*, 2000b).

Many of the physical qualities that distinguish elite and sub-elite players may not be apparent until late adolescence, confounding the early selection of performers (Reilly *et al*., 2000b). The implication is that the prediction of future elite players from anthropometric measurements may be unrealistic in younger age groups because performance could be affected by the player's rate of physical growth and maturation. Since late maturing children can compensate for any apparent disadvantage in size and strength by working on their technical capabilities or by improvements in other areas (such as agility and muscular power), it is important that the talent identification process is not overly biased toward the early maturing child. Any potential bias can result in late maturing and potentially talented players dropping out of the game at an early age. Furthermore, late maturing players are more likely to miss out on the experience of high quality coaching. So the young players should be selected on skill and ability rather than on physical size. Helsen *et al*. (2000) suggested some potential solutions to the problem of seasonal birth date distribution. A reduction in age-band range and closer matching of players into groups based on maturational rather than chronological age may be fruitful avenues to explore. Furthermore, more flexibility in allowing players to move between age-bands for certain training practices should also be helpful.

2.2. Physiological predictors of talent

Physiological measures have also been employed in an attempt to identify key predictors of performance (Reilly *et al.*, 2000b). A study compared successful and less successful 15–17-yearolds using measures of maximal oxygen uptake (VO_{2max}), anaerobic power, grip and trunk strength measures, and heart volume (Reilly *et al*., 2000b). They deemed successful players to be those who were later selected in clubs playing in the top league in Croatia, Germany, Italy and England, whilst those considered less successful did not progress beyond regional leagues. The successful players had superior physiological fitness compared to the others. It has been noted that performance in short (30 m) and prolonged 'shuttle' running discriminated between successful and less successful 11–12-year-old soccer players (Reilly *et al*., 2000b). Similarly, in a study on elite 16-year-olds recorded better performance in running and jumping than their less elite counterparts. Such findings led to conclude that physiological measures could be useful in predicting later success in soccer (Reilly et al., 2000b). Nevertheless, the possibility remains that in the above studies part of the physiological superiority of the successful players was due to a more systematic approach to training prior to their induction into the specialized under-age squad.

Although physiological measures such as maximal oxygen uptake (VO_{2max}) have been successful in distinguishing between expert and intermediate young players, they may not be sensitive enough to distinguish players already selected and exposed to systematised training for national teams. In a study, by Franks *et al*. (1999) analysed data from 64 players who attended the English Football Association's National School (14–16 years) between 1989 and 1993. Anthropometric characteristics as well as aerobic and anaerobic measurements were recorded. Players were categorized according to playing 'position' and whether they had signed a full-time 'professional' contract on graduation. No differences were observed between those who were deemed to be more or less successful. In a group of youth players already highly selected, other factors may determine their employability as professionals. It may well be that talent becomes harder to predict in later years since the population of players becomes smaller and more homogeneous, particularly with respect to their physical and physiological profiles. Those who have not developed the requisite characteristics tend to drop out of the sport at an early age.

Physiological measurements may be useful alongside subjective judgments of playing skills for initial detection of talent, but such measures do not appear sensitive performance indicators on a global basis and cannot be used reliably on their own for purposes of talent identification and selection. Moreover, while research using twin siblings has indicated that physiological characteristics are highly genetically predisposed, appropriate training can have a pronounced influence (Bouchard *et al.*, 1997). Although some people may be more favoured genetically than others to adapt and benefit from training, particularly with regard to the relative distribution of muscle fibre types (Bouchard *et al*., 1997), physiological responses to exercise are highly dependent on regular training and practice (Reilly *et al.*, 2000b). It is likely therefore that physiological correlates of work-rate during games have gained in importance in the context of fitness for soccer. Physiological values indicative of aerobic fitness, such as VO_{2max}, may be more influential in successful performance in the future. Consequently, a relatively high threshold for oxygen uptake capability may be a significant criterion when young players are assessed. However, there is concern regarding the extent to which a high fitness indicator tracks through from childhood to adulthood.

3. SOCCER TRAINING

Soccer players need a high level of fitness to cope with the physical demands of a game and to allow for their technical skills to be utilized throughout a match. Therefore, fitness training is an important part of the overall training programme. Common to all types of fitness training in soccer is that the exercise performed should resemble match-play as closely as possible.

3.1. Components of fitness training

Fitness training has to be multifactorial in order to cover the different aspects of physical performance in soccer. Thus, the training can be divided into a number of components based on the different types of physical demands during a match. The terms aerobic and anaerobic training are based on the energy pathway that dominates during the activity periods of the training session. Aerobic and anaerobic training represent exercise intensities below and above the maximum oxygen uptake, respectively. However, during a training game, the exercise intensity for a player varies continuously, and some overlap exists between the two categories of training (Bompa, 1999).

3.1.1. Aerobic training

Aerobic training causes changes in central factors such as the heart and blood volume, which result in a higher maximum oxygen uptake (Ekblom, 1969). A significant number of peripheral adaptations also occur with this type of training (Henriksson and Hickner, 1996). The training leads among other things to a proliferation of capillaries and an elevation of the content of mitochondrial enzymes, as well as the activity of lactate dehydrogenase 1–2 isozymes (LDH1–2). Furthermore, the mitochondrial volume and the capacity of one of the shuttle systems for NADH are elevated (Schantz and Sjøberg, 1985). These changes cause marked alterations in muscle metabolism. The overall effects are an enhanced oxidation of lipids and sparing of glycogen, as well as a lowered lactate production, both at a given and at the same relative work-rate (Henriksson and Hickner, 1996).

The optimal way to train the central versus the peripheral factors is not the same. Maximum oxygen uptake is most effectively elevated by exercise intensities around 80–100% of VO_{2max} (20–40% of maximal exercise intensity). For muscle adaptation to occur, an extended period of training appears to be essential, and therefore, the mean intensity has once in a while to be below 80% of VO2max. This does not imply that high-intensity training does not elevate the number of capillaries and mitochondrial volume in the muscles engaged in the training, but the duration of this type of training is often too short to obtain optimal adaptations at a local level (Reilly et al., 2000a; Reilly, 2005).

The dissociation between changes in VO2max and muscle adaptation by means of training and detraining is illustrated by results from a study on top-class players (Bangsbo and Mizuno, 1988). The players abstained from training for 3 weeks. It was found that VO2max was unaltered, whereas performance in a field test was lowered by 8%, and there was a reduction in oxidative enzymes of 20–30%.

The recovery processes from intense exercise are related both to the oxidative potential and to the number of capillaries in the muscles (Tesch and Wright, 1983). Thus, aerobic training not only improves endurance performance of an athlete, but also appears to influence an athlete’s ability to perform maximal efforts repeatedly. The overall aim of aerobic training is to increase the work-rate during competition, and to minimize a decrease in technical performance as well as lapses in concentration induced by fatigue towards the end of a game. The specific aims of aerobic training are as follows.

- To improve the capacity of the cardiovascular system to transport oxygen. Thus, a larger percentage of the energy required for intense exercise can be supplied aerobically, allowing a player to work at higher exercise intensity for prolonged periods of time.
- To improve the capacity of muscles specifically used in soccer to utilize oxygen and to oxidize fat during prolonged periods of exercise. Thereby, the limited store of muscle glycogen is spared and a player can exercise at a higher intensity towards the end of a game.
- To improve the ability to recover after a period of high-intensity exercise. As a result, a player requires less time to recover before being able to perform in a subsequent period of high-intensity exercise.

3.1.1.1. Components of aerobic training

Aerobic training can be divided into three overlapping components: aerobic low-intensity training (AerobicLI), aerobic moderate-intensity training (AerobicMI) and aerobic high-intensity training (AerobicHI). The principles behind the various categories of aerobic training, which take into account that the training may be performed as a game, and thus, the heart rate (HR) of a player will frequently alternate between categories during the training. During AerobicLI the players perform light physical activities, such as jogging and low-intensity games. This type of training may be carried out the day after a match or the day after a hard training session to help a player recover to a normal physical state. Aerobic may also be used to avoid the players getting into a condition known as ‘overtraining’ in periods involving frequent training sessions and a busy competitive schedule of matches. The purpose of AerobicMI training is to elevate the capillarization and the oxidative potential in the muscle (peripheral factors). The functional significance is an optimization of the substrate utilization and thereby an improvement in endurance capacity. The main aim of AerobicHI training is to improve central factors such as the pump capacity of the heart, which is closely related to VO_{2max}. These improvements increase a player’s capability to exercise repeatedly at high intensities for prolonged periods of time during a match (Bompa, 1999; Reilly, 2005).

3.1.2. Anaerobic training

During a match, a player frequently performs activities that require rapid development of force, such as sprinting or quickly changing direction. Furthermore, findings of high blood lactate concentrations in top-class players during match-play indicate that the lactate producing energy system (glycolysis) is highly stimulated during periods of a game. Therefore, the capacity to perform high-intensity exercise repeatedly should be specifically trained. This can be achieved through anaerobic training (Bompa, 1999).

Anaerobic training results in an increase in the activity of creatine kinase (CK) and glycolytic enzymes, such an increase implies that a certain change in an activator results in a higher rate of energy production of the anaerobic pathways. Intense training does not appear to influence the total creatine phosphate (CP) pool, but it leads to elevated muscle glycogen levels, which is of importance for performance during repeated high-intensity exercise (Reilly and Bangsbo, 1998). The capacity of the muscles to release and neutralize H+ (buffer capacity) is also increased after a period of anaerobic training (Pilegaard *et al.*, 1999). This will lead to a lower reduction in pH for a similar amount of lactate produced during high-intensity exercise. Therefore, the inhibitory effects of H+ within the muscle cell are smaller, which may be one of the reasons for a better performance in high-intensity tests after a period of anaerobic training. Another important effect of anaerobic training is an increased activity of the muscle Na+/K+ pumps resulting in a reduced net loss of potassium from the contracting muscles during exercise, which may also lead to increased performance (Bangsbo, 1997).

The overall aim of anaerobic training is to increase an athlete's potential to perform high intensity exercise. The specific aims of anaerobic training are summarized below. These are:

- To improve the ability to act quickly and to produce power rapidly. Thus, a player reduces the time required to react and elevates performance of sprinting.
- To improve the capacity to produce power and energy continuously via the anaerobic energy-producing pathways. Thereby, a player elevates the ability to perform high intensity exercise for longer periods of time.
- To improve the ability to recover after a period of high-intensity exercise, which is particularly important in soccer. As a result, a player requires less time before being able to perform maximally in a subsequent period of exercise, and the player will be able to perform high-intensity exercise more frequently during a match.

3.1.2.1. Components of anaerobic training

Anaerobic training can be divided into speed training and speed endurance training. The aim of speed training is to improve a player's ability to act quickly in situations where speed is essential. Speed endurance training can be separated into two categories: production training and tolerance training. The purpose of production training is to improve the ability to perform maximally for a relatively short period of time, whereas the aim of tolerance training is to increase the ability to sustain exercise at a high intensity (Bompa, 1999; Reilly, 2005).

Anaerobic training must be performed according to an interval principle. During speed training the players should perform maximally for a short period of time (10 s). The periods between the exercise bouts should be long enough for the muscles to recover to near resting conditions, so as to enable a player to perform maximally in a subsequent exercise bout. In soccer, speed is not merely dependent on physical factors. It also involves rapid decision-making, which must then be translated into quick movements. Therefore, speed training should mainly be performed with a ball. Speed drills can be designed to promote a player's ability to sense and predict situations, and the ability to decide on the opponents' responses in advance (Bompa, 1999; Reilly, 2005).

By speed endurance training, the creatine kinase and glycolytic pathways are highly stimulated. The exercise intensity should be almost maximal to elicit major adaptations in the enzymes associated with anaerobic metabolism. In *production training*, the duration of the exercise bouts should be relatively short (15 –40 s), and the rest periods in between the exercise bouts should be comparatively long (2–4 min) in order to maintain a very high intensity during the exercise periods throughout an interval training session. In *tolerance training* the exercise periods should be 20–90 s and the duration of the rest periods should be 1–3-fold longer than the exercise periods, to allow the players to become progressively fatigued (Bompa, 1999; Reilly, 2005).

The adaptations caused by speed endurance training are mostly localized to the exercising muscles. Thus, it is important that a player performs movements in a manner similar to match-play. This can be obtained with high-intensity games or drills with a ball. It also shows HR and blood lactate values for a player during the game illustrating that the game fulfills the criteria for speed endurance training (Bompa, 1999; Reilly, 2005).

Speed endurance training is both physically and mentally demanding for the players. Therefore, it is recommended that this type of training is only used by top-class players. When there is a limited time amount of time available for training, time can be better utilized on other forms of training (Bompa, 1999; Reilly, 2005).

3.1.3. Specific muscle training

Specific muscle training involves training of muscles in isolated movements. The aim of this type of training is to increase performance of a muscle to a higher level than can be attained just by playing soccer. Specific muscle training can be divided into muscle strength, muscle speed endurance and flexibility training. The effect of this form of training is specific to the muscle groups that are engaged, and the adaptation within the muscle is limited to the kind of training performed (Bompa, 1999; Reilly, 2005).

3.1.3.1 Strength training

Many activities in soccer are forceful and explosive, for example, jumping, kicking, tackling and turning. The power output during such activities is related to the strength of the muscles involved in the movements. Thus, it is beneficial for a player to have a high level of muscular strength, which can be obtained by strength training (Bompa, 1999; Reilly, 2005).

Strength training can result in hypertrophy of the muscle, partly through an enlargement of muscle fibres. In addition, training with high resistance can change the fibre type distribution in the direction of fast twitch fibres (Andersen *et al.*, 1994). There is also a neuromotor effect of strength training and part of the increase in muscle strength can be attributed to changes in the nervous system. Improvements in muscular strength during isolated movements seem closely related to training speeds. However, significant increases in force development at very high speeds (10–18 rad s-1) have also been observed with slow-speed high resistance training (Aagaard *et al.*, 1994).

One essential function of the muscles is to protect and stabilize joints of the skeletal system. Hence, strength training is of importance also in preventing injuries as well as re-occurrence of injuries. A prolonged period of inactivity, for example, during recovery from an injury, will considerably weaken the muscle. Thus, before a player returns to training after an injury, a period of strength training is needed. The length of time required to regain strength depends on the duration of the inactivity period but generally several months are needed. For a group of soccer players observed 2 years after a knee operation, it was found that the average strength of the quadriceps muscle of the injured leg was only 75% of the strength in the other leg (Reilly and Secher,1990).

The overall aim of muscle strength training is to develop an athlete's muscular make-up.

The overall aim of muscle strength training is to develop an athlete's muscular make-up. The specific aims of muscle strength training are as follows:

- To increase muscle power output during explosive activities such as jumping and accelerating.
- To prevent injuries.
- To regain strength after an injury.

3.1.3.2. Components of strength training

Strength training can be divided into functional strength training and basic strength training. In functional strength training, movements related to the sport are used. The training can consist of activities in which typical movements are performed under conditions that are physically more stressful than normal. During basic strength training, muscle groups are trained in isolated movements. For this training, different types of conventional strength training machines and free weights can be used, but body weight may also be used as resistance. Strength training should be carried out in a manner that resembles activities and movements specific to the sport. Based on the separate muscle actions the basic strength training can be divided into isometric, concentric and eccentric muscle strength training. Several principles can be used in concentric strength training (Bompa, 1999; Reilly, 2005).

Common to the two types of strength training is that the exercise should be performed with a maximum effort. After each repetition the player should rest a few seconds to allow for a higher force production in the subsequent muscle contraction. The number of repetitions in a set should not exceed 15. During each training session two to four sets should be performed with each muscle group, and rest periods between sets should be longer that 5 min. During this time, the athletes can exercise with other muscle groups (Bompa, 1999; Reilly, 2005).

3.1.4. Training methods

The yearly training plan is an important tool for achieving long-range athletic goals (Bompa, 1999). To achieve this high level of performance, the entire training program must be properly periodized and planned so that the development of skills and motor abilities proceeds logically and methodically throughout the year (Arnold and Gentry, 2005; Bompa, 1999). A periodized annual training plan is classically divided into different phases. The characteristics of a phase are that the overall goal of the training remains the same and that the tendency in the training load remains consistent over the phase. Phases are in turn, subdivided into smaller units, called macro cycles and micro cycles (Arnold and Gentry, 2005; Bompa, 1999). Macro cycles are used to control the training load and the fatigue level generated by training. The next level down is the micro cycle, which account for the volume of training, the intensity of the training, and the systems trained (Arnold and Gentry, 2005;

Bompa, 1999). The volume and intensity are inversely related to each other during the entire training programme (Arnold and Gentry, 2005; Bompa, 1999).

General Preparation is usually the first phase of any periodized plan. In this phase, training focuses on developing a foundation for the sport performance. This is where the athlete trains those systems that are slow to change, for example, the aerobic energy systems. Long term changes, such as increasing muscle mass and strength would also be targeted in this phase. Training is aimed primarily at overall fitness. Volume/load would be increasing throughout (Arnold and Gentry, 2005; Bompa, 1999).

Specific preparation is a continuation of the preparation phase, but signals a transition into more sport specific training. Also during this phase, the athlete would begin to work on systems that train more easily than those targeted in general preparation. Pre-competition is the phase where the athlete prepares specifically for competition. The peak volume (hr week-1) in this phase may be less than in the previous phase, or it may be more depending on the sport type, training history and the length of the Competition Phase. Generally, if the volume is less, the intensity of training will be increased. In order to perform well in the competition, the athlete should be relatively rested. To accomplish this, the total volume and the fatigue levels are reduced significantly in this phase (Bompa, 1999; Reilly, 2005).

Taper phase is primarily designed to lower the accumulated fatigue level to as low a value as possible. Volume is gradually lowered across the phase (Bompa, 1999). Peak is the peak performance time. It may be only one competition lasting two days, or it may be a week or more of play-downs leading to a final competition. Emphasis is on mental preparation, performance and recovery. Relax is a de-tuning phase, in which the training load and its intensity is gradually lowered from the levels experienced in the competition phase (Arnold and Gentry, 2005). Off-season is not a training phase; it is a stage in the year devoted to recovery and regeneration (Arnold and Gentry, 2005).

The most common approach to integrate dimensions of sports activities with the physiological mechanisms is to focus on metabolic systems, moreover as the dominant concern in training is with the energy production in support of muscular contractions. The metabolism during physical activity can be broadly divided into aerobic and anaerobic supply system (Katch *et al.*, 2011). The main task of the coach is to identify the physiological system involved in an event that needs to be trained for optimal work performance. Once the system to be trained is identified, then focus should be on how to improve it with training (Arnold and Gentry, 2005; Bompa, 1999).

4. MONITORING SOCCER PERFORMANCE

Regular monitoring of anthropometric, physical and physiological variables of soccer players can provide valuable information about their health, metabolic, cardiovascular status and performance at large.

4.1. Anthropometric Variables

The anthropometric profile reflects in part the ethnic background of a player, and occasionally individuals can be very successful because high skill and motivation compensate for what appears to be an unfavourable body type (Nedeljkovic *et al*., 2007). Equally, a skilful coach can modify tactics to accommodate an unusual body build in a particular player. In recent years, there has been a tendency to recruit taller and heavier players (Silvestre *et al,* 2006). Physical growth in children is measured by changes in body size and/ or composition as well as physical profile (Katch *et al.*, 2011). During childhood and adolescence, body size and composition markedly change. These changes are strongly associated with the development of various physical performance characteristics. Body size play important role during selection of players (Johnson *et al*., 2009). The tall players are generally recruited in soccer for goalkeeper, defender and forward position however a standard height should be maintained for selection of players for each position. Body mass come into play since body contact is essential in football. Heavy weight players get an advantage in defence. However, a standard body mass is required for every playing positions (Reilly and Secher, 1990). Body mass is a considerable factor in games and sports, since body contact is essential in soccer (Silvestre *et al,* 2006). The body mass varies with race and ethnic variation (Reilly and Secher, 1990). A recent study on talent selection has reported that height and body mass of the children increase linearly with their increasing age (Manna *et al.*, 2014). These changes might be because of level of maturation factors and / or motivation, and exposure to long term and higher intensity of training among the Postpubertal children when compared with Prepubertal and Pubertal children (Manna *et al*., 2014). In another study on the effects of 12 weeks of training on the soccer players has been reported that there is no significant influence of short duration of training on body mass (Manna *et al.*, 2010). The osteotropic effect of exercise is dependent on load dynamics, the volume, intensity and duration of training, administered on the individual and the period in life when exposure occurs (Katch *et al*., 2011). The gain in height is dependent on growth hormone and exercise is a potent stimulus for growth hormone (Katch *et al*., 2011). It has been reported that genetic influence can alter morphological status only within a narrow limit, set by his genotype (Impellizzeri *et al*., 2006). Growth in body weight follows the same trend as in case of height. Increase in muscle mass with age, appears to result primarily from hypertrophy of existing fibres. The gain in weight is dependent on growth hormone and exercise is a potent stimulus for growth hormone (Katch *et al*., 2011). Apart from the hormonal effects the neural maturity also helps to gain desirable body weight in the athletes (Katch *et al*., 2011). It is possible that a particular body size will encourage acquisition of certain skills and force gravitation towards a specific playing position: this is likely to occur before maturity so that the individual will tend to favour one positional role before playing at senior level (Silvestre *et al*, 2006). It was found that the shorter body size (height and body mass) of the Indian elite soccer players compared to their international counterparts may be one of the reasons of their limitation in success at the international arena (Manna *et al.*, 2010).

The percentage of body fat plays an important role for the assessment of physical fitness of soccer players (Ostojic, 2003). Generally, the amount of fat in an adult male in his mid-twenties is about 16.5% of body weight (Katch *et al*., 2011). A lean body is desirable for sports like soccer (Ostojic, 2003; Reilly *et al.*, 2000a). A low-body fat may improve athletic performance by improving the strength-to-weight ratio (Katch *et al*., 2011). Excess body fat adds to the load without contributing to the body's force-producing capacity (Katch *et al.*, 2011). It can be stated that excess body fat can limit the aerobic and anaerobic performance of the players. It has been noted that the postpubertal children had lower body fat values compared with Prepubertal and Pubertal children (Manna *et al.*, 2014). However, significant increase in LBM was noted in Postpubertal children when compared to Prepubertal and Pubertal children. This might be due to long term effect of exercise among the Postpubertal children than Prepubertal and Pubertal children which reduces the body fat and which shows higher LBM among the Postpubertal children (Manna *et al.*, 2014). It has also been reported that the body fat reduced after training with an increase in LBM among the soccer players (Manna *et al.*, 2010). The possible reason of reduction of body fat and increase in LBM is exercise training, which increases greater utilization of fat for energy (Katch et al., 2011). Similar findings were also noted by other research groups who studied on soccer players and reported that percent body fat decreased significantly during preparatory and competitive phases of training when compared to baseline data (Kutlu *et al.*, 2007). Therefore, it can be stated that soccer players can accumulate body fat in off seasons when there is no training, and lose body fat during preparatory and competitive phases of training (Katch *et al.*, 2011). This might be due to intensive training during preparatory phase and high levels of performance during competitive phase (Katch *et al.*, 2011). Before and after competition season, during the interval periods, fat content of most soccer player's increase presumably as a result of reduced aerobic activity along with nutritional and behavioral changes (Katch *et al.*, 2011). The body fat content of top players is ? 10% during the playing season, but can rise to 19-20% between seasons (Kutlu *et al.*, 2007). Football players, even at the highest level, tend to have depots of body fat that seem higher than optimal (Reilly, 2005). It is advised to perform low intensity aerobic endurance exercises during the off seasons in order to reduce the excess accumulation of body fat during the off seasons. It was found that the higher body fat of the Indian elite soccer players compared to their international counterparts may be one of the reasons of their limitation in success at the international arena (Manna *et al.*, 2010).

4.2. Physical Fitness Variables

Physical fitness of the athletes can be assessed by measuring motor skills and activities such as strength, power, speed, flexibility and reaction time (Reilly and Secher, 1990; Jonathan *et al.*, 2009). Soccer demands high anaerobic power as quick acceleration and deceleration are important in this sport (Hoff, 2005; Reilly *et al.*, 2000a). Although most time of the game is spent in low-level activities such as walking and light jogging, repeated back-to-back sprints make speed and tolerance to lactic acid an important characteristic in players (Hoff, 2005; Reilly *et al.*, 2000a). A high anaerobic power is essential for such activities (Hoff, 2005; Reilly *et al.*, 2000a). Thus a high anaerobic power helps to develop sprint quality of the players (Hoff, 2005; Reilly *et al.*, 2000a). Anaerobic power represents the highest rate of anaerobic energy released (Katch *et al.*, 2011). On the other hand, strength is the central component of a soccer training program (Hoff, 2005; Reilly *et al.*, 2000a). Playing football involve intermittent activities i.e., short sprinting and casual recovery (Asci and Acikada, 2007; Hoff, 2005). Thus a high anaerobic power helps to develop sprint quality of the players (Asci and Acikada, 2007).

Since the early part of the century strength has been used as an indicant of fitness and performance in the athletes. The muscular strength of the soccer players appears to be related to the position in the team (Reilly, 2005). In a study of top-class Danish soccer players, muscular strength was lowest for the midfield players than fullbacks, goalkeepers, forwards and central defenders (Reilly and Secher, 1990). Strength of the back muscles plays a key role of fitness among the ball games players, as kicking, passing, changing pace etc. are part of the game (Malina *et al.*, 2000). Therefore, the game demands high level of back strength. The strength of grips also has significant impact on the performance of the players, which is needed for throwing, catching or fisting the ball. Stronger than normal grip would be expected in soccer players from the trend towards mesomorphy that is apparent in experienced players (Reilly *et al*, 2000a). It has been reported that strength gain increased throughout the season (Hoff, 2005; Reilly *et al*, 2000a).

Flexibility is the ability to move a joint or series of joints smoothly and easily throughout a full range of motion. An athlete who has a restricted range of motion will realize a decrease in performance capabilities. Flexibility is important in preventing injury to the musculotendinous and skeletal anatomy (Katch *et al.*, 2011; Reilly, 2005). There are some factors that limit flexibility are bony structure, excessive fat, skin, muscles and tendons, and connective tissues. With the exception of bony structure, age, and gender, all of the other factors that limit flexibility may be altered to increase range of joint motion. The reaction time is the time the athletes take for the body to react to a stimulus. The reaction time is very important for the track and field athletes as well as for players of different sports disciplines (Katch *et al.*, 2011; Reilly, 2005).

In our previous study it has been reported that postpubertal children had higher flexibility, strength, speed and power; and lower reaction time than Prepubertal and Pubertal children (Manna *et al.*, 2014). This might be because of level of maturation factors and/or motivation of the Postpubertal children when compared with Prepubertal and Pubertal children. In another study it has been noted that anaerobic power and strength increased after the training among the soccer players (Manna *et al.*, 2010). The greater gain in anaerobic power and strength was observed in U16 and U19 age groups, but less gain was noted in U23 and senior age group players. This might be due to maturation factors and / or motivation. However, the less gain in relative anaerobic power and strength output in senior players might be due to age related decline. Monitoring of power and strength at regular intervals is essential during the training seasons, which helps in selection of players for competitions (Hoff, 2005; Reilly, 2005). Power and strength have great impacts over the game which is required during sprinting and in execution of various skills with the ball (Hoff, 2005; Reilly, 2005). It was found that the lower anaerobic power and strength values of the Indian elite soccer players compared to their international counterparts may be one of the reasons of their limitation in success at the international arena (Manna *et al.*, 2010).

4.3. Physiological Variables

The maximal oxygen uptake (VO_{2max}) is the best overall measure of aerobic power (Katch *et al.*, 2011). Aerobic capacity certainly plays an important role in soccer and has a major influence on technical performance and tactical choices (Reilly *et al.*, 2000a). The maximal oxygen uptake (VO_{2max}) is the best overall measure of aerobic power (Miller *et al.*, 2007).

The average values of VO_{2max} for top-level soccer players tend to be high supporting the belief that there is a large contribution from aerobic power to playing the game (Hoff, 2005). Values for elite players lie in the region 55-70 ml kg-1 min-1, the higher values tending to be found at the top level of play and when players are at peak fitness (Hoff, 2005; Metaxas *et al*., 2006). Nevertheless, the consistent observation of mean VO_{2max} values exceeding 60 ml kg-1 min-1 in elite teams suggests the existence of a threshold below which an individual player is unlikely to perform successfully in top-class football (Hoff, 2005; Metaxas *et al.*, 2006; Miller *et al*., 2007).It has been reported that Postpubertal children had higher VO2max when compared to Prepubertal and Pubertal children. The higher level of VO_{2max} value in the postpubertal children might be because of exposure to long term and higher intensity of aerobic endurance training compared with Prepubertal and Pubertal children (Manna *et al.*, 2014). These changes might be due to the result of increased volume of endurance training among the Postpurbertal children (Katch *et al*., 2011). It is likely that the VO_{2max} of professional soccer players does improve significantly in the pre-season period when there is an emphasis on aerobic training (Hoff, 2005; Miller *et al.*, 2007). In another studies it has been noted that in U16, U19 and U23 age groups soccer players VO2max value increased significantly in preparatory phases of training when compared with that of the baseline data, but not in senior age group players (Manna *et al*., 2010). In U16, U19 and U23 the increase in VO_{2max} after training might be due to an increase in the systemic a-v O2 difference and stroke volume, when compared to senior players (Katch *et al.*, 2011). Moreover, these changes may be the result of increased volume of endurance training in preparatory phase (Katch *et al*., 2011). The aerobic endurance training enhances the activity of the cardiovascular system as well as developed oxidative capacity of the skeletal muscles which leads to an increase in the delivery of oxygen to working muscles (Katch *et al*., 2011). This is accepted as the main reason for elevation of VO_{2max} after a training program (Katch *et al*., 2011). Furthermore, a decline in VO_{2max} values was observed, although non-significantly, from preparatory phase to competitive phase (Manna *et al*., 2010). This may be because of the reduction in aerobic training during competitive phase. On the other hand, no significant change was noted in VO_{2max} values of the senior age group after the training program in preparatory and competitive phases when compared with the baseline data. It shows that VO_{2max} of the U16, U19 and U23 age groups soccer players might improve significantly with training in comparison to the senior players (Manna *et al*., 2010). Similar observation has been reported previously (Hoff, 2005; Reilly, 2005; Miller *et al*., 2007). The extent by which VO_{2max} could be changed with training also depends on the starting point (Katch *et al*., 2011; Reilly and Secher, 1990). The fitter an individual is to begin with, the less potential there is for an increase and most elite athletes hit this peak early in their career (Katch *et al*., 2011; Reilly and Secher, 1990). There also seems to be a genetic upper limit beyond which further increases in either intensity or volume have no effect on aerobic power (Katch *et al*., 2011). It was found that the lower VO_{2max} values of the Indian elite soccer players compared to their international counterparts may be one of the reasons of their limitation in success at the international arena (Manna *et al*., 2010).

Lung function tests also have value for predicting fitness and exercise performance, provided that the values fall within a normal range. The values of FVC, FEV1 and PEFR are used as indicators of lung disease (Katch *et al*., 2011). In a recent study it has been noted that Postpubertal children had higher lung volumes and capacities when compared to Prepubertal and Pubertal children (Manna *et al*., 2014). The higher FVC, FEV1 and PEFR of the postpubertal children might be because of exposure to long term and higher intensity of aerobic endurance training when compared with Prepubertal and Pubertal children. Moreover, this might be because of level of maturation factors and / or motivation of the Postpubertal children when compared with Prepubertal and Pubertal children (Manna *et al.*, 2014). Monitoring of lung functions at regular intervals may provide information about the respiratory status of the athletes. In addition, these values are essential for selection of athletes for the training and competitions.

Heart rate and blood pressure are essential for assessing cardiovascular fitness of the athletes. Heart rate increases with an increase in work intensity and shows a linear relationship with work rate (Katch *et al.*, 2011). The highest rate at which the heart can beat is the maximal heart rate (HRmax). Quick recovery from strenuous exercise is important in sports which involve intermittent efforts interspersed with short rests (Katch *et al.*, 2011). The heart rate recovery curve is an excellent tool for tracking a person's progress during a training program (Katch *et al*., 2011). The maximal heart rates of football players are close to the rates expected for non-athletic populations of similar age and race (Katch *et al.,* 2011; Reilly, 2005). Nevertheless there is a large variation in the maximal heart rates reported and this may be due, in part, to the exercise protocol used for testing (Katch *et al*., 2011). It has been reported that Postpubertal children had lower maximal heart rate (HRmax) and recovery heart rates when compared to Prepubertal and Pubertal children. However, no change was reported in resting heart rate among the groups (Manna *et al*., 2014). In another studies it has been noted that recovery heart rate decreased after the training program among all age groups soccer players (Manna *et al*., 2010). Exercise cardio acceleration results from release of parasympathetic inhibition at low exercise intensities and from both parasympathetic inhibition and sympathetic activation at moderate intensities (Katch *et al.*, 2011). Nevertheless, para¬sympathetic activation is considered to be the main mechanism underlying exponential cardio deceleration after exercise (Katch *et al.*, 2011). On the other hand, no significant change was detected in HRmax of the players after the training course (Manna *et al.*, 2010). This might be due to short duration of the training which has been shown in former studies (Katch *et al.*, 2011). It can be suggest that the strain on the circulatory system during playing soccer is relatively high. Exercising at this intensity should provide a good training stimulus. Therefore, heart rate monitoring is essential during the training seasons, which also provides a database to the coaches for selection of players.

5. CONCLUSION

The anthropometric and physiological profiles of the soccer players influence their technical performance and tactical choices. Acting upon the presented information may give soccer players, teams and coaches a big advantage in the search for a successful career. Identification of children at early stage of their growth and development may produce elite soccer player in the future. In order to reach their goals, young children should be subjected to a series of tests reflecting anthropometric, physical and physiological fitness variables which indicate their present over all strengths and weaknesses. Training effects were reflected on various parameters like body fat, aerobic capacity, anaerobic power, strength, haemoglobin, urea, uric acid, and lipid profile of soccer players. Improvement in these parameters depends on level of maturation factors and/or motivation, and exposure to long term and higher intensity of training. The unique profile of age-related changes should be taken into consideration while administering training to the players. This would enable coaches to assess the current status of an athlete and the degree of training adaptability and to provide an opportunity to modify the training schedule accordingly to achieve the desired performance. The present status of the Indian soccer team is not satisfactory at international level. Therefore, an extensive research is required in this arena.

REFERENCES

Aagaard P, Trolle M, Simonsen EB, Klausen K and Bangsbo J (1994): Moment and power generation during maximal knee extension performed at low and high speed. Eu. J. Appl. Physiol. **69**, 376–381.

Andersen JL, Klitgaard H, Bangsbo J and Saltin B (1994): Myosin heavy chain isoform in single fibres from m. vastus lateralis of soccer players: effects of strength-training. Acta Physiol. Scand. **150**, 21–26.

Arnold P and Gentry M (2005): Strength training: what the team physician needs to know. Curr. Sports. Med. Rep. **4**, 305-308.

Asci A and Acikada C (2007): Power production among different sports with similar maximum strength. J. Strength. Cond. Res. **21**, 10-16.

Bangsbo J and Mizuno M (1988): Morphological and metabolic alterations in soccer players with detraining and retraining and their relation to performance. In: Science and football (eds Reilly T, Lees A, Davids K and Murphy WJ) E and FN Spon. London, 114-124.

Bangsbo J (1997): Physiology of muscle fatigue during intense exercise, in Clinical Pharmacology of Sport and Exercise (eds T. Reilly and M. Orme), Elsevier. Amsterdam, 123–131.

Bompa TO (1999): Periodization Training. In: Bompa TO (ed). Periodization Training for Sports. Human Kinetics. Champaign, IL. 147-311.

Bouchard C, Malina RM and Perusse L (1997): Genetics of Fitness and Physical Performance. Human Kinetics. Champaign, IL.

Ekblom B (1969): Effect of physical training on the oxygen transport system in man. Acta Physiol. Scand. (S). **328**, 5–45.

Franks A, Williams AM, Reilly T and Nevill A (1999): Talent identification in elite youth soccer players: physical and physiological characteristics. J. Sports. Sci. **17**, 812.

Gil SM, Gil J, Ruiz F, *et al* (2007): Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process. J. Strength. Cond. Res. **21**, 438-445.

Helsen WF, Hodges NJ, Van Winckel J and Starkes JL (2000): The roles of talent, physical precocity and practice in the development of soccer expertise. J. Sports. Sci. **18**, 727–736.

Henriksson J and Hickner RC (1996): Skeletal muscle adaptation to endurance training, in Intermittent High Intensity Exercise (eds D.A.D. MacLeod, R.J. Maughan, C. Williams, C.R. Madeley, J.C.M. Sharp and R. W. Nutton), E & FN Spon. London, 5–26.

Hoff J (2005): Training and testing physical capacities for elite soccer players. J. Sports. Sci. **23**, 573-582.

Impellizzeri FM, Marcora SM, Castagna C, *et al* (2006): Physiological and performance effects of generic versus specific aerobic training in soccer players. Int. J. Sports. Med. **27**, 483-492.

Johnson A, Doherty PJ and Freemont A (2009): Investigation of growth, development, and factors associated with injury in elite schoolboy footballers: prospective study. BMJ. **338**, b490.

Jonathan M, Mc Gavock BD, Torrance K, Mc Guire A, Wozny PD and Lewanczuk RZ (2009): Cardiorespiratory Fitness and the Risk of Overweight in Youth: The Healthy Hearts Longitudinal Study of Cardiometabolic Health. Obesity. **17**, 1802–1807.

Katch VL, Mc Ardle WD and Katch FI (2011): Essentials of Exercise Physiology. 4th ed. Lippincott Williams and Wilkins. Philadelphia PA.

Kutlu M, Sofi N and Bozkus T (2007): Changes in body compositions of elite level amature and professional soccer players during the competitive season. J. Sport. Sci. Med. **S10**, 53.

Malina RM, Peña Reyes ME, Eisenmann JC, Horta L, Rodrigues J and Miller R (2000): Height, mass and skeletal maturity of elite Portuguese soccer players aged 11–16 years. J. Sports. Sci. **18**, 685–693.

Manna I, Khanna GL and Dhara PC (2010): Effect of Training on Physiological and Biochemical Variables of Soccer Players of Different Age Groups. As. J. Sports. Med. **1**, 5-22.

Manna I, Pan SR and Chowdhury M (2014): Anthropometric, Physical, Cardiorespiratory Fitness and Lipids and Lipoproteins Profile of Young Indian Children of 10-16 Years Age Group. Am. J. Sports. Sci. Med. **2**, 154-160.

Metaxas T, Sendelides T, Koutlianos N and Mandroukas K (2006): Seasonal variation of aerobic performance in soccer players according to positional role. J. Sports. Med. Phys. Fit. **46**, 520-525.

Miller TA, Thierry-Aguilera R, Congleton JJ, *et al* (2007): Seasonal changes in VO2max among Division 1A collegiate women soccer players. J. Strength. Cond. Res. **21**, 48-51.

Nedeljkovic A, Mirkov DM, Kukolj M, Ugarkovic D and Jaric S (2007): Effect of maturation on the relationship between physical performance and body size. J. Strength. Cond. Res. **21**, 245-250.

Ostojic SM (2003): Seasonal alterations in body composition and sprint performance of elite soccer players. J. Exer. Physiol. on line. **6**, 24-27.

Pilegaard H, Domino K, Noland T, Juel C, Hellsten Y, Halestrap AP and Bangsbo J (1999): Effect of high intensity exercise training on lactate/H transport capacity in human skeletal muscle. Am. J. Physiol. **276**, E255–261.

Reilly T (2005): An Ergonomics model of the soccer training process. J. Sports. Sci. **6**,561-572.

Reilly T and Bangsbo J (1998): Anaerobic and aerobic training, in Applied Sport Science: Training in Sport (ed. B. Elliott), John Wiley. Chichester. 351–409.

Reilly T, Bangsbo J and Franks A (2000a): Anthropometric and physiological predispositions for elite soccer. J. Sports. Sci. **18**, 669-683.

Reilly T and Secher N (1990): Physiology of sports. E & FN Spon. London. 372-425.

Reilly T, Williams AM, Nevil A and Franks A (2000b): A multidisciplinary approach to talent identification in soccer. J. Sports. Sci. **18**, 695-702.

Schantz P and Sjøberg B (1985): Malate-aspartate and alpha-glycerophosphate shuttle enzyme levels in untrained and endurance trained human skeletal muscle. Acta. Physiol. Scand. 123, 12A.

Silvestre R, West C, Maresh CM, et al (2006): Body composition and physical performance in men's soccer: a study of a National Collegiate Athletic Association Division I team. J. Strength. Cond. Res. **20**, 177-183.

Tesch PA and Wright JE (1983): Recovery from short-term intense exercise: its relation to capillary supply and blood lactate concentration. Eu. J. Appl. Physiol. **52**, 98–103.